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Whitefly fauna (Hemiptera: Aleyrodidae) associated with guava (*Psidium guajava* L.) in Kerala, India

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ABSTRACT: This study documents the whitefly species associated with guava in Kerala, India, to facilitate early detection and management approaches. Extensive surveys were carried out in all five agro ecological zones of Kerala from 2020 to 2023. Eight species of whitefly were recorded infesting guava *viz*., *Aleurodicus dispersus*, *Aleurodicus rugioperculatus*, *Aleurothrixus floccosus*, *Paraleyrodes bondari*, *Paraleyrodes minei*, *Aleuroclava psidii*, *Aleurotracheulus tuberculatus*, and *Dialeuropora decempuncta*. The distribution and host range and morphological descriptions of the fourth instar puparia of the species are provided.

Keywords: Guava, whitefly, distribution, morphological description, Kerala

INTRODUCTION

The guava (*Psidium guajava* L) is a tropical fruit tree that originated in Central America but is now widely grown in many tropical and subtropical areas worldwide, because of its nutritional, commercial, and therapeutic qualities. India is the leading producer of guava in the world with an annual production of 4.92 million tonnes contributing to its importance in food security and local economies (Goswami *et al*., 2024). The fruit is rich in nutrients like calcium and phosphorus that promote health and wellness. It is high in other vital minerals, as well as vitamins A, C, and several B vitamins. Guava leaves and other plant parts are also used in traditional medicine to treat a range of diseases, such as diabetes, gastrointestinal disorders, and inflammation. In addition, the tree can be grown in a variety of climatic conditions due to its adaptability to different growing conditions.

Whiteflies (Hemiptera: Aleyrodidae) are tiny, sap-sucking insects representing a major threat to crops worldwide. They are well-known for their ability to multiply quickly which harms host plants considerably. Whiteflies suck the plant sap by piercing plant tissue and extracting nutrients which then weaken the plant and lead to stunted growth, yellowing, and withering. Apart from causing direct feeding damage, whiteflies also excrete a sticky substance called honeydew, which encourages the growth of sooty mould on plant surfaces. This mould lowers photosynthesis as well as the aesthetic and commercial value of the affected plant. Moreover, may species of whiteflies are vectors of several plant viruses, which exacerbates their negative impact on agricultural output.

Guava plants are highly susceptible to whitefly infestations, which can cause significant economic loss. The interaction between guava plants and whiteflies is complex and whiteflies often coexist with other species. In India, 13 whitefly species were reported from guava which includes *Aleurodicus dispersus* Russell, *Aleurodicus rugioperculatus* Martin, *Paraleyrodes bondari* Peracchi, *Paraleyrodes mine*i Iaccarino, *Aleurocanthus rugosa* Singh, *Aleuroclava citrifolii* (Corbett), *Aleuroclavapsidii* (Singh), *Aleurolobusmarlatti* (Quaintance), *Aleurolobuspsidii* Jesudasan & David, *Aleurothrixus floccosus* (Maskell), *Dialeuropora decempuncta* (Quaintance & Baker), *Fippataleyrodes rajmohani* Pushpa and Sundararaj and *Minutaleyrodes minuta* (Singh) (David *et al*., 2021). In 2019, a highly invasive woolly whitefly, *Aleurothrixus floccossus* (Maskell), was reported on guava from Calicut, Kerala (Sundararaj *et al*., 2020). Subsequently, it has spread quickly throughout the state within a short period. A similar invasion of the whitefly species, *A.dispersus* was recorded earlier in Kerala (David and Regu, 1995). Hence, it is important to monitor and document the whitefly fauna, for the early detection and identification of any exotic species.

MATERIALS AND METHODS

Purposive surveys were conducted from 2020 to 2023 in all five agro ecological zones of Kerala. Whitefly-infested guava leaves along with nymphs, puparium, pupal cases, and adults were collected by exercising the infested shoots using secateurs. The samples were placed in polythene bags separately, by furnishing the details of collection such as date of collection, locality

and GPS coordinates. The collected samples were then brought to the Insect Systematics Laboratory, Department of Agricultural Entomology, College of Agriculture Vellanikkara, KAU and assigned accession numbers.

