

Contribution to the knowledge of *Paraleyrodes* Quaintance (Hemiptera: Aleyrodidae: Aleurodicinae) in China

Xiao ZHANG¹, Qingsong LIN¹, Jirui WANG^{1,2}①

1. Key Lab for Biology of Crop Pathogens and Insect Pests and Their Ecological Regulation of Zhejiang Province, College of Advanced Agricultural Sciences, Zhejiang Agriculture & Forestry University, Lin'an, Zhejiang 311300, China

2. Department of Life Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, U.K.

Abstract: Four species of the invasive genus *Paraleyrodes* Quaintance known to occur in China are studied. *Paraleyrodes perplexus*, a newly recorded species to China, is re-described with morphological illustrations. *P. perplexus* is characterized by a row of rather large crater-like pores in the outer submargin and an aedeagus with many variations. Comments on the other three species, *P. minei*, *P. pseudonaranjae* and *P. bondari*, are provided. An identification key to the puparia and adult of members of the Chinese *Paraleyrodes* species is provided.

Key words: Aleyrodoidea; taxonomy; new record; key

中国巢粉虱属 *Paraleyrodes* Quaintance 分类研究 (半翅目: 粉虱科: 复孔粉虱亚科)

张晓¹, 林青松¹, 王吉锐^{1,2}①

1. 浙江农林大学现代农学院, 全省作物病虫生物学与生态调控重点实验室, 浙江 临安 311300;

2. Department of Life Sciences, Natural History Museum, Cromwell Road, London SW7 5BD, U.K.

摘要: 对中国粉虱科复孔粉虱亚科巢粉虱属 *Paraleyrodes* 种类进行了分类研究, 记述 1 中国新记录种: 迷惑巢粉虱 *Paraleyrodes perplexus*, 对其进行了重新描述, 并提供了其鉴别特征、寄主植物和形态特征图等。该种的主要鉴别特征是伪蛹体缘有火山口状的孔与形状变换多样的交尾刺。本文还对中国分布的另外 3 种巢粉虱: 小巢粉虱 *Paraleyrodes minei*, 双钩巢粉虱 *Paraleyrodes pseudonaranjae*, 庞达巢粉虱 *Paraleyrodes bondari* 进行了讨论, 并基于伪蛹与成虫特征编制了中国巢粉虱属种类的分类检索表。

关键词: 粉虱总科; 分类; 新记录; 检索表

Introduction

The whitefly genus *Paraleyrodes* was erected by Quaintance (1909) with *Aleurodes perseae* Quaintance 1900 as its type species by original designation. *Paraleyrodes* is a small genus of Aleyrodidae in the subfamily Aleurodicinae, containing 17 species feeding on a wide range of host plants (Martin 2004; Martin & Mound 2007; Evans 2008). No new species have

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① Corresponding author, E-mail: jrwang@zafu.edu.cn

been discovered since Martin (2004) described 7 species of *Paraleyrodes* from Belize. It is a typically Neotropical genus and all *Paraleyrodes* species are native to the Neotropical Region or the extreme southern USA. A few species are distributed in other Zoographical Regions, but not in Australasia. *Paraleyrodes* are gradually invading other regions, especially the Nearctic, Eastern Palearctic and Oriental Regions. The nesting whitefly (*P. minei*) and Bondar's nesting whitefly (*P. bondari*) are the most geographically mobile species (Martin 2004) and have been reported in many areas around the world in recent years due to their polyphagous nature and rapid dispersal potential. Most alien species of whiteflies are accidentally introduced with their host plant and regularly dispersed among countries during plant trade, and due to the small size of whiteflies, their cryptic nature and immature stages are attached to the host-plant. *Paraleyrodes* is an invasive genus to China. *P. bondari* was first reported in Taiwan (Hong *et al.* 1998); *P. pseudonaranjae* was described as a new species from Hongkong (Martin 2001); and *P. minei* was discovered by Martin on several host plants in Hong Kong, being the first records of this species occurring in Asia (Martin 2004).

Here, we collected *Paraleyrodes perplexus* Martin which were infesting leaves of *Piper* L. and *Michelia maudiae* Dunn from Yunnan Jinghong Xishuangbanna Wild Elephant Valley in Yunnan, China. This species is re-described with morphological illustrations and photographs, and the host plant and distribution are also provided. We also add details on other three Chinese species of this genus.

