APPROVED: 14 December 2018

doi:10.2903/sp.efsa.2019.EN-1565

Pest survey card on *Aleurocanthus spiniferus* and *Aleurocanthus woglumi*

European Food Safety Authority (EFSA),
Gritta Schrader, Melanie Camilleri, Ramona Mihaela Ciubotaru Makrina Diakaki, Sybren Vos

Abstract

This pest survey card was prepared in the context of the mandate on plant pest surveillance (EFSA-Q-2017-00831), upon request by the European Commission. The purpose of this document is to assist the Member States in planning annual survey activities of quarantine organisms using a statistically sound and risk-based pest survey approach, in line with the current international standards. The data requirements for such activity include the pest distribution, its host range, its biology, risk factors as well as available detection and identification methods. This document is part of a toolkit that consists of pest-specific documents, such as the pest survey cards and generic documents relevant for all pests to be surveyed, including, the general survey guidelines and statistical software such as RiBESS+.

Keywords: plant pest, survey, risk-based surveillance, *Aleurocanthus spiniferus*, *Aleurocanthus woglumi,* orange spiny whitefly, citrus blackfly

Requestor: European Commission

Question number: EFSA-Q-2018-00353

Correspondence: ALPHA@efsa.europa.eu

Acknowledgements: EFSA wishes to acknowledge the Netherlands Food and Consumer Product Safety Authority (NVWA) and the Julius Kuehn Institute (JKI) in Germany, for the support provided to this scientific output in the context of the grants GP/EFSA/ALPHA/2017/02. EFSA also wishes to thank EFSA Plant Health Panel member Alan MacLeod, for reviewing this document as well as the working group members that contributed to the preparation of this output.

Suggested citation: EFSA (European Food Safety Authority), Schrader G, Camilleri M, Ciubotaru RM, Diakaki M and Vos S, 2019. Pest survey card on *Aleurocanthus spiniferus* and *Aleurocanthus woglumi*. EFSA supporting publication 2019: EN-1565. 17 pp. doi:10.2903/sp.efsa.2019.EN-1565

ISSN: 2397-8325

Table of contents

Introduction

The information presented in this pest survey card is summarised from a recent pest categorisation of *Aleurocanthus* spp. (EFSA PLH Panel, 2018), European and Mediterranean Plant Protection Organisation (EPPO) diagnostic protocols on *Aleurocanthus spiniferus* and on *Aleurocanthus woglumi* (EPPO, 2002a,b), the Centre for Agriculture and Bioscience International (CABI) datasheet on *A. woglumi* (CABI, 2018) and the EPPO datasheets on *A. spiniferus* and on *A. woglumi* (EPPO and CABI, 1996 a,b).

Taxonomists have great difficulty in identifying and distinguishing some members of the genus *Aleurocanthus*. When specimens are intercepted, the host plant and country of origin help diagnosticians make an informed judgement as to what the species is likely to be. Morphology alone might not be sufficient as the genus consists of polyphenic species, i.e. the same species may express different morphological features when found on different hosts. The most common species moving via international trade are *A. spiniferus* and *A. woglumi*. These species are serious pests of citrus and are of concern to the EU. Adults of these two major *Aleurocanthus* pests, *A. spiniferus* and *A. woglumi* cannot be easily distinguished (Gyeltshen et al., 2017). Other *Aleurocanthus* species reported as having an economic impact on citrus include *A. citriperdus* in India and Pakistan and *A. husaini* in India (EFSA PLH Panel, 2018).

This survey card focuses specifically on the widely distributed and the two most documented individual *Aleurocanthus* species, *A. woglumi* (Figure 4) and *A. spiniferus* (Figure 5), which are considered to be significant pests for citrus, though the EFSA pest categorisation recognises that other *Aleurocanthus* species could also have the potential to be quarantine pests. Only scattered information was identified for these other species of the genus.

The objective of this pest survey card is to provide the relevant biological information needed to prepare surveys for *Aleurocanthus* spp. in EU Member States (EFSA, 2018). It is part of a toolkit that is being developed to assist Member States with planning a statistically sound and risk-based pest survey approach in line with International Plant Protection Convention guidelines for surveillance (FAO, 2016). The toolkit consists of pest-specific documents and generic documents relevant for all pests to be surveyed:

i. Pest-specific documents:
   a. The pest survey card on *Aleurocanthus* spp. [1]
ii. General documents:
   a. The general survey guidelines (to be finalised in 2019)
   b. The RiBESS+ manual available online[2]
   c. The statistical tools RiBESS+ and SAMPELATOR which are available online[3] with open access after registration.

[1] The content of this EFSA Supporting Publication is reproduced as a live document available at https://efsa.maps.arcgis.com/apps/MinimalGallery/index.html?appid=f91d6e95376f4a5da206eb1815ad1489 where it will be updated whenever new relevant information becomes available.
[2] https://zenodo.org/record/2541541/preview/ribess-manual.pdf
[3] https://websso-efsa.openanalytics.eu/auth/realms/efsa/protocol/openid-connect/auth?response_type=code&client_id=shiny-efsa&redirect_uri=https%3A%2F%2Fshiny-efsa.openanalytics.eu%2Fsso%2Flogin&state=d6f7f997-d09f-4bb0-afce-237f192a72d5&login=true&scope=openid

1. The pest and its biology

1.1. Taxonomy

Scientific name: *Aleurocanthus* spp., *Aleurocanthus spiniferus* (Quaintance, 1903) and *Aleurocanthus woglumi* (Ashby, 1915).

