Zoological Studies **47**(4): 507-518 (2008)

Zoological Studies

The Genus *Singhius* Takahashi (Hemiptera: Aleyrodidae): with Notes on Pupal Dimorphism and Intraspecific Variation, and a Key to the Species

Anil Kumar Dubey[1], Chiun-Cheng Ko[1,*], and Baliah Vasantharaj David[2]

[1]*Department of Entomology, National Taiwan University, Taipei 106, Taiwan*

[2]*Sun Agro BioTech Research Centre, Madanandapuram, Chennai 600116, India*

(Accepted January 23, 2008)

Anil Kumar Dubey, Chiun-Cheng Ko, and Baliah Vasantharaj David (2008) The genus *Singhius* Takahashi (Hemiptera: Aleyrodidae): with notes on pupal dimorphism and intraspecific variation, and a key to the species. *Zoological Studies* **47**(4): 507-518. The whitefly genus *Singhius* Takahashi (1932) is revised based on examination of types and other determined specimens. *Singhius ehretiae* Jesudasan and David is synonymized with *S. hibisci* (Kotinsky). Adult morphology is provided for the first time for *S. hibisci*. Notes on dimorphism, intraspecific variations, and new hosts are given. The study led to a generic redescription, and supports *Singhius* as a full genus; species diagnoses and an identification key to puparia are given.
http://zoolstud.sinica.edu.tw/Journals/47.4/507.pdf

Key words: *Singhius*, Morphology, Variation, Dimorphism, Key.

Takahashi (1932) described *Singhius* as a monotypic subgenus of *Dialeurodes* Cockerell, and Mound and Halsey (1978) subsequently raised this to genus level, and fixed *Aleyrodes hibisci* (Kotinsky) as its type species. It is a small genus which currently includes 4 species (Martin and Mound 2007), of which *S. hibisci* (Kotinsky) is known from Cambodia, the Hawaiian Is., India, Malaysia, New Caledonia, Taiwan, and Thailand, and *S. ehretiae* Jesudasan and David, *S. morindae* Sundararaj and David, and *S. russellae* (David and Subramaniam 1976) are known only from India. Puparia of species in this genus are distinguishable due to the rectangular shape of the vasiform orifice, and the anteriorly broad caudal furrow, which is equal to the posterior width of the vasiform orifice and filled with fine tubercles. The dorsum is variably tuberculated, and although these tubercles are variable, the occurrence pattern is useful for differentiating species. *Singhius* species feed only on dicotyledonous host plants, and 15 different plant families are reported here. Of these, the Euphorbiaceae, Malvaceae, and Moraceae hosts are associated with phenotypic plasticity in puparia of *S. hibisci*. Comparisons of adult morphology of *S. hibisci* and *Dialeurodes* species revealed differences between these genera that support *Singhius* being a full genus.

MATERIALS AND METHODS

In this study, holotypes of *S. ehretiae*, *S. morindae*, and *S. russellae*, a few slides of *S. hibisci*, and adults and immature stages of *S. hibisci* from *Phyllanthus reticulata* (provided by B.V. David, India; IDAV-personal collection of B.V. David) were studied. *Dialeurodes* species and additional material of *S. hibisci* were studied from the collection of National Taiwan Univ. (NTU), Taipei, Taiwan. The terminology for external and internal morphological structures follows Gill (1990) and Martin (1987). Micro-measurements and camera lucida drawings were made using an Olympus (Tokyo Japan) BX51 microscope. The scanning electron microscope study follows

*To whom correspondence and reprint requests should be addressed. Tel. 886-2-33665580. Fax: 886-2-27336703.
E-mail:kocc2501@ntu.edu.tw

the method given in Ko and Dubey (2007). *Dialeurodes* species examined in this study are listed in Appendix 1.

Holotypes of *S. ehretiae*, *S. morindae*, and *S. russellae* are deposited in the collections of the Division of Entomology, Indian Agricultural Research Institute, New Delhi, India.

Genus *Singhius* (Takahashi, 1932)

Dialeurodes (*Singhius*) Takahashi, 1932: 14. Type species: *Aleyrodes hibisci* Kotinsky 1907: 96; by monotypy.
Singhius Takahashi: Mound and Halsey 1978: 191. [full genus].