The leaf samples from different accessions were carefully examined under a microscope (Leica EZ4HD) and the puparium was slide-mounted for morphological characterisation, to establish the identity of the species. The adult whiteflies in the samples were preserved in 70 and 100 percent ethyl alcohol, and puparium in 70 percent alcohol, separately, for future studies.Permanent mounts of the whitefly puparium were made by following the procedure suggested by Martin (1987).Care was taken to mount only one specimen per slide to avoid more than one species on a slide. Slides were dried at room temperature for about 3- 4 weeks and labelled. The slide-mounted specimens were observed under a research microscope (RADICAL, RXLr-4) to study the key taxonomic features (Martin, 2004; Martin, 2005). The studied specimens are available in the collection of the Insect Systematics Laboratory, Department of Agricultural Entomology, College of Agriculture, Vellanikkara, Kerala Agricultural University (KAU).

RESULTS AND DISCUSSION

In this study, eight different species of whiteflies were recorded widely infesting guava in Kerala. They are, spiralling whitefly, *Aleurodicus dispersus* Russell, rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin, woolly whitefly, *Aleurothrixus floccosus* (Maskell), Bondar's whitefly, *Paraleyrodes bondari* Peracchi, *Paraleyrodes mine*i Iaccarino, Asian guava whitefly, *Aleuroclavapsidii* (Singh), *A. tuberculatus* Singh and bread fruit whitefly, *Dialeuropora decempuncta* (Quaintance and Baker). The host plants, distribution and important morphological characters of the species are detailed below.

1. Spiralling whitefly, *Aleurodicus dispersus* Russell

Material examined: India: Kerala, 5 puparia from Vellanikkara, Thrissur (10.5486111^{0}N, 76.2830556^{0}E); 8 puparia Alathur, Palakkad (10.638888^{0}N, 76.5613889^{0}E); 3 puparia at Balussery, Kozhikode (11.504676^{0}N, 75.813017^{0}E).

Host: There are 481 host plants worldwide, with 298 of them being found in India (David *et al*., 2021); these consist of fruit trees, vegetables, ornamental plants, and other crops of different families.

Distribution: Widely distributed throughout the world (Martin, 2004) and in India (Srinivasa, 2000)

Morphological characters (Plate. 1): *Aleurodicus dispersus* Russell, 1965. The Florida Entomologist, 48: 49 - 54.

A. dispersus adults are about 2 mm long and have a yellow body and white wings coated in a powdery, waxy substance. Eggs are yellowish and a characteristic spiral egg-laying pattern on the underside of leaves. They go through four instars covered in white, waxy filaments that give them a cotton look.

Taxonomy of fourth instar puparium: *Aleurodicus dispersus* Russell, 1965. *The Florida Entomologist,*48: 49 - 54. *Margin*. Smooth, not dentate.

Pores: Four abdominal compound pores present: the size decreases from abdominal segment 3 to abdominal segment 6, the largest is around 45 micrometers in diameter, the smallest is about 28 micrometers. The 8-shaped pores in a single row from the body margin. Sub marginal double-rimmed notched pores in a single row; wide-rimmed pores distributed 1 or 2 deep between septate and double-rimmed pores; wide-rimmed pores in a single row between the 8-shaped and the double-rimmed pores; septate pores present in median and sub median area of most segments.