Class: Insecta, Order: Hemiptera, Family: Aleyrodidae, Genus: *Aleurocanthus*, Species: *Aleurocanthus spiniferus* and *Aleurocanthus woglumi*.

Synonyms for *Aleurocanthus spiniferus*: *Aleurodes spinifera*, *Aleurodes citricola*, *Aleurocanthus citricolus*, *Aleurocanthus rosae*.

Synonyms for *Aleurocanthus woglumi*: *Aleurocanthus punjabensis*, *Aleurocanthus woglumi* var. *formosana*, *Aleurodes woglumi*.

Common names in English for *Aleurocanthus spiniferus*: Orange spiny whitefly, spiny blackfly.

Common name in English for *Aleurocanthus woglumi*: Citrus blackfly.

The EFSA PLH Panel (2018) described *Aleurocanthus* spp. as a well-defined and clearly identifiable insect genus which includes a variable number of species according to different sources: 82 are reported in Evans (2007); 79 in Quaintance and Baker (1914); 78 in Martin and Mound (2007) and 93 in the Arthemis database (online). However, difficulties within the taxonomy of the genus raise doubts about the ability to accurately identify some specimens to species level.

1.2. EU pest regulatory status

Aleurocanthus spp. are regulated on plants of *Citrus* L., *Fortunella* Swingle, *Poncirus* Raf., and their hybrids, other than fruit and seeds (Annex II/AI of Council Directive 2000/29/EC[4]). There are no specific requirements for *A. woglumi* or *A. spiniferus*.

Legislation addressing regulated hosts and commodities that may involve *Aleurocanthus* spp. is laid down in Annexes III, IV and V of Council Directive 2000/29/EC and has been summarised in the EFSA pest categorisation of *Aleurocanthus* spp. (EFSA PLH Panel, 2018).

1.3. Pest distribution

Aleurocanthus spp. are widespread mainly in the tropical and subtropical areas of Africa, North and South America, Asia and Oceania. The distribution of the most widely distributed and the most economically important species are illustrated in Figure 1 (*A. spiniferus*) and Figure 2 (*A. woglumi*). Only *A. spiniferus* is known to be present in the EU, in restricted areas of Italy and Greece, where it is under official control. No other *Aleurocanthus* spp. are known to occur in the EU (EFSA PLH Panel, 2018).

[4] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. OJ L 169, 10.7.2000, p. 1–112. Consolidated version of 01/04/2018

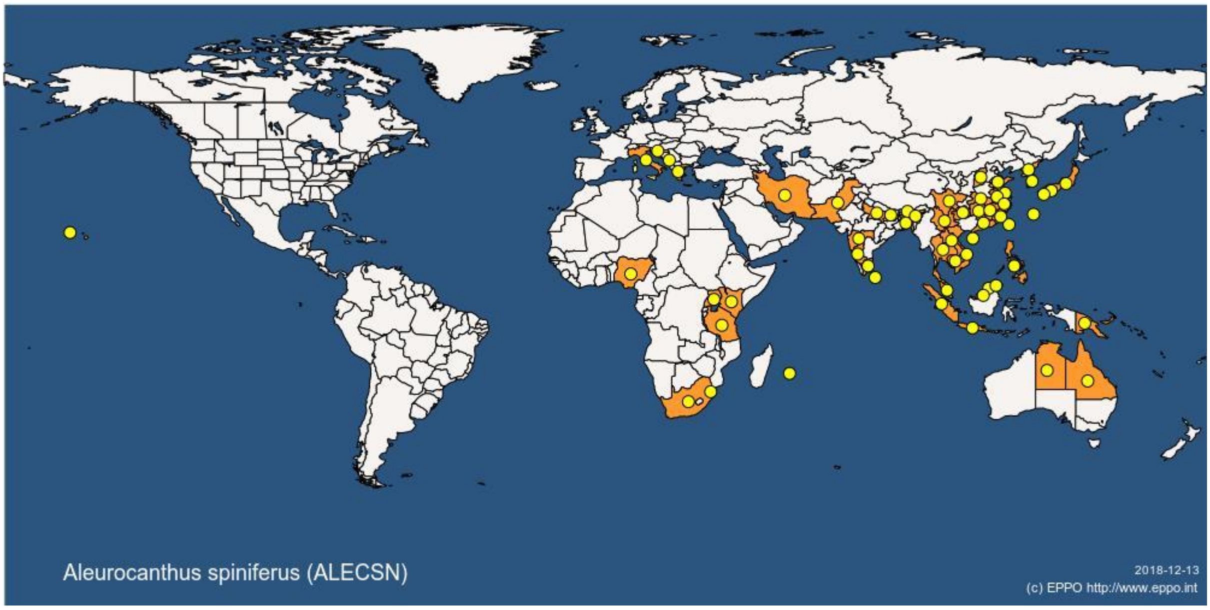

Figure 1: Global distribution of *Aleurocanthus spiniferus*. The pest status in countries or states is reported as present (yellow dots) (Source: EPPO global database, www.eppo.int).

