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Whiteflies (Hemiptera: Aleyrodidae) intercepted on plant product imported to South Korea from 2013–2021

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Abstract. Current globalization and technological progress has facilitated and increased the international trade of plant products worldwide and has promoted the long-distance movement of immobile sucking pests such as whiteflies attached on plants. Therefore, being able to compile and update information on intercepted insect pests will help to improve the inspection procedures, to detect, identify and mitigate the damage caused by exotic invasive pests. Records of whiteflies (Hemiptera: Aleyrodidae) intercepted on import plants from 2013 to 2021 in the Pest Information System (PIS) database of South Korea were analyzed. A total of 32 species belonging to 19 genera were intercepted on plants imported into South Korea from 20 countries, mostly located in the Oriental region including China. Brief diagnoses, an identification key and photographs of the 32 species intercepted on agricultural commodities and the countries from which they were detected on plants are given to assist in their identification. In addition, this information provides background data and scientific rationale for decisions regarding the management of whiteflies intercepted at the South Korean ports on imported plant products to prevent the introduction and establishment of exotic whiteflies into South Korea.

Key words. Exotic whiteflies, invasive species, plant trade, pathways, quarantine.

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Introduction

Exotic pests have caused huge losses to agriculture, forestry and human health (Zhao et al. 2021). Current globalization and technological progress have facilitated and increased the international trade of plant products worldwide and has promoted the longdistance movement of sessile sucking pests such as whiteflies, scale insects, psyllids and aphids attached on plants. To prevent the introductions of harmful insects along these pathways, countries apply biosecurity measures to imported plant goods and products, including visual inspections at the points of entry (Saccaggi et al. 2021). Therefore, being able to compile and update information on intercepted insect pests will help to improve the inspection procedures, to detect, identify and mitigate the damage caused by exotic invasive exotic pests. Records of whiteflies (Hemiptera: Aleyrodidae) intercepted on import plants from 2013 to 2021 in the Pest Information System (PIS) database of South Korea were analyzed. A total of 32 species belonging to 19 genera were intercepted on plants imported from 20 countries into South Korea. Whiteflies are quite small (usually 1 to 3 mm in body length) and are prolific insects that feed on plants. They have long been considered as economically important insect pests on a global scale, and present a special challenge to regulatory efforts since they are of economic importance as direct feeders and/or vectors of plant viruses and are often difficult to detect (Mound and Halsey 1978; Gerling 1990). Recently, the amount of plant material imported from other countries into South Korea has increased significantly and many of these plants serve as hosts for whiteflies (PIS 2022). As a result, the number of whiteflies intercepted at various ports of entry in South Korea has also increased and may pose a threat to Korean agriculture if they escape detection and become established. The invasive whiteflies such as *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood), are now major pests in South Korea and cause severe damage to crops in glasshouses and are the most commonly reported whiteflies in South Korea (Park 2010; Suh 2014; Park et al. 2019).

This paper includes a checklist, a brief diagnosis of the puparium, and identification key and photographs of 32 species of whiteflies intercepted on plants imported into South Korea from 2013 to 2021 and is aimed at facilitating the identifications of whitefly species by port identifiers at the various stations of the Animal and Plant Quarantine Agency (APQA). In addition, this information provides a background data and scientific rationale for managing whiteflies intercepted in quarantine at South Korean ports on imported plant material and will help to prevent the entry and establishment of exotic whiteflies into South Korea and the subsequent damage they would cause to domestic agriculture.

Materials and Methods

Data on whiteflies intercepted at ports of entry to South Korea on imported plants between 2013 and 2021 was extracted from the Pest Information System (PIS), a database developed by the Animal Plant Quarantine Agency (APQA). In total, 2301 specimens of whiteflies were intercepted during phytosanitary inspections on plants imported into South Korea from 2013 to 2021. When cataloguing intercepted whiteflies, the checklist contains the identification of specimens to the level of species or genus depending upon the quality of the sample and the life stage and a summary of distribution and host information based on data provided by Jensen (2001), Evans (2007), Dubey and Ko (2010), Kondo and Evans (2012), Suh and Evans (2012) and Ouvrard and Martin (2022). The identification of whiteflies is mainly based on characteristics found in the 4th-stage nymph, known as the puparium. The other stages can usually be obtained by breeding. Of the specimens that were detected, approximately 76% (1753 specimens), 0.8% (18) and 23.2% (530) of them were identified to species, genus and family level, respectively. Slide-mounted specimens examined are deposited in the Collection of Plant Quarantine Technology Center (PQTC), APQA. Terminology for morphological structures follows Martin (1987). Photographs were taken using an AxioCam MRC5 camera mounted on a ZEISS Axio Imager M2 microscope. The taxonomy used follows Ouvrard and Martin (2022).

Results and Discussion

Table 1 presents a list of the whiteflies that were intercepted on plants imported into South Korea during the survey (2013 to 2021), along with South Korea quarantine pests, total number of interceptions, countries from which whiteflies were intercepted on plants and whether or not the whitefly species occurs in South Korea. Of whitefly species detected at ports of entry during this survey, 78% (25 species) were not known to occur in South Korea at the time they were detected and 38% (12 species) are categorized as quarantine pests in South Korea. Whiteflies were intercepted at South Korean ports on plant material imported from 20 different countries of which quarantine whiteflies were intercepted from 17 countries. The largest numbers of whiteflies were intercepted from the Oriental (91.5%) region, followed by the Palaearctic (5.3%), Nearctic (2.4%), Afrotropical (0.5%) regions; the other regions (0.3%) are each represented by only one or a few interceptions. The country of origin with the most frequent interceptions was China (69.2%; 1225 times) followed by Vietnam (12.7%; 225), Thailand (4.3%; 77), Netherlands (3.1%; 55), Japan (2.4%; 42), USA (2.4%; 42), Israel (2.0%; 36) and the remaining 13 countries comprised 3.9% (69).

Of the 32 species collected, *Bemisia tabaci* (Gennadius) constitutes 81.2% (1438 times) of the interceptions and it is the most common intercepted species followed by *Trialeurodes vaporariorum* (Westwood) at 6.9% (122), *Tetraleurodes ursorum* (Cockerell) at 1.5% (27) and *Parabemisia myricae* (Kuwana) at 1.4% (25). In terms of host plants, *Chrysanthemum* spp. (cut flowers) accounts for 53.9% (956 times) of the interceptions and it is the most common intercepted host plant followed by *Brassica* spp. (vegetables) at 16.8% (299). The following notes outline the main characters of the 32 species of whiteflies, along with their region of origin and host species or genera of agricultural commodities.

