

Chapter 10

Invasive Sap-Sucker Insects in the Mediterranean Basin

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Abstract The chapter provides information on 15 species of invasive sucking insects on forest trees in the Mediterranean basin. Four Psyllids and one Thaumastocorid bug develop on *Eucalyptus* spp. and are native to Australia, although all of them possibly arrived in the Mediterranean area via South America. Among the five *Cinara* spp. those which develop on cedar trees spread inside the Mediterranean area, two of the aphids are North American species and one is probably from China. The discussed scale insects, two *Matsucoccus* spp. and *Marchalina hellenica* extend their range inside the Mediterranean basin. Finally, we report on two tingid species (*Corythucha* spp.) both originate from North America. We review their biology, the injury they inflict, their spread, as well as their natural enemies and the required management.

10.1 Introduction

Sap-sucker insects (Hemiptera) constitute the major feeding guild of invasive insect species affecting forest trees in the Mediterranean basin. They include mostly scale insects, aphids and psyllids (Sternorrhyncha) as well as some phytophagous bugs (Heteroptera). Some of these invasive insect species affect exotic tree species in the Mediterranean, such as *Eucalyptus*, whereas others mainly affect native ones, such as some Mediterranean conifers. Many invasive species originated from other regions outside the Mediterranean basin, such as those affecting *Eucalyptus*, which are all native to Australia (Table 10.1). Still, some species are distinguished to be simultaneously native in some regions of the Mediterranean basin and invasive on

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Table 10.1 List of sap-suckers insects invasive in the Mediterranean basin

Species	Family	Host trees	Origin	Distribution in the invaded range
<i>Ctenarytaina eucalypti</i>	Psyllidae	<i>Eucalyptus</i>	Australia	Western Europe
<i>Ctenarytaina spatulata</i>	Psyllidae	<i>Eucalyptus</i>	Australia	Mediterranean
<i>Glycaspis brimblecombei</i>	Psyllidae	<i>Eucalyptus</i>	Australia	Mediterranean
<i>Blastopsylla occidentalis</i>	Psyllidae	<i>Eucalyptus</i>	Australia	Mediterranean
<i>Thaumastocoris peregrinus</i>	Thaumastocoridae	<i>Eucalyptus</i>	Australia	Mediterranean
<i>Cinara cedri</i> ^a	Aphididae	<i>Cedrus</i>	Turkey, Syria	Mediterranean
<i>Cinara cupressi</i>	Aphididae	<i>Cupressaceae</i>	North America	Mediterranean
<i>Cinara tujafilina</i>	Aphididae	<i>Cupressaceae</i>	Iran, Asia	Mediterranean
<i>Cinara fresai</i>	Aphididae	<i>Juniperus</i>	North America	Europe
<i>Cinara laportei</i> ^a	Aphididae	<i>Cedrus</i>	North Africa	Mediterranean
<i>Marchalina hellenica</i> ^a	Marchalinidae	<i>Pinus</i>	Caucasus, Turkey	Greece, Italy
<i>Matsucoccus feytaudi</i> ^a	Matsucoccidae	<i>Pinus</i>	Morocco, Iberian Peninsula, SW France	Southern Europe
<i>Matsucoccus josephi</i> ^a	Matsucoccidae	<i>Pinus</i>	Turkey, Syria, Lebanon, Crete	Middle East
<i>Corythucha ciliata</i>	Tingidae	<i>Platanus</i>	North America	Europe
<i>Corythucha arcuata</i>	Tingidae	<i>Quercus</i>	North America	Europe

^aNative in some parts of the Mediterranean and invasive in other parts

other regions of the basin, such as two pine bast scales, *Matsucoccus* spp. The mode of life of sap-suckers, frequently concealed on foliage, wind dispersed, small sized, and rapid development of high population densities on young trees, facilitates their easy spread on nursery stock.

The piercing of the parenchyma or the phloem tissues and the uptake of plant sap, characteristic of their feeding habit, cause plant damage resulting in leaf bruising, leaf and twigs distortion, inhibition of new shoot formation, loss of apical dominance and eventually dieback when trees are intensively attacked. The honeydew produced by the phloem sucker species often lead to subsequent development of sooty mold fungi on the foliage, have further negative effects on tree physiology, interfering in the photosynthesis and transpiration. Additionally, the honeydew, the sooty mold fungi, and the dead bodies and waxy residues produced by some of the species have a substantial unaesthetic impact by soiling the ground covering surfaces and parked vehicles, which might be particular important in urban and recreation areas.

10.2 Eucalyptus Sap-Suckers

Sap-suckers is the major group of invasive insect species affecting *Eucalyptus* in the Mediterranean basin, most of the species become established during the last two decades. Currently they comprise four Psyllidae species, *Ctenarytaina eucalyptii* Maskell, *Ctenarytaina spatulata* Taylor, *Glycaspis brimblecombei* Moore and *Blastopsylla occidentalis* Taylor and one Thaumastocoridae, *Thaumastocoris peregrinus* Carpintero et Dellape. All these insect pests originated from Australia, but most of them, if not all, found their way to the Mediterranean basin through other regions; South Africa, South America and North America are the most plausible important regions, which served as bridgehead to the Mediterranean basin (Paine et al. 2011).

All these species have several overlapping generations per year. In the Mediterranean climate conditions their population growth starts with the development of new shoots and leaves in spring and develops through summer. Irrigation and nitrogen fertilization are favorable for the outbreak of the populations, especially in urban areas.

10.2.1 Psyllids

The blue gum psyllid *C. eucalyptii* was the first eucalyptus feeding invasive species established in the Mediterranean basin. The psyllid was primarily observed in 1971 in Portugal (Azevedo and Figo 1979). The severity of damage recorded by that time on *E. globulus* plantations was so high that it caused alarm among forest owners (Azevedo and Figo 1979). Still, since this psyllid only affects the juvenile's growth, before leaf differentiation takes place, only the young plantations were at risk. A specialized parasitoid *Psyllaephagus pilosus* Noyes (Hymenoptera: Encyrtidae) was introduced in Southeastern France in 1997 to control *C. eucalyptii* (Malausa and Girardet 1997). Later, the parasitoid was introduced in Ireland from individuals collected in France (Chauzat et al. 2002). In both locations, the success was very high, the parasitoid quickly established and in a few months the parasitism rates reached almost 100 % in the released areas. Currently, *C. eucalyptii* may episodically pose slight concern in nurseries but not in forest stands (Ferreira and Ferreira 1991).

Three decades later a congener species *C. spatulata* become also established in the Mediterranean basin (Fig. 10.1). The species was first recorded in 2002 in central Portugal affecting several *E. globulus* plantations. In 2003 the psyllid was observed all over the country and in Spain (Valente et al. 2004). Like *C. eucalyptii*, *C. spatulata* was mostly found on *E. globulus*, but large populations were also found on other tree species, namely *E. nitens* and *E. dalrympleana*. *C. spatulata* feeds on adult shoots and is more damaging to Eucalyptus trees than the congener *C. eucalyptii*. Before its introduction in the Mediterranean basin, *C. spatulata* was first observed in South America in 1994 (Burckhardt et al. 1999; Santana et al. 1999),



Fig. 10.1 *Ctenarytaina spatulata*, nymph (left) and adult (right) (Photos: C. Valente)

which suggests that this region might have acted as bridgehead for its introduction in Europe. On the contrary, *C. eucaliptii* was observed in South America only in 1999 (Burckhardt et al. 1999), 20 years before its first observation in Europe, suggesting a reverse flux of invasions. A new species of the same genus *C. peregrina* was described from UK, where it was first found in 2006 in *Eucalyptus parvula*. Until present, this species did not expand to the Mediterranean Basin.