***Vasiform orifice*:** Chordate; lingula is large, blunted, and excerted with four setae

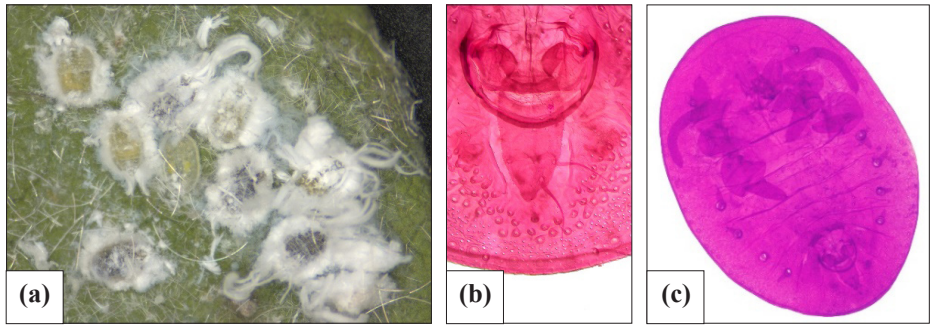

Plate.1. (a) Colony of *Aleurodicus dispersus* on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

2. Rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin

Material examined: India: Kerala, 5 puaparia of *A. rugioperculatus* from Adoor, Pathanamthitta (9.398354^{0}N, 76.788646^{0}E); 7 puparia from Majeswar, Kasaragod (12.753252^{0}N, 74.948014^{0}E).

Host: *Aleurodicus rugioperculatus* is highly polyphagous with 118 hosts from 43 plant families including economically important crops (Francis *et al*., 2016). Following its accidental introduction, a wide host range was recorded for *A. rugioperculatus* from Kerala including coconut, banana, and guava (Shanas *et al*., 2016). In India *A. rugioperculatus* was reported in 80 host plants from 38 families (David *et al*., 2021).

Distribution: Since its first discovery in Florida, USA, in 2009, the *A. rugioperculatus*, has rapidly expanded its worldwide distribution. (Stocks, 2012). It was reported recently from India, particularly in Kerala, Tamil Nadu, and Karnataka as an invasive pest of coconut (Shanas *et al*., 2016).

Morphological characters (Plate. 2): The adults of *A. rugioperculatus* measure about 2 mm long, with a yellowish body covered in a waxy, powdery substance. They can be distinguished by their rugose pattern when laying eggs. The infestation is often indicated by the accumulation of sooty mold on leaves and fruits, resulting from the honeydew excreted by the whiteflies.

Taxonomy of fourth instar puparium: *Aleurodicus rugioperculatus*, Martin, 2004. *Zootaxa*, 681: 1-119.

***Margin*:** Smooth *Chaetotaxy.* Posterior marginal setae present; 12 pairs of sub marginal setae

***Pores*:** 7 pairs of compound pores are present including larger cephalic and first four pairs of abdominal pairs with central processes dagger-shaped, and protruding just beyond pore rim; the last two posterior pairs reduced, Broad, sub marginal dense band of wide-rimmed pores forming mesially-directed lobes present; band interrupted below apex of lingula. Subdorsum with a reticulated pattern from cephalothorax to abdomen.

***Vasiform orifice*:** broadly chordate, slightly emarginate to either side of lingula; operculum broadly elliptical; lingula apically acute.

3. Woolly whitefly, *Aleurothrixus floccosus* Maskell

Material examined: India: Kerala, 8 puaparia of *A. floccosus* from Kottarakkara, Kollam (8.981482^{0}N, 76.810939^{0}E); 5 puparia from Mannuthy, Thrissur (10.536111^{0}N, 76.2608333^{0}E).

Host: *A. floccosus* is highly polyphagous feeding on more than 20 families of host plants (Malumphy *et al*., 2015). In India, it was reported from guava plants by Sundararaj *et al*. (2020).

Distribution: Maskell first reported *A. floccosus* in 1895 from specimens taken on *Guaiacum officinale* from Jamaica (Martin and Mound, 2007). In India, it was first reported from Kerala (Sundararaj *et al*., 2020). Now it is distributed in all the five agro ecological zones of Kerala.