1. *Aleurocanthus rugosa* Singh (Fig. 1–2)

Diagnosis. Puparium pale or light yellow. Dorsomedial setae on at least abdominal segment (A) 1–A5 much longer than the vasiform orifice. Dorsal disc with more than 19 pairs of spines with fimbriate apices.

Korean quarantine notes. This species was described from India (Oriental region) and was intercepted five times from Myanmar and Vietnam on *Piper betle* (Piperaceae). However, this whitefly species is not known to occur in South Korea (Lee 2019).

2. *Aleurocanthus spiniferus* (Quaintance) (Fig. 3)

Diagnosis. Puparium black. Puparial margin covered with wax secretion. Margin toothed; at least 6 teeth occupying 0.1mm of margin (Martin 1987). Dorsal disc spines acute; submargin normally with 11 pairs of stout spines in a row, all similar in length.

Korean quarantine notes. This species was described from Java (Oriental region) and was intercepted four times; China on *Pieris japonica* (Ericaceae), Japan on *Camellia japonica* and *Camellia sinensis* (Theaceae) and Thailand on *Musa sapientum* (Musaceae). It is distributed in South Korea (Lee 2019).

3. *Aleurocanthus woglumi* Ashby (Fig. 4–5)

Diagnosis. Puparium black. Puparial margin covered with wax secretion. Margin toothed; about 3.5–5 teeth per 0.1mm of margin (Martin 1987). Dorsal disc spines acute; submargin usually with 11 pairs of stout spines in a row with cephalothoracic and caudal pairs alternately longer than adjacent ones.

Korean quarantine notes. Although this whitefly was described from Jamaica (Neotropical region), it is probably native to southeast Asia where effective natural enemies have been found. It is nearly worldwide in distribution and was intercepted five times; Myanmar on *Citrus medica* (Rutaceae); Thailand on *Citrus aurantifolia* (Rutaceae). It is not known to occur in South Korea (Lee 2019).

4. *Aleuroclava aucubae* (Kuwana) (Fig. 6)

Diagnosis. Puparium black. Submarginal area well defined with many furrow-like lines. With linear pale patches on the cephalothorax. Abdomen with a very sclerotised median rachis without lateral arms. Thoracic tracheal clefts distinct with its fold represented by an oval or semi-circular shaped area extending into the submarginal area. Vasiform orifice circular. Caudal furrow slender, narrow and slightly widened towards the hind end.

Korean quarantine notes. This whitefly species was described from Japan (Eastern Palaearctic region) and was intercepted once from Japan on *Diospyros rhombifolia* (Ebenaceae). It is distributed in South Korea (Suh 2014).

5. *Aleuroclava euryae* (Kuwana) (Fig. 7)

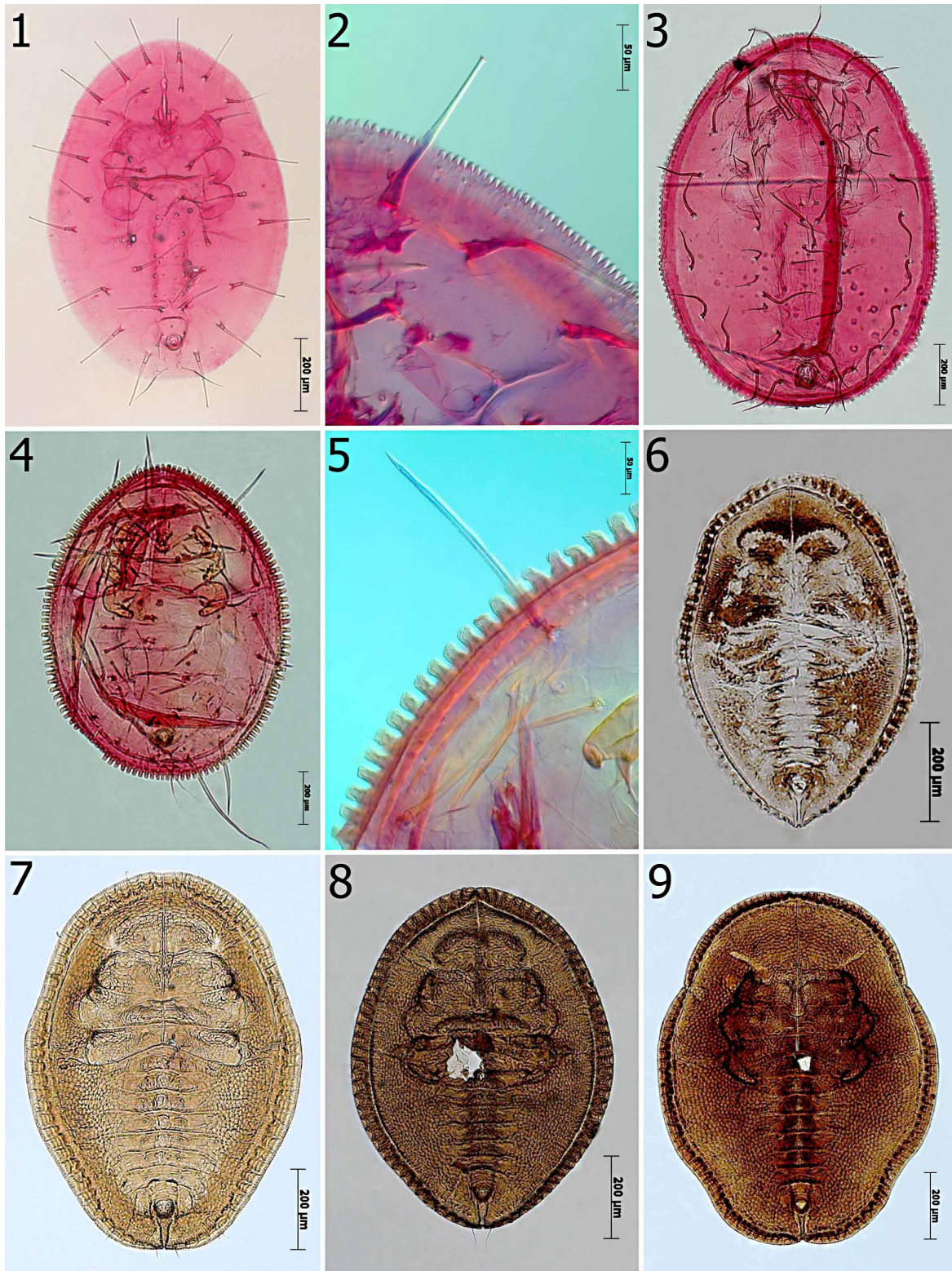
Diagnosis. Puparium black. Submarginal area well defined. Abdomen usually with a slightly elevated median area with lateral arms; two rows of minute circular pores present. Thoracic tracheal clefts small. Vasiform orifice circular. Caudal furrow distinct, slightly narrowed towards the hind end.