Diagnosis redefined: Puparia elliptical or oval, pale white, usually with little wax exudation, margin dentate, thoracic and caudal tracheal pore regions usually differentiated from margin, anterior and posterior marginal setae present, cephalic, 1st and 8th abdominal and caudal setae present, dorsum usually tuberculate, geminate pores evident on dorsum; median length of abdominal segment VII possibly shorter than or equal to segment VI; vasiform orifice rectangular, wider than long, posteriorly truncate, inner wall of orifice without comb of teeth; operculum subcordate, sometimes anterolateral margins invaginated; lingula usually obscured, sometimes excluded reaching 1/2 of caudal furrow; caudal furrow broad anteriorly, merging with posterior end of vasiform orifice, filled with minute tubercles. Ventrally antennae extended through inside of prolegs. Caudal tracheal fold with few spinules, spinules absent on thoracic tracheal folds (Figs. 4, 6).

Key to puparia of *Singhius* species

1. Median length of abdominal segment VII ≤ 1/2 length of segment VI; longitudinal row of submedian tubercles present near termination of abdominal segment sutures; tracheal characters highly variable, dorsal setae short or long and pointed, capitate, or fimbriate of variable length. .....*S. hibisci*
- Median length of abdominal segment VII more than 1/2 length or equal to segment VI (Fig. 55); lacking row of submedian tubercles on abdominal segments; tracheal pores may be indicated; dorsal setae capitate or fimbriate 2
2. Thoracic tracheal pores indicated by smooth emargination or not; transverse molting suture not turned anteriorly; entire dorsum tuberculated; tubercles strongly sclerotized (Figs. 53, 54), not made up of granules; outer margin of legs not irregular; lacking tubercles laterad of legs .... *S. russellae*
- Thoracic tracheal pores indicated by C-shaped invagination; transverse molting suture turned anteriorly; only subdorsum tuberculated, lacking tubercles on submedian area of cephalothorax and abdomen, tubercles less sclerotized and appear to be made up of granules (Figs. 55-57); outer margin of legs irregular (Figs. 33, 56); a pair of faint tubercles present laterad of pro- and metalegs .....*S. morindae*

Singhius hibisci (Kotinsky)
(Figs. 1-31, 39-52, 61)