Morphological characters (Plate. 3)**:** *Aleurothrixus floccosus* Martin. 1987. *Tropical Pest Management,* **33** (4): 298 - 322

Pupa typically has white wax threads covering it and are highly noticeable on heavily infested leaves. Puparia are covered in fluffy wax and range from pale white to brown

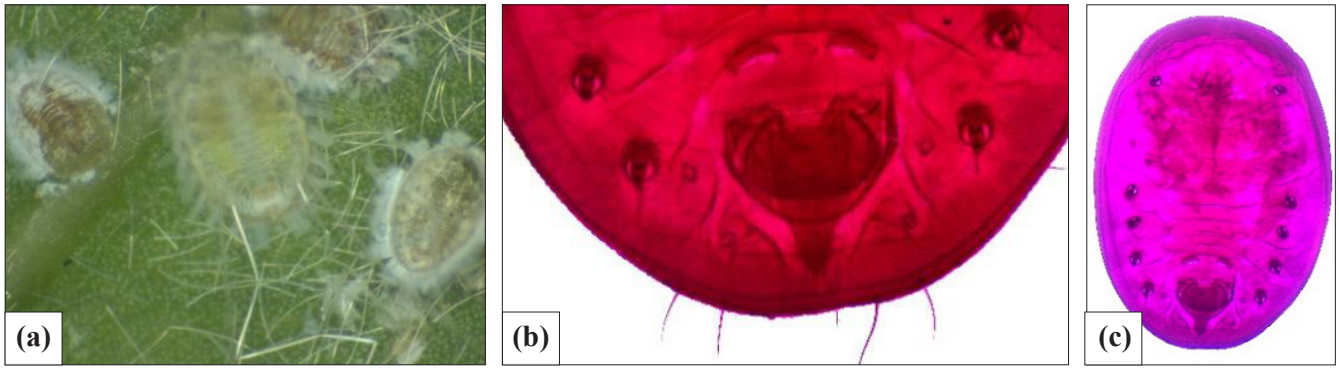

Plate.2. (a) Colony of *Aleurodicus rugioperculatus* on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

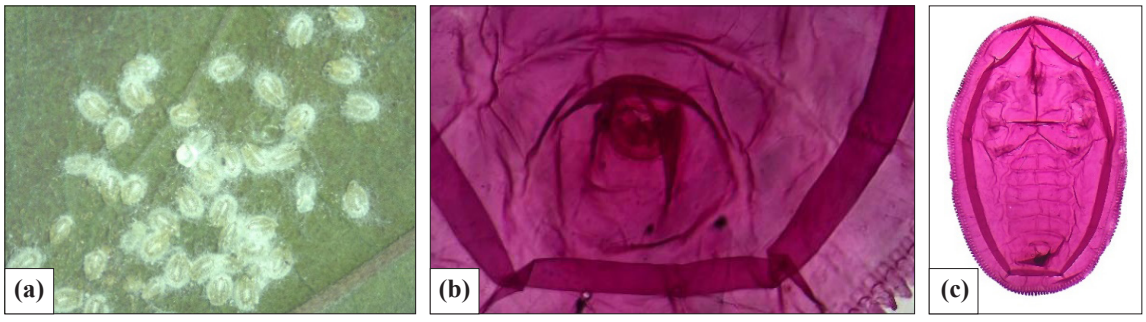

Plate .3. (a) Colony of *Aleurothrixus floccossus* on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

Taxonomy of fourth instar puparium:

***Margin*:** regularly toothed each tooth with a basal gland, and thoracic tracheal pore regions without any alterations.

***Submargin*:** widely separated from the dorsal disc by the sub marginal/sub dorsal fold.

***Vasiform orifice*:** transversely elliptical, operculum similarly shaped nearly filling the orifice.

4. Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi

Material examined: India: Kerala, 4puparia of *P. bondari*on *Psidium guajava* from Kottarakkara, Kollam (8.981482^{0}N, 76.810939^{0}E); 9 puparia from Palode, Thiruvananthapuram (8.7536111^{0}N, 77.0277778^{0}E).

Host*: P. bondari* has a broad host range, infesting a variety of plants across multiple families. Significant hosts include economically important species like *Mangifera indica* (Anacardiaceae), *Cocos nucifera* (Arecaceae), and *Psidium guajava* (Myrtaceae). These diverse plant families highlight the wide adaptability of *P. bondari* and its potential impact on agriculture and forestry (Vidya *et al*., 2019).