Material and methods

The puparia of *Paraleyrodes perplexus* were collected by Lingfeng WEI from *Piper* L. in the Xishuangbanna Wild Elephant Valley, Yunnan, China. The puparia were mounted following the method suggested by Dubey and David (2012). The terminology for morphological structures follows Bink-Moenen (1983), Martin (1985) and Gill (1990). Adults were collected by using a trematode tube and stored in 75% ethanol in the field. Measurements, observations and microphotographs of the specimens were made and taken using the Olympus microscope CX33, BX63 imaging microscope (Olympus Corporation, Tokyo, Japan) and the cellSens imaging software (Olympus Corporation, Tokyo, Japan). These images were then concatenated into stacked images using the Helicon Focus software (Helicon Soft Ltd., Kharkiv, Ukraine). Some specimens of *Paraleyrodes* species collected from China which are deposited in the aleurodid collection of the Natural History Museum in London (NHMUK) are also used for study, and all data associated with the material examined is reproduced verbatim from the labels. Specimens are deposited in the Insect Collection of Zhejiang Agriculture & Forestry University (ZAFU).

Taxonomy

Paraleyrodes Quaintance

Paraleyrodes Quaintance 1909: 169–170. Type species: *Aleurodes perseae* Quaintance, 1900, by monotypy.

Diagnosis. In the Aleurodicinae, members of *Paraleyrodes* are much smaller than

members of other genera (Quaintance 1909; Martin 2004). Puparium with 5 or 6 pairs of geminate pores, the first 1 or 2 pairs being much smaller than the last four pairs; lingula with 2 pairs of setae; 1 pair of cephalic setae; submargin with a row of 14 pairs of setae; vasiform orifice semicircular; thorax with two pairs of cicatrices and a pair of submedian setae (Martin 2004; Evans 2008). Adults with all wing veins unbranched; females have 4 articulated antennal segments; males have only 3 articulated antennal segments and complex aedeagal apices (Martin 2004; Sundararaj *et al.* 2019). Unique among known whiteflies, all species of *Paraleyrodes* are most reliably diagnosed from the structure of the male aedeagus, with the puparia of some being difficult to distinguish from those of similar species when males are not present.

Biology. Some species are known as the nesting whitefly and are suspected as being vectors of plant viruses. Puparia and larvae secrete long waxy filaments that often form an annular nest surrounding the insect. Members of this genus secrete a characteristic filamentous wax that deposits and forms a nest in which adults emerge and the female rests and lays eggs. Exuviae of previous instars are also seen within the nest with the female.

Key to the Chinese invasive species of *Paraleyrodes*

1. Adults measure about 1 mm long, and have a dull yellow body with white wings. Two oblique grey bands occur on each forewing, and converge toward the midline such that it appears to form an “X”-pattern with the center of the “X” missing..... 2
- Adults measure about 1 mm long, and have a dull yellow body with white wings. The wings are not spotted, Aedeagus with the “cock head”-shaped apex, with 3 short appendixes located on upper and posterior surface, 2 long and thin appendixes below an anterior short appendix *P. minei*
2. Aedeagus with three subapical aedeagal processes of which two are in one direction and one opposite to them, and one process near mid-length of aedeagus.....*P. bondari*
- Aedeagus with a “double hook”-shaped apex 3
3. A row of rather large crater-like pores in the outer submargin; a small bright pore to either side of the vasiform orifice (abdominal segment VIII)..... *P. perplexus*
- No crater-like pores in the outer submargin; no bright pore to either side of the vasiform orifice.....
.....*P. pseudonaranjiae*

1. *Paraleyrodes bondari* Peracchi (Figs 1, 2)

Paraleyrodes bondari Peracchi, 1971: 146–148.

Specimens examined. 3 puparium on 1 slide, **China**, Taiwan, 17-VIII-1998, leg. LY CHOU, from *Citrus reticulata*, deposited in Natural History Museum (NHMUK010134472); 2 puparia on 1 slide, **China**, Taiwan, 12-IX-2005, leg. Yeh & Ko, from *Citrus japonica*, deposited in Natural History Museum (Yeh & Ko 2837) (NHMUK010134469).

Hosts. Anacardiaceae: *Mangifera indica*; Anonaceae: *Anona squamosa*; Boraginaceae: *Cordia dichotoma*; Combretaceae: *Terminalia catappa*; Ebenaceae: *Diospyros kaki*; Euphorbiaceae: *Aleurites fordii*, *Bischofia jaranica*; Lauraceae: *Cinnamomum*, *Camphora*, *Persea americana*; Leguminosae: *Bauhiniosae variegata*; Magnoliaceae: *Michelia alba*; Malpighiaceae: *Prunus pseudocerasus*; Moraceae: *Ficus retusa*, *Morus australis*; Musaceae: *Musa sapientum*; Myrtaceae: *Eucalyptus* spp., *Eugenia uniflora*, *Psidium guajave*, *Syzygium samarangeuse*; Oleaceae: *Jasminum sambac*; Palmae: *Cocos nucifera*; Rutaceae: *Citrus* sp., *Paederia chinensis* (Wen & Chen 2001).