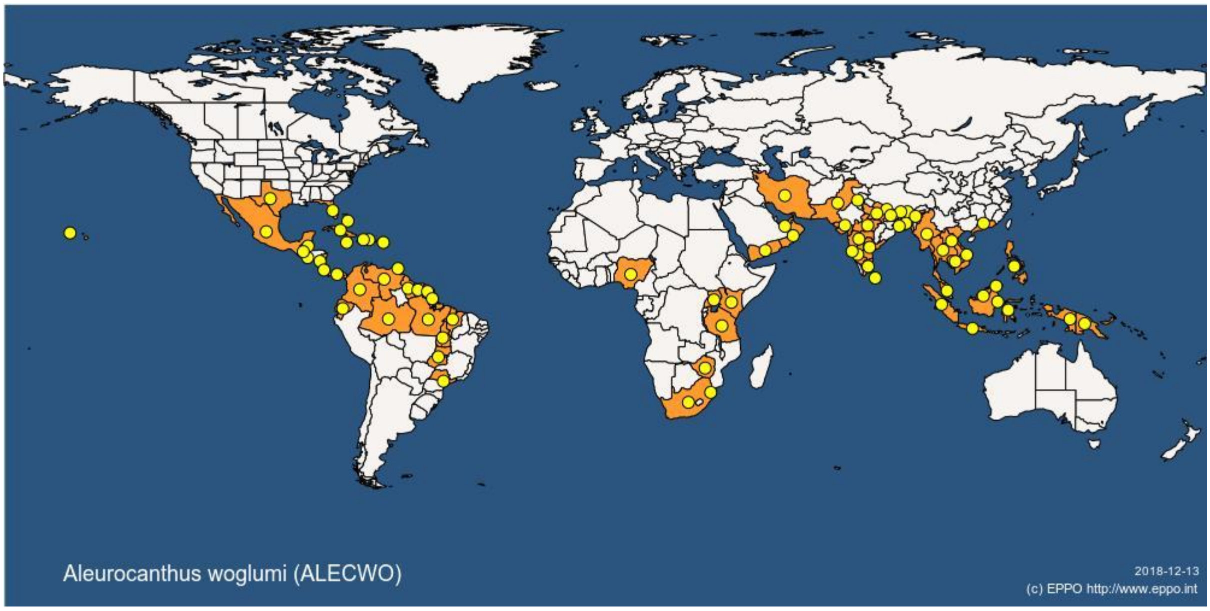

Figure 2: Global distribution of *Aleurocanthus woglumi.* The pest status in countries or states is reported as present (yellow dots) (Source: EPPO global database, www.eppo.int).

1.4. Life cycle

All species in the genus *Aleurocanthus* have six developmental stages: egg, 1st instar, two sessile nymphal instars (2nd and 3rd instars), pupa (4th instar) and adult.

Eggs are laid in a characteristic spiral on the underside of young leaves in batches of 35–50 and hatch in 4–12 days in favourable conditions (CABI, 2018; EPPO and CABI, 1996a,b). The first instars are active and disperse over a short distance, avoiding strong sunlight and usually settling in a dense colony of up to several hundred on the undersides of young leaves. The next three immature instars are attached to the leaf by their mouthparts. All stages feed on phloem sap, except the fourth instar or 'pupa' which is a resting phase (CABI, 2018).

The duration of the life cycle and the number of generations per year are greatly influenced by the prevailing climate (Gyeltshen et al., 2017). CABI (2018) mentions that the life cycle takes 2–4 months depending on conditions (see Section 1.6) developing from three to six generations per year. In tropical and subtropical climates continuous overlapping generations may occur with slowed development during short, cold periods (Hodges and Evans, 2005).

The biology of *A. spiniferus* is similar to that of *A. woglumi.*

Infestations occur mainly on the lower parts of the trees (EPPO, 2002a,b).

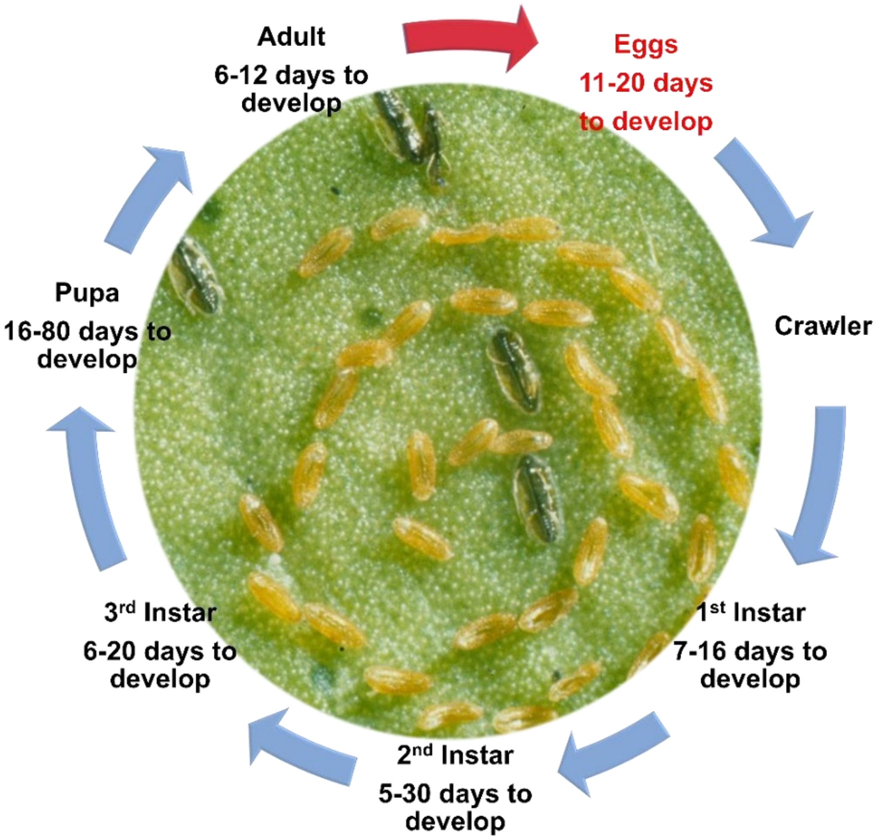

Figure 3: Life cycle of *Aleurocanthus spiniferus* and *Aleurocanthus woglumi*. Note the characteristic pattern of oviposition (Source of insect eggs picture: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org)

1.5. Host range and main hosts

According to the literature research carried out by the EFSA PLH Panel (2018), the genus comprises polyphenic species (i.e. the same species may express different character states when found on different hosts). *A. woglumi* and *A. spiniferus* are two of the major citrus pests and are both highly polyphagous.

