CHAPTER 11

Aleyrodidae

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Abstract: The adults of the Aleyrodidae (whiteflies) are small winged insects usually yellow-white in colour; some species bear grey marks on the wings or are darker, even brown-black. Immatures may be misidentified as aphids or scale insects, but the "vasiform orifice" will help in separating whiteflies from other groups in slide mounted and red-stained puparia. All instars secrete wax, in the shape of powder, curls, threads or as vitreous layers. They are called "whiteflies" due to their general whitish appearance. They are mostly bisexual, but several species or "strains" show both arrhenotokous and thelytokous parthenogenesis, usually in relation to insemination. The post-embryonic development is neometabolic, consisting of four larval instars, pupae (immotile and not-feeding) and adults. Whiteflies share with other Sternorrhyncha the piercing-sucking mouthparts and the specialized "filter chamber" mid gut. They suck plant sap, killing their host plants in heavy infestations and excreting abundant liquid faeces as honeydew drops. These drops cover infested plants, which then blacken because of colonization by sooty mold fungi. The blackened plants or products are untradeable due to the sooty mold. Whiteflies may also cause physiological changes and transmit viruses. In the Mediterranean Region whiteflies live mostly on woody perennial plants. Natural or classical biological control programmes have successfully controlled current or potential pest species by the introduction of effective natural enemies. *Aleurocanthus spiniferus* Quaintance is currently of major concern to citriculture in the Mediterranean Region because it was recently introduced and no indigenous natural enemies seem to control it. As in the past, unwanted, introduced whiteflies may become key pests of citrus in the Mediterranean Region.

Keywords: Citriculture, Mediterranean Region, citrus whiteflies, bio-ecology, damage, control.

1. INTRODUCTION

The family Aleyrodidae (Hemiptera) is a taxon of nearly 161 genera placed in about 1,556 species [1]. The adults of both sexes are winged, covered with waxy powder and resemble tiny moths. Because of this they are also known as "whiteflies".

Aleyrodidae are small insects, but species up to 10 mm long occur in tropical areas [2]. Immature instars are mostly oval or elongated-oval but some species may be sub-circular, elongated or nearly cordate [3]. The whitefly life cycle consists of an egg, 4 larval instars, pupa and adult. They are neometabolic, having an immotile and unfeeding pupal stage.

Eggs have a short sub-terminal stalk [4] inserted by the ovipositor into the tissue of the host plant. The first instar larvae (crawlers) are minute, with relatively long legs and antennae. They move on the plant surface till they find a suitable site for feeding. Once settled, they remain sessile until reaching the adult stage.

The pupal stage is immotile, encased in the "pupal case" or "puparium" [5], actually the shed cuticle of the fourth stage. The identification of Aleyrodidae is based on the characters of puparium [6, 7], and the "vasiform orifice" helps in discriminating whiteflies from other Hemiptera. Aleyrodidae secrete wax in the shape of powder, curls, threads or vitreous layers by more or less obvious epithelial glands that open in simple or compound pores, mainly on exposed body surfaces.

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Whiteflies damage host plants by sucking phloem sap; heavy infestations can kill the plant. Moreover, due to their specialized "filter chamber" in the mid gut, they excrete large amount of honeydew. This is subsequently colonized by sooty mold fungi, which hinder the development of the host plant. Whiteflies also induce irregular ripening and others physiological changes and can transmit more than 100 viral diseases [8].

In Europe and in the Mediterranean Region the whiteflies fauna consists of 57 native or naturalized species in 26 genera [9, 10], mostly living on woody perennials [4, 5].

Six species of whiteflies are major pests of citrus in the Mediterranean Region, whereas three others occasionally feed on citrus. *Aleurodicus dispersus* Russell is not yet present in the continental area, having been found only in Madeira and the Canary Islands.