More recently, two other psyllids were found in the Mediterranean basin, the red gum lerp psyllid *Glycaspis brimblecombei* and the eucalyptus psyllid *Blastopsylla occidentalis*. Both species were found in the Mediterranean basin about 10 years after its first detection in South and North America in the late 1990s (Gill 1998; Brennan et al. 1999; Halbert et al. 2001). The red gum lerp psyllid *G. brimblecombei* was observed in the Iberian Peninsula in 2007 (Borrajó et al. 2009; Valente and Hodkinson 2009). In a few years multiple first records were registered, and this insect species became an invasive pest all over the Mediterranean basin, first in Italy in 2009 (Laudonia and Garonna 2010) and in the following years in Tunisia, Morocco, Turkey and Israel (Maatouf and Lumaret 2012; Dhari et al. 2014; Spodek et al. 2015). *G. brimblecombei* nymphs are characteristically concealed by shield-like conical white waxy coverings, lerps, which the nymphs secrete to protect themselves from natural enemies (Fig. 10.2). This particularity allows its easy distinction from the other invasive psyllid species feeding on *Eucalyptus*. In other psyllid species, such as *B. occidentalis*, the nymphs may be protected by white flocculent wax but do not form lerps. *Blastopsylla occidentalis* was observed in the eastern Mediterranean, in 2006 in Italy and 1 year later in Turkey (Aytaç et al. 2011). Its occurrence in the western Mediterranean is dated from 2009 (Otero et al. 2011). Due to the low temporal distance and the high geographical distance among these regions, multiple introductions in the Mediterranean basin are plausible.

Both *G. brimblecombei* and *B. occidentalis* were found mainly associated with *E. camaldulensis*, although infestations may also be observed in other *Eucalyptus* species (Laudonia 2006; Valente and Hodkinson 2009; Otero et al. 2011). Since



Fig. 10.2 *Glycaspis brimblecombei*, nymphs covered by the lerp and an adult (left), uncovered nymph (right) (Photos A. Garcia)

E. globulus is a less susceptible tree species, the forest owners and the pulp industry in Southern Europe are not particularly alarmed. Still, the two psyllids may cause concern in urban parks and side roads, especially due to the honeydew production and sooty mold fungi. In North Africa and Middle East countries, *E. camaldulensis* is one of the most used Eucalyptus tree species for soil conservation, in recreation areas for shade, as windbreaks, as source of pollen and nectar for honeybees and for fuelwood. In these regions the two psyllids are considered a menace as they threaten these services provided by these trees.

The parasitoid *Psyllaephagus bliteus* Riek (Hymenoptera: Encyrtidae) was found established in the Mediterranean basin more or less at the same time as its host *G. brimblecombei*, which suggests that the host and the parasitoid might be introduced together. No country reported its deliberate introduction, but the parasitoid occurred all over the Mediterranean as documented in Spain (Otero et al. 2011), Italy (Caleca et al. 2011), Greece (Bella and Rapisarda 2013), Algeria and Morocco (Reguia and Peris-Felipo 2013). No parasitoid species was so far introduced for the control of *B. occidentalis*.

Many non-specific predators native to the invaded regions may feed on the eucalypts psyllids, especially those that feed on other sap-sucker insects, including green lacewings (Chrysopidae: Neuroptera), ladybeetles (Coccinellidae: Coleoptera), hoverflies (Syrphidae: Diptera), pirate bugs (Anthocoridae: Hemiptera) and spiders (Azevedo and Figo 1979; Valente and Hodkinson 2009; Laudonia and Garonna 2010; Otero et al. 2011). European native parasitoids (Ichneumonidae: Hymenoptera) were also found parasitizing *C. eucalypti* and *C. spatulata* (Azevedo and Figo 1979). These generalist natural enemies are usually considered ineffective in reducing psyllid populations to satisfactory levels (Hodkinson 1999). Nevertheless, the activity of these predators may contribute to reduce the psyllids abundance. Apart from biological control, no other measures have been extensively used for the control of these psyllids in the Mediterranean basin.

10.2.2 *Thaumastocoris peregrinus*

The Eucalyptus bronze bug *Thaumastocoris peregrinus* Carpintero et Dellape (Hemiptera Thaumastocoridae), is a small bug, 2–3 mm in length, which feeds on the Eucalyptus leaves. Thaumastocoridae is a small family occurring mainly in the southern Hemisphere, and believed to be closely related to the widespread family Anthocoridae (Drake and Slamr 1957). Both nymphs and adults are found gregariously on the *Eucalyptus* leaves and spread rapidly when disturbed. Aggregation and possible alarm pheromones determine its peculiar behavior (Martins et al. 2012; Garcia et al. 2013). Egg masses are laid in small dark clusters on the surface of leaves (Fig. 10.3).

The Eucalyptus bronze bug was first reported in South Africa in 2003 (Jacobs and Naser 2005) and 2 years later in Argentina (Nadel et al. 2010). DNA bar-coding distribution of the haplotypes indicates that several distinct introductions of this insect occurred into several regions of the southern Hemisphere, probably originated from Sydney, where populations frequently reach outbreak levels in urban areas (Nadel et al. 2010).

In Europe the Eucalyptus bronze bug was first reported on the eastern Mediterranean basin, in Italy in 2011 (Laudonia and Sasso 2012). Only 1 year later it was found on the most extreme of the western Mediterranean (Garcia et al. 2013). Again, the proximity of dates in two opposite sides of the Mediterranean basin suggests that multiple introductions might have occurred. Yet, in this case the introductions were most probably from other regions in the Southern Hemisphere where the species was already present, and which served as bridgehead and not directly from Australia. At the same time in the western Mediterranean, an alien predator *Hemerobius bolivari* Banks (Neuroptera Hemerobiidae) was also observed preying on *T. peregrinus* nymphs. This predator species is native to South America and was then first recorded in Europe (Garcia et al. 2013; Monserrat et al. 2013). Therefore,

Fig. 10.3 *Thaumastocoris peregrinus* adults and small dark clusters of egg masses on *Eucalyptus camaldulensis* leaves (Photo A. Garcia)



the authors hypothesized that the predator may have reached Europe together with prey species, either *T. peregrinus* or previously introduced sap-suckers.

Surveys confirmed a long list of host species of the bronze bug. Out of 30 Eucalyptus species present in a Eucalyptus arboretum in Portugal, 19 were infested by *T. peregrinus*, being *E. camaldulensis*, *E. pauciflora* and *E. viminalis* the most infested species. Although, *T. peregrinus* may occasionally infest *E. globulus*, this species was found to be less preferred. No specific biological agent was so far recorded in the Mediterranean and no control strategies were developed.

In Australia where Eucalyptus bronze bug represent a problem in urban trees, specially *E. nicholii* and *E. scoparia*, chemical control based on tree microinjection with imidacloprid proved to be efficacious for the control of *T. peregrinus* as the bug populations declined significantly on treated trees for more than a year (Noack et al. 2009).