Distribution: *P. bondari* was initially identified on Brazilian citrus in the Neotropics, (Peracchi 1971). Vidya *et al.* (2019) identified and confirmed Bondar's nesting whitefly, *P. Bondari* from the Indian mainland and Andaman Nicobar Island. It is widely distributed in all the agro ecological zones of Kerala.

Morphological characters (Plate. 4)**:**

Paraleyrodes bondari Peracchi 1971. *Archos Mus Nacional do Rio de Janeiro*, 146-148.

The adult whiteflies rest within a fluffy small nest, which resembles a bird's nest, thus the genus is usually referred to as Bondars nesting whiteflies. Also, the adults with oblique "X"-shaped grey wings and the peculiar fuzzy wax surrounding the pupa are the characteristic features of *P. bondari*.

Taxonomy of fourth instar puparium:

***Margin*:** Smooth

***Pores*:** One larger cephalic pore, four abdominal compound pores about, and an outer ring with ovoid cellular facets that resemble stylized flower petals. Two to three discoidal pores are associated with the two reduced abdominal pores which are half the size of the larger abdominal pores and comprise 7 to 8 flower petal-like facets (Peracchi 1971; Martin 2004).

***Vasiform orifice*:** tongue-like lingula is extended beyond the posterior margin vasi form orifice with two pairs of apical setae.

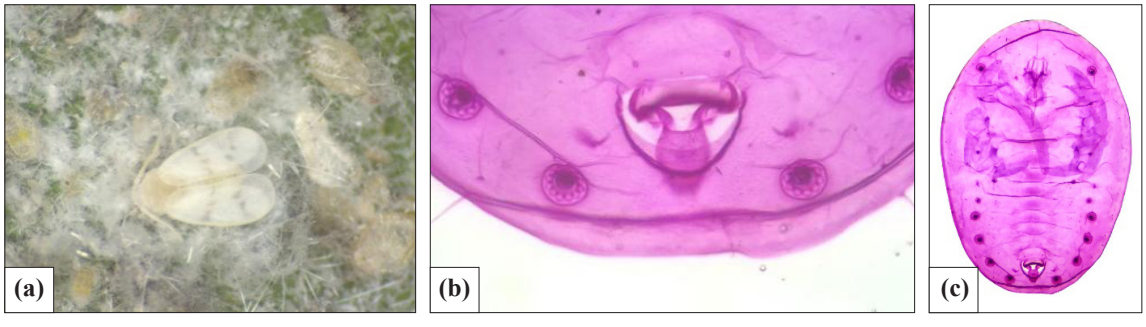

Plate .4. (a) *Paraleurodes bondari* adult on guava (4x)
(b) Vasi form orifice (40x) (c) Slide mounted fourth instar puparium (10x)

5. Nesting whitefly, *Paraleyrodesminei* Iaccarino

Material examined: India, Kerala-5 puparia of *P. minei*from Odakkali (10.0930556^{0}N, 76.5602778^{0}E) and 7 puparia from Palath, Kozhikode (11.33711^{0}N, 75.8272^{0}E).

Host: *P. minei*, is a highly polyphagous pest that feeds on various host plants including fruit guava. In India *P.minei* exhibits a diverse host range, infesting plants from various families, making it a significant pest across multiple environments. Economically important families include Arecaceae, Anacardiaceae, Myrtaceae, Combretaceae, Heliconiaceae, Musaceae, Myrtaceae, Rubiaceae (Sujithra *et al*., 2019; Mohan *et al*., 2019)

Distribution: All *Paraleyrodes* species are thought to be originated from the neotropical region, even though this species was initially reported from Syria on citrus in 1990 (Iaccarino, 1990). *P. bondari* and *P. minei* are two of the extremely mobile *Paraleyrodes*species that have been found worldwide. Mohan *et al*. (2019) reported *P. minei* from Kayamkulam in Kerala.