2. FIELD KEY TO CITRUS ALEYRODIDAE

1. Puparia black, bordered by white wax, adults bright red; wings grey-bluish with white markings ……. …… .....…***Aleurocanthus spiniferus***

-. Puparia not black, adult yellowish-white…….....2

2. Waxy secretion abundant in curls, segments and threads..... 3

-. Waxy secretion scarce, obscure …… 6

3. Puparia hidden by a copious woolly wax thick felt on the undersides of leaves; dense, sticky, large and confluent honeydew drops ……..... ....***Aleurothrixus floccosus***

-. Puparia not thus hidden even in dense populations..... 4

4. Puparia oval and prominent on the leaf undersurface because of a waxy marginal palisade..... .....***Trialeurodes vaporariorum***

-. Puparia without a waxy marginal palisade …… .....…….5

5. Puparia bearing long arched threads and curled wax ribbons, eggs on long spiralling tracks all around adults and nymphs….. ……..... ....***Aleurodicus dispersus***

-. Puparia wax-bordered, wax threads cover and are around the nymphs; eggs laid in circles, adults nest in their centre, among the egg-circles.....…***Paraleyrodes minei***

6. Puparia visible on the underside of leaves …….....…….....7

-. Puparia almost flattened and transparent, scarcely visible on the underside of leaves. Anterior spiracular and anal furrows are evident in living puparia.....…***Dialeurodes citri***

7. Puparia white to yellowish, surrounded by a translucent and faint wax fringe ……..... .....…....***Parabemisia mirycae***

-. Puparia spindle-like, not surrounded by a translucent and faint wax fringe, flattened on the underside of leaves, dorsally convex …….....……8

8. Puparia less than 1 mm long, anal setae visible..... ....***Bemisia tabaci***

-. Puparia more than 1 mm long, anal setae not visible.....***Bemisia afer***

3. MICROSCOPIC KEY TO CITRUS ALEYRODIDAE

1. Compound pores present…….....**Aleurodicinae**...2

-. Compound pores absent.....**Aleyrodinae**..3

2. Five pairs of compound pores on the dorsum: one on the cephalic area, the others on the abdomen and all are of the same size …..... ***Aleurodicus dispersus***

-. Seven pairs of compound pores, one cephalic and six abdominal. Abdominal pores of the first two pairs are smaller than the others..... .....***Paraleyrodes minei***

3. Dorsum with many (> 40) long and acute glandular spines. .....***Aleurocanthus spiniferus***

-. Dorsal disc without spines..... 4

4. Lingula head distinctly lobulate, vasiform orifice triangular with a lobulate lingual head … .....***Trialeurodes vaporariorum***

-. Lingula head not lobulate..... 5

5. Vasiform orifice triangular..... 6

-. Vasiform orifice usually circular or round…….....……8

6. Lingula with two blunt lateral tubercles, 26 short marginal setae and six anterior, posterior and caudal. Simple pores scattered on dorsum. Anterior spiracular furrows are barely visible and caudal furrow is slightly, longitudinally ridged.....*.....***Parabemisia mirycae***

-. Lingula without tubercles..... 7

7. Lingula hairy because of microtrichia. Ventral abdominal setae are almost as long as vasiform orifice..... .....***Bemisia tabaci***

-. Ventral abdominal setae are considerably shorter than vasiform orifice..... . ***Bemisia afer***

8. Wax pores at the base of the marginal teeth resemble a row of double teeth..... ..... ***Aleurothrixus floccosus***

-. No double teeth row, round vasiform orifice with indented inner posterior margin. Anterior spiracular and anal furrows evident. The puparium with one pair of dorsal papillae on prothorax, on metathorax and on the 2nd abdominal segment. Many wax pores scattered all over the pupal case dorsum.... .... ***Dialeurodes citri***

4. CITRUS ALEYRODID SPECIES

4.1. *Aleurocanthus spiniferus* Quaintance

Aleurocanthus spiniferus (Orange Spiny Whitefly, OSW) was recently found in Europe. It was collected in the Apulia Region (South Italy), where it has become acclimatized and is spreading [10]. To date the insect is widespread not only in citrus groves but also in fruit orchards, vineyards and in private gardens, on weeds and ornamental plants [11].

Diagnostic characters: Puparium: ovate, shiny-black, bordered by a fringe of white wax secretions. The female puparium is about 1.25 mm long, while that of males is about 1 mm long (Fig. **1**). OSW adults are distinctive in being bright red with metallic grey-blue wings, which cover most of the body. Light markings on the wings appear to form a across band. The eyes are reddish-brown and the antennae and legs are white with pale-yellow markings. Adult males are smaller than females (Fig. **2**). Many (>40) long and acute glandular spines project from the dorsum. Corbett [12] showed that specimens collected from *Rosa* sp. possess six pairs of submarginal spines posterior to the transverse suture, whereas specimens from *Citrus* spp. bear seven pairs, the fourth and fifth pairs being close together.

Fig. (1). Puparia of OSW on the underside of an orange leaf.