10.3 Pine Scale Insects

A few invasive species of aphids and scale insects affect conifers, *Abies*, *Cedrus*, *Cupressus* and *Pinus* in the Mediterranean basin. Some of these species are also native to the Mediterranean or neighbor areas (Table 10.1). Among these species, the most destructive ones have been the pine bast scales (*Matsucoccus* spp.) and the Greek pine scale *Marchalina hellenica*

10.3.1 *Matsucoccus* spp. (Hemiptera: Matsucoccidae)

Pine bast scales (Hemiptera: Matsucoccidae) are among the oldest known organisms closely associated with pines (Koteja 1990) and currently include the oldest known scale insect fossils (Foldi 2004). The stenophagous character of bast scales and their prolonged co-evolution with the genus *Pinus*, can explain not only the present distribution of *Matsucoccus* spp. but also the past geographic distribution of pine (Mendel 1998). Cockerell named the genus in 1909 from material originating from both Japan; the etymology is from the Japanese ‘Matsu’ meaning pine, and Greek ‘coccus’ for berry or a small ball. *Matsucoccus* spp. feed exclusively on pine; each species develops on one or a few host species of a given section or subsection of the genus *Pinus*. The genus is exclusive to the Northern Hemisphere including both Palearctic and Nearctic regions. Among the 33 modern *Matsucoccus* species, 20 have survived in North America, and only five occur in the west Palearctic region (Booth and Gullan 2006). Three European native *Matsucoccus* species occur in the Mediterranean basin, *M. pini* (Green), *M. feytaudi* Ducassee and *M. josephi* Bodenheimer and Harpaz Foldi (2004). According to Ray’s (1982) classification of the North American *Matsucoccus* spp., *M. feytaudi* and *M. pini* belong to Apachecae section whereas *M. josephi* may assign to Alabamae section. The three species



Fig. 10.4 Lures with the *Matsucoccus feytaudi* female sex pheromone with male attracted (*left*) and larvae of *Iberorhynchobius rondensis* (Coleoptera: Coccinellidae) (*right*) (Photos M. Branco)

differ in their distinct host range and by number of annual generations. *M. pini* is a bivoltine species which has a broad geographic distribution in Europe; it develops on *P. nigra*, *P. sylvestris*, *P. pumilio*, *P. uncinata* and *P. mugo*. In the Mediterranean basin at high elevation, its area of distribution overlaps those of the other two *Matsucoccus* species, which are endemic to restricted regions of the Mediterranean. *Matsucoccus feytaudi* naturally occurs in the Iberian Peninsula, southwestern France and North Africa and feeds exclusively on the maritime pine, *Pinus pinaster*. *M. josephi* is indigenous in the north rim of the East Mediterranean and develops on several closely species of Mediterranean pines, including *Pinus brutia*, *P. halepensis*, but may be found also on *P. canariensis* and *P. pinea*.

Speciation and evolutionary processes of the two Mediterranean species are considered to be linked to the glacial periods during which the ancestors of these *Matsucoccus* species become isolated together with its host pines in the specific areas of the Mediterranean basin. During the twentieth century the two species spread to neighbor regions of the Mediterranean, where they cause considerable devastation to pine forests. *M. feytaudi* spread to eastern France, Italy and Corsica, *M. josephi* spread southward to Israel and Jordan. Therefore, both species are considered invasive within the Mediterranean basin. All three *Matsucoccus* species are biparental, males are attracted to the female sex pheromone (Fig. 10.4). All three are rather rare in their native habitat or occur in very low population densities. Yet, severe outbreaks, resulted in the destruction of large forest areas due to tree mortality inflicted by both *M. feytaudi* and *M. josephi* in its introduced range. Susceptible tree genotypes of their pine hosts or genetically closely related host species has been suggested as one of the main reasons of the aggressive attacks on their introduced range, justified by lack of a co-evolutionary history. *Matsucoccus* spp. are not attacked by hymenopteran or dipteran parasitoids, but several predators are known from its native range. There is probably a linkage among the triad *Pinus*, *Matsucoccus* and the predatory bugs (Anthocoridae) of the genus *Elatophilus* (Mendel et al. 1991).

10.3.1.1 *Matsucoccus feytaudi*

The maritime pine bast scale *M. feytaudi* was first recorded from France in 1938, by that time identified as *M. matsumurae* Kuwana, from specimens collected from *P. pinaster* trees in the region of Bordeaux. Later, in 1942 the species was described by Ducasse as *M. feytaudi*. In the early 1960s, extensive damage to *P. pinaster* plantations was reported in the Massif of Maures, southeast of France (Riom and Gerbinot 1977). Initially the damage was assigned to the attack of bark beetles, such as *Ips sexdentatus*, *Tomicus destruens*, *Orthotomicus erosus* and *Pissodes castaneus*, which attacked the dying trees, later it was found that the primary cause for the tree decline was *M. feytaudi*. The symptoms of attack comprise yellowing of the crown, exudation of resin and tree death, which can be confused with injury inflicted by bark beetles. About 120,000 ha of maritime pine forest were seriously affected and thousands of pine trees died in a few years (Schvester 1967). During this period *M. feytaudi* was also found to occur endemically in Spain, Portugal and Morocco, which corresponds to its native range, but causing no damage. In the late 1970s the pine bast scale expanded its invasive range from the eastern of France till the north of Italy (Covassi and Binazzi 1992). In 1994 the insect was found in Corsica for the first time causing tree mortality on large area (Jactel et al. 1996). Currently *M. feytaudi* is still expanding southwards in Italy and in Corsica where it spreads at a rate of 2 km/year (Jactel et al. 2012). Molecular markers showed that the population in Corsica originated from individuals coming both from the populations in Italy and southeastern France (Kerdelhué et al. 2014).

The maritime pine bast scale is univoltine. The adults emerge in February–March when they mate and lay eggs. The first instar nymphs (L1) appear about 1 month later. This is the dispersal stage, L1 are crawlers which are easily dispersed by the wind from one tree to another. Once they reach a suitable host, they become sedentary and begin feeding on the parenchyma layer. Second instar nymphs (L2) are dark, about 1.3 mm long, and develop through August until December–January living fixed on the tree trunk inside bark crevices (Riom and Gerbinot 1977). By December–January the males pupate within waxy cocoons hidden in the bark. The females emerge from L2 after molting and are mobile. The males are short lived and attracted by the sex pheromone emitted by the females. Each female lays a single egg mass, containing usually more than 300 eggs, inside bark crevices and protected by silky wax. The dead body of the female is usually attached to the egg mass.

In its native regions *M. feytaudi* populations can be found in all *P. pinaster* stands at low density and the impact on the host tree is negligible (Tavares et al. 2014). The insect only becomes a serious pest on the invaded range. Genetic differences among *P. pinaster* populations may explain this outcome. The populations of the maritime pine and *M. feytaudi* were isolated together in small areas in the Iberian Peninsula and North Africa during the last glaciations, from where both *P. pinaster* and *M. feytaudi* spread to north (Burban et al. 1999). As both host tree and insect pest share the same geographical range of origin, probably also where the speciation of *M. feytaudi* occurred, a co-evolutionary history leading to highly resistant genotypes.