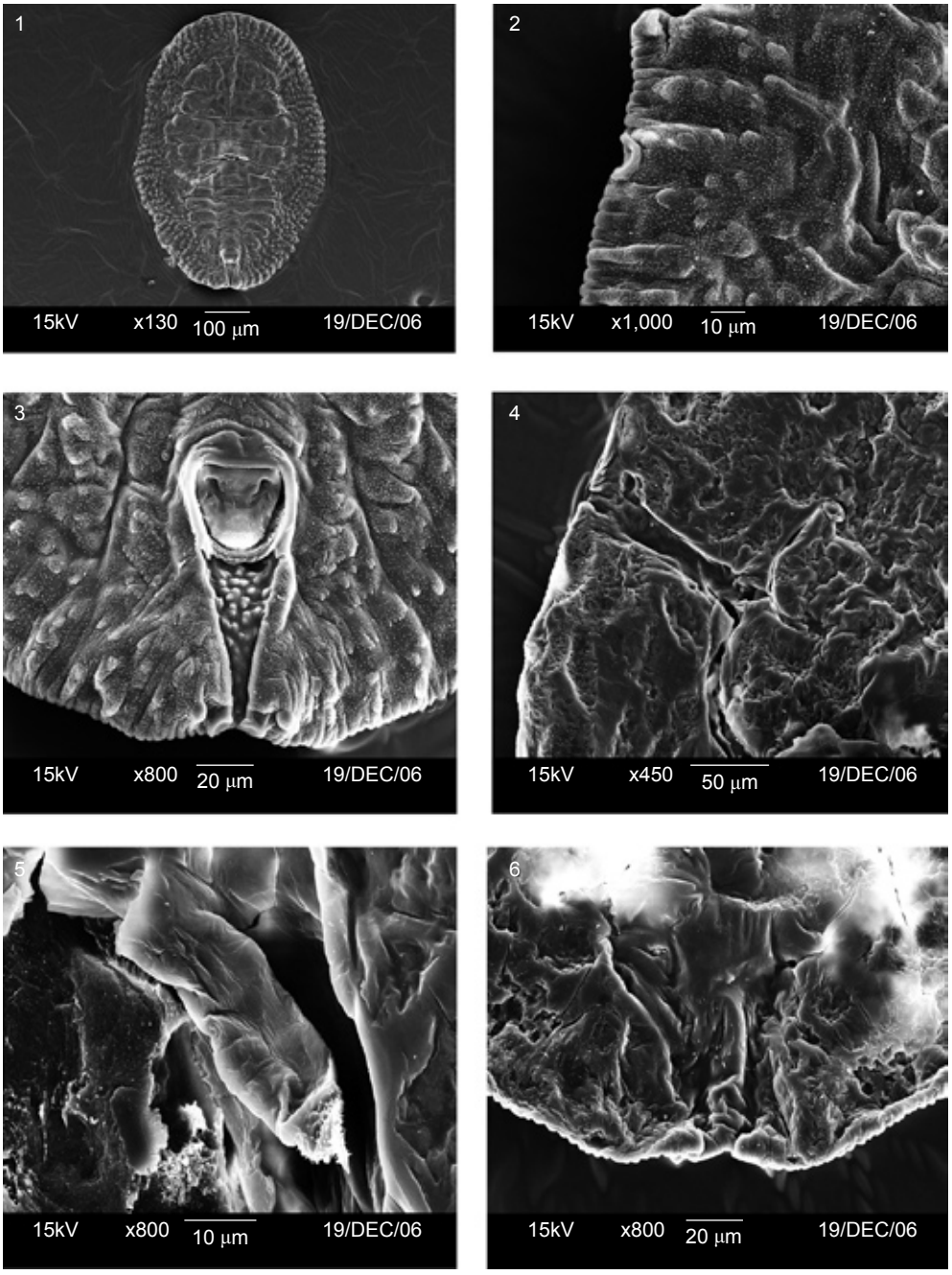
Aleyrodes hibisci Kotinsky 1907: 96.
Pealius hibisci (Kotinsky): Cohic 1959: 242-243.
Pealius hibisci (Kotinsky): Quaintance and Baker 1914: 99.
Dialeurodes fletcheri Singh 1931: 39 (synonymized by Takahashi 1932: 14).
Dialeurodes hibisci (Kotinsky): Takahashi 1932: 14.
Dialeurodes hibisci (Kotinsky): Corbett 1935: 772-773.
Singhius hibisci (Kotinsky) Mound and Halsey 1978: 191.
Singhius ehretiae Jesudasan and David 1991: 328-329. syn. nov.

Material examined: Holotype of *Singhius ehretiae* Jesudasan and David: India. Tamil Nadu, Tambaram, on *Ehretia ovalifolia*, 19 Nov. 1984, A. Jesudasan (IARI); India: Tamil Nadu, Chennai, Porur, 4 second instars, 21 third instars, 151 puparia, 8 ♂♂, 10 ♀♀ on *Phyllanthus reticulata* on 16 slides, 11 Sept. 2006, B.V. David (IARI, NTU); Tamil Nadu, Tambaram (Madras Christian College), 3 puparia on 3 slides, *Melanthesa rhamnoides*, 10 Nov. 1984, A. Jesudasan; 4 puparia on *Phyllanthus reticulata*, Port Blair (Andaman and Nicobar Is.), 21 Apr. 2001, B.V. David (David's reexamination confirmed it to be *S. hibisci* not *S. morindae*) (IDAV). Taiwan. Chiayi: 12 puparia on *Cleistocalyx* sp., 4 Nov. 1994, K.C. Chou (1372); Kaoshiung: Meinung, 13 puparia on unidentified plant, 4 June 2005, H.T. Yeh (2609); Kaoshiung: Fooyin Univ. campus: 32 puparia on 12 slides, on *Breynia officinalis*, 25 Aug. 2005, C.C. Hung (2813); Laonong: 5 puparia on *Breynia officinalis*, 8 Apr. 2006, H.T. Yeh (3447); Pingtung: 4 puparia on *Macaranga tanarius*, 10 Dec. 2005, F.S. Wu (2924); 7 puparia on *Gardenia jasminoides*, 29 Nov. 2005, Y.F. Chen (2912); 2 puparia on *Paederia foetida*, 23 Mar. 2004, H.T. Yeh (2205); Orchid I. (*Lanyu*): 9 puparia, 2 ♀♀, 3 ♂♂ on *Omalanthus fastuosus*, 30 July 2003, Y.F. Chen (1979); 8 puparia, 3 ♂♂, 2 ♀♀ on *Glochidion zeylanicum*, 30 July 2003, Y.F. Chen (1977); Taipei: 1 puparium on unidentified plant, 9 July 2005, Y.F. Chen (2640); 7 puparia on *Macaranga tanarius*, 11 Aug. 2005, C.C. Hung (2751); Tainan: 13 puparia on Euphorbiaceae, 30 June 2005, C.C. Ko (2633); Taoyuan: 3 puparia on *Euphorbia pulcherrima*, 18 Aug. 2005, C.C. Chen et al. (2794); Wufeng: 1 puparium on *Mallotus japonicus*, 12 Aug. 1985, C.C. Ko; Xindian: 10