Morphological characters (Plate. 5): *Paraleyrodesminei* Iaccarino (Iaccarino, 1989: 131-149) (Martin, 1996: 1856)

Adult whiteflies are small and construct relatively less-denser woolly wax nest than that of *P. bondari*. Occurrence of cream-coloured egg clusters with short stalks and flat creamy-yellow nymphs with prominent fibreglass strands from the dorsum, are some characteristic features for the identification of *P. minei*.

Taxonomy of fourth instar puparium:

***Margin*:** Smooth

***Submargin*:** 14 pairs of hair-like setae arranged in a row.

***Pores*:** One large cephalic compound pore, four large and two small abdominal compound pores are present. compound pores with conspicuous flower petal structures, parameres pointed at the tip with swollen mid-region.

***Vasiform orifice*:** The operculum partially covers the lingula and the vasiform orifice. The tongue-like lingula is extended beyond the posterior margin vasiform orifice with two pairs of apical setae.

6. Asian guava whitefly, *Aleuroclava psidii* (Singh)

Material examined: India: Kerala, 6 puparia of *A. psidii*from Adhur, Kasargod (12.561639^{0}N, 75.181002^{0}E); 3 puparia from Tavanur(10.8530556^{0}N, 75.9866667^{0}E).

Host: In India, *A. psidii* has been reported from different plant families which include Moraceae, *Morus alba* Linn. (David and Regupathy, 2004); Myrtaceae, *Psidium guajava* Linn. (Singh, 1931); Rubiaceae, *Oxycerosrugulosus* (Thwaites) Tirveng., *Tarenna asiatica* (Linn.) Kuntze ex K. Schum; Salicaceae, *Scolopia crenata* (Wt. and Arn.) Clos; Dipterocarpaceae, *Dipterocarpusindicus* Bedd; Menispermaceae, *Tiliacora acuminata* (Lam.) Hook. f. & Thoms.; Verbenaceae, *Clerodendrum* sp. (Dubey and David, 2012); Theaceae, *Schima wallichii* (DC.) Korth. (Lalneihpuia and William, 2011)

Distribution: *A. psidii* is widely distributed in India, particularly in areas with guava cultivation including Bihar (Singh, 1931); Andhra Pradesh (Rao, 1958); Tamil Nadu (David and Subramaniam, 1976); Karnataka (Dubey andSundararaj, 2005); Kerala (Pushpa and Sundararaj., 2010).

Morphological characters (Plate. 6)**:** *Aleurotracheluspsidii* Singh, 1931. Memoirs of the Department of Agriculture in India, Entomological Series, 12 (1): 61.

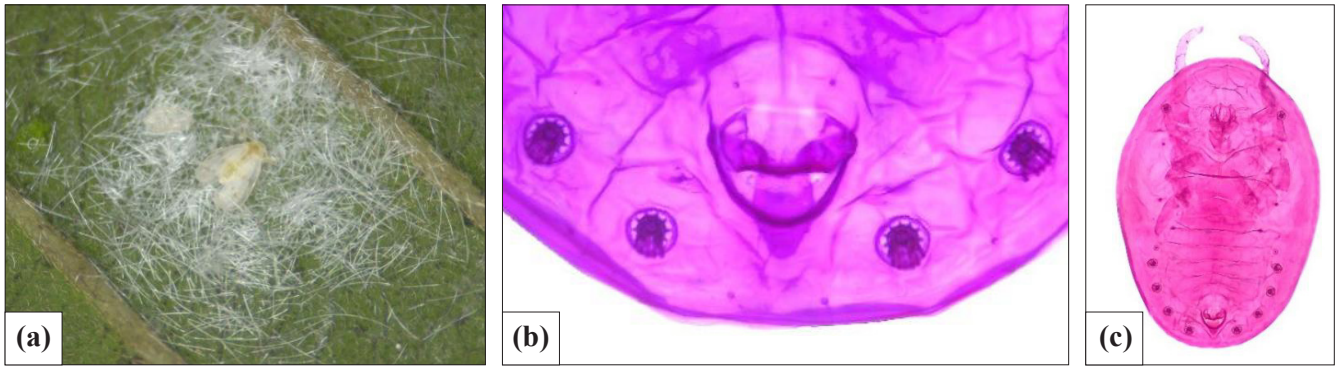

Plate.5. (a) *Paraleurodes minei* adult on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

Plate.6. (a) Puparium of *Aleuroclava psidii* on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

Puparium is small, white, pyriform shaped; found scattered on the leaf's undersurface.