Korean quarantine notes. This species was described from Japan (Eastern Palaearctic region) and was intercepted three times from Japan on *Pieris japonica* (Ericaceae). It is distributed in South Korea (Suh 2014).

6. *Aleuroclava gordoniae* (Takahashi) (Fig. 8)

Diagnosis. Puparium black. Submarginal area with many transverse ridges. Thoracic tracheal folds faintly discernible; tracheal pore with small projections. Vasiform orifice subcordate. Caudal furrow distinct, expanded basally.

Korean quarantine notes. This species was described from Taiwan (Oriental region) and was intercepted nine times from China on *Pieris japonica* (Ericaceae). It is not known to occur in South Korea (Lee 2019).



Figures 1–9. Seven species of whiteflies. 1–2) *Aleurocanthus rugosa* Singh, puparium and spines with fimbriate apices. 3) *Aleurocanthus spiniferus* (Quaintance), puparium. 4–5) *Aleurocanthus woglumi* Ashby, puparium and thoracic margin. 6) *Aleuroclava aucubae* (Kuwana), puparium. 7) *Aleuroclava euryae* (Kuwana), puparium. 8) *Aleuroclava gordoniae* (Takahashi), puparium. 9) *Aleuroclava hikosanensis* (Takahashi), puparium.

7. *Aleuroclava hikosanensis* (Takahashi) (Fig. 9)

Diagnosis. Puparium black. Abdomen much constricted at the posterior half. Submarginal area well defined. Eyespots pale, oblique slender rod-shaped. Scattered minute circular pores present on dorsum. Thoracic tracheal folds broadened basally; tracheal clefts small, but distinct. Caudal furrow distinct, somewhat longer than the vasiform orifice.

Korean quarantine notes. This species was described from Japan (Eastern Palaearctic region) and was intercepted 24 times from Japan on *Pieris japonica* and *Enkianthus perulatus* (Ericaceae). Although this whitefly is known to occur in South Korea, it is rarely collected (Suh 2010, 2014; Lee 2019).

8. *Aleuroclava jasmini* (Takahashi) (Fig. 10)

Diagnosis. Puparium white to pale. Small papillae arranged in a single row along the margin of the puparium. Cephalothorax with 5 pairs of submedian tubercles. Median tubercles on abdominal segment present. Metathoracic tubercles with brown pigment.

Korean quarantine notes. This species was described from Taiwan (Oriental region) and was intercepted four times; Japan on *Jasminum sambac* (Oleaceae), Thailand on *Citrus hystrix* (Rutaceae) and Myanmar on *Madhuca longifolia* var. *latifolia* and *Mimusops elengi* (Sapotaceae). It is not known to occur in South Korea (Lee 2019).

9. *Aleuroclava neolitseae* (Takahashi) (Fig. 11)

Diagnosis. Puparium black. Cephalothorax without tubercles. Transverse suture reaching the margin. With many small circular papillae distributed on the dorsum. Vasiform orifice with 2 eminent pointed lateral tubercles.

Korean quarantine notes. This species was described from Taiwan (Oriental region) and was intercepted twice; Indonesia on *Rhaphidophora foraminifera* (Araceae) and Malaysia on *Monstera lechleriana* (Araceae). It is not known to occur in South Korea (Lee 2019).

10. *Aleuroclava similis* (Takahashi) (Fig. 12)

Diagnosis. Puparium pale, about 0.73–0.81 mm long. Marginal teeth rounded. Cephalothorax not indented at the front, not constricted across the thoracic tracheal pores, caudal furrow not constricted near the base. Venter with many faint circular markings. Vasiform orifice rounded.

Korean quarantine notes. This whitefly was described from Japan (Eastern Palaearctic region) and was intercepted eight times from Japan on *Pieris japonica* (Ericaceae). It is not known to occur in South Korea (Lee 2019).

11. *Aleurodicus dispersus* Russell (Fig. 13)

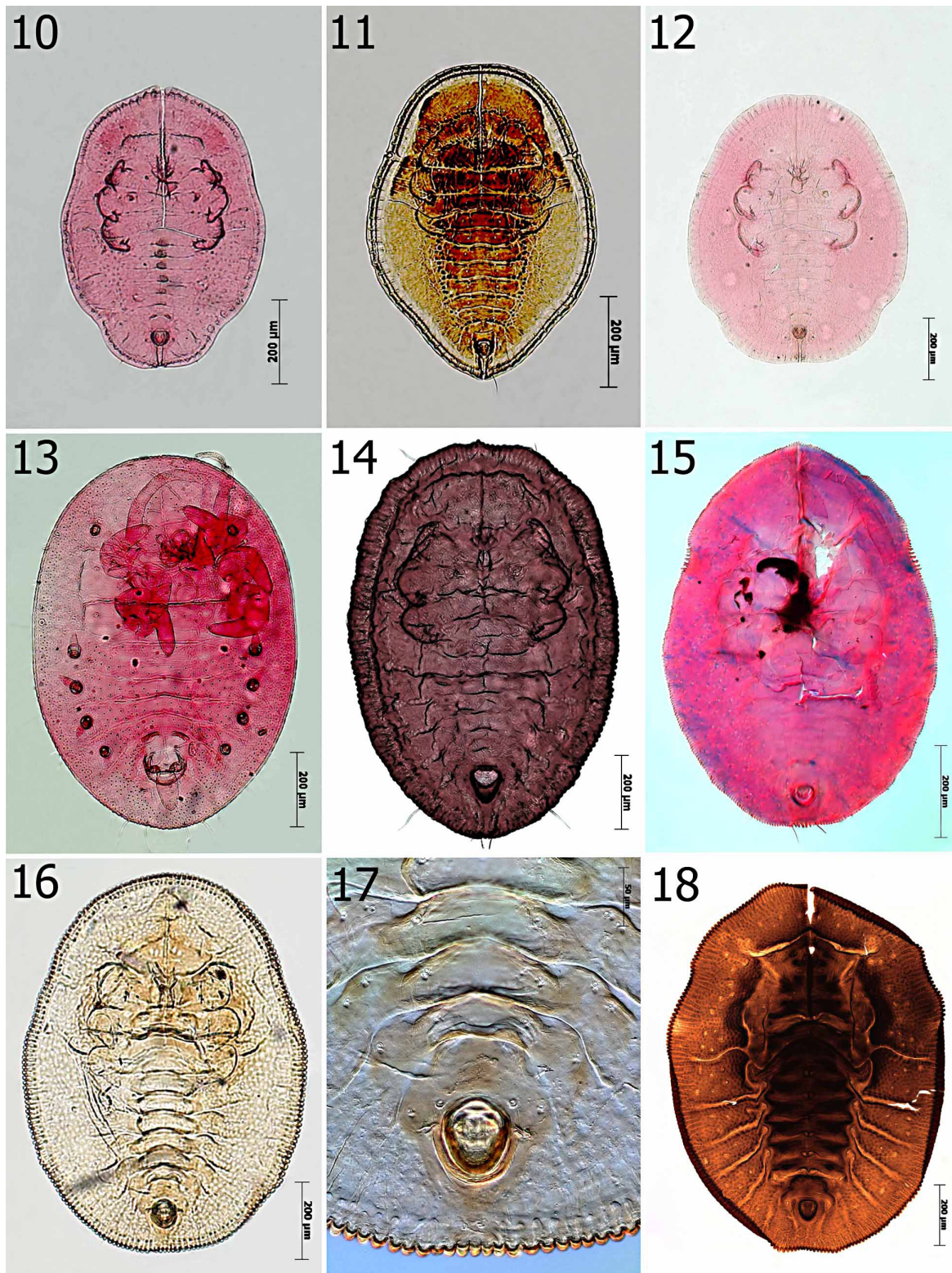
Diagnosis. Puparium pale to yellowish. Subdorsum with wax producing compound pores similar in size, compound pores with central process, one cephalic pair and 4 abdominal pairs. Vasiform orifice subcordate wider than long; lingula large, tongue-shaped, extending beyond posterior margin of vasiform orifice, with 2 pairs of setae at apex.