puparia on *Macaranga tanarius*, 15 Aug. 2005, H.T. Yeh (2760) (all NTU).

Detailed descriptions of this species are available in Corbett (1935), Singh (1931), and Jesudasan and David (1991) hence, only intraspecific variations are discussed here. The adult morphology is provided for the first time. Drawings for puparia and adults are given with illustrations. It is a polyphagous species and heavily infests many ornamental plants in Taiwan.

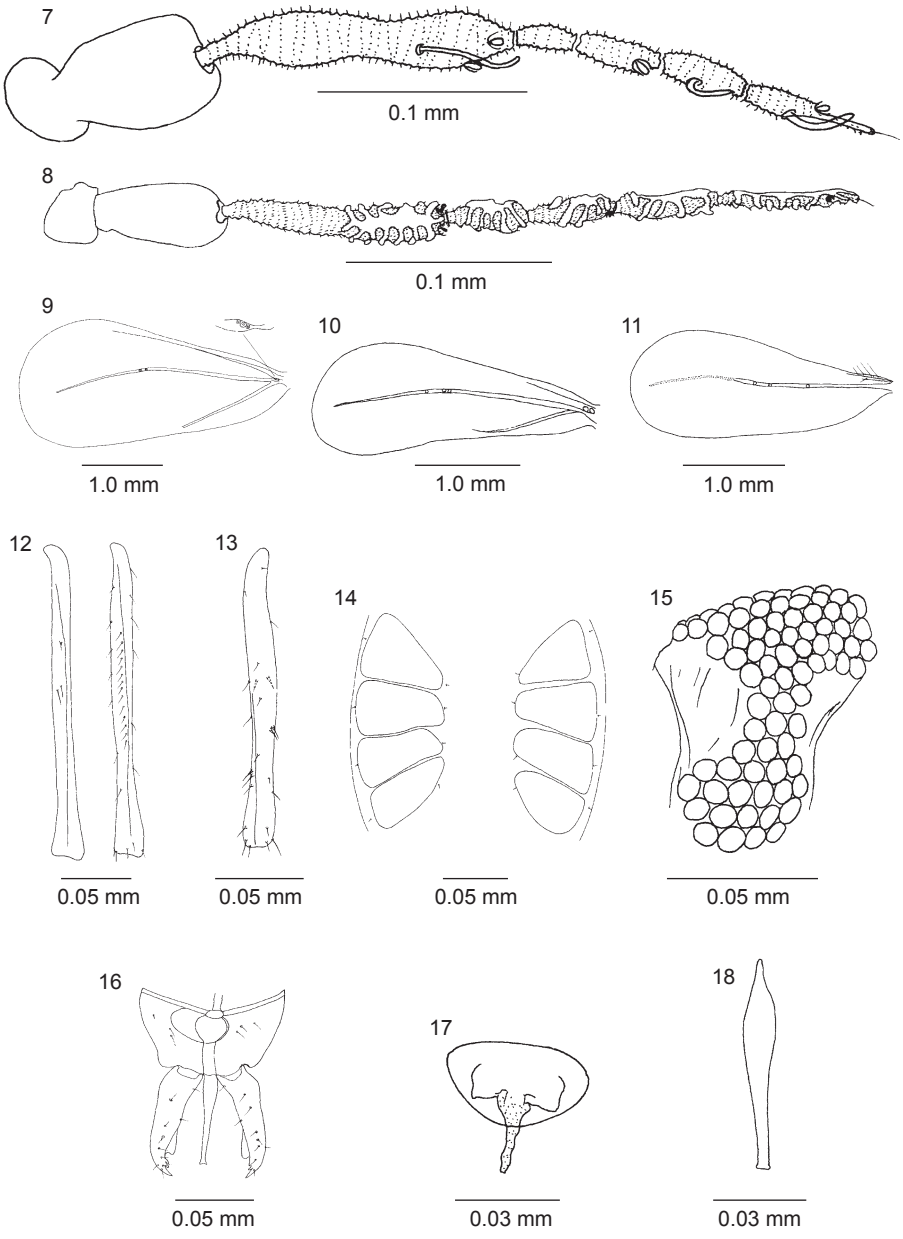
Diagnosis of puparium: Puparia covered with thin layer of white wax on dorsum, thoracic and caudal tracheal pores with small waxy fringes, dorsal tubercles visible under microscope. Generally, longitudinal row of enlarged tubercles present near termination of abdominal segment sutures. Dorsal setae length and shape varying (see below for details under "Dimorphism and