Taxonomy of fourth instar puparium:

***Margin*:** faintly crenulated

***Submargin*:** submarginal area differentiated from dorsal disc by an elevated fold with many microtubercles. The microtubercles on cephalothorax appearing in T-shaped pattern.

***7. Aleurotracheulus tuberculatus* Singh**

Material examined: India: Kerala, 3 puaparia of *A. tuberculatus* from Vellanikkara, Thrissur (10.5486111^{0}N, 76.2830556^{0}E); 8 puparia from Kothamangalam, Ernakulam (10.057002^{0}N, 76.636883^{0}E)

Host: *A. tuberculatus* exhibits a wide host range, including a diverse array of plant species across multiple families. Major families include Calophyllaceae, *Mesua nagassarium* (Burm); Fabaceae, *Bauhinia racemosa* (Lam.) and *Dalbergia* sp.; Geraniaceae, *Pelargonium* sp.; Malvaceae, *Helicteresisora* Linn., Moraceae, *Ficus* sp. and *Morus alba* Linn.; Portulacaceae, *Portulaca oleracea* Linn.; Rubiaceae, *Tarenna asiatica* (Linn.). (Dubey and David, 2012).

Distribution: Singh (1933) described A. *tuberculatus* for the first time from India. *A. tuberculatus* is primarily distributed in India and is mainly in the Western Ghats, particularly within Kerala, with additional occurrences in the Andaman Islands and neighboring regions.

Morphological characters(Plate. 7)**:** *Aleurotrachelus tuberculatus* Singh, 1933. *Oriental Insects*, 25: 290. Puparia is black, elliptical, or oval

Margin: marginal tooth is conical or sharply pointed. The raised median abdominal area with a rachis from the margin

Chetotaxy: Cephalic setae, meso, and metathoracic setae reaching beyond the puparial margin. The submedian area of the cephalothorax with a pair of longitudinal folds overlaying legs.

Vasiform orifice: elevated rectangular vasiform orifice with a pair of eighth abdominal setae.

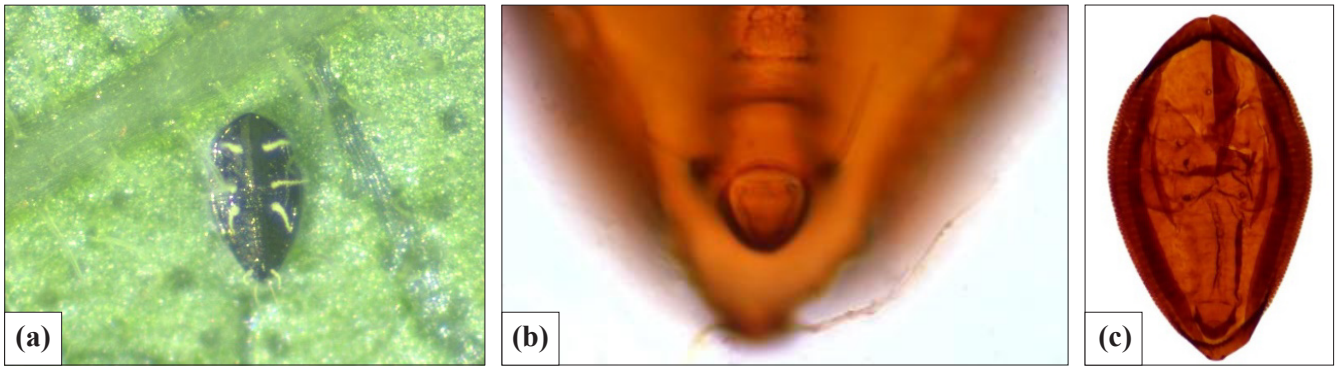

Plate.7. (a) Puparium of *Aleurotracheulus tuberculatus* on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