OSW identification requires slide mounting of puparia (Fig. **3**) and reliable knowledge, because of its similarity with *Aleurocanthus woglumi* Ashby, another major citrus pest not yet introduced into the EPPO area [13].

Fig. (2). *Aleurocanthus spiniferus* Quaintance Adult female.

Life history: Adults aggregate in groups on the underside of leaves to mate and lay eggs, which are fixed by a short pedicel in an arched line, consisting of 10-20 elements (Fig. **4**). Adult aggregation may be spotted by observing young leaves against the sun even from a considerable distance. Each female may lay 35 to >100 eggs, which are initially yellowish, becoming dark to brown-black as the embryo develops. Immature leaves are preferred for egg laying; infestation thus starts from the new twigs in spring. Active, black, flattened crawlers emerge and soon insert their mouthparts into the leaves to suck phloem sap. After moulting, their legs atrophy and the nymphs remain fixed to the underside of leaves by their ventral surface. Immature stages often form dense aggregations, of up to several hundred individuals, on a single leaf. Adults fly around briefly if disturbed, landing everywhere and thus dispersing passively. Dispersion may take place even by passing cars or by adhering to humans. The life cycle generally takes 2-4 months, with three to four annual overlapping generations, the number being mainly climate-dependent. OSW development slows down considerably during winter. *Citrus* spp. are the main hosts of economic importance, but in Italy the insect also infests *Vitis* cv, *Parthenocissus tricuspidata* (Sieb. and Zucc.) Planchon, *Hedera helix* Linnaeus, *Fatsia* sp., *Diospyros kaki* Linnaeus, *Laurus nobili*s Linnaeus, *Malva* sp., *Ficus carica* Linnaeus, *Morus alba* Linnaeus, *Punica granatum* Linnaeus, *Hybiscus rosa-sinensis* Linnaeus cv, *Prunus armeniaca* Linnaeus, *Cydonia* cv, *Malus* cv, *Pyrus pyraster* Burgsd., *Pyrus* cv, *Rosa* cv, *Pyracantha coccinea* M.J. Roemer, Plum cv, and *Eryobotrya japonica* (Thunb.) Lindley.

Economic importance: OSW is a well-known pest of fruit trees, mainly of citrus. In Italy *A. spiniferus* excretes copious amounts of sugary honeydew, which coat the leaf and fruit surfaces. Sooty mold fungi then quickly develop and form thick black layers that can be peeled off the leaves. Plant blackening reduces respiration and photosynthesis, resulting in low quality, small and permanently blackish products unsuitable for commerce (Figs **5-7**). This pest is therefore of much concern to citrus growers in the Mediterranean Region today. Other plants, like apples, are heavily infested by OSW, which can cause their death. Ornamentals like *Pyracantha* or *Parthenocissus*

may be ruined due to blackening. The pest is spreading on wild plants, which are now its main refuge in Italy. EPPO recently moved the OSW to the A2 list (List of Pests Recommended for Regulation as Quarantine Pests). It is also a quarantine pest for NAPPO and threatens citrus production throughout the Mediterranean Region.

Fig. (3). A slide-mounted puparium of *Aleurocanthus spiniferus* Quaintance. Note the long dorsal glandular spines.

Management: Chemical control is expensive and ineffective, and infestations build-up considerably in spring-summer, starting from neglected orchards and the wild flora. Nor is chemical control an option in citrus orchards, because it disrupts the effective classical biological control of *Aleurothrixus floccosus,* with consequent pest resurgence and pesticide resistance. Infested plants weaken and in order to dispose of blackened plant parts, growers prune the orchards severely, burning the infested cut branches. This measure however results in much re-sprouting of twigs and thus in new pest infestations. As a result the orchard can be severely damaged and even destroyed by the pest. Low impact insecticides and fungicides, like soap salts and oils, could be useful in controlling the crawlers and reducing the sooty mold, until effective classical biological control will be established.

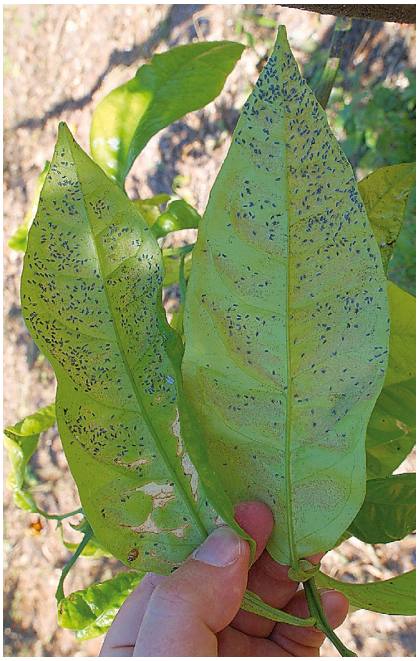

Fig. (4). A reproductive aggregation of OSW adults underside immature orange leaves.