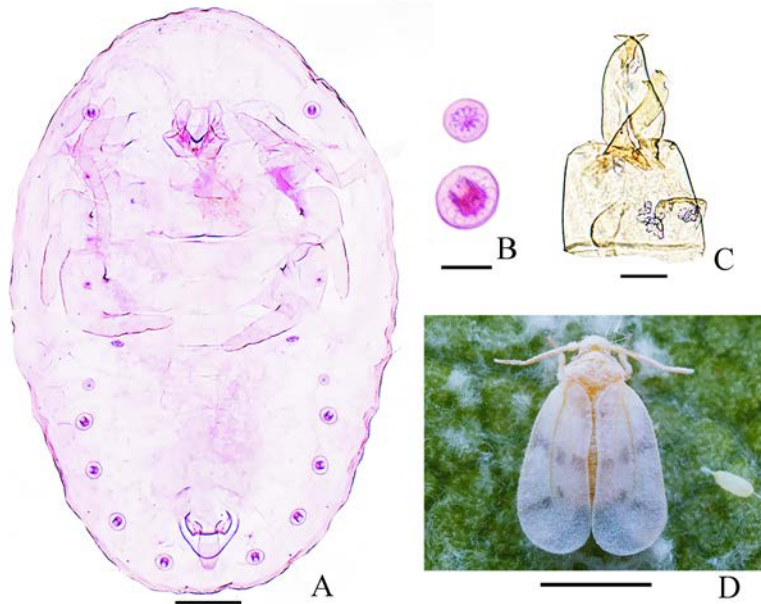


Figure 1. *P. bondari*. A. Puparium; B. Abdominal compound pores; C. Terminal abdominal segment and genitalia; D. Adult. Scale bars = 100 μm (A); 20 μm (B); 50 μm (C); 0.5 mm (D).

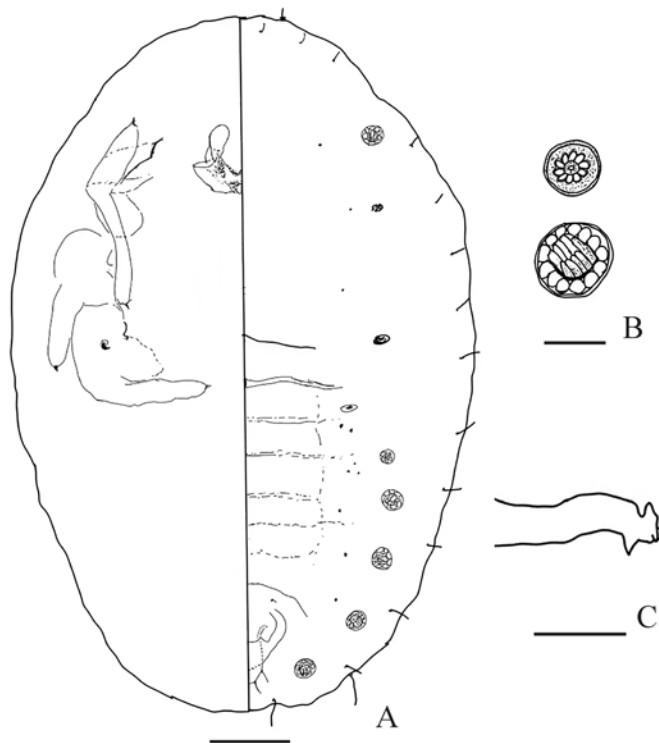


Figure 2. *P. bondari*. A. Puparium; B. Abdominal compound pores; C. Aedeagus. Scale bars = 100 μm (A); 20 μm (B); 50 μm (C).

Remarks. The adult fore-wings are with two rows of mottelings. The large puparial geminate pores of *P. bondari* are distinctive, like stylized flower petals (Fig. 1B). The aedeagus of *P. bondari* (Fig. 1C) is unique and easily distinguishable from other *Paraleyrodes* species in having three subapical aedeagal processes of which two are in one direction and one opposite to them, and one process near mid-length. In 1998, it was found in Chiayi and Kaohsiung in Taiwan to damage *Citrus reticulata* and *Syzygium samarangense* (Hong *et al.* 1998). Since then, it has expanded to infest various parts of Taiwan, and the host is very widespread.

Distribution. Bangladesh; Belize; Brazil; China (Taiwan); Comoros Islands; Egypt; France; Gabon; Honduras; India; Kenya; Madeira; Mauritius; Puerto Rico (greenhouse only); Reunion; Uganda; USA (California, Florida, Hawaii); Venezuela. (Hong *et al.* 1998; Yasodha *et al.* 2020; Evans 2008).

2. *Paraleyrodes minei* Iaccarino (Figs 3–5)

Paraleyrodes minei Iaccarino, 1990: 132.