Korean quarantine notes. This whitefly was described from the United States (Nearctic region) and was intercepted three times; Thailand on *Musa sapientum* (Musaceae) and Vietnam on *Phrynium* sp. (Marantaceae). It is not known to occur in South Korea (Lee 2019).

12. *Aleurolobus marlatti* (Quaintance) (Fig. 14)

Diagnosis. Puparium black. Puparial margin covered with waxy secretion, also with fine waxy sculpturing delineating segmentation and folds. Dorsal disc separated from submarginal region by suture. Eye spots present. Thoracic and caudal tracheal combs present, three thoracic and three caudal tracheal teeth. Vasiform orifice surrounded by a trilobed figure. Abdominal segmentation distinct, rachis present.

Korean quarantine notes. This whitefly was described from Japan (Eastern Palaearctic region) and was intercepted 20 times; Thailand on *Musa sapientum* (Musaceae) and *Rhaphidophora hongkongensis* (Araceae). It is distributed in South Korea (Suh 2014).



Figures 10–18. Eight species of whiteflies. **10**) *Aleuroclava jasmini* (Takahashi), puparium. **11**) *Aleuroclava neolit-seae* (Takahashi), puparium. **12**) *Aleuroclava similis* (Takahashi), puparium. **13**) *Aleurodicus dispersus* Russell, puparium. **14**) *Aleurolobus marlatti* (Quaintance), puparium. **15**) *Aleuroplatus alcocki* (Peal), puparium. **16–17**) *Aleuroplatus bossi* Takahashi, puparium and vasiform orifice. **18**) *Aleurotrachelus dryandrae* Solomon, puparium.

13. *Aleuroplatus alcocki* (Peal) (Fig. 15)

Diagnosis. Puparium pale. Cephalic median area usually with an elevated longitudinal moulting suture keel. Puparium suboval, much constricted at thoracic tracheal pore area; with a comb of teeth. Vasiform orifice circular; caudal tracheal opening with a comb of teeth.

Korean quarantine notes. This species was described from India (Oriental region) and was intercepted once from India on *Ficus religiosa* (Moraceae). It is not known to occur in South Korea (Lee 2019).

14. *Aleuroplatus bossi* Takahashi (Fig. 16–17)

Diagnosis. Puparium black. Margin toothed. Constricted near the transverse moulting suture, transverse moulting suture almost reaching margin. Eyespots present. Dorsal surface with paired row of simple pores. Vasiform orifice elevated, large, distance to posterior margin of puparium less than its length. Operculum filling vasiform orifice, concealing lingula tip.

Korean quarantine notes. This species was described from South Africa (Afrotropical region) and was intercepted twice from South Africa on *Paranomus reflexus* (Proteaceae). It is not known to occur in South Korea (Lee 2019).

15. *Aleurotrachelus dryandrae* Solomon (Fig. 18)

Diagnosis. Puparium black. Puparial margin covered with wax secretion. Margin toothed. Dorsal disc with a pair of longitudinal cephalothoracic folds, with many subcircular papillae. Rachis present. Vasiform orifice subcircular, elevated; operculum occupies most of the orifice.

Korean quarantine notes. This species was described from Australia (Australasian region) and was intercepted four times from Australia on *Persoonia longifolia* (Proteaceae). It is not known to occur in South Korea (Lee 2019).

16. *Aleurotrachelus* sp. (Fig. 19–20)

Diagnosis. Puparium brown to black. Margin toothed. Puparial subdorsal area with a pair of longitudinally pigmented area on cephalothorax. Thoracic tracheal and caudal combs not clear, but their margin thick or sclerotized. Rachis present. Vasiform orifice subcordate, elevated.

Korean quarantine notes. This species was intercepted nine times on *Pieris japonica* (Ericaceae) from China.

