Aleurocanthus camelliae (Hemiptera: Aleyrodidae), a species possibly new for the European fauna of a genus in great need of revision

Maurice Jansen & Francesco Porcelli

The genus Aleurocanthus Quaintance & Baker, 1914 comprises about 80 species worldwide, several of which are of economic importance for crops including Aleurocanthus woglumi and A. spiniferus. During import interceptions A. camelliae, a look-alike of the former species, has occasionally been found on imported Camellia bonsai, pot plants and shrubs in the Netherlands. Living populations of this species may be locally found on imported and traded plants in the EPPO region. In Europe all species of the genus Aleurocanthus are regulated, which makes early recognition necessary. A reliable identification is needed to take adequate measures that prevent the establishment and spread of newly intercepted species in Europe. A key is given to related genera and to developmental stages, together with an overview of field views of puparia and the main discriminating morphological and microscopic characters of both adult and pre-adult stages of three species. Since 2008, A. spiniferus is established in southern Italy and is spreading, both in Italy and in surrounding countries in the Mediterranean region, causing severe economic and ecological damage not only to the Citrus culture but because of its polyphagy to many other host plants as well. The early recognition of species newly introduced into Europe is complicated by the loss of taxonomical knowledge and the diminishing number of taxonomic workers. A revision of the genus should include the delimitation of the genus, separating it from related genera, the (re)description of the intraspecific variation of known species and the description of newly collected species by molecular techniques and morphological methods.

Keywords: Hemiptera; Aleyrodidae; Aleurocanthus; Netherlands; import

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Introduction

The genus Aleurocanthus Quaintance & Baker, 1914 comprises about 80 species world-wide (Martin & Mound 2007, Kanmiya et al. 2011, Gillespie 2012, Dubey & Ko 2012). The literature on this taxonomic group is scattered, there are keys to the species of countries or regions such as India (Dubey & Sundararaj 2004), Sri Lanka (David 1993), Taiwan (Dubey & Ko 2012) and Australia (Martin 1999) but no world key exists for the genus. The type material may not always be traceable and part of the species in collections all over the world is waiting to be described. The morphological variety of these species and of the new species that may be collected in the field in the future may contribute to an amended genus concept. Sexual dimorphism, which

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is a character of the species treated in this paper, and host-induced forms complicate the recognition of new species. A revision of the genus is necessary but also a challenge. The purpose of this communication is to report the first incursions of *A. camelliae* Kanmiya, 2011 in Europe. For recognition purposes of *A. camelliae* this paper gives a key to genera related to or morphologically near the genus *Aleurocanthus* and it summarizes important characters of instars, puparia and adults in this species and the related *A. spiniferus* (Quaintance, 1903) and *A. woglumi* Ashby, 1915.

**The genus *Aleurocanthus***

Species of the genus *Aleurocanthus* feed both on monocotyledonous and dicotyledonous host plants. Ten species are listed from *Citrus* spp. (Evans 2008): *A. citriperdus* Quaintance & Baker, 1916, *A. spiniferus* and *A. woglumi* are considered to be invasive and to cause serious damage (Dubey & Ko 2012) (Fig. 13 below). Other *Aleurocanthus* species reported from *Citrus* are: *A. cocos* Corbett, 1927; *A. delottoi* Cohic, 1969; *A. husaini* Corbett, 1939; *A. ineratus* Silvestri, 1927; *A. mackenziei* Cohic, 1969 and *A. spinosis* (Kuwana, 1911). However, an identification key to the microscopic morphological characters of the aforementioned group of species is not available. Little is known about characters that are useful for a first recognition in the field. There exists no key to the microscopic morphological characters of the *Aleurocanthus* species of the world.