Specimens examined. China, Yunnan, 6 puparium and 1 male on 5 slides, on *Ficus benjamina*, Pu'er Jiusi Suyuan Hotel, 22° 45' 22" N, 100° 58' 19" E, alt. 1,273.5 m, 23-VII-2023, leg. Xiao ZHANG & Qingsong LIN; 2 puparium on 2 slides, on *Elaeocarpus sylvestris*, Meizihu Park, 22° 45' 11" N, 100° 58' 28" E, alt. 1,346.7 m, 23-VII-2023, leg. Xiao ZHANG; 1 puparia on 1 slide, on *Ficus tinctoria* subsp. *gibbose*, Xishuangbanna Tropical Botanical Garden of Chinese Academy of Sciences, 21°92.94'N, 101°25.88'E, 29-VII-2023, leg. Xiao ZHANG; 1 puparia on 1 slide, on *Dalbergia hainanensis*, 31-VII-2023, leg. Xiao ZHANG, 1 puparia on 1 slide, on *Parashorea chinensis*, 01-VIII-2023, leg. Xiao ZHANG, Xishuangbanna Tropical Rainforest National Park scenic Skytree, 21°35'45"N, 101°35'17"E, alt. 652.4 m. All specimens are deposited in ZAFU.



Figure 3. *P. minei* infesting the leaf of *Piper* sp. A. Egg; B. Adult; C. IV instar nymph; D. III instar nymph. Scale bars = 500 μ m.

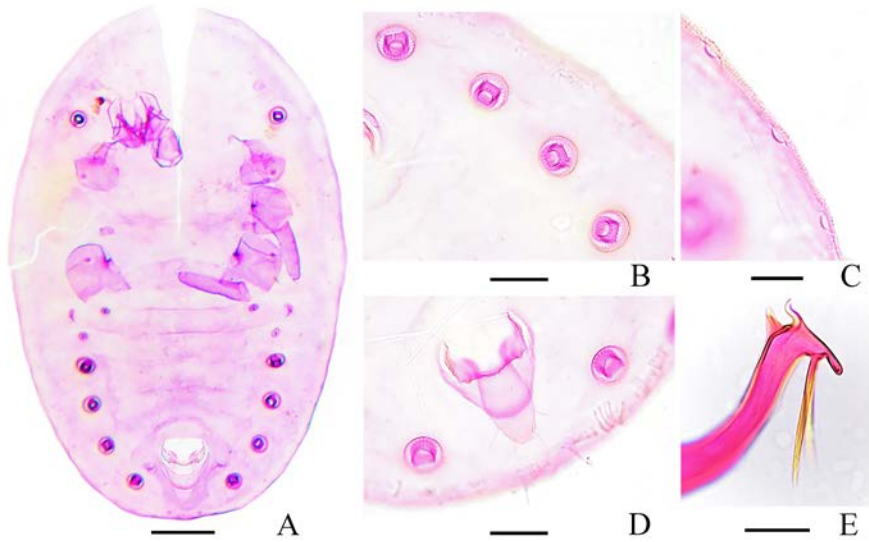


Figure 4. *P. minei* slide mounted specimen. A. Puparium; B. Abdominal compound pores; C. Margin; D. Vasiform orifice; E. Aedeagus. Scale bars = 100 μ m (A); 50 μ m (B–E).

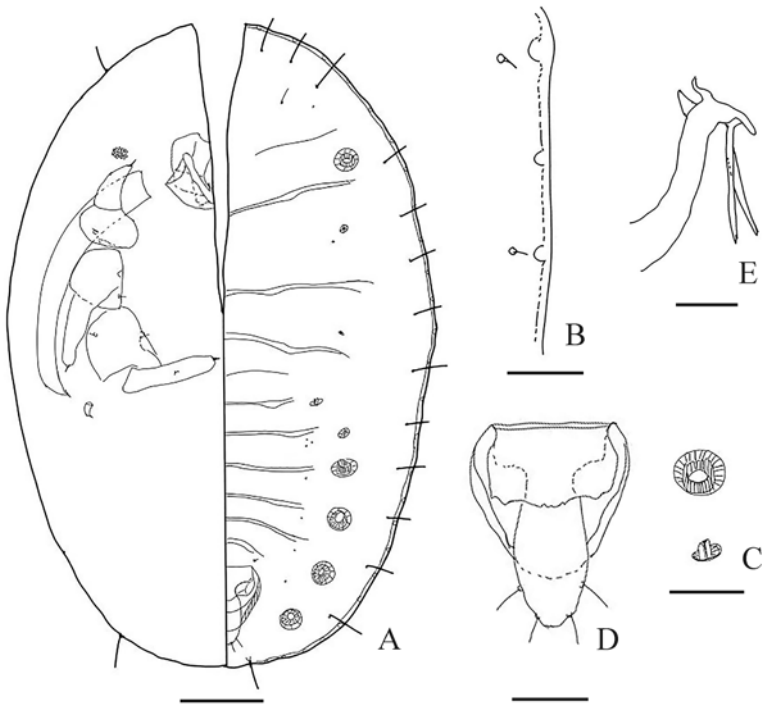


Figure 5. *P. minei*. A. Puparium, dorsal (right) and ventral (left) views; B. Margin; C. Abdominal compound pores; D. Vasiform; E. Aedeagus. Scale bars = 100 μ m (A); 50 μ m (B–E).