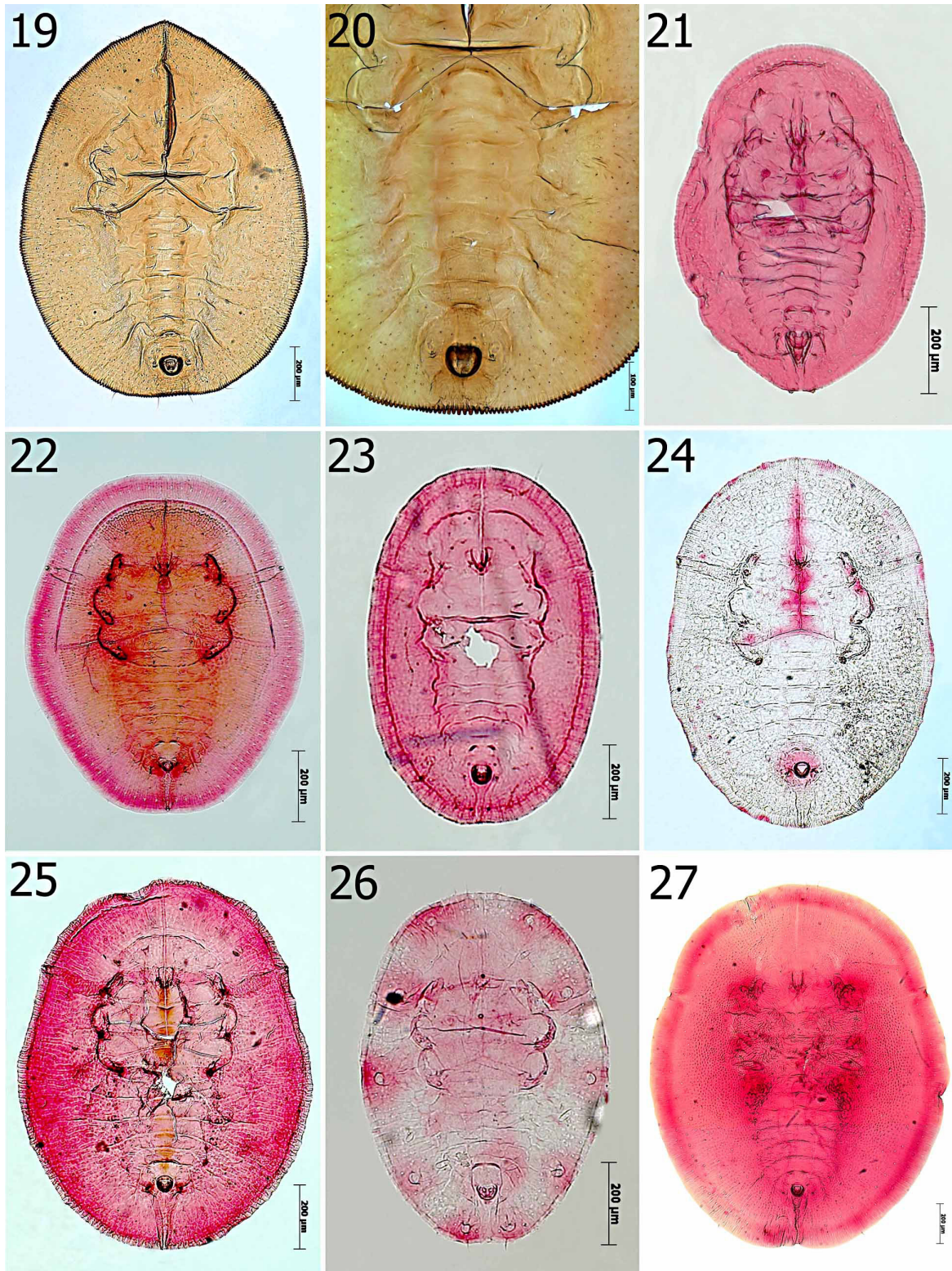
17. *Bemisia tabaci* (Gennadius) (Fig. 21)

Diagnosis. Puparium pale, oval. Median moulting suture reaching margin, transverse moulting suture ending on subdorsum. Thoracic tracheal openings with subtle combs. Vasiform orifice elongate triangular, caudal furrow well defined by a pair of ridges. Caudal setae long and stout, longer than vasiform orifice.

Korean quarantine notes. This species was described from Greece (Western Palaearctic region) and was intercepted 1438 times at Korean ports from China, Japan, Malaysia, Myanmar, Sri Lanka, Thailand, Vietnam, Uzbekistan, Israel, Belgium, Netherlands, Kenya, South Africa, Canada, USA and Colombia and on a wide variety of host plants. In 1998, *B. tabaci* was reported as introduced in South Korea; this species is now a major pest in South Korea and causes severe damage to crops in greenhouses (Park 2010; Lee 2019).

18. *Cockerelliella psidii* (Corbett) (Fig. 22)

Diagnosis. Puparium pale with localized brownish markings, elliptical. Crenate margin. Thoracic and caudal tracheal openings at margin marked by invaginated pores; pores smooth internally. Longitudinal and transverse moulting sutures joined distally by a cephalothoracic suture which is concentric with margin; longitudinal moulting suture does not extend anteriorly beyond its junction with cephalothoracic suture. Tracheal pore sclerotized, opens at margin, tracheal fold generally only slightly indicated near margin. Caudal pore and fold conspicuous; fold dotted. Vasiform orifice elevated, subcordate, broadly recessed at posterior outer margin.



Figures 19–27. Eight species of whiteflies. 19–20) *Aleurotrachelus* sp., puparium and abdomen detail of the vasiform orifice. 21) *Bemisia tabaci* (Gennadius), puparium. 22) *Cockerelliella psidii* (Corbett), puparium. 23) *Crenidorsum aroidophagus* Martin and Aguiar, puparium. 24) *Dialeurodes citri* (Ashmead), puparium. 25) *Dialeurodes kirkaldyi* (Kotinsky), puparium. 26) *Dialeuropora decempuncta* (Quaintance and Baker), puparium. 27) *Massilieuodes* sp., puparium.

Korean quarantine notes. This species was described from Malaysia (Oriental region) and was intercepted four times from China on *Pieris japonica* (Ericaceae). It is not known to occur in South Korea (Lee 2019).

19. *Crenidorsum aroidephagus* Martin and Aguiar (Fig. 23)

Diagnosis. Puparium pale, elongate-oval. Margin evenly crenate. Dorsal disc with a pair of distinct longitudinal folds leads from lateral to cephalic setae to abdominal segment V; submedian dorsum of meso- and metathorax with scalloped longitudinal folds, distribution of geminate pore, porettes and thick-rimmed pores. Longitudinal moulting suture slightly crimped in appearance. Vasiform orifice elevated, subcircular, defining a caudal furrow; caudal fold slightly marked by very fine stippling, posterior to vasiform orifice.

Korean quarantine notes. This species was described from Madeira (Western Palaearctic region) and was intercepted five times from Indonesia on *Philodendron* sp. and *Syngonium variegata* (Araceae). It is not known to occur in South Korea (Lee 2019).

20. *Dialeurodes citri* (Ashmead) (Fig. 24)

Diagnosis. Puparium pale, broad suboval. Ventral caudal and thoracic tracheal folds distinct, covered with spinules; thoracic and caudal tracheal openings marked by invaginated pores; with smooth teeth internally. First abdominal setae absent (Ko et al. 2010).

Korean quarantine notes. Although this species was described from the United States it is probably native to the Oriental region; it was intercepted once from Japan on *Gardenia jasminoides* (Rubiaceae)). It is distributed in South Korea (Suh 2014).