Cioffi et al. (2013) listed 90 plant species of 38 plant families to be infested by *A. spiniferus* and although *Citrus* spp. are the main hosts of economic importance (major hosts in the EPPO global database), *A. spiniferus* has also been recorded on other crops, such as grapes (*Vitis vinifera*), guavas (*Psidium guajava*), pears (*Pyrus* spp.), persimmons (*Diospyros kaki*) and roses (*Rosa* spp.).

In the EU, *A. spiniferus* was reported for the first time on *Citrus limon* (Porcelli, 2008). It was also reported to infest plants of other Rutaceae, as well as Vitaceae, Araliaceae, Ebenaceae, Leguminosae–Caesalpiniaceae, Malvaceae, Lauraceae, Moraceae, Punicaceae and Rosaceae. *A. spiniferus* was found to infest the leaves of plants in urban areas, parks and natural protected habitats such as *Citrus* spp., *Diospyros kaki*, *Ficus carica*, *Laurus nobilis*, *Malus*, *Morus alba*, *Punica granatum*, *Pyrus* spp., *Rosa* spp. and *Vitis* spp. The pest also infests wild plants such as *Hedera helix*, *Laurus nobilis*, *Prunus* spp. and *Salix* spp. (Cioffi et al., 2013).

A. woglumi can infest more than 300 plant species, including cultivated plants, ornamentals and weeds, but mostly occurs on plants of the genus *Citrus* (lemon and tangerine; major hosts in the EPPO global database; EFSA PLH Panel, 2018). *A. woglumi* also occurs on a wide range of other crops, mostly fruit trees, including avocados (*Persea americana*), bananas (*Musa* spp.), cashews (*Anacardium occidentale*), coffee (*Coffea arabica*), ginger (*Zingiber officinale*), grapes (*Vitis vinifera*), guavas (*Psidium guajava*), lychees (*Litchi chinensis*), mangoes (*Mangifera indica*), pawpaws (*Carica papaya*), pears (*Pyrus* spp.), pomegranates (*Punica granatum*), quinces (*Cydonia oblonga*) and roses (*Rosa* spp.). According to EPPO, 75 species in 38 families have been reported in Mexico as hosts on which *A. woglumi* can complete its life cycle (EPPO, 2002b).

Uncertainty has been mentioned on the ability of *A. woglumi* to permanently infest plants other than citrus (EFSA PLH Panel, 2018).

As of 28 August 2018, ten records of *Aleurocanthus* spp. interceptions are listed in the EUROPHYT database. Six of them were identified as *A. woglumi* on *Citrus hystrix*, *Annona reticulata* or Musaceae. Four interceptions were identified as *A. spiniferus* on either *Camellia sasanqua* or *Camellia japonica.*

Both species under scrutiny are polyphagous and therefore the import inspections should attempt to address their full host range, while for the yearly or multiannual surveys on quarantine organisms within the EU territory the focus should be on citrus as the main hosts.

1.6. Environmental suitability

In tropical conditions, all stages of *A. woglumi* may be found throughout the year, but reproduction stops during cold periods.

CABI (2018) mentions that the optimal conditions for development of *A. woglumi* are 28–32°C and 70–80% relative humidity. The pest does not survive temperatures below freezing and does not occur in areas where temperatures exceed 43°C. Dowell and Fitzpatrick (1978) indicate 13.7°C as the lower threshold of development for *A. woglumi*.

A. spiniferus and *A. woglumi* both occur on citrus in Kenya where they seem to have different ecological preferences, with *A. spiniferus* being dominant at higher altitudes and *A. woglumi* at lower altitudes. Also, *A. woglumi* does not occur in Korea, whereas *A. spiniferus* does. This may reflect less tolerance to low temperatures in *A. woglumi* relative to *A. spiniferus* (CABI, 2018).

According to the EFSA PLH Panel (2018), in the EU where the host plants are available, citrus in particular, the climate is not limiting the establishment of the pest. Therefore, the citrus-growing areas in the EU are the target for the surveillance of the pests under scrutiny.

1.7. Spread capacity

Adults of *Aleurocanthus* spp. are capable of limited down-wind flight but this is not a major means of long-range dispersal. The whiteflies are most likely to be moved between countries on planting material of citrus or other host species, or probably also by contamination of fruit and leaves being transported (CABI, 2018).

1.8. Risk factor identification

Identification of risk factors and their relative risk estimation is essential for performing risk-based surveys. A risk factor is a biotic or abiotic factor that enhances the probability of infestation by the pest. The identification process needs to be tailored to the situation of each Member State. To allow for sample size calculations, each Member State needs to know (or estimate) the proportion of the target population for each risk factor.