Hosts. Annonaceae: *Annona squamosa*; Arecaceae: *Areca catechu*, *Cocos nucifera*, *Dypsis lutescens*; Aquifoliaceae: *Ilex pubescens*; Asteraceae: *Emilia sonchifolia*; Araliaceae:

Schefflera heptaphylla; Euphorbiaceae: *Aporusa dioica*, *Bauhinia purpurea*, *Desmos chinensis*; Elaeocarpaceae: *Elaeocarpus dubius*, *Elaeocarpus sylvestris*; Fabaceae: *Dalbergia hainanensis*; Gnetaceae: *Gnetum luofuense*; Lauraceae: *Machilus* sp.; Malvaceae: *Hibiscus rosa sinensis*; Myrtaceae: *Psidium guajava*, *Syzygium hancei*; Moraceae: *Ficus benjamina*, *Ficus elastica*, *Ficus lacor*, *Ficus macrocarpa*, *Ficus concinna*, *Ficus tinctoria* subsp. *gibbose*, *Ficus superba* var. *japonica*; Musaceae: *Musa basjoo*; Phyllanthaceae: *Bischofia javanica*; Rosaceae: *Eriobotrya japonica*; Rubiaceae: *Gardenia jasminoides*; Rutaceae: *Citrus grandis*, *Citrus reticulata*, *Citrus mitis*, *Clausena lansium*; Sapindaceae: *Aesculus chinensis*, *Litchi chinensis*; Smilacaceae: *Smilax* sp.; Theaceae: *Gordonia axillaris*, *Schima superba*; Thymelaeaceae: *Aquilaria sinensis*; Zingiberaceae: *Alpinia japonica*, *Alpinia hainanensis* (Martin & Lau 2011; Yu *et al.* 2014; Dubey 2019); other references Evans (2008).

Remarks. *P. minei* is similar to *P. perplexus*, except that it does not have the special characteristics of *P. perplexus*. The adult males can be identified by the complex shape of the aedeagus, whose apex bears three dorsal and one ventral horn, and a pair of long ventral spines (Martin 1996; Sanchez-Flores 2017) (Fig. 4E). *P. minei* was originally described from specimens collected from Citrus crops in Syria by Iaccarino (1990), noting the long wax filaments and fluffy wax that form around the ovipositing females, and long wax rods that form around the fourth larval instar, known as the “puparium” or “pupal case” after adult emergence and hence the common name of “nesting whitefly”. Martin (2004) discovered *P. minei* in HK on several host plants. Yu *et al.* (2014) recorded *Annona squamosa* and *Psidium guajava* as its host plants in Hainan.

Distribution. Belize; Bermuda; Benin; China (Hainan, Hong Kong, Yunnan); Gabon; Greece (Kalaitzaki *et al.* 2016); Guatemala; USA (California, Florida, Texas, Hawaii) (Martin 1996; Martin 2004); Honduras; India (Yasodha *et al.* 2020); Iran; Italy (Iaccarino 2011); Indonesia; Israel; Lebanon; Malta (Malumphy & Mifsud 2016); Malaysia; Mexico; Morocco; Puerto Rico; Spain; Syria; Turkey (Evans 2008).

3. *Paraleyrodes perplexus* Martin (Figs 6–8), new record to China

Paraleyrodes perplexus Martin, 2004: 67.

Puparium. Subelliptic, 810 μm in length, 508 μm in width, widest at about metathorax.

Margin. Smooth to slightly irregular, not modified at thoracic tracheal openings; unlike other species, on inside margin the *P. perplexus* has crater-like pores, about 2 pores per pair of submarginal setae (Fig. 7E); 14 marginal setae, on every side, alternate, irregular. One pair of caudal setae, about 38.5 μm long.

Dorsum. The abdomen septum is obvious, almost as far back as the geminate pores, and the puparium has no pigmentation. The shape and size of the four pairs of geminate pores on the abdomen and the pair on head are almost the same, 22–23 μm long, 20–21 μm wide (Fig. 7C); inner ring bearing splines, each of them secreting single white wax rods upward that. The anterior two pairs of abdominal geminate pores are much smaller than posterior four pairs (Fig. 7B), with an outer diameter of 16–20 μm . Thorax with two pairs of “cicatrices” scars of compound pores found in the third instar. Abdominal segment IV, each submedian side with 2–5 bright pores, abdominal segments III and V–VIII usually with a single subdorsal pore.

Vasiform orifice. Elevated posteriorly, cordate, slightly wider than long, about 79.8 μm long, 87.1 μm wide; operculum rectangular, 70.8 μm long, 44 μm wide, not filling the orifice.