In Europe a minority of the Aleurodidae have black puparia; some of them are sometimes confused with representatives of other hemipterous families and a new introduction may therefore be overlooked. One of these look-alikes is the aphid Cerataphis brasilensis (Hempel, 1901) (Fig. 17 below). Another example is the coccid Parlatoria ziziphi (Lucas, 1853) (Fig. 18 below), an exotic scale insect that has become established in South Europe which has a similar size and colour and also possesses a wax fringe (Dekle, 1976; Llorens Climent, 1990). This species was confused with *Aleurocanthus spiniferus* after its introduction in Italy. An early recognition of newly introduced species is important for taking measures after introduction and therefore traditional taxonomic knowledge of this and related groups is needed. The fungus Myrothecium roridum Tode may cause lesions on leaves. These lesions are dark greyish, circular to irregular oval-shaped (5–10 mm in diameter) and surrounded by chlorotic halos so that smaller wounds may be confused with *Aleurocanthus*. Careful examination will reveal black fruiting bodies with a narrow white whorl that are formed on diseased lower and upper leaf surfaces (Fitton & Holliday 1998).

Only one species occurs in Europe: *A. spiniferus*, which is an exotic pest species. A native species in the Middle East is *A. ziziphi* Priessner & Hosny, 1934, which is recorded from Egypt and Jordan.

The generic characters of the genus *Aleurocanthus* based on the puparia are given in Martin (1999) and redefined by e.g. Dubey & Sundararaj (2004), Dubey & Ko (2012) and Kanmiya et al. (2011). Puparia of the genus *Aleurocanthus* are readily recognised by the presence of many stout conspicuous spines on the dorsal disc and submargin, the white marginal waxy fringes and the carriage of exuviae of earlier instars in a stack on the dorsum (Fig. 1). The spines actually are glands (Carver 1991) and their shape, length, position and number are used for diagnostic purposes including the recognition of species. Martin (1999) stated that the puparia of some species have their glandular spines reduced and located on tubercles; these species were included in *Aleurocanthus* based on the presence of spines in third-instar larvae.

Molecular diagnostics to differentiate *A. spiniferus* from *Diauleurodes citri*, *Bemisia tabaci*, *Trialeurodes vaporariorum* and *Aleurodicus dispersus* are reported (Liu et al., 2009); however, morphological distinction of these species is not problematic.

**Legal framework**

Whiteflies (Aleyrodidae) are commonly transported in the plant trade and many species have become widely distributed due to anthropogenic activities. Europe is entered along with imported products such as vegetables, fruits, pot plants and bonsai (penjing) plants. All *Aleurocanthus* specimens on which this paper is based, are found on imported plants. These introduced exotic taxa may be a nuisance to products in greenhouses, may establish in the open or become invasive and of economic and ecological concern by changing the faunal composition. Species are spread by national and international trade and may include regulated species and undescribed ones. To prevent this spread of non-native introductions, phytosanitary inspections are required for many plant products. In the Netherlands these inspections are carried out by inspectors of the Netherlands Food and Consumer Product Safety Authority (NVWA) and three Inspection Services which send detected specimens and infested parts of plants to the laboratory of the NVWA in Wageningen for identification.

Actually two supragovernmental organisations exist in Europe, with their own quarantine lists: the EPPO and the EU lists, which share about 95% of the species. Both have a different status. The EU-list is obligatory for making decisions if any *Aleurocanthus* species is intercepted, some of which are a major concern for European *Citrus* growers (Anonymous 2000). However, only two species are regulated on
Fig. 1. Puparia of *Aleurocanthus camelliae* with exuviae of previous instars
Photos: M. Jansen.

Fig. 2. Puparia of *Aleurocanthus spiniferus* on a leaf (left) and on a branch covered with sooty mold (right).
Photos: F. Porcelli.

Fig. 3. Leaves infested by citrus blackfly, *Aleurocanthus woglumi*. Left photograph: Division of Plant Industry, Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org. Right photograph: Natalie Hummel, Louisiana State University AgCenter, Bugwood.org.
the EPPO-list: *Aleurocanthus spiniferus* and *A. woglumi*. Measures are obligatory if these are detected on *Citrus, Fortunella, Poncirus* and their hybrids (Anonymous 2017a, b).