In the invaded areas, a lack of tree defense mechanism is probably the reason for the high susceptibility of the trees (Schvester and Ughetto 1986).

Matsucoccus feytaudi is accompanied by several species of natural enemies, all of them are predators. Interestingly, many of these predators, both adult and larvae, are attracted to the sex pheromone of the scale. This is the case of Anthocoridae belonging to the genus *Elatophilus*, namely *E. nigricornis* (Zetterstedt) and *E. crassicornis* Reuter, the Hemerobiidae, *Hemerobius stigma* Stephens (Fig. 10.7), and three Coleopteran species, *Aplocnemus raymondi* Deville, (Dasytidae), *Malachiomimus pectinatus* (Kiesenwetter) (Malachiidae), and *Iberorhizobius rondenensis* (Eizaguirre) (Coccinellidae) (Fig. 10.4) (Mendel et al. 2004; Branco et al. 2006a, 2011; Rodrigo et al. 2013). Other generalist predators such as of ladybirds of the genus *Scymnus* and *Rhizobius chrysoloides* are also found preying on the egg masses of *M. feytaudi* (Toccafondi et al. 1991), although these do not display a kairomonal attraction to the sex pheromone of the prey. In the invaded range, *E. nigricornis*, *H. stigma* (Fabre et al. 2000) and *Aplocnemus brevis* Rosenhauer are also found preying on *M. feytaudi*. Possibly by shifting from *M. pini* to the new prey as they also respond to sex pheromone of *M. matsumurae* (Branco et al. 2006b, c; Jactel et al. 2006). Nevertheless, these predators do not seem to effectively reduce *M. feytaudi* population densities to acceptable levels in its invaded range (Schvester and Fabre 2001).

Direct insecticide applications did not show to be efficient or economically justified for the control of *M. feytaudi*, in part due to the concealed living habitats of its life stages. Silvicultural methods, eliminating susceptible and symptomatic trees, have been the most used practices. Since tree vigor and bark thickness were found positively correlate with tree resistance, selective thinning by promoting tree vigor was also proposed as an adequate strategy to reduce the damage caused by the pine bast scale (Gaulier et al. 2001). Due to the differences in susceptibility to *M. feytaudi* for different *P. pinaster* provenances, genetic improvement was further considered a possibility to explore (Schvester and Ughetto 1986). Following the identification and synthesis of the *M. feytaudi* sex pheromone (Jactel et al. 1994), studies were conducted to optimize pheromone baited traps for monitoring *M. feytaudi* populations and its principal predators (Branco et al. 2004).

10.3.1.2 *Matsucoccus josephi*

The Israeli pine bast scale *Matsucoccus josephi* Bodenheimer et Harpaz was first recorded in newly afforested area in Ramot Menashe in North Samaria, in the early 1930s (Bodenheimer and Neumark 1955). It was named 'josephi' after Joseph Weitz, the first head of the Forests Department of the Land and Development Authority (KKL) in Israel. The scale was probably spread southern with prevailing winds from old *Pinus halepensis* stands on Mt Carmel to Ramot Menashe. Until the 1980s *M. josephi* was considered to be an endemic insect of Aleppo pine, and in Israel was known only on Aleppo pine. In the early 1990s the scale was found in *P. brutia* forests in Cyprus and Turkey (Mendel 1992; Mendel and Schiller 1993).

The patterns of DNA fragments displayed a positive association between the Israeli and Cypriot populations and a negative association between the Israeli and the Turkish populations. Hence, *M. josephi* probably arrived in Israel on fresh timber of *P. brutia* that was brought from Cyprus by the British forces during the First World War (Mendel et al. 1994c).

Speciation of *M. josephi* could have occurred in the south of the areas between the Black and the Caspian Seas from a progenitor that came into contact with *P. brutia* ssp. *brutia*, brutia pine after speciation of brutia pine and *P. halepensis* (Mendel 1998). The primary range of *M. josephi* encompasses the entire distribution area of brutia pine in western Turkey, including the Turkish European areas in Thrace and the islands of Cyprus and Crete. The scale is probably also present on the islands off the Anatolian coast. *M. josephi* also occurs on *P. halepensis* in small enclaves near Adana and Marmaris in Turkey (which were planted over there for harvesting the resin for production of Greek retsina win), and on brutia pine in southern Lebanon. Its natural range most probably also includes the brutia pine forests along the coastal mountain range of Syria and northern Lebanon. *M. josephi* may be found in natural relic stands of brutia pine in Kurdistan (northern Iraq) and eastern Turkey. It is also infests the *P. halepensis* forest in Jordan. About 80 % of the area covered with *Pinus halepensis* in Israel is affected to some degree by the scale (Mendel et al. 1994a) (Fig. 10.5).

The adult males emerge from their pupation sites in the forest litter are attracted to the sex pheromone emitted by the females (Mendel et al. 1990b; Dunkelblum



Fig. 10.5 Chronic injury inflicted by *Matsucoccus josephi* on *Pinus halepensis* in Israel (Photo Z. Mendel)



Fig. 10.6 Egg masses (right) and first and second instar larvae (left) of *Matsucoccus josephi* (Photos A. protasov)

et al. 1993, 2000). They live for about 8 h, during which time each may fertilize several females. The female may be successfully inseminated up to 10 days after emergence. Soon after mating the females seek an oviposition spot, usually under bark scales or in crevices, but when there are high population densities egg mass may also be found on main branches and twigs (Mendel et al. 1998). Adult females weigh between 40 and 340 mg, and fertility is closely correlated with body weight. Thus, an egg mass may consist of 44–350 eggs (Fig. 10.6). Ovipositing females tend to congregate, and thus produce large combined egg masses. Egg laying occurs 24 h after mating (Mendel et al. 1990a). Soon after hatching the crawlers start to disperse along the host plant. They tend to leave the egg mass site and on adult trees they go up the trunk seeking for loose bark scales under which live bark can be reached (Bodenheimer and Neumark 1955). In case of 2–3-year-old saplings they prefer to descend and to colonize the lower part of the plant. However, they may settle on any part of the tree, including the bases of the brachyblasts, branches, twigs and flower stalks, and exposed roots. On growth that is covered with thick rhytidome, their settling is limited to lenticell openings. *M. josephi* displays low temperature thresholds of the feeding stages (larvae) and the non-feeding stages (eggs and pupae) are 2.4 °C and 7.4 °C, respectively (Mendel et al. 1988).

M. josephi is well adapted to the Mediterranean climate and thus occurs at all altitudes of its principal host, brutia pine; it has been found from sea level up to 1200 m. The scale is invasive in the natural areas of *P. halepensis* in the Near East. The pest does not favor areas with a long dry summer and a short period of width

growth of the plant host. Thus, in the desert areas in Israel the population of the scale is very low, with the exception of rare episodes of rainy years, following which the population increases steeply (Mendel 1987, 1992, 1998; Mendel and Schiller 1993). Unlike other studied *Matsucoccus* spp. *M. josephi* displays multivoltinuous characteristics (Bodenheimer and Neumark 1955; Mendel et al. 1990b). In Israel, on Aleppo pine trees, it breeds through 5–7 generations annually, with the peaks in the spring and early summer, and the autumn (Mendel et al. 1997a). The population density coincides closely with the physiological activity of the host tree, displaying intensive width growth from February till May and in September (Mendel et al. 1997b). The pest displays a typical clumped distribution (Nestel et al. 1995).