Two pairs of lingula setae, 26.1–27.9 μm long, lingula setae extending beyond posterior margin of the orifice (Fig. 7D).



Figure 6. The leaves of host plant *Ficus altissima* infested by nymphs of *Paraleyrodes perplexus* Martin. Nesting females. (Photographed by Lingfeng Wei).

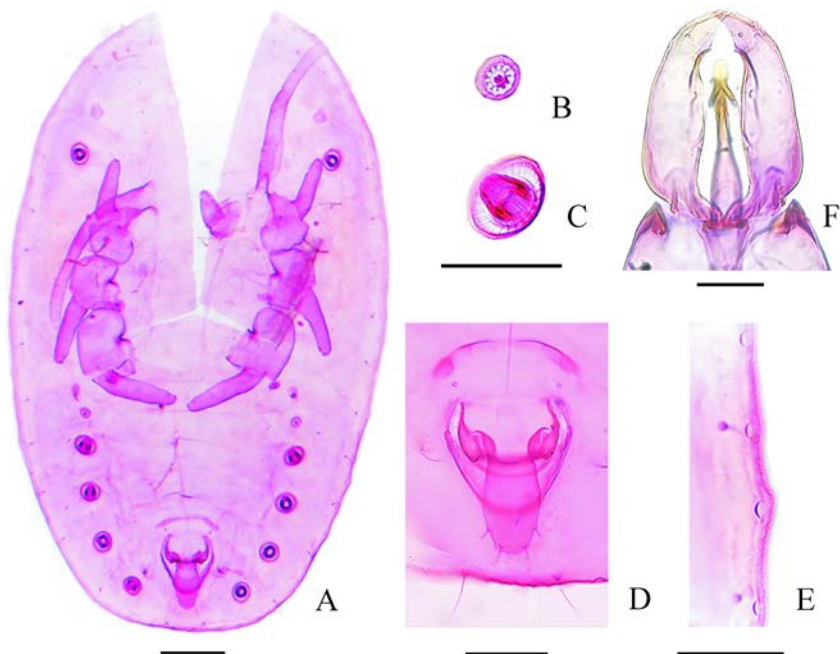


Figure 7. *P. perplexus* slide-mounted specimen. A. Puparium; B. Anteriormost pair of abdominal compound pores; C. Posteriormost four abdominal pairs of compound pores; D. Vasiform orifice; E. Margin; F. Genitalia. Scale bars = 100 μm (A); 50 μm (B–F).

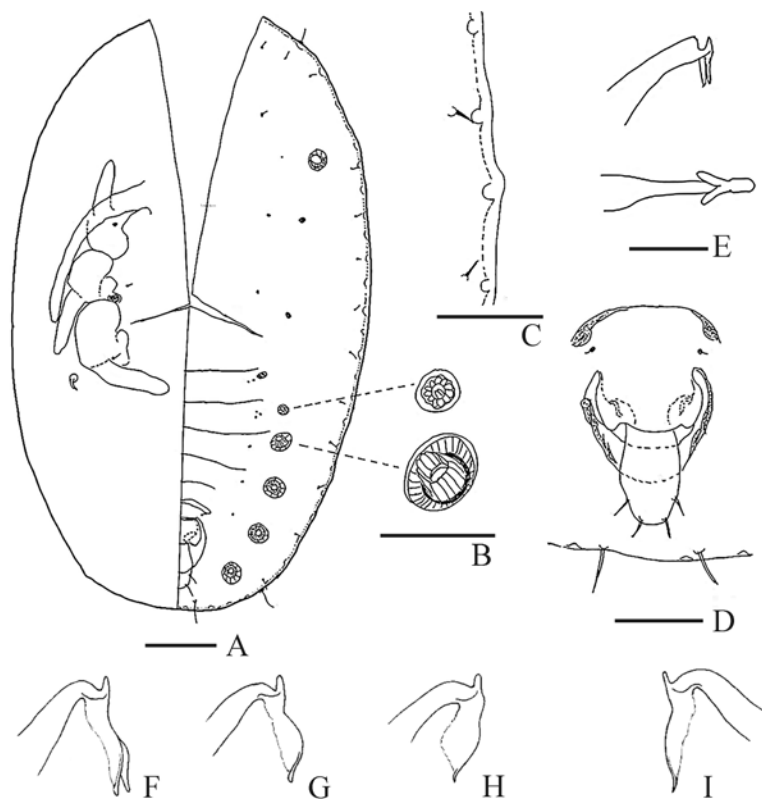


Figure 8. *P. perplexus*. A. Puparium, dorsal (right) and ventral (left) views; B. Abdominal compound pores; C. Margin; D. Vasiform; E. Aedeagus, lateral and dorsal aspects; F–I. Aedeagus, lateral aspects (after Martin 2004). Scale bars = 100 μ m (A); 50 μ m (B–E).