### Diagnostic protocols

Since 1998, the European and Mediterranean Plant Protection Organization (EPPO) has established a work programme in its region to harmonize diagnostic procedures. This programme was initiated to develop diagnostic protocols for the recognition of all insect species listed on the EPPO A1 and A2 lists (Petter et al. 2011, Žlof et al. 2000). The practical implications for the use and compilation of these protocols are not always well understood. According to Petter et al. (2011) protocols contain all information necessary for an identification. Because
not all detailed information may be included which is needed for a reliable identification, diagnostic protocols are considered to be a guidance (Anonymous 2017c). Experience is a prerequisite for reliable identifications and diagnostic protocols are no replacement. The identification process is not necessarily linear in time, decisions are a result of interpretations and morphological characters are subject to interpretations which take into account the known intraspecific variation. As a consequence this knowledge-driven work cannot be standardized or harmonized. Besides, the decrease of the number of experienced taxonomic workers hampers the progress of taxonomic knowledge of this economic important group of insects. Although the premises are that diagnostic protocols do not contain original work, their compilation may require additional taxonomic work, which in the case of Aleurocanthus, is presented here.

Methods
The taxonomy of Aleyrodidae is based on the structures of the fourth nymphal instar, which is usually called a puparium or pupal case when empty. Table 1 summarizes the characteristics of pre-adult stages. Puparia have many more definitive morphological structures than the adult stage, making it easier to separate the genera and species. Distinctive microscopic characteristics were studied by means of microscopic examination. Puparia were treated with cold 10% KOH for several days to bleach the black cuticle and the bleaching process was stopped when the specimen turned light brown. It was then rinsed in ethanol 70% for several minutes for cleaning, placed in glacial acetic acid for several minutes, transported to clove oil for at least 15 minutes and finally mounted in Canada balsam. Prepared slide-mounted specimens were observed and identified by using an interference contrast compound light microscope.
Measurements were made with a micrometer eyepiece and a micrometric slide for comparison.

**Taxonomy**


1. With subdorsal compound pores (Fig. 22), each of which may bear a central process; lingula (Fig. 4) large, with four stout setae; each leg with an apical claw (Fig. 23) .................

2. Dorsum of puparia with many long acute spines or siphon-like setae (Fig. 10) .............. 3

- Dorsum of puparia without long acute spines or siphon-like setae but stout normal setae (Fig. 8) may be present on dorsal disc or sub-margin ................... other genera of Aleyrodidae

3. Puparia with acute spines-like gland duct tips (Figs 6, 9); posterior edge of vasiform orifice elevated (Fig. 10), operculum always covering lingula; margin regularly toothed (Figs 11, 12), double-toothed or deflexed; cuticle coloration very variable, may be black (Figs 1, 2), dark brown, pale or dusky....... *Aleurocanthus*

- Puparia with siphon-like gland duct with blunt or expanded apices (Fig. 7) ............... 4

4. Puparial margin smooth and not deflexed; vasiform orifice not elevated (Fig. 8), operculum often not covering lingula (Fig. 4)... *Siphoninus*

- Puparial margin toothed; dorsum with only four pairs of blunt siphon-like setae; vasiform orifice slightly elevated, operculum fully occupying the orifice and obscuring lingual ...........

Key to some closely related black *Aleurocanthus* species. Puparia may be very similar in appearance to related species including *A. camelliae*. Kanmiya et al. (2011) summarize all morphological differences in puparial and adult stages between *A. camelliae* and *A. spiniferus*. Future studies may reveal additional
new cryptic species; three species are compared in this key.

1. Marginal teeth (Fig. 11) large, blunt, only 3.5–5 (rarely 6) per 0.1 mm; third posterior-most pair of spines usually doubled in females (Fig. 21).........................A. woglumi
   - Marginal teeth smaller, rounded, 6–12 per 0.1 mm (Fig. 12); third posterior–most pair of submarginal spines always single .................. 2
2. Range of number of marginal teeth 158–196; marginal wax secretion relatively narrow, 11.2–15.8% of puparial width...............A. camelliae
   - Range of number of marginal teeth 205–242; marginal wax secretion relatively broader, 17.3–30.0% of puparial width...............A. spiniferus

Species information

Aleurocanthus camelliae Kanmiya & Kasai, 2011 or tea spiny whitefly (TSW)
Figs 1, 25, 27, 29, 31