21. *Dialeurodes kirkaldyi* (Kotinsky) (Fig. 25)

Diagnosis. Puparium pale. Median line of pupal case with some pigment from mouth parts to abdominal segment I. Ventral caudal and thoracic tracheal folds distinct, covered with spinules. First abdominal setae present (Ko et al. 2010).

Korean quarantine notes. This species was described from Hawaii but is probably native to Asia; it was intercepted twice from Japan on *Jasminum nudiflorum* (Oleaceae). It is not known to occur in South Korea (Lee 2019).

22. *Dialeuropora decempuncta* (Quaintance and Baker) (Fig. 26)

Diagnosis. Puparium pale. Submargin with normally 12 pairs of short lanceolate setae; cephalic, caudal and two pairs of eighth abdominal setae similar in form, but longer and slender. Subdorsum with 5 pairs of large simple pores, more-or-less evenly spaced. Vasiform orifice triangular; head of lingula densely setose and protruding beyond posterior margin of vasiform orifice.

Korean quarantine notes. This species was described from Sri Lanka (Oriental region) and was intercepted 12 times; Myanmar on *Piper betle* (Piperaceae); Thailand on *Musa sapientum* (Musaceae); Vietnam on *P. betle* and on *Annona muricata* (Annonaceae). It is not known to occur in South Korea (Lee 2019).

23. *Massilieurodes* sp. (Fig. 27)

Diagnosis. Puparium pale, broad suboval. Venter of thoracic and caudal tracheal areas smooth; thoracic and caudal tracheal openings marked by invaginated pores; with teeth internally. Head region not delimited by suture. Caudal furrow distinct, widened on the anterior part, narrowed towards the hind end on the posterior part. Vasiform orifice circular.

Korean quarantine notes. This species was intercepted four times on *Pieris japonica* (Ericaceae) from China.

24. *Orchamoplatus mammaeferus* (Quaintance and Baker) (Fig. 28)

Diagnosis. Puparium pale. Submargin with a single row of dentate glands. Thoracic and caudal tracheal openings with distinct combs of teeth; dentate glands immediately adjacent to thoracic tracheal combs longer than remainder, often overlapping margin. Vasiform orifice circular.

Korean quarantine notes. This species was described from Java (Oriental region) and was intercepted seven times from Sri Lanka on *Codiaeum variegatum* (Euphorbiaceae). It is not known to occur in South Korea (Lee 2019).

25. *Parabemisia myrica* (Kuwana) (Fig. 29)

Diagnosis. Puparium pale. Submargin with usually 14 pairs of fine, acute setae. Vasiform orifice triangular, sides straight to slightly concave, posterior apex not sharply defined, orifice inset from posterior margin of puparium by about its own length; operculum occupies basal half of vasiform orifice, remainder being occupied by laterally-bilobed, exposed, head of the lingula.

Korean quarantine notes. This species was described from Japan (Eastern Palaearctic region) and was intercepted 25 times; Myanmar on *Piper betle* (Piperaceae) and Vietnam on *Annona muricata* (Annonaceae). It is not known to occur in South Korea (Lee 2019).

26. *Pealius mori* (Takahashi) (Fig. 30)

Diagnosis. Puparium white to pale. Vasiform orifice situated in a pit. Dorsal disc with many small circular pores densely scattered except on the median and submarginal areas, the latter with many papillae in about three irregular rows, 14 pairs of short setae in a row along the whole margin.

Korean quarantine notes. This species was described from Taiwan (Oriental region) and was intercepted once from China on *Ficus* sp. (Moraceae). It is not known to occur in South Korea (Lee 2019).

27. *Singhiella simplex* (Singh) (Fig. 31)

Diagnosis. Puparium white to pale. Dorsal disc covered with circular, raised papilla-like pores and porettes, thoracic tracheal fold and caudal furrow distinct. Thoracic and caudal tracheal openings with slightly stronger with an oval pore with a rim in the specimen examined; dorsal setae with fringed apices.

Korean quarantine notes. This species was described from India (Oriental region) and was intercepted once from China on *Ficus* sp. (Moraceae). It is not known to occur in South Korea (Lee 2019). This species has spread to all of the regions of the world except to Australia and the Afrotropical region and is a major pest of *Ficus* trees.

28. *Tetraleurodes* sp. (Fig. 32)

Diagnosis. Puparium black. Dorsal disc separated from submarginal region by suture. Thoracic tracheal and caudal pores or notches absent. One pair of long stout setae present on abdominal segments I and VIII, caudal extremity with a pair of long stout setae. Rachis present.

Korean quarantine notes. This species was intercepted four times on *Pieris japonica* (Ericaceae) from China.

29. *Tetraleurodes ursorum* (Cockerell) (Fig. 33)

Diagnosis. Puparium black. Margin toothed with pale glandular area. Dorsal disc separated from submarginal region by suture. Submargin strongly elevated, almost vertical, forming ridge-like rim around body. Dorsal disc with disc pores and porettes. Subdorsal disc with longitudinal ridge elevated on thorax and anterior abdominal segments. Rachis present and slightly elevated. Vasiform orifice subcordate; with two cell-like structures on lateral part of rim of vasiform orifice.

Korean quarantine notes. This species was described from the United States (Nearctic region) and was intercepted 27 times from USA on *Gaultheria shallon* (Ericaceae). It is not known to occur in South Korea (Lee 2019).

30. *Trialeurodes glacialis* (Bemis) (Fig. 34)

Diagnosis. Puparium pale. Marginal crenulations relatively broad. Dorsal disc with many papillae on the marginal and submarginal areas; outer papillae in a row, inner papillae scattered or irregular rows. First abdominal setae present.



Figures 28–36. Nine species of whiteflies. **28)** *Orhamoplatus mammaeferus* (Quaintance and Baker), puparium. **29)** *Parabemisia myricae* (Kuwana), puparium. **30)** *Pealius mori* (Takahashi), puparium. **31)** *Singhiella simplex* (Singh), puparium. **32)** *Tetraleurodes* sp., puparium. **33)** *Tetraleurodes ursorum* (Cockerell), puparium. **34)** *Trialeurodes glacialis* (Bemis), puparium. **35)** *Trialeurodes vaporariorum* (Westwood), puparium. **36)** *Tuberaleyrodes* sp., puparium.

Korean quarantine notes. This species was described from the United States (Nearctic region) and was intercepted 13 times from the USA on *Gaultheria shallon* (Ericaceae). It is not known to occur in South Korea (Lee 2019).

31. *Trialeurodes vaporariorum* (Westwood) (Fig. 35)

Diagnosis. Puparium white. A single submarginal row of papillae present; lateral margin with relatively broad crenulations. Eighth abdominal setae located anterior to widest part of operculum.