Venter. Thoracic and caudal tracheal folds discernible. Thoracic legs very obvious.

Biology. Specimens were found at a rate of 1–3 per leaf, distributed throughout the under surface of leaves. The adult females lay pale yellow eggs usually surrounded, especially in heavy infestations, by annular fluffy wax secreted by the adults and thus they appear to be in a white “nest” of woolly wax. There is another whitefly species co-existing on this same host plant: *Paraleyrodes minei* Iaccarino. No ants were observed.

Specimens examined. 2 puparia and 1 male on 3 slides, **China**, Yunnan, Xishuangbanna Wild Elephant Valley, periphery of the scenic area, 22°10'35"N, 100°51'30"E, alt 852 m, 13-IX-2022, leg. Lingfeng WEI, on *Piper* leaves. Above collection data are available at ZAFU; 1 female on 1 slide, **Belize**, Cayo, Chiquibul Forest Reserve, Las Cuevas plots, 30-V-2004, leg. Martin, from *Casearia sylvestris*, deposited in Natural History Museum in London (JH Martin 7950) (NHMUK010163276); 7 puparia on 1 slide, **Belize**, Cayo, Chiquibul Forest Reserve, Las Cuevas plots, 06-VII-2004, leg. Martin, from *Piper yucatanense*, deposited in Natural History Museum in London (JH Martin 8003A) (NHMUK010163283).

Host. Asteraceae; Flacourtiaceae: *Casearia sylvestris*; Piperaceae: *Piper yucatanense*; Moraceae: *Ficus altissima* (Martin 2004).

Remarks. This species was described from Belize by Martin (2004) on *Piper yucatanense* (Piperaceae). This species is very similar to *P. pseudonaranjae* Martin (2001), but both adult male and the puparium display differences. *P. perplexus* has some special features: crater-like pores on the inner side of margin; a small bright pore to either side of the vasiform orifice. There is a degree of variation shown in the aedeagus of *P. perplexus* (Fig. 8 F–I) seemingly to do with the degree of development of the membranous posterior edges of the ventral prongs (Martin 2004).

Distribution. China (Yunnan); Belize (Martin 2004).

4. *Paraleyrodes pseudonaranjae* Martin (Figs 9–11)

Paraleyrodes pseudonaranjae Martin, 2001: 104.

Specimens examined. 4 puparia on 1 slide, **China**, HK, NT Tai Lung Farm, 22-XI-1999, leg. Martin, from *Cirus paradisi*, deposited in Natural History Museum (JH Martin 7252) (NHMUK010164274); 4 puparia on 1 slide, **China**, HK, Botanical & Zoological Gardens, 07-XII-1999, leg. Martin, from *Randia spinosa*, deposited in Natural History Museum in London (JH Martin 7319) (NHMUK010163688); 7 puparia on 1 slide, **China**, Hainan, Danzhou City, IV–VII-2008, leg. Wenjing ZHU, from *Annona glabra*, deposited in Natural History Museum (Wenjing Zhu 1) (NHMUK010163842).



Figure 9. *P. pseudonaranjae*. A. Nymph; B. Adult. (Photographed by Guoyue YU).

Hosts. Altingiaceae: *Liquidambar formosana*; Annonaceae: *Annona muricata*, *Annona squamosa*; Aquifoliaceae: *Ilex asprella*; Araliaceae: *Heptapleurum heptaphyllum*; Arecaceae: *Areca catechu*, *Cocos nucifera*; Ericaceae: *Rhododendron pulchrum*, *Enkianthus quinqueflorus*; Euphorbiaceae: *Aporosa dioica*, *Bridelia tomentosa*, *Glochidion zeylanicum*; Fabaceae: *Pterocarpus indicus*; Gnetaceae: *Gnetum luofuense*; Hypericaceae: *Cratoxylum cochinchinense*; Malvaceae *Talipariti tiliaceum*; Melastomataceae: *Melastoma sanguineum*; Myrtaceae: *Psidium guajava*; Moraceae: *Ficus rumphii*; Myrtaceae: *Psidium guajava*; Phyllanthaceae: *Bischofia polycarpa*; Rubiaceae: *Psychotria asiatica*, *Randia spinosa*; Rutaceae: *Citrus mitis*, *Citrus paradisi*, *Citrus sinensis*, *Citrus grandis*, *Citrus reticulata*, *Clausena lansium*; Sapindaceae: *Dimocarpus longan*, *Litchi chinensis*; Smilacaceae: *Smilax corbularia*; Theaceae: *Polyspora axillaris*; Ulmaceae: *Celtis* sp. (Yu *et al.* 2010; Martin & Lau 2011). Other references in Evans (2008).