A. camelliae, a cryptic species morphologically near to A. spiniferus, has recently been described from Japan (Kanmiya et al. 2011). Samples with
Aleurocanthus puparia were intercepted in consignments with Camellia originating from China since 8.xii.2005. Once, in 2017, the species was found on an unidentified Camellia plant species in the Netherlands on a direct import from Japan. Later on this species was found on Camellia japonica, C. sasanqua and C. sinensis on pot plants in four different localities in the Netherlands: De Kwakel, Harmelen, Bleiswijk and Bergschenhoek. The identification was confirmed by Prof. Kanmiya (personal communication, 2 February 2018). The species had never been recorded elsewhere in Europe and as far we know Aleurocanthus specimens have never been intercepted on imported Camellia plants in other European countries. Nevertheless, it is possible that small populations survive on single pot plants or it may be introduced in the rare places with Camellia exhibitions or tea production with a fertile acid soil, sufficient rainfall and a mild climate. In the northwestern part of Turkey, a large amount of tea is produced in the Rize province.

Aleurocanthus camelliae is probably native to Taiwan or China and introduced into Japan where it has

Fig. 18. Field view of the scale insect Parlatoria ziziphi.
Photo: F. Porcelli.

Fig. 19. Aleurocanthus spiniferus. Antenna (arrows) of puparium.
Photo: M. Jansen.

Fig. 20. Aleurocanthus spiniferus. Arrows indicate the legs of the third-instar nymph, orientated towards the body margin.
Photo: M. Jansen.

Fig. 21. Part of female puparium of Aleurocanthus. woglumi with the third posterior-most submarginal spine (arrows) which is doubled; males have a single spine in this position. Specimen on Citrus, Trinidad, 28.vii.2005, leg. P. Ram.
Photo: M. Jansen.
been spreading throughout tea plantations ever since 2004 (Kanmiya et al. 2011, Saito et al. 2012).

This species is recorded from three plant families: Theaceae: *Camellia sinensis* (L.) Kuntze (Kanmiya et al. 2011), *C. sasanqua* Thunb. (Kanmiya et al. 2011), *C. japonica* L. (Kanmiya et al. 2011), Eurya japonica Thunb. (Kanmiya et al. 2011) and *Cleyera japonica* Thunb. (Kanmiya et al. 2011); Illiciaceae: *Illicium anisatum* L. (Yamashita et al. 2016); Rutaceae: *Zanthoxylum piperitum* (L.) DC. (Yamashita et al. 2016). The present host plants are of East Asian origin and not very commonly traded, nor widely used as amenity trees in the public green. Local populations on single or groups of plants are likely to survive the
Mediterranean climate. In Japan *A. camelliae* is supposed to have 2–5 generations per year (Kasai et al. 2012).

In China several outbreaks in tea regions have been recorded from Hainan Province, Southern China, and the middle and lower reaches of the Yangtze River, and outbreaks were reported all over the tea growing areas in China in 1989 (Han & Cui 2003 as *A. spiniferus*, Yamashita et al. 2016 as *A. camelliae*). Whitefly damages tea production by reducing tree vigour as a result of sap loss and sooty mold and negatively affects harvest productivity by degrading tea-leaf quality (Uesugi et al. 2016, Yamashita et al. 2016). Farmers suffer discomfort from inhaling the adults through the mouth and nose during harvesting operations and other work in the field (Kasai et al. 2012). Yamashita et al. (2016) recorded densities of *A. camelliae* adults of up to several hundred individuals on the lower surface of a leaf. In the Shizuoka prefecture, Japan, the highest population densities were 123 nymphs per leaf in September. In some sites of this region the rate of parasitism by the hymenopterous parasite *Encarsia smithi* (Silvestri, 1926) tended to remain at low levels or declined with increasing population density of *A. camelliae* (Uesugi et al. 2016) whereas Ozawa & Uchiyama (2013) recorded 1.5% to 97.0% parasitism in investigated tea fields. Differences may have to do with the moment of introduction of the whitefly: “The fields in which no parasitism was detected are the fields where the pest was first identified in 2012, whereas the fields where the pest was earlier...”
identified in 2010 had higher parasitism than others” (Ozawa & Uchiyama, 2013, p. 91).