M. josephi develops and reproduces on all five taxa of subsection *Halepenses* in the Section *Pinea*: (1) *Pinus brutia* ssp. *brutia*, is highly resistant to infestation; (2) *Pinus brutia* ssp. *stankewiczii* (Sukaczew) Nahal; (3) *Pinus brutia* ssp. *pithyusa* (Stevenson) Nahal; (4) *Pinus brutia* ssp. *eldarica*; and (5) *P. halepensis*. It may develop on *Pinus pinea* L. (section *Pinea*, subsection *Pinea*) and on *P. canariensis* Smith and *Pinus roxburghii*; these belong to a sister pine section, *Sula* (subsection *Canarienses*) (Lipshitz and Mendel 1989b). It is suggested that the host specificity to *M. josephi* relates to the suitability of the pest's saliva composition (Lipshitz and Mendel 1987, 1989a). Infestation by closely related species is prevented, since the growing larvae trigger the development of wound periderm which eventually leads to the death of the pest (Lipshitz and Mendel 1989a). In pine species that are genetically remote from the suitable host, the tree's hypersensitive reaction prevents any development of the scale's crawlers (Lipshitz and Mendel 1989b). Provenances of *P. halepensis* from Greece and the Near East are relatively resistant, as compared with those of the West Mediterranean which are highly susceptible. The Caucasian subspecies of brutia pine, *Pinus brutia pithyusa*, *P. brutia stankewiczii*, and *P. brutia eldarica* are highly susceptible. Even brutia pine or less susceptible *P. halepensis* provenances may be severely affected under irrigation and fertilization. Hybrids of brutia pine x *P. halepensis* and brutia pine x *Pinus nigra* (the latter species is immune to *M. josephi*) display similar susceptibility to that of *P. halepensis* (Madmony et al. 2003; Mendel 1992, 1998).

The typical injury consists of accelerated drying of infested growth. The injuries include drying of buds, shortened needles, twig flagging, twisting of twigs and young branches, yellowish dry or sparse crowns. Drying of young trees within a few months of infestation is common on natural regeneration sites and on 2–5-years-old plantations close to adult stands (Bodenheimer and Neumark 1955; Mendel et al. 1994a). High seedling mortality rates caused by the scale occur from the winter (February) till early summer (early June) (Mendel et al. 1997b). Seedling mortality decreases steeply from the sixth year onward. In older stands, 18–40 years after planting or regeneration, as soon as the tree canopy is closed and typical cork scale peeling of the stem appears the *M. josephi* population increases. The damage is characterized by progressive drying of branches from the lowest ones upwards, a process which may last for several decades. Heavily infested sections of the trunk become reddish, with typical premature cork scale peeling, which leads to excretion of numerous resin drops, cracked bark and separation of numerous bark flakes.



Fig. 10.7 (Left), *Elatophilus hebraicus* feeding on *Matsucoccus josephi* female (Israel), (right) *Hemerobius stigma* (Portugal) (Photos Z. Mendel)

When it switches from the latent to the epidemic state, *M. josephi* covers much of the branch bases and 1–2-years-old shoots, resulting in the dying of the tree crown.

The spread of the scale into Aleppo stands in the Near East has gradually led to heavy losses of those stands (Mendel et al. 1994a), and introduction of *M. josephi* into the natural Aleppo pine areas around the western Mediterranean poses a serious risk to large forest areas in north Africa and along the Mediterranean coast of Italy and France (Mendel 1998).

Elatophilus hebraicus Péricart, a specific predator, is the most common enemy of *M. josephi* (Mendel et al. 1995) (Fig. 10.7). Similar to other principal predators of pine bast scale *E. hebraicus* is highly attracted to the sex pheromone of its prey (Mendel et al. 2004). Apart from *E. hebraicus* all predators associated with *M. josephi* are polyphagous and occur in several different sylvan and agricultural ecosystems. The main associates (in Israel) are: *Dufouriellus ater* (Heteroptera: Anthocoridae) that preys on other natural enemies of the scale. *Cryptolestes halevyae* Thomas (Coleoptera: Laemophleoidae), *Ulrike Syriaca* (Steinmann) (Raphidioptera: Raphidiidae), *Anystis baccarum* L. (Acari; Anystidae) and *Hysterochefiler gracilimanus* Beier (Pseudoscorpiones; Cheliferidae).

The inspection of stands for typical chronic injury symptoms is based on the observation of the extent of the tree canopy drying up, the distinct twisting of twigs, flagging and dry needles (Bodenheimer and Neumark 1955; Liphshitz and Mendel 1989a). *Matsucoccus josephi* is confirmed by examining occurrences of larvae or remains of larvae and empty ovisacs, at the base of the brachyblasts, when removing loose bark flakes of partial scaly-bark stem sections. The population density of *M. josephi* can be estimated by counting the number of ovisacs, on jute belt wrapped around each tree, at breast height (Mendel and Rosenberg 1988). Sticky traps baited with female sex pheromone are also used to determine the presence of the scale (Dunkelblum et al. 2000; Mendel et al. 1997a). The traps are highly selective and strongly attractive to males of *M. josephi* as well as to the adults, both male and female, of its specific predator, *E. hebraicus* (Mendel et al. 1997a, 2004).

Prevention of injury to newly established stands or to young natural regeneration by *M. josephi* is achieved by pruning the lower branches, and extensive thinning of

dense regeneration. Planted stands of Aleppo pine more than 10 years old should be thinned, in at least two thinning cycles, to open the canopy and avoid tree stress. Trees with big crowns are less susceptible to the scale epidemic.

Matsucoccus josephi spreads between pine stands by crawlers carried by the prevailing wind, and it may be transferred between regions on fresh timber that is harvested in the areas of *P. brutia* and *P. halepensis* in the eastern Mediterranean. The pest may be moved on young saplings older than 6 months. No precautionary measures are taken to prevent the spread of *M. josephi* from infested to non-infested areas.

10.3.2 *Marchalina hellenica*

Marchalina hellenica (Gennadius) (Hemiptera: Coccoidea, Marchalinidae) is a scale insect feeding on Pinaceae. The insect species is distributed in the eastern part of the Mediterranean Basin, in the Turkish and Greek coastal zones of the Aegean and Black seas up to 1200 m (Petraakis et al. 2011). The family Marchalinidae is one of 10 families previously grouped as “Margarodidae” and contains a single genus *Marchalina* with two described species, *M. azteca* Ferris from Mexico and *M. hellenica* (Kozár et al. 2013). A similar species distributed in Caucasus was described by Hadzibeyli in 1969 as *M. caucasica* and later synonymised with *M. hellenica* (Hodghson and Gounari 2006). Still, differences in morphological traits, life history, host species and geographic distribution, all support that *M. caucasica* and *M. hellenica* are probably two separate species (Hodghson and Gounari 2006).