Korean quarantine notes. This species was described from England (Western Palaearctic region) and was intercepted 122 times at Korean ports of entry on cut flowers, trees and Brassicaceae from China, Colombia, France, Japan, Kenya, Netherlands, Thailand, USA and Vietnam. In 1977, *T. vaporariorum* was documented as introduced in South Korea; this species is now the most commonly reported whitefly in South Korea and causes severe damage to crops in greenhouses (Park 2010; Lee 2019).

32. *Tuberaleyrodes* sp. (Fig. 36)

Diagnosis. Puparium light yellow, suboval. Margin smoothly crenulate; not modified at thoracic tracheal pore openings, but slightly emarginated at caudal tracheal pore opening. Seven pairs of simple submarginal setae present along the bases of tuberculate setae. Vasiform orifice subcordate, elevated.

Korean quarantine notes. This species was intercepted once on *Cinnamomum loureirii* (Lauraceae) from China. The specimen was carefully examined based on the key to Chinese *Tuberaleyrodes* (Wang et al. 2013). However, it was hard to determine the specific level. This species might be included in the six other *Tuberaleyrodes* species that were not described in their paper.

Key to whiteflies intercepted at South Korean ports of entry

(based on the puparium)

- | | | |
|-------|---|---|
| 1. | Puparium black | 2 |
| — | Puparium pale | 14 |
| 2(1). | Dorsum with elongate spines with acute apices | 3 |
| — | Dorsum without elongate spines with acute apices | 4 |
| 3(2). | Marginal teeth not large with at least 6 teeth occupying 0.1 mm of margin; submargin normally with 11 pairs of stout spines in a row, all similar in length | <i>Aleurocanthus spiniferus</i> (Quaintance) (Fig. 3) |
| — | Marginal teeth very large and rounded with 3.5–5.0 teeth per 0.1 mm of margin; submargin usually with 11 pairs of stout spines in a row with cephalothoracic and caudal pairs alternately longer than adjacent ones | <i>Aleurocanthus woglumi</i> Ashby (Fig. 4–5) |
| 4(2). | Tracheal opening notch or pore present | 5 |
| — | Tracheal opening notch or pore absent | 9 |
| 5(4). | Head with a T-shaped sculpture | 6 |
| — | Head without a T-shaped sculpture | 7 |
| 6(5). | Submarginal furrow crenulate (wavy); tracheal opening flat, without internal loop; body oval; dorsum with small bumps | <i>Aleuroclava gordoniae</i> (Takahashi) (Fig. 8) |
| — | Submarginal furrow not crenulate; tracheal opening thong-shaped; body elliptical with pointed posterior margin; dorsum coarsely sculptured | <i>Aleuroclava aucubae</i> (Kuwana) (Fig. 6) |
| 7(5). | Dorsum with large areolae in abdominal submarginal row | <i>Aleuroclava neolitseae</i> (Takahashi) (Fig. 11) |
| — | Dorsum without large areolae in abdominal submarginal row | 8 |
| 8(7). | Body elongate, widest in middle, lips-shaped; eye spots long, oblique slender rod-shaped; dorsum with minute circular pores | <i>Aleuroclava hikosanensis</i> (Takahashi) (Fig. 9) |
| — | Body elliptical to oval; eye spots not as above; dorsum coarsely sculptured | <i>Aleuroclava euryae</i> (Kuwana) (Fig. 7) |

- 9(4). Submargin and subdorsum separated by a distinct dorsal suture-like furrow which is almost always margin-concentric or cephalothorax and/or abdomen with submedial longitudinal folds **10**
 — Submargin and subdorsum not separated by a distinct dorsal suture-like furrow *Aleurolatus bossi* Takahashi (Fig. 16–17)
- 10(9). Submedial furrow absent, dorsal disc separated from submarginal region by suture; margin with 1 row of teeth **11**
 — Submedial furrow present; dorsal disc not separated from submarginal region by suture (in the species that key here); margin with 1 or 2 rows of teeth **13**
- 11(10). Vasiform orifice surrounded by a trilobed figure *Aleurolobus marlatti* (Quaintance) (Fig. 14)
 — Vasiform orifice not surrounded by a trilobed figure (*Tetraleurodes*) **12**
- 12(11). Subdorsal disc with longitudinal ridge elevated on thorax and anterior abdominal segments; with 2 cell-like structures on lateral part of rim of vasiform orifice; one pair of long stout setae absent on A1 and A8, caudal extremity without 1 pair of long stout setae *Tetraleurodes ursorum* (Cockerell) (Fig. 33)
 — Subdorsal disc without longitudinal ridge as above; without cell-like structures on lateral part of rim of vasiform orifice; one pair of long stout setae present on A1 and A8, caudal extremity with 1 pair of long stout setae *Tetraleurodes* sp. (Fig. 32)
- 13(10). Dorsal disc with 1 pair of longitudinal cephalothoracic folds, with many subcircular papillae; thoracic tracheal and caudal combs absent; rachis with pronounced ridges *Aleurotrachelus dryandrae* Solomon (Fig. 18)
 — Dorsal disc with 1 pair of longitudinally pigmented area on cephalothorax, but without subcircular papillae; thoracic tracheal and caudal combs not clear, but their margin thick or sclerotized; rachis present but not as pronounced *Aleurotrachelus* sp. (Fig. 19–20)
- 14(1). Puparium with compound pores present, abdomen with 4 pairs of compound pores similar in size and shape; a claw present at the apex of each thoracic leg; the lingula very long, extending past the vasiform orifice with two pairs of setae at its apex (Aleurodicinae) *Aleurodicus dispersus* Russell (Fig. 13)
 — Puparium without compound pores present (large simple pores present in *Dialeuropora*); thoracic legs with adhesive or circular disc at the apices of the legs; lingula usually not long and extending past the vasiform orifice and with 1 pair of setae (Aleyrodinae) **15**
- 15(14). Dorsum with elongate spines with clavate or fimbriate apices **16**
 — Dorsum without elongate spines with clavate or fimbriate apices **17**
- 16(15). With 7 pairs of long submarginal setae with clavate apices each on a tuberculate base *Tuberaleyrodes* sp. (Fig. 36)
 — With more than 19 pairs of long spines with fimbriate apices *Aleurocanthus rugosa* Singh (Fig. 1–2)
- 17(15). Subdorsum with 5 pairs of large simple pores, more-or-less evenly spaced; with normally 12 pairs of short lanceolate setae on subdorsum *Dialeuropora decempuncta* (Quaintance and Baker) (Fig. 26)
 — Subdorsum without large simple pores; without lanceolate setae on subdorsum **18**
- 18(17). Thoracic and/or caudal openings at margin in form of distinct pore or notch **19**
 — Thoracic and usually caudal openings at margin either unmarked or in the form of .modified marginal teeth **26**
- 19(18). Submargin of cephalothorax separated from dorsal disc by a suture *Cockerelliella psidii* (Corbett) (Fig. 22)
 — Submargin not separated from dorsal disc by a suture **20**
- 20(19). Submargin with a row of many dentate glands; marginal crenulations at thoracic and caudal openings strongly differentiated to form combs of narrowly elongate teeth *Orchamoplatus mammaeferus* (Quaintance and Baker) (Fig. 28)