At import inspections in the Netherlands the species was present in low to moderate numbers on inspected plants, not causing much honeydew, and infested leaves did not have a spotty appearance due to discolorations caused by sap sucking or saliva toxicity.

Aleurocanthus spiniferus (Quaintance, 1903) or orange spiny whitefly (OSW)

Figs 2, 5, 6, 10, 12–14, 19, 20, 24, 26, 28, 32, 33

The widespread tropical species A. spiniferus is native to South and East Asia. At present it is widely distributed: Asia: Bangladesh (Alam et al. 1965), Bhutan, Brunei Darussalam (Jeffers 2009), Cambodia (Takahashi 1942), China, Democratic People’s Republic of Korea (Jeffers 2009), India (Singh 1931), Indonesia (Fletcher 1919; Sumatra: Weems 1974), Iran (Jeffers 2009), Japan (Moutia 1955), Republic of Korea, Laos (Jeffers 2009), Malaysia (Gater 1924), Marianas Islands, Mauritius (Moutia 1955), Pakistan (Gentry 1965), Philippines (Person 1955), Sri Lanka (Takahashi 1956), Thailand (Takahashi 1942), Taiwan, Vietnam (Jeffers 2009); Oceania: Caroline Islands, Federated States of Micronesia (Takahashi 1956), Guam, Palau, Papua New Guinea (Jeffers 2009); Australia (Carver & Reid 1996); Africa: Kenya, Mauritius, Nigeria, South Africa (Van den Berg et al. 1990), Swaziland (Van de Berg & De Beer 1997), Tanzania, Uganda (Jeffers 2009); North-America: Hawaii (Anonymous 1974).

It is established and spreading in Italy (Puglia) and thus recorded from the EPPO region (Porcelli 2008, Cioffi et al. 2013, El Kenawy et al. 2016). It is a highly polyphagous insect that is threatening European Citrus culture and also infests the wild flora. The species is known to feed on plants of at least 38 plant families. After its introduction in Italy it was reported from several new hosts (Cioffi et al. 2013, El Kenawy et al. 2016): Araliaceae: Hedera helix L., Fatsia sp.; Lauraceae: Laurus nobilis L.; Malvaceae: Malva sp.; Moraceae: Ficus carica L., Morus alba L.; Punicaceae: Punica granatum L.; Rosaceae: Cydonia sp., Malus sp., Prunus armeniaca L., P. cv, P. domestica L., Pyracantha coccinea M.Roem.; Pyrus pyraster (L.) Burgsd., Pyrus sp.; Salicaceae: Salix sp.; Vitaceae: Parthenocissus tricuspidata (Siebold & Zucc.) Planch., Vitis vinifera L. cv. The most recent contribution (Nugnes et al. 2018) updates the OSW knowledge about new host plants with Ailanthus altissima (Mill.) Swingle, Arbutus unedo L., Citrus medica L., Citrus reticulata Blanco, Clematis vitalba L., Pistacia vera L., Rosa × damascena Herm. and R. banksiae R.Br. (Ranunculaceae, Anacardiaceae, Simaroubaceae). This study introduces the possible effective predatory role of an alien Coccinellidae of the genus Delphastus Casey, 1899 found in Campania and finds a single Mt haplotype in the Italian populations studied. This strongly suggests that OSW could have reached Italy either by a single invasion event or by multiple invasive events from the same haplogroup source. The same authors (Nugnes et al., 2018) report OSW also in Campania, Liguria and Lazio and Montenegro (Radonjić et al. 2014, Radonjić & Hrnčić 2017). The accidental find in a single garden centre in Split, Croatia, in 2012 (Šimala & Masten Milek 2013) proves that the species may easily spread to other countries in the Mediterranean region. The accidental find in a single garden centre in Split, Croatia, in 2012 (Šimala & Masten Milek 2013) proves that the species may easily spread to other countries in the Mediterranean region.
region. Heavy infestations of *A. spiniferus* may lead to mortality of young trees. We consider the recent host shift onto deciduous host plants by OSW as an attempt to conquer areas a little colder than optimal. Actually the pest invades grape, *Parthenocissus* sp. and *Ailanthus altissima* leaves in summer, building up a huge adult population that will help as a biological flywheel to survive the winter cold, a non-density-dependent mortality factor. The shift to deciduous plants is now evolving in Southern Italy and will, possibly, make further hosts available to the pest.