According to the EFSA PLH Panel (2018) and to the EUROPHYT interceptions database, *A. spiniferus* and *A. woglumi* were mostly identified on ornamental plants of the *Camellia* genus and *Annona reticulata.*

Therefore, higher risk locations can be defined where there is a higher probability of detecting the pest, such as nurseries, pack houses, garden centres and other facilities handling imported plants for planting or plant commodities from infested areas that are identified as the main pathways of entry of the flies.

2. Detection and identification

Detection is possible using standard techniques in entomology, e.g. yellow sticky traps to capture adults. Since adult and immature stages are present on aboveground plant parts, Aleyrodidae can be detected by plant sampling (Augustin et al., 2012). There are keys available for identification at the genus level (Nguyen et al., 2016; and web key https://www.freshfromflorida.com/Divisions-Offices/Plant-Industry/Science/Key-to-Whitefly-of-Citrus-in-Florida/Key-To-Whitefly-On-Citrus-In-Florida/I.-Key-To-Whitefly-Fourth-Instars-On-Citrus).

Species identification is extremely difficult and identity is not established for all *Aleurocanthus* spp. (EFSA PLH Panel, 2018).

2.1. Visual examination

2.1.1. Pest

Adult *Aleyrodidae*, or whiteflies, are minute insects, rarely more than 2 or 3 mm in length, that resemble tiny moths. The adults of both sexes are winged and the wings are covered with a waxy powder. The wings of adults of both *A. spiniferus* and *A. woglumi* are metallic grey-blue in appearance and light markings on the wings appear to form a band across the middle of the red abdomen (EPPO and CABI, 1996a,b).

Figure 4: Adult of *Aleurocanthus woglumi* – a clearly distinguished species (Source: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 5: Adult of *Aleurocanthus spiniferus* – a clearly distinguished species (Source: MA van den Berg, Institute for Tropical and Subtropical Crops, Bugwood.org)

Risk of misidentification

A. woglumi and *A. spiniferus* might be confused with several similar species of *Aleurocanthus* that occur on citrus, including *A. citriperdus*, and *A. husaini*. They can also be confused with each other since these species differ from one another only in microscopic characteristics (CABI, 2018).

Therefore, the required stage for identification purposes is the puparium (pupal case) of the pupa. It is characterised by numerous dorsal spines and is often surrounded by a white fringe of waxy secretion typical of the species (Figure 6).

Figure 6: Multiple life stages of *Aleurocanthus spiniferus*. Eggs and nymphal instars 1, 2 and 4 (pupae, 1.2 mm in length). The white waxy filaments are typical of the species (Source: MA van den Berg, Institute for Tropical and Subtropical Crops, Bugwood.org)

The pupal cases of *A. spiniferus* and *A. woglumi* are very similar in appearance, but they differ in some morphological aspects. *A. woglumi* has smaller marginal teeth (7–11 per 0.1 mm of margin) and 'the spines of the submarginal row are subequal in length and none of which are doubled' (EPPO, 2002b). *A. spiniferus* has coarser marginal teeth (less than 7 per 0.1 mm) and the spines of the submarginal row have some pairs much longer than others, the third hindmost pair usually being doubled (EPPO, 2002a).

2.1.2. Symptoms

Aleurocanthus spp. can cause distorted leaves with abnormal forms. The insects are most noticeable grouped into very small, black spiny lumps on the undersides of leaves (CABI, 2018).

Sticky honeydew deposits accumulate on leaves and stems, usually developing black sooty mould fungus, giving the foliage (even the whole plant) a sooty appearance (Figure 7). The presence of ants is due to their attraction by the honeydew (CABI, 2018).

Figure 7: Sticky honeydew deposits produced by *Aleurocanthus woglumi* on a citrus plant with sooty mould fungus (Source: Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org)

A monitoring programme was established by the Campania Region in Italy to verify the spread of *A. spiniferus* or the presence of its symptoms.

The monitoring is based primarily on visual observations, investigating any symptoms of the infestation and in doubtful cases laboratory investigations are required.

The examined host plants belong mainly to the genus *Citrus*, followed by *Vitis* spp. and *Rosa* spp. located in areas next to possibly infested plants (at least 100 m radius), mainly along the outer border of the infested area.

Visual surveys were more efficient than sticky traps (see below) for detecting *A. woglumi* at low densities (<5% leaves infested) on citrus trees in urban areas (Dowell and Cherry, 1981). Visual surveys detected the first infestation with *A. spiniferus* in Italy (Porcelli, 2008).

2.1.3. Traps

According to Wang et al. (2015), *A. spiniferus* preferred yellow trap colours in tea gardens, followed by pink, red, white and other colours. Most attractive were 20 traps per 667 m^2 of trial area at a height of 10 cm above the tea canopy. Male adults were most active between 11:00 and 15:00 (283 male adults compared with 15 females) and between 7:00 and 11:00 (215 males compared with 11 females). No information on temperature and humidity was given in the article.

According to Meyerdirk et al. (1979a), *A. woglumi* was more attracted by translucent traps than opaque ones and fluorescent yellow traps had a greater attractiveness than simple yellow ones.

Trap shape has, according to Meyerdirk et al. (1979a), no influence on efficiency. The optimum trap height in citrus orchards was found to be at 2–3 m above ground level at the maximum thickness of the tree foliage (Hart et al., 1978) or 1.5 m above ground level (Meyerdirk et al. 1979b).

A few reports suggest that attractive odours could improve trapping efficacy (Li and Maschwitz, 1983; Baranowski and Blaszak, 1996; Gorski, 2003), but there is no standardised procedure available.