Pesticides should be applied when the pest populations are at a very low level and may be sampled on young, fully extended leaves, due to the oviposition preferences of the pest. A Hymenopteran natural enemy complex was applied against *Aleurocanthus spiniferus* by Silvestri [14], and has proven to be effective in different parts of the world [15 - 17]. *Encarsia smithi* (Silvestri) and *Amitus hesperidum* Silvestri have been successfully used to control the pest in Japan and in Guam [17] and in Ponape, Federated States of Micronesia [18]. The introduction of such useful parasitoids in a IPM program seems to be the only effective measure to control *A. spiniferus.*

4.2. *Aleurodicus dispersus* Russell

The spiralling whitefly (SW) is not yet recorded in continental Europe and Mediterranean countries, but it occurs in the Canary Islands [19 - 21], and more recently became established in Madeira [9] where it is a major pest.

Fig. (5). Sooty mold on OSW infested mandarin leaves.

Fig. (6). Orange blackened by sooty mold due to OSW honeydew.

Both places are politically linked with Mediterranean countries, so the pest is discussed herein due of its quarantine importance.

Fig. (7). Stained, unmarketable fruits from OSW infested plants.

Diagnostic characters: SW adults are almost uniformly white, about 2 mm long. The fourth instar nymph is colourless or yellowish. It secretes wax in long arched threads by its multilocular pores and curled ribbons by the dorsal and marginal pores. The shape of these secretions is singular but ephemeral and may be obscured in dense, overcrowded populations. SW secretes an impressive amount of wax and a thick layer of white matter covers leaves under the surface of infested plants (Fig. **8**). On slides the puparium is 1 mm long and 0.75 mm wide; five pairs of compound pores are on the dorsum: one on the cephalic area, the others on the abdomen [22].

Life history: Each female lays about 21 eggs along a semicircular track marked by white wax, hence the common name of the species (Fig. **9**). Each egg is fixed at right angles to the leaf veins. The eggs hatch after 7-10 days and the crawlers settle near the eggshell, thus maintaining the spiral pattern.

Fig. (8). SW infesting a *Ficus reticulata* (?) urban ornamental tree in Las Palmas de Gran Canaria (photo of May, 2003).

Few larvae move to the leaf margin. Total development time is 22-47 days and adults live about two weeks [23].

Fig. (9). The typical egg laying pattern of the spiraling whitefly on the underside of a leaf of *Strelitzia nicolai* Regel and K. Koch.

Populations of SW may decrease following heavy rains and low temperatures but the pest resurges in warmer and drier weather. Adults suffer at temperature over 35°C and there is much mortality of the young above 40°C. The low temperature limit for SW is around 10°C [24]. This whitefly is highly polyphagous, being common on many different plant families of shrubs and trees, but *Citrus* spp. are among the less susceptible economic host plants known [25].

Economic importance: *Aleurodicus dispersus* damages plants directly by sucking sap, and indirectly by the wax, by the excretion of honeydew and due to the resulting sooty mold. As with *Aleurocanthus spiniferus*, recently introduced and established species are a problem because of their sudden economic impact as they enter a new biogeographical area. Although at this time *A. dispersus* presents only a moderate phytosanitary risk to the tropical and subtropical areas at the limits of its distribution [9], its introduction nevertheless represents a considerable economic risk for citrus and fruit producers in the Mediterranean Region.

Management: The avoidance of unwanted pests is beyond the scope of this chapter. Whiteflies are quite small and cryptic organisms that can pass even the most diligent quarantine inspection services.

However, a careful check of the citrus orchard and the exclusive use of official or certified propagation material are good starting points for a less risky citrus orchard management. Ornamental plants also play a role in the dispersion of such polyphagous pests like SW or *A. spiniferus*, as there are ornamental or garden citrus species that can host these whitefly pests.

Finally we emphasize the role of classical biological control in whitefly IPM, even though some natural enemies are not sufficiently effective in reducing pest populations to below their economic threshold levels. Nevertheless, natural enemies greatly contribute to whitefly IPM.