It is believed that *M. hellenica* was introduced in northern Greece from Turkey by late Romans and Byzantines; there are no records of its presence in Greece at prehistoric and classical times (Petraakis et al. 2011). The recent expansion of the pine scale was due to the activity of beekeepers which exploit the abundant honeydew excreted by the scale insect to produce the so much appreciated “Greek pine honey”. With the intent of increasing honeydew production, beekeepers deliberately introduced *M. hellenica* in sites where the insect did not exist before, in particular at high elevation in mountain areas (Bacandritsos 2004). It was introduced in the 1960s in the Italian island of Ischia, where it does still occur and threaten ornamental pine trees (EPPO 2007).

M. hellenica has one generation a year presenting three immature instars for females, and four for the males, before reaching the adult stage. Only the second and third instars feed on the sap phloem in the tree trunk and branches, 1st instar are crawlers. Overwintering occurs at the third instar. All stages are yellow colored. The adult females start to occur by the end of March and may be easily observed on the branches and trunk of pine trees due to its large size and bright color until the end of April, beginning of May. Female are large and oval, about 8–13 mm length and 4–5.5 mm width. Males are apterous with elongated body and dark-yellow legs. Yet, males are rare. *M. hellenica* reproduces mostly by parthenogenesis, a trait which

further distinguishes this species from *M. caucasica* (Hodgson and Gounari 2006). Females lay a woolly ovisac containing 130–400 eggs on the bark of the host tree (Gounari 2006).

In its distribution range, *M. hellenica* feeds on a few pine species, namely *P. halepensis*, *P. brutia*, *P. pinea*, *P. nigra* and *P. silvestris* and sporadically on *Abies* sp. The insect usually attacks mature and old pines, with about 35 years or older (Yesil et al. 2005).

In Turkey many native predators were found preying on immature and adult stages of *M. hellenica* (Ülgentürk et al. 2013). The most important and most widespread predator was *Neoleucopis kartliana* (Diptera: Chamaemyiidae). Other predators include three species of mites (Acarina), ladybird species (Coleoptera: Coccinellidae), *Myrrha octodecimguttata*, *Rodolia cardinalis* and *Scymnus subvillosus*, generalist Neuropteran predators, both from Chrysopidae and Hemerobiidae families, and two Anthocoridae, *Cardiastethus nazarenus* and *Elatophilus pachynemis*. Whereas *N. kartliana* appeared to be a monophagous predator of *M. hellenica*, the other predators are mostly generalists feeding on other scale insects occurring on pines. In other regions, many predators were also found associated with *M. hellenica*, including Chamaemyiidae (Diptera), Coccinellidae (Coleoptera), Raphidiidae (Raphidioptera) and Chrysopidae (Neuroptera) Ben-Dov et al. (2013). Some of these predators also feed on honeydew produced by the scale insects. The honeydew also attracts ants which may play an important role in protecting the scale insect from its natural enemies (Petraakis et al. 2011).

M. hellenica is an economically important scale insect due to the honeydew produced by the insect which is one of the most important resources for Greek and Turkish apiculture. In fact, pine honey represents 60–65 % of total honey production in Greece (Thrasylvoulou and Manikis 1996) and approximately 50 % of Turkish honey production (Miguel et al. 2014). The density of beehives may attain more than 225 hives/km² in the sites most populated with the pine scale (Gounari 2006). To keep the honey production at high levels, beekeepers intentionally introduce the scale insect into new areas and increase infestations with new inoculations.

The high densities of *M. hellenica* populations observed in the affected areas are severe, causing tree growth loss, crown transparency and tree decline (Yesil et al. 2005). The phenomenon is further considered to negatively affect the biodiversity in the affected areas (Petraakis et al. 2011). The beekeepers are blamed to “kill the goose that laid the golden egg” as reductions and fluctuations of the quantity of honeydew produced has further caused some concern among beekeepers (Petraakis et al. 2011).

Silvicultural practices such as thinning, removing of decaying trees, and the use of genetic materials resistant to the scale insect in afforestation and plantation programs, have been proposed as major measures to control this pine scale on the affected areas (Gallis 2007).

10.4 Conifer Aphids

The conifer aphids of the genus *Cinara* Curtis are soft-bodied, generally gregarious insects that often found in large groups. Most members of the genus are known from North and Central America (Blackman and Eastop 1994); in the West Palaearctic region the genus is represented by 47 species (Nafria et al. 1984). These aphids do not perform host alternate, but remain on their chosen host species throughout the year. They may feed on the roots, branches, or foliage. In the Mediterranean, these species mainly occur on members of the genera *Pinus* and *Cedrus* (Pinaceae) and *Juniperus* and *Cupressus* (Cupressaceae).

Most species feed on a single or a few closely related congeners. Species of *Cinara* have specific feeding sites on their host plants (Bradley 1959); those in the Mediterranean usually feed on young shoots and 2–3 year old branches. The life cycles of *Cinara* spp. in their holocyclic sequence include males and egg laying females, which after pairing, give rise to overwintering eggs. Where favorable climatic and host plant conditions persist, the sexual reproduction may be omitted altogether and anholocyclic colonies may persist for many generations (Binazzi 1978; Carter and Maslen 1982). Many *Cinara* spp. are attended by ants and the host plants benefit from this association. Honeydew supply usually increases the frequency of ant interactions with the aphids (Mooney and Tillberg 2005). Although tending ants not always benefit their hemipteran partners (e.g. Styrsky and Eubanks 2007), the host trees usually gain from this interaction as the ants decrease the soiling of the canopy with honeydew and sooty mold and encourage arthropod predation by the ants (Bach 1991; Rosengren and Sundström 1991). *Cinara* spp. display limited dispersal ability, compared to other aphid species (Voegtlin 1988; Blackman and Eastop 1994). However, few species have become invasive pests and spread on large areas. Among these, few species have become a major pests while other did not reach any significant economic status although there were not accompanied by their principal natural enemies.

Several *Cinara* spp. are considered invasive pests in the Mediterranean region and are presented below. Two of these species are invasive within the region: *Cinara* (*Cedrobium*) *laportei* spread from *Cedrus atlantica* forests in the Atlas Mountains in North Africa (Fabre and Rabasse 1987a) and *Cinara* (*Cinarella*) *cedri* which is probably indigenous to *Cedrus libani* forests in the North East Mediterranean (e.g. Michelena et al. 2005). Three other species arrived from other regions. *Cinara* (*Cupressobium*) *tujafilina* is common in the Mediterranean region on oriental thuja (e.g. Halperin et al. 1988) probably spread from the Far East. Two other species are from North America, *Cinara* (*Cupressobium*) *fresai*, which was reported in Israel (Mendel and Zehavi 1987), and *Cinara cupressi sensu stricto* (Watson et al. 1999) which is distributed over the distribution range of *Cupressus* spp. in the Mediterranean basin. It is interesting to note that none of the invasive *Cinara* spp. in the Mediterranean inflicts any serious damage on native trees, with the only exception of *C. cupressi* which is known to cause rapid dieback of tree canopy in spring (Roques and Battisti 1999).