Figs. 1-6. Puparium of *Singhius hibisci* (India. Chennai: Porur). **1.** Dorsal view; **2.** thoracic tracheal pore, dorsal view; **3.** vasiform orifice, dorsal view; **4.** thoracic tracheal fold and proleg, ventral view; **5.** antenna, ventral view; **6.** caudal tracheal fold.

intraspecific variation").

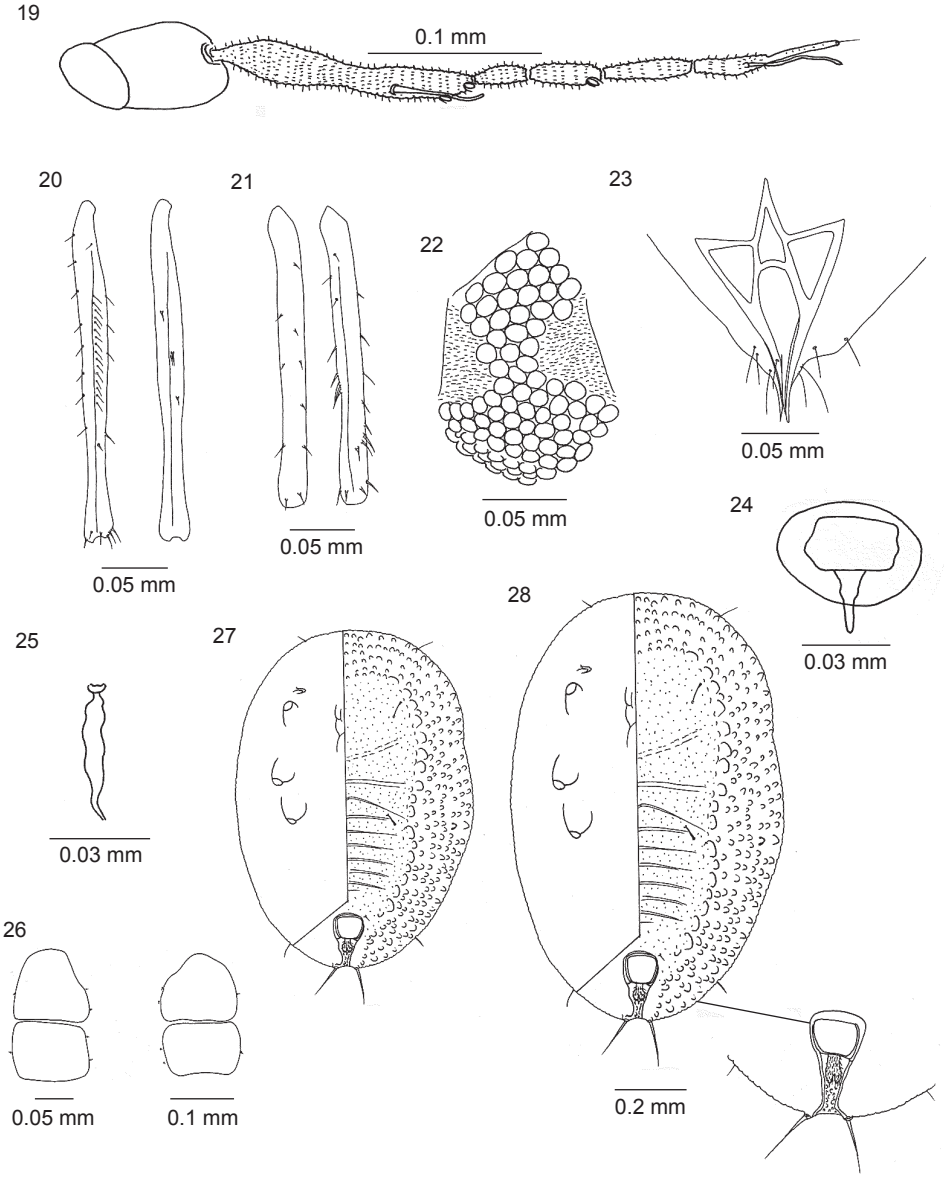
Adult morphology: *Male*: Antenna (Fig. 7) 7-segmented, segment III longest, 3 sensorial cones, 1 located each on segments III, VI, and VII; sensorial cones reaching front of apex of segments on which they are located; 4 primary sensoria, 2 located on segment III subapically, and 1 each on segments V and VII; segment I 1.75 μm long and 2.5 μm wide, II 3.75, III 7.25, IV 1.50, V 2.25, VI 2.50, and VII 3.62 μm long. Forewing (Fig. 10), subcosta, media, and radius present; hindwing (Fig. 11), only subcosta and radius present, upper basal margin with 2 long and 3 or 4 small setae. Legs: Metatibia (Fig. 12) 22.5 μm long, metatibial comb comprising 14 setae, 1 metatibial brush comprising 2 setae, in addition 16 setae (except those on apical end of tibia) variably placed; mesotibia (Fig. 13) 16.5 μm long, with 2 brushes, each comprising 2 setae. Four abdominal wax plates (Fig. 14), each associated with 1 min seta on its inner and outer margins. Eye (Fig. 15): Unpigmented, upper and lower lobes joined by 3 facets. Genitalia (Figs.