The sensitivity of the traps is limited by the fact that yellow traps are not specific for *Aleurocanthus* spp.

Detection of the *Aleurocanthus* spp. by trapping should be done mainly in the citrus orchards, particularly in the vicinity of the higher risk locations as defined in Section 1.8.

2.2. Laboratory testing and pest identification

CABI (2018) states that for a clear identification of the two species the microscopic examination of the fourth puparium by a whitefly specialist is mandatory.

Taxonomy of the two individual species is based on the empty pupal cases and their external surface morphology. These morphological characteristics can be seen under a microscope following the procedure for microscope examination described by Martin (1999).

Once intercepted, identification of the species is based on either morphological characteristics or molecular markers (Bosco et al., 2006; Papayiannis et al., 2009).

Diagnostic protocols for *A. woglumi* and *A. spiniferus* were prepared by EPPO (2002a,b). The same diagnostic protocols cite Bink-Moenen (1983) who gives information on morphological characteristics to distinguish the pupal cases of *Aleurocanthus* from other genera.

3. Key elements for survey design

Based on the analyses of the information on the pest–host plant system, the different units that are needed to design the survey have to be defined and tailored to the situation of each Member State. The size of the defined target population and its structure in terms of the number of epidemiological units need to be known. When several pests have to be surveyed in the same crop, it is recommended to use the same epidemiological and inspection units for each pest in order to optimise the survey programme as much as possible.

Table 1 shows an example of these definitions.

Table 1: Example of definitions of the target population, epidemiological unit and inspection unit for the *Aleurocanthus spiniferus* and *A. woglumi* surveys in citrus.

	Definition	Unit
Target population	Total area of citrus orchards and citrus trees in backyards and gardens	Total hectare
Epidemiological units	Orchards of citrus and citrus trees in backyards and gardens	e.g. Half hectare*
Inspection units	Individual trees, leaves and traps	

*In Spain, half a hectare of citrus orchard is assumed to represent the average size of a farm area in which the cultivar (citrus species and variety), the cultural practices and the ownership are similar or the same.

The general guidelines for the risk-based statistically sound surveillance are presented in a separate document and describe the process of the survey design step by step and include:

1/ the choice of the type of survey to develop depending on the objectives of the survey
2/ a manual for guiding the user through the statistical tools for sample size calculations
3/ essential considerations when:

- choosing the sampling sites and taking the samples
- collecting the data
- reporting the data and the survey results.

References

Arthemis (Arthropod Ecology, Molecular Identification and Systematics) database, online. INRA/CBGP http://arthemisdb.supagro.inra.fr/ [accessed on 10 December 2018]

Augustin S, Boonham N, De Kogel WJ, Donner P, Faccoli M, Lees DC, Marini L, Mori N, Toffolo EP, Quilici S, Roques A, Yart A and Battisti A, 2012. A review of pest surveillance techniques for detecting quarantine pests in Europe, EPPO Bulletin, 42 (3), 515-551

Baranowski T and Blaszak D, 1996. The influence of colour and smell on the effectivity in catching greenhouse whitefly. Roczniki Nauk Rolnicczych 25, 59–61.

Bink-Moenen RM, 1983. Revision of the African Whiteflies (Aleyrodidae), mainly based on a collection from Tchad. Monografieën van de Nederlandse Entomologische Vereniging 10, 1–210.

Bosco D, Loria A, Sartor C and Cenis JL, 2006. PCR-RFLP identification of Bemisia tabaci biotypes in the Mediterranean basin. Phytoparasitica 34, 243–251.

CABI (Centre for Agriculture and Bioscience International), 2018. *Aleurocanthus woglumi*. In: Invasive Species Compendium. Wallingford, UK: CAB International. Available online: https://www.cabi.org/ISC/datasheet/4137 [accessed 10 December 2018].

Cioffi M, Cornara D, Corrado I, Gerardus M, Jansen M and Porcelli F, 2013. The status of *Aleurocanthus spiniferus* from its unwanted introduction in Italy to date. Bulletin of Insectology 66: 273-281.

Dowell RV and Fitzpatrick GE, 1978. Effects of temperature on the growth and survivorship of the citrus blackfly (Homoptera: Aleurodidae). Canadian Entomologists, 110: 1347-1350.

Dowell RV and Cherry RH, 1981. Detection of, and sampling procedures for, the citrus blackfly in urban southern Florida. Researches on Population Ecology 23:19-26.

EFSA PLH Panel (EFSA Panel on Plant Health), 2018. Scientific opinion on the pest categorisation of *Aleurocanthus* spp. EFSA Journal 16 (10):5436, 17 pp. doi:10.2903/j.efsa.2018.5436

EFSA (European Food Safety Authority), 2018. Technical report of the methodology and work-plan for developing plant pest survey guidelines. EFSA supporting publication 2018: EN-1399. 36 pp. doi:10.2903/sp.efsa.2018.EN-1399

EPPO (European and Mediterranean Plant Protection Organization) and CABI (Centre for Agriculture and Bioscience International), 1996a. *Aleurocanthus spiniferus*. In: Smith IM (ed.). Quarantine pests for Europe. 2nd Edition. CABI Bioscience, Egham.

EPPO (European and Mediterranean Plant Protection Organization) and CABI (Centre for Agriculture and Bioscience International), 1996b. *Aleurocanthus woglumi*. In: Smith IM (ed.). Quarantine pests for Europe. 2nd Edition. CABI Bioscience, Egham.