Fig. 10.8 *Cinara laportei* on *Cedrus atlantica*, aphid colony (left) and dying branches with typical damage (Photos Z. Mendel)

10.4.1 *Cinara (Cedrobium) laportei* Remaudière

Cinara laportei is a rather small aphid, the apterous adult length is 1.7–2.0 mm rather flat, pale brown and grey-greenish with a narrow pale spinal stripe from head to anterior abdomen and shiny, legs and antennae are pale (Fig. 10.8). The alates are a bit small 1.6–1.9 mm long and darker. The colonies are usually small and located at the base of the needles or on 1-year-old twigs. These colonies seemed to develop in low dry areas in early spring (February) and reach a high number of individuals during the succeeding months, until June–July. In higher elevations of its range, it occurs in high number in mid-summer. In Israel, the population almost disappeared in the second half of the summer and became conspicuous again in early February. Detection of small populations of *C. laportei* may be difficult since the aphids settle deep in small crevices in the outer bark and are not always attended by ants (see also Covassi and Binazzi 1974; Notario et al. 1984). The overwintering eggs are black and deposited on the needles. They may be found also during aestivation periods on the roots of the host plants (e.g. Binazzi and Pennacchio 1996).

C. laportei is indigenous to the Atlas Mountains, North Africa, where it occurs on the Atlantic cedar. Conclusive evidence of the aphid out of its natural range was first recorded in the early 1970s in the cedar populations of southeast France. Since then the aphid spread to vast areas where Atlantic cedar is planted in the Mediterranean, but also in other European regions, Africa and Asia (Nafria et al. 1984).

Infested trees are evidenced by the typical injury; lower branches may be covered with sooty-mold, while honeydew is usually not noticeable (Fig. 10.8). Intensive feeding of *C. laportei* may cause rapid loss of needles (Notario et al. 1984). Often, trees, especially from most susceptible host species, do not recover from the damage inflicted by the aphid. Fabre et al. (1988) tested the susceptibility of provenances of cedar to *C. laportei* and found that *Cedrus atlantica* was most susceptible to *C. laportei*, while infestation on Himalayan cedar *C. deodara* were moderate and Lebanon Cedar *C. libani* and Cyprus cedar *C. brevifolia* were not susceptible. Damage was more severe in elevated regions above 700 m. Similar susceptibility picture was obtained in Israel (Saphir et al. 2000). This geographical pattern may be related to the typical feeding habit of the aphid (Fabre and Chalon 2005). *C. laportei* consumes relatively low amount of the phloem sap and thus there is a reduced flow of honeydew, especially when compared with that produced by *C. cedri* (see below), but its feeding involves the injection of toxins causing plant injury.

We may safely assume that the effective biological control of the aphid in its native area initially prevents the injury inflicted on *C. atlantica*. Typical aphid predators, such as green lacewings and lady beetles were observed in *Cinara laportei* infestations (Fabre 1990). However, only after the introduction of *Pauesia cedrobii* (Hym.: Aphidiidae) from High Atlas range to France, in 1981, the aphid was efficiently controlled (Fabre and Rabasse 1987a). The wasp spread fast and 12 years later it was found in the forests of Vincennes, 600 km away from where they had been introduced (Fabre and Rabasse 1987b; Remaudiere and Starý 1993). The successful biological control in France was repeated in Israel by releasing several hundred individuals originated from parasitized aphids collected in Avignon (Saphir et al. 2000).

10.4.2 *Cinara (Cinarella) cedri Mimeur*

Cinara cedri is probably native to the natural distribution range of the Lebanese cedar where its principal parasitoid was located (Michelena et al. 2005). The aphid is well known for many years on planted cedars trees in Europe, Asia and South America (Covassi and Binazzi 1974; Carter and Maslen 1982; Notario et al. 1984). In Israel and Turkey the aphid forms small colonies on the twigs and small to large colonies on branches (Fig. 10.9).

The apterae forms of the large cedar aphid are dark gray in color; its body length reach up 3.8 mm; a pair of bracket longitudinal band on the body is rather conspicuous as well as its black *siphunculi*. The alates have similar appearance but lack the dark band and their wings are grayish –yellow (Carter and Maslen 1982; Notario



Fig. 10.9 Colony of *Cinara cedri* on a branch of *Cedrus atlantica* (left) and tree covered with sooty mold (right) (Photos Z. Mendel)

et al. 1984). The aphid covered large compact colonies on the twigs and the branches and even trunks (5–6 cm diameter) of *C. atlantica*, *C. libani* and *C. deodora*. Populations start to build up early in the spring (February–March in Israel) and reach high densities during the succeeding months. In mid-summer the populations decline and become quite rare although small colonies may be found by tracing ant activity on the trees.

The feeding involves secretion of large amount of honeydew which cover the foliage and the bark upon which dense layer of sooty mold develops (e.g. Covassi and Binazzi 1974; Fabre 1976; Carter and Maslen 1982; Saphir et al. 2000). Susceptible provenances may suffer more from the infestation which may lead to significant loss of needles (e.g. Nafriá et al. 1984).

On the background of severe infestation in Israel during the late 1990 a search for its principal parasitoid was initiated with the idea that the aphid was originated from Asia Minor. From parasitized individuals collected in this region *Pauesia anatolica* nov. sp. immersed (Michelena et al. 2005). Releasing of the wasps in Israel helped to decrease the population of the aphid, although, unlike the very effective control of *C. laportai*, the populations of *C. cedri* are still easily detected and responsible for the infrequently soiling of the lower branches canopy with honeydew, although the damage is limited.

10.4.3 *Cinara* (*Cupressobium*)

Cinara (*Cupressobium*) *tujafilina* (del Guercio) It is a relatively large aphid; the alates are 1.7–3.5 mm long, brownish-yellow in color and slightly covered with a dorsal pattern of bluish-white wax layer. They display a broad body with long legs;

siphunculi are broad, short, and cone-shaped and two dark brown divergent curved bands running from head to *siphunculi* level are visible (Blackman and Eastop 1994; Binazzi and Scheurer 2009). *Cinara tujaefilina* develops on variety of Cupressaceae genera, such as *Callitris*, *Chamaecyparis*, *Cupressus*, *Juniperus*, *Libocedrus*, *Thuja* and *Widdringtonia* (Nafria 2007; Blackman and Eastop 2010). Apparently, almost all known populations are anholocyclic, but sexual forms, oviparae and males have been recorded from Iran and Kirghizia (Remaudière and Binazzi 2003; Zhuravlev 2003). Although it produces a huge amount of honeydew, it is scarcely attended by ants.

The area of origin of the aphid is not clear. The occurrence of several *Cinara* spp. on oriental thuja in Iran (Hodjat 1993) and the finding the principal parasitoid *Pauesia hazratbalensis* Bhagat (Starý et al. 2005) may suggest that Iran may be source of the aphid in the Mediterranean. However, this plant is probably naturalized in Iran; whereas Oriental thuja is actually *Platyclusus orientalis* originated from China and therefore we may assume that *C. tujaefilina* is native in that area (Wikipedia 2014, <http://en.wikipedia.org/wiki/>). Many coniferous species have been distributed by humans to other areas over the world. Hence, we may suggest that associated *C. tujaefilana*, like other *Cinara* spp., often followed its host plant species more or less simultaneously or successively (Starý et al. 2005). *Cinara tujaefilina* become cosmopolitan (Eastop and Lambers 1976; Binazzi 1978) and is widely distributed in the Mediterranean region (Nafria et al. 2012). It usually infests well-lignified twigs, produces large quantities of honeydew and often attended by ant and bees. Development of conspicuous sooty mold is not common and usually the aphid is not considered a pest in the Mediterranean region.