Figs. 7-18. Adult male. *Singhius hibisci* (India. Chennai: Porur). **7.** Antenna; **8.** *Dialeurodes citri* (Taiwan. Tainan: Paiho), antenna, male; **9.** forewing; **10.** *Singhius hibisci* (India. Chennai: Porur), forewing; **11.** hindwing; **12.** metatibia; **13.** mesotibia; **14.** abdominal wax plates; **15.** compound eye; **16.** genitalia; **17.** lingula; **18.** aedeagus.

16-18): Aedeagus shorter than claspers, swollen at base, gradually reduced towards apex, apically truncate. Clasper apically pointed, 2 subapical teeth present, located near apex of clasper, each clasper with 11 setae, of which 5 on dorsal surface, 3 near outer apical margin, 2 on inner margin, and 1 on ventral surface. Vasiform orifice subcordate; lingula small, unsegmented, setose; 3 pairs of setae placed laterad to orifice, 2 set closer to each other and 1 located far from them.

Female: As for male except antenna (Fig. 19) with 3 sensorial cones, 1 each on segments III and VI, located in front of middle, reaching beyond apical end of respective segments, 1 on segment VII, located before middle of segment, reaching beyond apex. Metatibia (Fig. 20) 27.25 μm long, metatibial comb comprising 15 or 16 setae, sometimes number of setae varying ± 1 on right and left metatibia of same individual, 1 metatibial brush, comprising 2 setae, in addition 14 setae (except those on apical end of tibia) placed at variable positions. Mesotibia (Fig. 21) 19.25 μm long. Apical seta present at distal tarsus. Eye (Fig. 22): Unpigmented, upper and lower lobes joined by 2 or 3 ommatidia. Genitalia (Figs. 23-25): Each paired gonopophysis with 4 setae, 2



Figs. 19-28. Adult female. *Singhius hibisci* (India. Chennai: Porur). **19.** Antenna; **20.** metatibia; **21.** mesotibia; **22.** compound eye; **23.** genitalia; **24.** lingula; **25.** cement gland; **26.** abdominal wax plates; **27.** 3rd instar; **28.** 2nd instar.

placed closer subapically; unpaired gonopophysis with a pair of setae. Vasiform orifice subcordate, lingula excluded, 2-segmented, lateral margin of basal segment with 2 small teeth; cement gland constricted at 3 or 4 places, segmentation not clear at constrictions. Two abdominal wax plates (Fig. 26), each associated with 1 seta on outer margin and 2 on inner margin.