In the Netherlands *A. spiniferus* is regulated (“Q-waardig”) for all plants intended for planting which are not regulated by the EU-directive (Anonymous 2000).

Aleurocanthus woglumi Ashby, 1915 or citrus blackfly

*Figs 3, 9, 11, 15, 16, 21, 30*

*Aleurocanthus woglumi* originates from Southeast Asia and has spread throughout Asia and to the Central Pacific, Southern Africa, Central America and parts of North and South America. It is absent from EPPO member countries. The species is highly polyphagous and recorded from at least 80 host plant species in 40 families (Khan et al. 1985; Serrano et al. 1993; Dubey & Sundararaj, 2004; Martin & Lau, 2011; Dubey & Ko, 2012; Gillespie, 2012). *Citrus* species are the main hosts of economic importance. The taxonomy and a description of the puparium and adult are given by Caballero (1992).

Diagnostics of *A. camelliae*, *A. spiniferus* and *A. woglumi*

The puparia are very similar in appearance and have several characters in common:

- Cuticle dark brown to black;
- Venter smooth with a transparent submarginal row of dark papillae;
- Presence of a submarginal row of pointed, smooth and single stout spines (Fig. 6);
- The presence of a white wax fringe (Figs 1, 2).

**Table 2.** Microscopic differences between puparia of *Aleurocanthus* species independent of the sex, after Kanmiya et al. (2011), Dubey & Ko (2012) and Gillespie (2012), and observations of M. Jansen.

<table>
<thead>
<tr>
<th>Character</th>
<th><em>A. woglumi</em></th>
<th><em>A. camelliae</em></th>
<th><em>A. spiniferus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of marginal teeth per 0.1 mm/100 μm</td>
<td>3.5–5 (rarely 6) (Fig. 11)</td>
<td>6–8 in female, 7–10 in male (rarely) 6–11 (rarely 12) (Fig. 12)</td>
<td>7–11 (rarely 12) (Fig. 1)</td>
</tr>
<tr>
<td>Crenulation: total number of marginal teeth</td>
<td>About 130</td>
<td>Teeth lined with loose gaps, 158–196 (1 : 7)–(1 : 14) (Figs 25, 31)</td>
<td>Teeth lined with narrow gaps 205–242 (1 : 9)–(1 : 17) (Figs 6, 26)</td>
</tr>
<tr>
<td>Ratio of longest spines: length of spine to basal width</td>
<td>(1 : 28)–(1 : 48) (Figs 9, 21)</td>
<td>(1 : 7)–(1 : 14) (Figs 25, 31)</td>
<td>(1 : 9)–(1 : 17) (Figs 6, 26)</td>
</tr>
<tr>
<td>Width of white wax fringe to width of black disk</td>
<td>Narrow fringe: about 0.1x disk (Fig. 3)</td>
<td>Intermediate: 11.2–15.8% of puparial width (Fig. 1)</td>
<td>Wide fringe: 17.3–30% of puparial width (Fig. 2)</td>
</tr>
<tr>
<td>Submedian abdominal spines*</td>
<td>Sockets not in line: 2nd placed distal and 4th placed proximal</td>
<td>Sockets of 2nd to 5th spines lined up roughly linearly (Fig. 27)</td>
<td>Sockets not in line, 2nd and 4th placed distal and 3rd and 5th proximal (Fig. 26)</td>
</tr>
<tr>
<td>Cephalic eye spot</td>
<td>Sharply defined</td>
<td>Clearly defined, placed very closely to 3rd cephalothoracic submarginal spine (Fig. 25)</td>
<td>Weakly defined, placed closer to 3rd submarginal spine than to the 2nd (Fig. 24)</td>
</tr>
<tr>
<td>Microscopic papillae</td>
<td>3–5 duct-like papillae present outside submarginal spines between each two spines near abdomen; 2 between frontal spines (Fig. 30)</td>
<td>3–5 microscopic papillae lined outside submarginal spines between each two spines (Fig. 29)</td>
<td>Microscopic papillae (arrow) are situated between submarginal spines (Fig. 28)</td>
</tr>
</tbody>
</table>