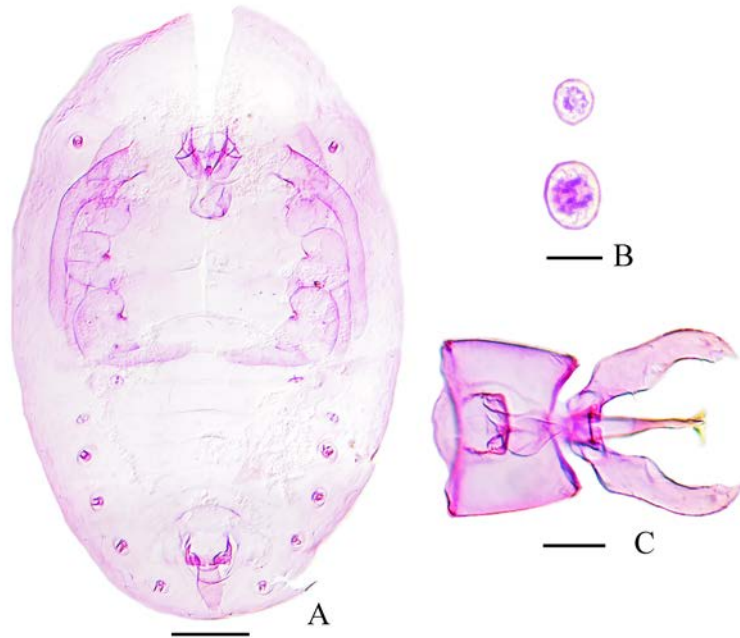


Figure 10. *P. pseudonaranjae*. A. Puparium; B. Abdominal compound pores; C. Terminal abdominal segment and genitalia. Scale bars = 100 μm (A); 20 μm (B); 50 μm (C).

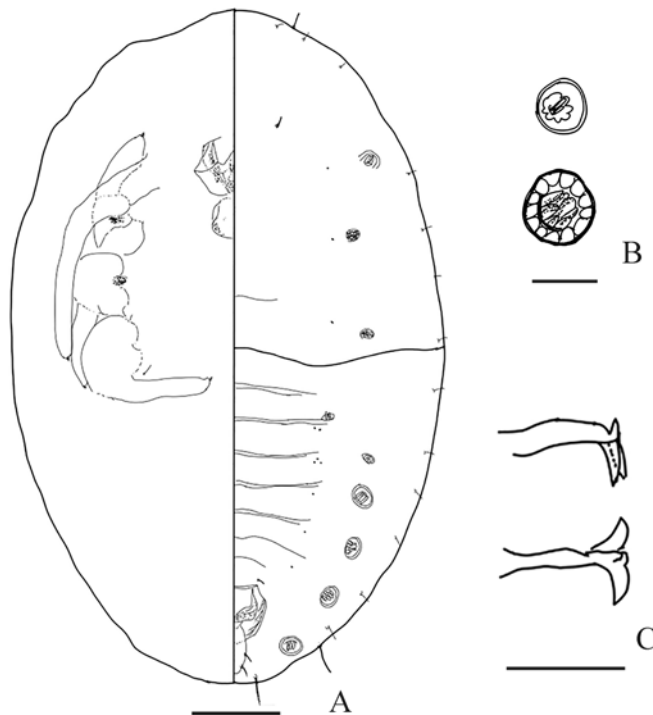


Figure 11. *P. pseudonaranjae*. A. Puparium, dorsal (right) and ventral (left) views; B. Abdominal compound pores; C. Aedeagus, lateral and dorsal aspects. Scale bars = 100 μm (A); 50 μm (B, C).

Remarks. Fore and hind wings each with a single main vein; fore wings with a pattern of brownish clouds. Apex of aedeagus (Fig. 10C) with a pair of ventro-laterally directed apically acute processes, and a single dorso-medially directed process that is slightly less acute. *P. pseudonaranjae* is very similar to *P. perplexus* but differs in this species lacks the submarginal crater-like pores and a bright discoidal pore between the vasiform orifice last posterior compound pore. *P. pseudonaranjae* was described from HK (Martin 2001) on *Citrus grandis* and other hosts, with holotype collected at TLF (Tai Lung Experimental Station). It was first found in *Cocos nucifera* in Sanya and Wenchang, Hainan, and on the Chinese mainland in 2006 (Zhu *et al.* 2010). It was also found to damage citrus in Nanning, Guangxi, China in 2007 (Yu *et al.* 2010). There are many hosts of *P. pseudonaranjae*. It has been found to damage a variety of important fruit trees, cash crops and ornamental plants in Hainan. Zhu *et al.* (2010) reported that it has seriously damaged fruit trees such as chirimoya, guava, coconut, betel nut, avocado and citrus.

Distribution. China (Guangxi, Yunnan, Hainan, Guangdong, Hong Kong) (Zhu *et al.* 2010; Yu *et al.* 2010; Martin 2001); USA (Florida, Hawaii); Puerto Rico (Martin & Lau 2011).

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