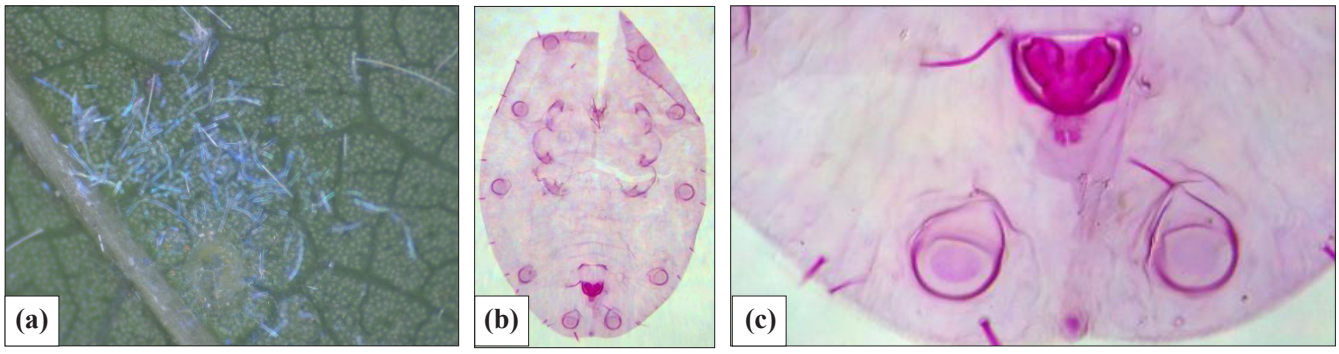

Plate.8. Puparium of *Dialeuropora decempuncta* on guava (4x)
(b) Vasiform orifice (40x) (c) Slide mounted fourth instar puparium (10x)

8. Breadfruit whitefly, *Dialeuropora decempuncta* (Quaintance and Baker)

Material examined: India: Kerala, 4 puaparia of *D. decempuncta*from Kattussery, Palakkad (10.626787^{0}N, 76.55097^{0}E) 7 puparia from Choondal, Thrissur (10.620567^{0}N, 76.099525^{0}E).

Hosts: *D. decempuncta* exhibits a wide host range. In India, it has been reported from 59 host plants from 24 families. Major families include Myrtaceae, Anacardiaceae, Annonaceae, Euphorbiaceae, Fabaceae, Lauraceae, Moraceae*etc* (David *et al*., 2021)

Distribution: *D. decempuncta* is native to Asia (Evans, 2008) It has been recorded in several regions within the country - Andaman and Nicobar Islands, West Bengal, Sikkim. In Kerala, it is reported from Thrissur, Kozhikode districts.

Morphological characters (Plate. 8)**:** Adults with banded wings, puparium suboval, pale with blue iridescent wax secretions

Taxonomy of fourth instar puparium:

***Margin*:** with tooth-like corrugations, tracheal pores present

***Submargin*:** 1 to five pairs of large submarginal discoidal pores present a caudal furrow indistinct, 12 pairs of spearhead-like setae are present.

***Vasiform orifice*:** subcircular, operculum nearly filling orifice.

CONCLUSION

This study documents the occurrence and distribution of eight whitefly species infesting guava in Kerala viz., *A. dispersus*, *A. rugioperculatus*, *A. floccosus*, *P. bondari*, *P. minei*, *A. psidii*, *A. tuberculatus*, and *D. decempuncta* which reflect the host range and adaptability of whiteflies.

The study emphasizes the urgent need for vigilant monitoring and early detection of whitefly species, particularly invasive species like *A. floccosus* and *A. rugioperculatus*, which have been shown to spread quickly throughout the state. Identifying these species, supported by taxonomic keys and morphological characteristics, provides vital information for developing targeted management strategies. Further research must be done to study the ecological interactions between these whiteflies and their natural enemies as well as the impact of climate change on their population dynamics.

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