4.3. *Aleurothrixus floccosus* Maskell

Diagnostic characters: The Woolly Whitefly (WW) pupal case is yellowish, with brown to black individuals being scattered in the population, and the case is usually hidden by copious amounts of greyish white wax threads. The underside of infested leaves is layered by thick woolly wax with dense, sticky, large and confluent honeydew drops (Fig. **10**). The pupal case is less than 1.0 mm long to 0.6 mm wide. The dorsum of the pupal case bears metathoracic setae, 8th abdominal setae, and stout caudal setae. The vasiform orifice is nearly circular, almost filled by the operculum (Fig. **11**). Wax pores occur at the base of the marginal teeth that resemble a double teeth row (Fig. **12**). Adult woolly whiteflies are small, flying insects similar to small white-winged moths, with a yellowish-white abdomen and a light dusting of white powder.

Life history: Each female may lay up to 200 eggs that are inserted into the undersides of fully expanded leaves by a stalk. Eggs are small (<0.3 mm in length), kidney shaped, and are placed in circle or semicircle. The egg laying site is distinctive for the species because of the light dusting of wax that surrounds the egg circles. The eggs hatch in 4-12 days. WW require about 21 day to complete its life cycle and has five to seven broods per year [26-28], with a moderate

summer decline. Population outbreaks of *Aleurothrixus floccosus* occur from late May to November, depending on the climate and on host plant sprouting. The pest overwinters mainly as third and fourth instars or as eggs.

Economic importance: WW sucks phloem sap and excretes large amount of dense honeydew droplets that are trapped by the woolly wax layer, thus constituting a thick sticky felt (Fig. **6**). Black sooty mold fungi soon colonize this felt, causing leaves to wilt and drop in heavy infestations, which can result in the blackening of entire trees. Moreover, the viscous honeydew collects dust particles, thus further reducing photosynthesis and gas exchange and resulting in decreased fruit size. Although some of this contamination may be washed off at packaging, harvesting is slowed in infested orchards and workers hesitate or refuse to enter heavily infested orchards. This species was one of the most important citrus pests in the Mediterranean Region until it was controlled by two small Hymenopteran parasitoids, namely *Amitus spiniferus* (Brethes) (Platygastridae) and *Cales noacki* Howard (Aphelinidae).

Fig. (10). A moderate infestation of the woolly whitefly on the underside of a citrus leaf. Note the large confluent drops of thick honeydew.

Management: Chemical control of *A. floccosus* is mostly ineffective, whereas biological control is the best and most effective means of controlling this pest (Fig. **13**). There are several natural enemies that attack the immature stages of WW. Apart from parasitoids, which have proven to be extremely effective and are the key antagonists of the pest, useful arthropods include the mite *Tydeus* spp., lacewings, coccinellid beetles, nabids, *Orius*, and six-spotted thrips. Unfortunately parasitoids are less heat tolerant than WW, which results in local pest outbreaks in late summer. This engenders pesticide applications that eliminate the natural enemies, resulting in pest resurgences. Outbreaks of WW can be contained by the release of suitable parasitoids, by "soft" insecticides and by tree pruning.

Fig. (11). Slide mounted puparium of *Aleurothrixus floccosus*. The metathoracic dorsal setae are broken (red stain is artificial).

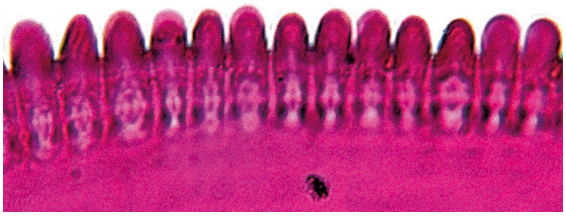

Fig. (12). The row of false double teeth at the border of the WW puparium.

4.4. *Bemisia afer* Priesner and Hosny

Diagnostic characters: The puparium is oval in outline, yellow, flattened, placed on the undersides of leaves, dorsally convex. It is about 1 mm long. The vasiform orifice is triangular in shape. The ventral abdominal setae are short and invisible on living puparia when observed through a dissecting microscope.

Life history: Life cycle of the species is unknown; in general its populations are low because of the natural biological control brought about by parasitoids. *Bemisia afer* is very polyphagous [4, 29].

Economic importance: *Bemisia afer* has no economic importance.