EPPO (European and Mediterranean Plant Protection Organization), 2002a. Diagnostic protocols for regulated pests PM7/7 (1) *Aleurocanthus spiniferus*. Bulletin OEPP/EPPO Bulletin 32, 241–243.

EPPO (European and Mediterranean Plant Protection Organization), 2002b. Diagnostic protocols for regulated pests PM7/8 (1) *Aleurocanthus woglumi*. Bulletin OEPP/EPPO Bulletin 32, 241–243.

EPPO (European and Mediterranean Plant Protection Organization), online. EPPO Global Database. Available online: https://gd.eppo.int [accessed 12 December 2018]

Evans G, 2007. The whiteflies (Hemiptera: Aleyrodidae) of the world and their host plants and natural enemies. Available online: http://keys.lucidcentral.org/keys/v3/whitefly/PDF_PwP%20ETC/world-whitefly-catalog-Evans.pdf

FAO (Food and Agriculture Organization of the United Nations), 2016. Plant Pest Surveillance: A guide to understand the principal requirements of surveillance programmes for national plant protection organizations. Version 1.1. FAO, Rome, Italy. Available online: https://www.ippc.int

Gorski R, 2003. Evaluation of the effectiveness of natural essential oils in the monitoring of the occurrence of greenhouse whitefly. Journal of Plant Protection Research 43, 393–397.

Gyeltshen J, Hodges A and Hodges G, 2017. Orange Spiny Whitefly, *Aleurocanthus spiniferus* (Quaintance) (Insecta: Hemiptera). US Department of Agriculture, UF/IFAS Extension Service, University of Florida. EENY34. Available online: https://edis.ifas.ufl.edu/pdffiles/IN/IN61800.pdf

Hart W, Meyerdirk D, Sanchez M, Stone W, and Rhode R, 1978. Development of a trap for citrus blackfly, Aleurocanthus woglumi Ashby. Southwestern Entomologist 3:219-225.

Hodges GS and Evans GA, 2005. An identification guide to the whiteflies (Hemoptera: Aleyrodidae) of the Southeastern United States. Florida Entomologists 88(4): 518-534.

Li T and Maschwitz U, 1983. Sexual pheromone in the greenhouse whitefly Trialeurodes vaporariorum Westw. Zeitschrift fur Angewandte Entomologie 95, 439–446.

Martin JH, 1999. The whitefly fauna of Australia (Sternorrhyncha: Aleyrodidae). A taxonomic account and identification guide. CSIR Entomology Technical Paper 38, 1–197.

Martin JH and Mound LA, 2007. An annotated check list of the world's whiteflies (Insecta: Hemiptera: Aleyrodidae Zootaxa, 1492, pp.1–84.

Meyerdirk DE, Hart WG, Burnside JA, 1979a. Evaluation of a trap for the citrus blackfly, Aleurocanthus woglumi (Homoptera: Aleyrodidae). Canadian Entomologist 111:1127-1129.

Meyerdirk DE, Hart WG, Burnside JA, 1979b. Flight behavior of the citrus blackfly. Journal of Economic Entomology 72:395-398.

Nguyen R, Hamon AB and Fasulo TR, 2016. Featured Creatures – citrus blackfly. Publication number EENY-42. University of Florida, Florida USA. Available online: http://entnemdept.ufl.edu/creatures/citrus/citrus_blackfly.htm [accessed 24.10.2018].

Papayiannis LC, Brown JK, Seraphides NA, Hadjistylli M, Ioannou N and Katis NI, 2009. A real-time PCR assay to differentiate the B and Q biotypes of the Bemisia tabaci complex in Cyprus. Bulletin of Entomological Research 99, 573–582.

Porcelli F, 2008. First record of *Aleurocanthus spiniferus* (Homoptera: Aleyrodidae) in Puglia, Southern Italy, EPPO Bulletin, 38(3): 516-518.

Quaintance AL and Baker AC, 1914. Classification of the Aleyrodidae Part II. Technical Series, United States Department of Agriculture Bureau of Entomology 27: 95-109 [102].

Wang Y, Gao N, Shi L, Qin Z, He P, Hu D, Tan X and Chen Z, 2015. Evaluation of the attractive effect of coloured sticky traps for Aleurocanthus spiniferus (Quaintance) and its monitoring method in tea garden in China. Journal of Entomological and Acarological Research, 47(3), 86-90. doi:10.4081/jear.2015.4603