* Note: Care should be taken not to confuse these spines with median and submedian spines (Fig. 26), which may be double in *A. spiniferus* as well. In *A. woglumi*, those from the cephalothorax do not reach beyond the margin, except the anterior pair. Moreover, the submarginal spines are sometimes doubled (Fig. 21) only on one half of the puparium.
Table 3. Adult characters and puparium field view of three *Aleurocanthus* species based on EPPO/CABI 1997, Nguyen et al. 2010, Kanmiya et al. 2011, Sullivan et al. 2011 and own observations. Adults of *A. spiniferus* (Fig. 14) and *A. woglumi* cannot be distinguished morphologically (Gyeltshen et al., 2011).

<table>
<thead>
<tr>
<th>Character</th>
<th><em>A. woglumi</em></th>
<th><em>A. camelliae</em></th>
<th><em>A. spiniferus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td></td>
<td></td>
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<tr>
<td>Length of adult</td>
<td>Females 1.7 mm, males 1.35 mm</td>
<td>Female 1.25–1.4 mm; male 0.9–1.1 mm</td>
<td>Females approximately 1.7 mm; males up to 1.33 mm</td>
</tr>
<tr>
<td>Male microscopic view:</td>
<td>Not yet described (Fig. 15)</td>
<td>Distally upcurved on dorsal margin</td>
<td>Distally straight on dorsal margin</td>
</tr>
<tr>
<td>aedeagus lateral view</td>
<td>Not yet described</td>
<td>Deeply incised on anterior and ventral margins</td>
<td>Weakly depressed on anterior margin, rather convex on ventral margin</td>
</tr>
<tr>
<td>Male (Fig. 15): subgenital plate lateral view</td>
<td>No discriminating characters described</td>
<td>No discriminating characters described</td>
<td>No discriminating characters described</td>
</tr>
<tr>
<td>Female microscopic view</td>
<td>No discriminating characters described</td>
<td>Intermediate: 0.2–0.3x disk (Fig. 1); relatively narrow, width 11.2–15.8% of puparial width</td>
<td>Wide, about 0.5x disk (Fig. 2); relatively broad, width 17.3–30.0% of puparial width</td>
</tr>
<tr>
<td>(Fig. 16). Puparium field view</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width of white wax fringe</td>
<td>Narrow, about 0.1x disk; generally half as wide as in <em>A. spiniferus</em></td>
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<td></td>
</tr>
</tbody>
</table>

Table 4. Differences between male and female puparia of three *Aleurocanthus* species.

<table>
<thead>
<tr>
<th><em>A. woglumi</em></th>
<th><em>A. camelliae</em></th>
<th><em>A. spiniferus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length: 1.24 mm;</td>
<td>Length: 0.98–1.23 mm;</td>
<td>Length: 1.08–1.28 mm;</td>
</tr>
<tr>
<td>Width: 0.71 mm;</td>
<td>Width: 0.62–0.85 mm;</td>
<td>Width: 0.8–1 mm;</td>
</tr>
<tr>
<td>6–7 pairs of submarginal spines, posterior most third pair are doubled (Fig. 21) (Dubey &amp; Ko 2012)</td>
<td>11 submarginal spines (Fig. 31), posterior most third pair with a single spine</td>
<td>11 submarginal spines (Fig. 32), posterior most third pair (n = 11) rarely doubled and then 12 spines</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length: 0.99 mm;</td>
<td>Length: 0.65–0.85 mm;</td>
<td>Length: 0.8 mm;</td>
</tr>
<tr>
<td>Width: 0.61 mm;</td>
<td>Width: 0.39–0.57 mm;</td>
<td>Width: 0.58 mm;</td>
</tr>
<tr>
<td>10 pairs of submarginal spines, none of them are doubled (Dubey &amp; Ko 2012)</td>
<td>10 submarginal spines, posterior most third pair with a single spine</td>
<td>10 submarginal spines (Fig. 33)</td>
</tr>
</tbody>
</table>