4.5. *Bemisia tabaci* Gennadius

Diagnostic characters: The Sweet Potato Whitefly (SPW) puparium is similar to that of *B. afer*, but smaller, being about 0.75 mm long and bearing long and apparent ventral abdominal setae. The adults are pale yellow and the wings are powdered by white wax. Slide mounted puparia show the wide morphological variability of the species, which is caused by the host plant. The vasiform orifice is triangular in shape; the lingula is devoid of a tubercle but hairy because of microtrichia. The ventral abdominal setae are considerably longer that those of *B. afer,* almost as long as the vasiform orifice.

Fig. (13). Three puparia of the woolly whitefly with holes bored by emerging adult parasitoids. From the fourth (top, right) a whitefly had emerged.

Life history: *Bemisia tabaci* reproduces by parthenogenetic arrhenotoky, unmated females laying haploid eggs from which only male crawlers emerge. Fertilized females lay both haploid (male) and diploid (female) eggs, placed on the leaves' surface [3] [30]. The pest is very polyphagous, infesting over 500 plant species in 63 families [31, 4], including vegetables, field and ornamental crops. Citrus trees are not among its preferred hosts.

Economic importance: SPW causes direct and indirect damage to plants [30]; on citrus it is only a secondary pest.

Management: Several natural enemies regulate SPW populations in citrus orchards. They include the Hymenopterous *Encarsia pergandiella* (Howard), *Encarsia transvena* (Timberlake), *Encarsia nigricephala* (Dozier) and several species of *Eretmocerus.* Effective parasitoids, such as *Eretmocerus eremicus* Rose and Zolnerowich, or lacewings and coccinellid predators are commercially available to control the SPW.

4.6. *Dialeurodes citri* Ashmead

Diagnostic characters: The Citrus Whitefly (CW) adults are pale yellow, 1.4 mm long, coated with white wax. Each wing has a weak area near the apex of the fore wings. The puparia are almost flattened and diaphanous, thus somewhat obscure on the undersides of the leaves (Fig. **14**). Wax secretion is meagre and hyaline, thus apparently absent. The pupal case (Fig. **15**) is elliptic, 1.3 mm long and 0.9 mm wide. The confluences of the anterior spiracular and anal furrows form a whitish Y-like mark on living puparia. The exuvial casts are pale after the emergence of the adults and then resemble whitish spots on the undersides of infested leaves. The puparium has one pair of dorsal papillae on the prothorax, on the metathorax and on the 2nd abdominal segment; in addition, many wax pores are scattered all over the dorsum of the pupal case. The vasiform orifice is round with an indented inner posterior margin and covered by the operculum. Anterior spiracular and anal furrows are evident.

Life history: A female lays about 90-110 eggs on the undersides of citrus leaves and on many other host plants. The inner, shaded tree parts are the preferred oviposition sites, the stalked eggs being inserted into fully extended leaves. The pest also occurs on coffee, gardenia, lilac, myrtle, mock olive (*Notelaea venosa* F. Muell.), pear, *Smilax* sp. and wild olive (*Olea europaea* Linnaeus *oleaster*) [32]. SPW reproduces by parthenogenetic arrhenotoky, unmated females laying haploid eggs from which only male crawlers emerge. Under long day conditions at 25°C, a life cycle requires about 54 days. The adults live for about two weeks. On citrus in the eastern Mediterranean Region the pest usually completes three generation, the first (April-June) in about ten weeks, the second (July-August) in seven weeks and the third, which usually overwinters as egg or as IV larva, lasts until the following spring. A small fraction (5%) of the population develops in the autumn, thus creating a fourth generation, whose adults also emerge in the spring [33]. CW populations peak from May to July. The threshold of development is at 11.3°C.

Fig. (14). CW puparia the undersurface of a tangerine leaf in a mixed infestation with *Lepidosaphes beckii* (Newman) (Diaspididae: Coccoidea).

Economic importance: The citrus whitefly invaded the Mediterranean Region in 1945. Most of its damage is due to copious amounts of honeydew secreted by its nymphs that are colonized by sooty mold fungi (Fig. **16**). These fungi

contaminate the fruit, obstruct respiration and disrupt photosynthesis, leading to leaf drop and yield reduction [34]. Heavily infested citrus trees weaken and produce small and flavourless low-quality fruits. The black sooty mold interferes in the ripening process, which is delayed in infested trees.