Glossary

Term	Definition*
Component (of a survey)	In the general framework of surveillance, with the goal of demonstrating pest freedom, a component is an activity characterised by a given sensitivity of the method of detection and identification. The overall confidence of the survey for pest freedom will result from the combination of the different components. Two components of the same survey could have different target populations. E.g. Survey on an insect performed by trapping of the pest (component 1) and sampling the host plants for visual examination of signs or symptoms (component 2).
Confidence	Sensitivity of the survey. Is a measure of reliability of the survey procedure (Montgomery and Runger, 2010).
Design prevalence	It is based on a pre-survey estimate of the likely actual prevalence of the pest in the field (McMaugh, 2005). The survey will be designed in order to obtain at least a positive test result when the prevalence of the disease will be above the defined value of the design prevalence. In 'freedom from pest' approaches, it is not statistically possible to say that a pest is truly absent from a population (except in the rare case that a census of a population can be completed with 100% detection efficiency). Instead, the maximum prevalence that a pest could have reached can be estimated, this is called the 'design prevalence'. That is, if no pest is found in a survey, the true prevalence is estimated to be somewhere between zero and the design prevalence. (EFSA, 2018)
Diagnostic protocols	Procedures and methods for the detection and identification of regulated pests that are relevant to international trade (ISPM 27: FAO, 2016).
Epidemiological unit	A homogeneous area where the interactions between the pest, the host plants and the abiotic and biotic factors and conditions would result in the same epidemiology should the pest be present. The epidemiological units are subdivisions of the target population and reflect the structure of the target population in a geographical area. They are the units of interest, on which statistics are applied (e.g. a tree, orchard, field, glasshouse, or nursery) (EFSA, 2018).
Expected prevalence	In prevalence estimation approaches, it is the proportion of epidemiological units expected to be infected or infested.
Identification	Information and guidance on methods that either used alone or in combination lead to the identification of the pest (ISPM 27: FAO, 2016).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine whether pests are present or to determine compliance with phytosanitary regulations (ISPM 5: FAO, 2018).
Inspection unit	The inspection units are the plants, plant parts, commodities or pest vectors that will be scrutinised to identify and detect the pests. They are the units within the epidemiological units that could potentially host the pests and on which the pest diagnosis takes place. (EFSA, 2018).
Inspector	Person authorised by a national plant protection organisation to discharge its functions (ISPM 5: FAO, 2018).
Method sensitivity	The conditional probability of testing positive given that the individual is diseased (Dohoo et al., 2010). The method diagnostic sensitivity (DSe) is the probability that a truly positive epidemiological unit will give a positive result and is related to the analytical sensitivity. It corresponds to the probability that a truly positive epidemiological unit that is inspected will be detected and

	confirmed as positive.
Pest diagnosis	The process of detection and identification of a pest (ISPM 5: FAO, 2018).
Pest freedom	An area in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (ISPM 5: FAO, 2018).
Population size	The estimation of the number of plants in the region to be surveyed (EFSA, 2018).
Relative risk	The ratio of the risk of disease in the exposed group to the risk of disease in the non-exposed group (Dohoo et al., 2010).
Representative sample	A sample that describes very well the characteristics of the target population (Cameron et al., 2014).
RiBESS+	An online application that implements statistical methods for estimating the sample size, global (and group) sensitivity and probability of freedom from disease. Free access to the software with prior user registration is available at: https://shiny-efsa.openanalytics.eu/
Risk assessment	Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences (ISPM 5: FAO, 2018).
Risk factor	A factor that may be involved in causing the disease (Cameron et al., 2014). It is defined as a biotic or abiotic factor that increases the probability of infestation of the epidemiological unit by the pest. The risk factors relevant for the surveillance should have more than one level of risk for the target population. For each level, the relative risk needs to be estimated as the relative probability of infestation compared to a baseline with a level 1. Consideration of risk factors in the survey design allows the survey efforts to be enforced in those areas where the highest probabilities exist to find the pest should the pest be present.
Risk-based survey	A survey design that considers the risk factors and enforces the survey efforts in the corresponding proportion of the target population.
Sample size	The number of sites that need to be surveyed in order to detect a specified proportion of pest infestation with a specific level of confidence, at the design prevalence (McMaugh, 2005).
Survey	An official procedure conducted over a defined period of time to determine the characteristics of a pest population or to determine which species are present in an area (ISPM 5: FAO, 2018).
Target population	The set of individual plants or commodities or vectors in which the pest under scrutiny can be detected directly (e.g. looking for the pest) or indirectly (e.g. looking for symptoms suggesting the presence of the pest) in a given habitat or area of interest. The different components pertaining to the target population that need to be specified are: • Definition of the target population – the target population has to be clearly identified • Target population size and geographic boundary. (EFSA, 2018)
Test	Official examinations, other than visual, to determine whether pests are present or to identify pests (ISPM 5: FAO, 2018).
Test specificity	The conditional probability of testing negative given that the individual does not have the disease of interest (Dohoo et al., 2010). The test diagnostic specificity (DSp) is the probability that a truly negative epidemiological unit will test negative and is related to the analytical specificity. In freedom from disease it is assumed to be

	100%.
Visual examination	The physical examination of plants, plant products or other regulated articles using the unaided eye, lens, stereoscope or microscope to detect pests or contaminants without testing or processing (ISPM 5: FAO, 2018).

*References
Cameron A, Njeumi F, Chibeu D, Martin T, 2014. Risk-based disease surveillance. FAO (Food and Agriculture Organization of the United Nations), Rome.
Dohoo I, Martin W and Stryhn H, 2010. Veterinary epidemiologic research. 2nd Edition. VER Inc., Canada.
EFSA (European Food Safety Authority), 2018. Technical report of the methodology and work-plan for developing plant pest survey guidelines. EFSA supporting publication 2018: EN-1399. 36 pp. doi:10.2903/sp.efsa.2018.EN-1399
FAO (Food and Agriculture Organization of the United Nations), 2016. ISPM (International Standards for Phytosanitary Measures) 27. Diagnostic protocols for regulated pests. FAO, Rome, Italy. Available online: https://www.ippc.int/en/publications/593/
FAO (Food and Agriculture Organization of the United Nations), 2018. ISPM (International Standards for Phytosanitary Measures) 5. Glossary of phytosanitary terms. FAO, Rome, Italy. Available online: https://www.ippc.int/en/publications/622/
McMaugh T, 2005. Guidelines for surveillance for plant pests in Asia and the Pacific. ACIAR Monograph No.119, 192 pp.
Montgomery DC and Runger GC, 2010. Applied statistics and probability for engineers. Fifth Edition, John Wiley & Sons. 792 pp.