- Submargin without a row of many dentate glands; marginal crenulations at thoracic and caudal openings without combs as above **21**
- 21(20). Tracheal opening notch-like, with or without teeth (*Aleuroclava*) **22**
- Tracheal opening round, pore-like, with or without teeth **23**
- 22(21). Cephalothorax with 5 pairs of submedian tubercles; metathoracic tubercles with brown pigment
. *Aleuroclava jasmini* (Takahashi) (Fig. 10)
- Cephalothorax without submedian tubercles; metathoracic tubercles without brown pigment
. *Aleuroclava similis* (Takahashi) (Fig. 12)
- 23(21). Caudal and tracheal ventral areas lined with spinules or nodules; head region delimited by faint suture; 10–12 pairs of submarginal setae (sm) present (sm1–5 before the anterior spiracle, sm6–12 (7) after, sm12, last pair before es setae, laterad to vasiform orifice) (*Dialeurodes*) **24**
- Caudal and tracheal ventral areas not lined with spinules or nodules (usually smooth); head region not delimited by faint suture; 13–15 pairs of submarginal setae present (sm1–5 before the anterior spiracle, sm6–14,15 (9,10) after) **25**
- 24(23). First abdominal setae present; longitudinal brown pigmentation present on cephalothorax and abdominal segments on median area; eighth abdominal setae medio-lateral to vasiform orifice
. *Dialeurodes kirkaldyi* (Kotinsky) (Fig. 25)
- First abdominal setae absent; longitudinal pigmentation absent on cephalothorax and abdomen; eighth abdominal setae medio-anterior to the orifice or nearly lateral to the base of operculum
. *Dialeurodes citri* (Ashmead) (Fig. 24)
- 25(23). Posteriormost pair of submarginal setae (sm14 usually 14th pair) nearly always situated on caudal ridges between caudal setae and vasiform orifice (vo), but if laterad to furrow then caudal furrow wider than vo and lined with many rows of small nodules; fore and mid-legs closely appressed; caudal furrow more or less lined with transverse rows of nodules *Massilieurodes* sp. (Fig. 27)
- Posteriormost pair of submarginal setae always situated laterad to the caudal ridges (not directly under the vasiform orifice); fore and mid-legs not closely appressed; caudal furrow not ornamented
. *Singhiella simplex* (Singh) (Fig. 31)
- 26(18). Submargin and subdorsum separated by a distinct dorsal suture-like furrow which is almost always margin-concentric or cephalothorax and/or abdomen with submedial longitudinal folds
. *Crenidorsum aroidephagus* Martin and Aguiar (Fig. 23)
- Submargin and subdorsum not separated by a distinct dorsal suture-like furrow **27**
- 27(26). Vasiform orifice located in a pit; lingula exposed with a short, D-shaped head
. *Pealius mori* (Takahashi) (Fig. 30)
- Vasiform orifice not located in a pit; lingula without a D-shaped head **28**
- 28(27). Vasiform orifice cordate or subcordate, either mostly or fully occupied by the operculum, with the lingula completely or partially covered, or lingula fully exposed; first abdominal setae absent in most species *Aleuroplatus alcocki* (Peal) (Fig. 15)
- Vasiform orifice triangular or elongate-cordate, operculum only occupying half of the orifice and lingular head clearly defined, mostly or fully exposed, finely spinulose, included in or slightly extending beyond orifice; first abdominal setae present in most species **29**
- 29(28). Submargin with usually 14 pairs of long slender setae, extending beyond the lateral margin; transverse suture extends to lateral margin; sides of lingula with a pair of protuberances
. *Parabemisia myricae* (Kuwana) (Fig. 29)
- Submargin without long slender setae as above, but if setae present in outer submargin then usually less in number and not extending beyond the lateral margin; transverse moulting suture usually not reaching the lateral margin; sides of lingula without a pair of protuberances **30**
- 30(29). Lingular head not distinctly lobulate; glandular papillae not present around the margin
. *Bemisia tabaci* (Gennadius) (Fig. 21)

- Lingular head distinctly lobulate (usually with 3 lobes); glandular papillae present or absent (*Trialeurodes*) 31
- 31(30). Dorsal disc with many papillae on the marginal and submarginal areas, outer papillae in a row, inner papillae scattered or irregular rows; thoracic tracheal pore area obscure or poorly marked by weak indentations in 2 or 3 marginal crenulations *Trialeurodes glacialis* (Bemis) (Fig. 34)
- A single submarginal row of papillae present; thoracic tracheal pore area marked by a pore-shaped design on submarginal ridges and by narrowness of 4 or 5 marginal crenulations *Trialeurodes vaporariorum* (Westwood) (Fig. 35)

Discussion

A total of 32 species in 19 genera were intercepted on plants imported into South Korea over the last nine years. Many whiteflies, including the 32 species discussed are of quarantine significance because they are highly prolific, phytophagous, and some are vectors of plant viruses. The amount of plant material imported into South Korea has increased and many of the plant species are known hosts for whiteflies. It is inevitable that an increase in the international trade of plants will lead to an increase in the number of potentially invasive species encountered during inspection and preventive measures are required to overcome this challenge. The most effective approach to block the introduction of an invasive species is to regularly update a list of pests intercepted on imported plants, list potential species at risk of being introduced by analyzing information on their possible pathways based on records of intercepted whiteflies, and keep them under constant surveillance. This is especially important in the case of *Bemisia tabaci*, the most frequently intercepted whitefly species. *Bemisia tabaci* is a widespread cryptic species complex with the species MEAM1 (Middle East Asia Minor 1) and MED (Mediterranean) which include differences in insecticide resistance, host preference and range. For strict quarantine controls of *B. tabaci*, an integrated genetic/molecular and morphological species-diagnoses will be required. Also, researchers and inspectors related to quarantine works need to be aware of which species occur in South Korea and which species are being intercepted on imported plants at South Korean ports of entry.

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