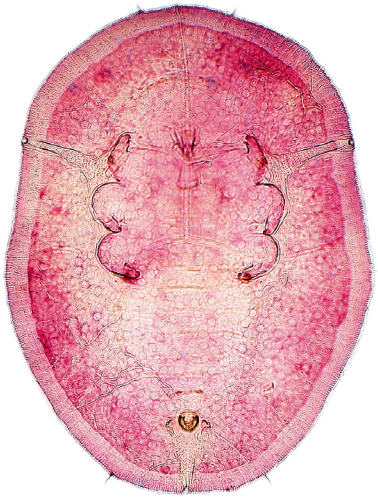

Fig. (15). Slide mounted puparium of *Dialeurodes citri* Ashmead (slide thanks to M.G.M. Jansen, Plant Protection Service, Wageningen, The Netherlands).

Heavily infested leaves become intermittently white-and-black, due to the pest's colouring and the sooty mold. Among citrus hosts it prefers orange and Easy Peeler cultivars.

Fig. (16). Sooty mold blackening a CW-infested tangerine leaf. *Lepidosaphes beckii* (Newman) (Coccoidea Diaspididae) that co-infests the leaf does not excrete honeydew.

Management: The sooty mold may be washed away before marketing, as a commercial management measure [32]. Two natural enemies can be employed to control this pest, both attacking the nymphs: the predator *Clitosthetus arcuatus* (Rossi) (Coccinellidae: Coleoptera) and the chalcid endoparasitoid *Encarsia lahorensis* (Howard) (Hymenoptera), which has been successfully introduced into Italy. Entomopathogenic fungi, like *Aschersonia aleyrodis* Webber and *Aegerita webberi* Fawcett may reduce CW populations, only in tropical moist climates rather than in the Mediterranean Region, where whiteflies are secondary targets of the chemical control of scale insects control.

Two introduced hymenopterous endoparasitoids, namely *E. lahorensis* and an *Encarsia* sp., usually control the pest in Israel [34]. Two predatory coccinellids, *C. arcuatus* and *Serangium montazerii* (Fürsch) also feed on the CW [35]. When chemical control is required, several IGRs (*e.g.* buprofezin that affects molting if applied in early June, or pyriproxifen, which kills developing eggs) should be applied in late April to early May [36, 37]. Oils are useful in removing the sooty mold from the fruits and leaves. Due to the oviposition preferences of the pest, only young, fully extended leaves should be sampled for eggs during its first generation. The recommendation is to sample four leaves per tree, one from the interior of each examined tree, plus three from the periphery, preferably from the northern and southern sides. A good precision level of 0.30 can be achieved by leaves from 11 trees, coming to a total of 44 leaves. For larval sampling (which incorporate sooty mold threshold levels) seven trees (28 leaves) may be taken for the same precision level.

In the second and third generations, one of the four leaves should be young and leaves from nine trees, a total of 36, would suffice to obtain a precision level of 0.25, whereas nine trees (36 leaves) should be sampled for the second and third generations [38]. In the past the CW was a primary citrus pest in the Mediterranean Region, but its importance has considerably decreased during the years [39].

4.7. *Parabemisia myricae* Kuwana

Diagnostic characters: The Japanese Bayberry Whitefly (JBW) lays white eggs that turn black as the embryos develop. Nymphs are white to yellowish, with a faint translucent wax fringe that borders the 4th instar nymph. The puparium is flattened and devoid of prominent setae or spines. It averages 0.85 mm in length and 0.65 mm in width. The adults are smaller than those of WW and CW, about 1.10 mm long, lemon yellow with white wax powered wings. The cuticle of slide-mounted fourth-instar nymphs shows only few details, such as 26 short marginal setae plus six anterior, posterior and caudal setae and scattered dorsal pores. The first abdominal tergum is devoid of setae. The anterior spiracular furrows are barely visible and the caudal furrow is slightly longitudinally ridged. The vasiform orifice is elongate-triangular; the lingula has two blunt lateral tubercles [40].

Life history: JBW is thelytokous, the males being quite rare [41]. Each female produces about 70 eggs that are inserted singly or in semi-circles, mostly into the leaf margins [40] of very young leaves in the "feather" stage [42]. The crawlers usually migrate to the underside of the leaf to settle and feed, but some remain on the upper surface. At 23.3°C a life cycle required 17-23 days. The pest develops throughout the year; its populations surging during the spring growth flush, as the temperatures rise [43]. Among citrus species it developed fastest on lemons, whereas the highest mortality rates of the immature stages was on trifoliate (*Poncirus trifoliata* (Linnaeus) Raf.) [44]. The pest also infests many tropical and subtropical fruit trees.