The microscopic differences between the puparia of these three species are summarised in Table 2. The differences between adult characters and the differences in field views of puparia of *A. spiniferus* and *A. camelliae* are given in Table 3. Given the apparent resemblance among the puparia of the considered species, knowledge is required about the intra-specific variation of at least the next characters:

- The number and position of the spines. Corbett (1935) showed that specimens of *A. spiniferus* from *Rosa* sp. possess six pairs of submarginal spines posterior to the transverse moulting suture, all arising in different places, whereas specimens from *Citrus* spp. show seven pairs of spines, the four and fifth pairs being close together. In females of *A. woglumi* the third posterior-most pair of the submarginal row of spines is usually doubled, whereas males have a single spine in that position.
- The number of marginal teeth per 0.1 mm (=100 μm) (Figs 11, 12) varies: within populations of *A. woglumi* from 3.5 to 5 (rarely 6) and within *A. spiniferus* from (rarely 6) 7 to 11 (rarely 12). In rare cases where six teeth per 0.1 mm are found, the study of several specimens may be of help.
- Female puparia are larger than male ones. Puparia of *A. spiniferus* and *A. camelliae* do not differ significantly in each sex (Table 4). On the other hand, the female and male puparia of *A. woglumi* are both wider (Fig. 11) than in the other species.

Morphological resemblance with other organisms

Depending on the experience of the diagnostician other *Aleurocanthus* species may be confused with *A. spiniferus* or *A. woglumi*. Kanmiya et al. (2011) noted that, compared to *A. spiniferus* and *A. camelliae*:

- *Aleurocanthus hibisci* Corbett, 1935 has longer cephalothoracic spines and closely arranged 9th and 10th submarginal spines.
- *Aleurocanthus gordoniae* Takahashi, 1941 has a perfectly circular vasiform orifice and a reduced number of abdominal spines: 8 abdominal pairs (2 submedian + 6 subdorsal) whereas *A. spiniferus* and *A. camelliae* have 10 pairs.
Discussion

Although the presence of spines is a shared common character of the genus *Aleurocanthus*, the variation of the shape and the number of spines may be an indication for distinguishing several genera. The species which are ascribed to the genus (e.g., Evans 2008 and others) may partly include synonyms and already collected specimens may include new species. Recent studies have revealed that a considerable number of species of the genus *Aleurocanthus* are not yet described (e.g., Dubey & Ko 2012, Gillespie 2012 and unpublished results). A lot of material collected by various workers is waiting for identification or is present in various collections of museums and research institutes. As in other Aleyrodid genera, host-induced variations are observed. These are changes in the morphological structures of puparia depending on the host plant on which they develop. This complicates species description and species identification.

Therefore, newly discovered characters will contribute to an improvement of the species descriptions and a better discrimination between species and species groups. Single species or groups of species within the genus may even actually represent different genera. Much of the collected material now available in collections of workers, museums and research institutes all over the world, is waiting for identification. The study of this material and of the natural occurrence, together with field-oriented ecological studies may result in the recognition and description of new and cryptic species.

These challenges can only be solved by combining all available data. Studying morphological structures in relation to their intraspecific variation may be a challenge as the making of a good slide of a bleached specimen is already a challenge in itself. Support of molecular tools such as barcoding, sequencing and phylogenetic studies and the study of type material are needed to clarify the taxonomy and status of species of this genus. The quality of older type material, which in the case of *Aleurocanthus* is present in various countries, may complicate the study as well. For single species, transplantation experiments may be needed to elucidate the relation of a certain whitefly with various plant hosts. New species descriptions based on new or additional characters and a critical consideration of already existing species descriptions are needed. Normally the puparium is used for identification purposes but in such a study all instars are of importance.

Most species live in the Oriental Region and the majority of species can be distinguished based on small differences in the number of spines (Dubey & Ko 2012). As there is no key available for all the described *Aleurocanthus* species of the world or even for the species of major geographical regions, an identification of *Aleurocanthus* species is always tentative and needs confirmation by a specialist.

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