Cinara (Cupressobium) fresai *Cinara fresai* is probably indigenous in North America where it is widespread in different areas in both Northern and Southern hemisphere on several conifer genera. In the Mediterranean it is known from Israel and Spain in *Juniperus* spp. (Bustillo 1975; Mendel and Zehavi 1987; Carter and Watson 1991; Remaudière and Binazzi 2003; Lázzari et al. 2004; Nafria et al. 2012). In the Mediterranean and Europe the aphid does not seem to inflict any significant damage. *Cinara fresai* is anholocyclic with no sexual morphs (Blackman and Eastop 1994). Apteræ individuals are 3.4–4.2 mm long, pinkish-grey to dark brownish-grey, dusted with white wax, especially on the sides of thorax. It has also characteristic pairs of black patches on thoracic and anterior abdominal tergites diverging in an inverted “V” (Blackman and Eastop 1994). This aphid usually prefers the branches and trunk of a host plant and forms very small colonies always visited by ants (Durak 2012; Durak et al. 2014).

Cinara (Cupressobium) cupressi (**Buckton**) The cypress aphid *Cinara cupressi* Buckton is native to North America (Watson et al. 1999) and widely distributed in Southwest Asia, India, Africa, and South America (Carter and Maslen 1982; Murphy 1994; Blackman and Eastop 1994; Mujtar et al. 2009). *C. cupressi* is particularly known for causing extensive dieback and mortality of *Cupressus lusitanica* Miller. The tree species is native to Mexico and Guatemala and was introduced in Europe

Fig. 10.10 Damage of *Cinara cupressi* on *Cupressus sempervirens* (Photo A. Battisti)



by the Portuguese in the seventeenth century. From Portugal, *C. lusitanica* was introduced in other Mediterranean countries as well as in Brazil. The tree species is also widely planted in the East and Central African region on farmlands where it is grown for timber production.

In the Americas and Africa, *C. cupressi* develops on *Juniperus*, *Cupressus*, *Thuja*, *Chamaecyparis*, *Widdringtonia* and other Cupressaceae. In the Mediterranean basin outbreak of the aphid were observed in several countries on *Cupressus* spp., including native and exotic species (Fig. 10.10). In Italy and Israel the first outbreaks were recorded in late 1970s and early 1980s (Binazzi 1997; Mendel and Golan 1983, respectively). In Italy, the outbreaks were repeated in 1997 when the effect on the tree was much tougher than in the past; an unusual spring frost that destroyed much of the insect enemies of the aphid held responsible for the outbreak (Binazzi 1997). In Israel, no damage was recorded since the last and single outbreak.

Apterae and alatae are orange-brown to yellowish-brown, the dorsum dusted with pale grey wax making a pattern of cross-bands, with two dark wavy longitudinal stripes (Fig. 10.11). Body length is 1.8–3.9 mm. The alates are similar in appearance to the apterous viviparae. It may produce more than ten annual generations (Binazzi 1997). The life cycle is holocyclic, but in warmer and drier areas, *C.*



Fig. 10.11 Aphids of *Cinara cupressi* (left) and the honeydew (right) on *Cupressus sempervirens* (Photo A. Battisti)

cupressi shows an anholocyclic way of life (Delfino and Binazzi 2005). Although it produces a huge amount of honeydew, it is scarcely attended by ants. The aphids feed on small twigs, less than 1 cm thick, in the foliated part of the crown and inject salivary toxins which may cause branch dieback. Reddening is first recorded in the inner part and later on the whole crown, but very quickly, generally in about 10–15 days. Damage is generally associated to cool summers followed by mild winters. Surveillance of aphid colonies under such situation is thus essential, and it may lead to applications of insecticides or just water to disperse founder colonies in the very early spring (Roques and Battisti 1999).

The taxonomy of *C. cupressi sensu lato* is controversial (Remaudière and Binazzi 2003) and the fact that *C. cupressi* is an invasive species in the Mediterranean is not all clear. Watson et al. (1999) suggested that *C. cupressi* appear to belong to a species complex, *C. sabiniae*, *C. canadensis* and *C. cupressi* all occurring in North America. These authors also proposed that populations introduced from the Middle East to Africa eventually belong to a separate species, *C. (Cupressobium) cupressivora* whose origin is related to the Italian cypress *Cupressus sempervirens* forests native from eastern Greece to south of the Caspian Sea. Still, Remaudière and Binazzi (2003) rejected the proposal of *C. cupressivora* as a new species. They indicated that nearly 25 % of the specimens of the type series could not be identified using the discrimination function and since morphologically intermediate populations are found in Pakistan the distinction of the former species from *C. cupressi* is unjustified. However, the absence of specific *Cinara* sp. (if *C. cupressivora* is not a valid species) in *C. sempervirens* suggests that a molecular analysis is needed in order to clarify this question.

Murphy et al. (1991 and cited literature) listed five aphidiid species reared from *C. cupressi* from different areas, *Aphidius* sp., *Adialytus salicaphis*, *Lysephedrus validus*, *Pauesia antennata* and *Praon volucre*, and the syrphid *Scaeva selentica*. Yet, it may be important to note that both on Italy and Israel parasitoids were not recovered from the aphid population. In Chile the aphid is attacked by the fungus *Neozigites osornensis* (Retamal et al. 2013)

10.5 Broadleaves Invasive Sap–Suckers: *Corythuca* spp.

Two species from the genus *Corythuca* (Heteroptera Tingidae), native to North America are invasive in the Mediterranean basin affecting broadleaved trees (Fig. 10.12).

Corythuca ciliata The sycamore lace bug *C. ciliata* is a species associated with *Platanus occidentalis* in its native range. The bug has colonized southern Europe by infesting native *Platanus orientalis* and introduced sycamore trees, and their hybrids, either in towns or in forests. Being sycamore trees growing often on roadsides, the pest behaves like a hitchhiker and has quickly occupied the whole sycamore range after its introduction in the 1960s. The sycamore lace bug has three generations a year and overwinters as an adult under the bark scales. A female lays about 100 eggs on the lower side of the leaves, close to the ribs, and the nymphs suck out the cytoplasm of the leaf cells, causing discoloration of the blade. In case of heavy infestation, the trees turn yellow in the middle of the summer and lose the leaves earlier than usual. The species has a great potential to adapt to temperature extremes, and can tolerate exposure to temperatures as high as 41 °C (Ju et al. 2013), making it a serious threat at lower latitudes and elevations where its hosts are widely planted. In spite of active searches of natural enemies in the native range, so far no species has been shown suitable for biological control of this pest, and the management relies mainly on cultural control methods.

Corythuca arcuata The oak lace bug *C. arcuata* has a similar colonization history of the sycamore lace bug but it has arrived to Europe more recently (Bernardinelli 2006) and since then it has slowly expanded to other countries and to Middle East. Life history and damage are similar to those of the sycamore lace bug, although more limited so far. It seems that the species requires special conditions of light and water, avoiding drought-stressed trees (Barber 2010). Its role in the general syndrome of oak decline has to be further investigated.



Fig. 10.12 Adults of *Corythuca arcuata* (left) and *C. ciliata* (center) and damage of *C. arcuata* on *Quercus* indicated by the red arrow (right) (Photos: I. Bernardinelli)

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