Economic importance: Injury is due mostly to the copious amounts of honeydew secreted by the juveniles and colonized by sooty mold fungi. These fungi obstruct respiration and hinder photosynthesis, leading to disruptions in growth and to yield reductions, sometimes causing defoliation [41]. There is also a direct feeding damage, because the pest feeds mostly on leaves that develop on the new terminal growth, leading to pit-like leaf distortions and to twig deformations [43].

Management: Natural enemies such as *Encarsia bemisiae* De Santis (Aphelinidae) [45] control *Parabemisia myricae* in Japan. The aphelinid endoparasitoid *Eretmocerus debachi* (Rose and Rosen) [46] completely controls the pest in most Mediterranean countries. In Israel, several parasites and predators have been found on *P. myricae*, including phytoseiid mites [47]. Prospects for biological control thus seem good, should the pest invade other Mediterranean countries. Outdoors JBW is usually under biocontrol, outbreaks occurring only after applications of inappropriate pesticides that disrupt the activities of its natural enemies.

4.8. *Paraleyrodes minei* Iaccarino

Diagnostic characters: The Nesting Whitefly (NW) adults are uniformly pale yellow and lay pale yellow eggs, usually surrounded by fluffy wax. The pupal case is fringed by broad ridged wax ribbons that curve downward and usually cover and surround the case. The pupal case is 0.8 mm long and 0.6 mm wide, with six distinctive pairs of compound wax pores on the dorsal abdominal segments. Seven pairs of compound pores, one cephalic and six abdominal, are on located on the puparium. The abdominal pores of the first two pairs are smaller than the others [48]. Such compound wax pores are diagnostic of the sub-family Aleurodicinae. In the field NW may be misidentified as *Aleurodicus dispersus* (SW) due to its prominent ribbon-like wax matter, as *Metaleurodicus cardini* (Back), which shows a weak ribbon-like wax border, or as *Aleurothrixus floccosus* that secretes abundant thread-like wax.

Life history: This species is arrhenotokous. It lays about 60 eggs/female in rings on the undersides of leaves, protected by the adult or nymphal wax secretions. The common name "nesting whitefly" is due to the behaviour of the adult, as it nests in the centres of the egg-rings. NW is very polyphagous and annually raises up to nine overlapping generations, with continuous development on mandarins. It overwinters as adult in the Middle East [49] as well as in California [50].

Economic importance: NW is not considered an invading species in Syria [51], being only considered as a potential pest [52], but in Lebanon it infests citrus orchards in large numbers [53]. The species is invasive also in California [54]. NW causes direct damage by sucking plant sap and injecting toxic saliva. Sooty mold fungi colonize the large amounts of excreted honeydew, affecting plant metabolism and lowering the quantity and quality of the product.

Management: Chemical control of the NW is expensive and difficult, and no effective natural enemies of this whitefly are known. Pest levels may be lowered by agronomic measures, like pruning, along with mineral oil sprays. Natural enemies, like *Encarsia variegata* Howard [55] are promising, but have not yet been assayed against NW.

4.9. *Trialeurodes vaporariorum* Westwood

Diagnostic characters: The Greenhouse Whitefly (GW) puparium is oval and prominent on the leaf underside because of a waxy marginal palisade. Individuals on hairy leaves bear long thorn-like wax filaments on their dorsum, which may not be seen on glabrous host plants. Adults are faintly yellow, about 1 mm long. The vasiform orifice is triangular with a distinctly lobulate lingula.

Life history: The duration of the development of GW depends on the ambient temperatures. Reproduction is by parthenogenesis, and several generations may overlap on the hosts. The adults aggregate at the tips of shoots, as they prefer young leaves on which they attain high densities, even on unsuitable hosts. When disturbed the adults suddenly fly away. GW is extremely polyphagous, having been recorded from more than 200 plant genera, including many herbaceous and some monocotyledonous plants, and even a cycad [4]. Many more hosts have been recorded since, included *Citrus* spp.

Economic importance: GW is a major pest that reduces plant vigour, sucking sap from leaves and excreting honeydew that is colonized by sooty mold fungi. It may also transmit virus diseases. Nevertheless, it is only a secondary, occasional pest of citrus.

Management: Oil sprays can control WG population outbreaks until the buildup of a local or a temporarily-missing natural enemy complex.

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