Third instar nymph (Fig. 27): Length 0.41 mm, width 0.30 mm; subelliptical. Margin crenulate, 28-38 crenulations in 0.1 mm. Anterior and posterior marginal setae 3.25 and 2.25 μm long, respectively. Three pairs of capitate setae of cephalic, 1st and 8th abdominal, and a pair of pointed caudal setae, 2.62, 2.12, 1.75, and 4.25 μm long, respectively. Longitudinal molting suture defined with minute tubercles on anterior subdorsal area. Submedian area granulated, subdorsum tuberculate, large tubercles visible near termination of segment sutures. Cephalothoracic and abdominal segment sutures widely separated, a longitudinal row of tubercles present near termination of abdominal segment sutures. Vasiform orifice subrectangular, 2.50-3.00 μm long, 3.50-4.87 μm wide; operculum subcordate, 2.00-2.25 μm long, 2.62 μm wide. Caudal furrow 3.00-3.25 μm long, 2.00-2.25 μm wide at base, filled with minute tubercles. Ventral abdominal setae, anterior to vasiform orifice 0.62-1.00 μm long, 1.72-2.12 μm apart. Antenna anterior to proleg, hook-like, distance between proleg and antenna 2.5 μm long. Legs conical-shaped. Caudal and thoracic tracheal folds slightly indicated.

Second instar nymph (Fig. 28): Elongate, 0.50 mm long, 0.30 mm wide. Margin smoothly crenulate, 15 crenulations in 0.1 mm. Anterior and posterior marginal setae each 3.00 μm long. Four pairs of pointed setae of cephalic, 1st and 8th abdominal and caudal setae 1.5, 1.25, 1.25, and 6.25 μm long, respectively. Subdorsum with wavy markings. Submedian depressions on abdominal segments visible. Vasiform orifice rectangular, 4.25 μm long, 5.37 μm wide, inner lateral and caudal margin with irregular ridges; operculum subrectangular, 2.75 μm long, 4.5 μm wide. Lingula exposed, resembling that of *Trialeurodes*, including a pair of long setae present at tip. Caudal furrow cylindrical, 4.5 μm long. A pair of ventral abdominal setae present. Antenna anterior to proleg, placed very near, hook-like. Adhesive sacs and pads on apical end of legs visible.

Host plants:

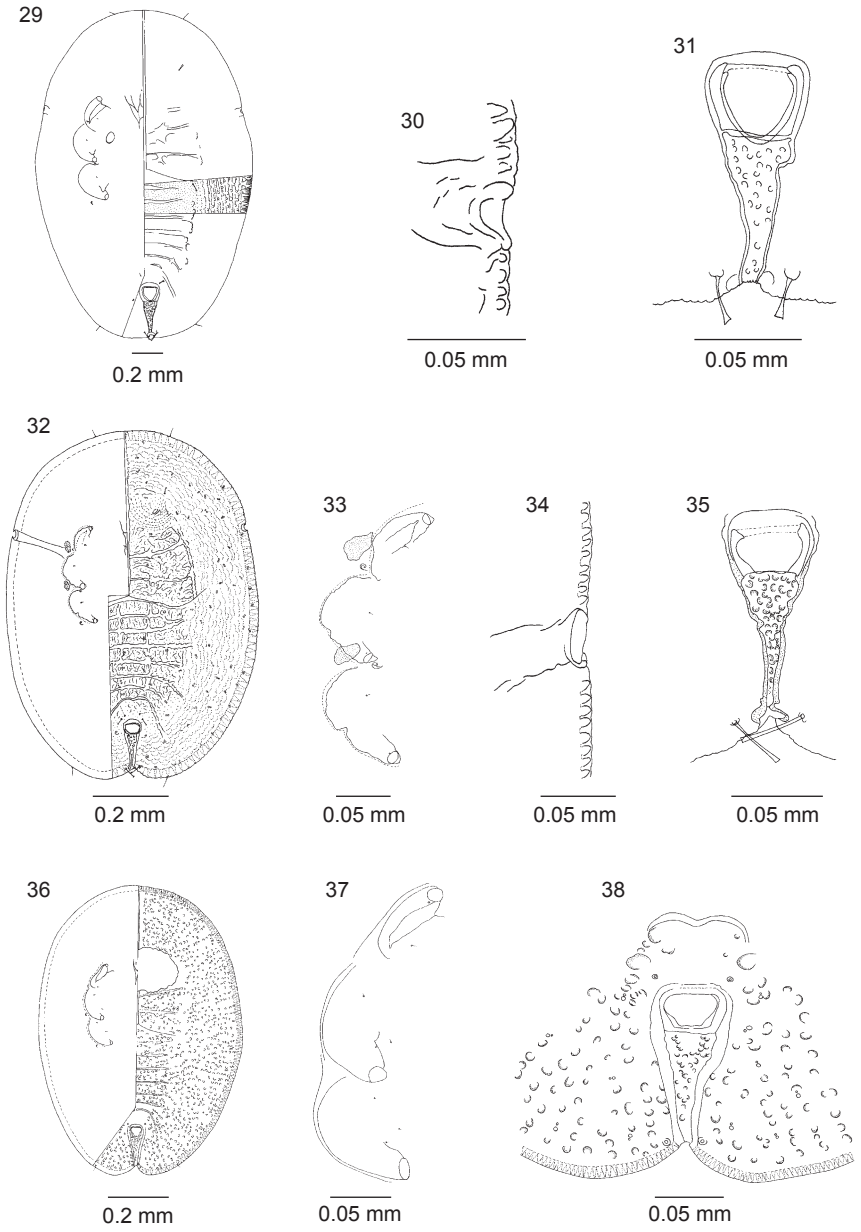
Annonaceae: *Fissistigma oldhami* (Mound and Halsey 1978); Asteraceae (Compositae): *Synedrella nodiflora* (Meganathan and David 1994, misspelled as *nidofloea*); *Omalanthus fastuosus* (new record); Boraginaceae (Ehretiaceae): *Ehretia ovalifolia* (Jesudasan and David 1991); Convolvulaceae: *Ipomoea batatas* (Corbett 1935); Euphorbiaceae: *Breynia rhamnoides* (= *Melanthesa rhamnoides*) (Singh 1931), *Glochidion hongkongensis*, *Macaranga tanarius*, *Sapium sebiferum* (Takahashi 1932), *Baccaurea motleyana* (Corbett 1935), and *Phyllanthus reticulata* (not "*reticulatus*") (David and Dubey 2006); *Breynia officinalis*, *Euphorbia pulcherrima*, *Glochidion zeylanicum*, and *Mallotus japonicus* (new records); Lauraceae: *Cinnamomum camphora*, and *Machilus* sp. (Takahashi 1932); Malvaceae: *Hibiscus rosa-sinensis* and *Hibiscus* [*Paritium*] *tiliaceus* (Kotinsky 1907, Cohic 1959); Moraceae: *Ficus elastica* (Corbett 1935); Myrtaceae: *Cleistocalyx* sp. (new record); Oleaceae: *Forsythia suspensa* (Mound and Halsey 1978) and *Jasminum* sp. (Takahashi 1932); Phyllanthaceae: *Bridelia monoica* (Takahashi 1935); Rubiaceae: *Gardenia* sp. (Evans 2007) (documented on a website (http://www.sel.barc.usda.gov:591/1WF/whitefly_catalog.htm (accessed 6 Sept. 2007)); *Gardenia jasminoides*, and *Paederia foetida* (new record); Salicaceae: *Salix* sp. (Takahashi 1932); Solanaceae: *Physalis peruviana* (Mound and Halsey 1978); Ulmaceae: *Celtis sinensis* (Takahashi 1932); and Vitaceae: *Vitis vinifera* (Mound and Halsey 1978).

Distribution: Cambodia, Hawaiian Is., India, Malaysia, New Caledonia, Taiwan, and Thailand.

Remarks: The study of the holotype of *Singhius ehretiae* Jesudasan and David (IDAV coll.) (examined by the senior author) and paratype (examined by Jon Martin, British Museum of Natural History, London) revealed that it has a C-shaped thoracic tracheal pore, and the median length of abdominal segment VII is ≤ 1/2 of segment VI. Jesudasan and David (1991) designated *S. ehretiae* as a new species stating "characteristic tracheal pore regions and size of seventh segment" . Our observations confirm that *S. ehretiae* should be considered a junior synonym of *S. hibisci*. *Singhius hibisci* differs from *S. morindae* and *S. russellae* in the median reduction of abdominal segment VII that is < 1/2 of segment VI. The length and shape of the dorsal setae vary, and they may be capitate or pointed (see intraspecific variation below). Singh (1931)

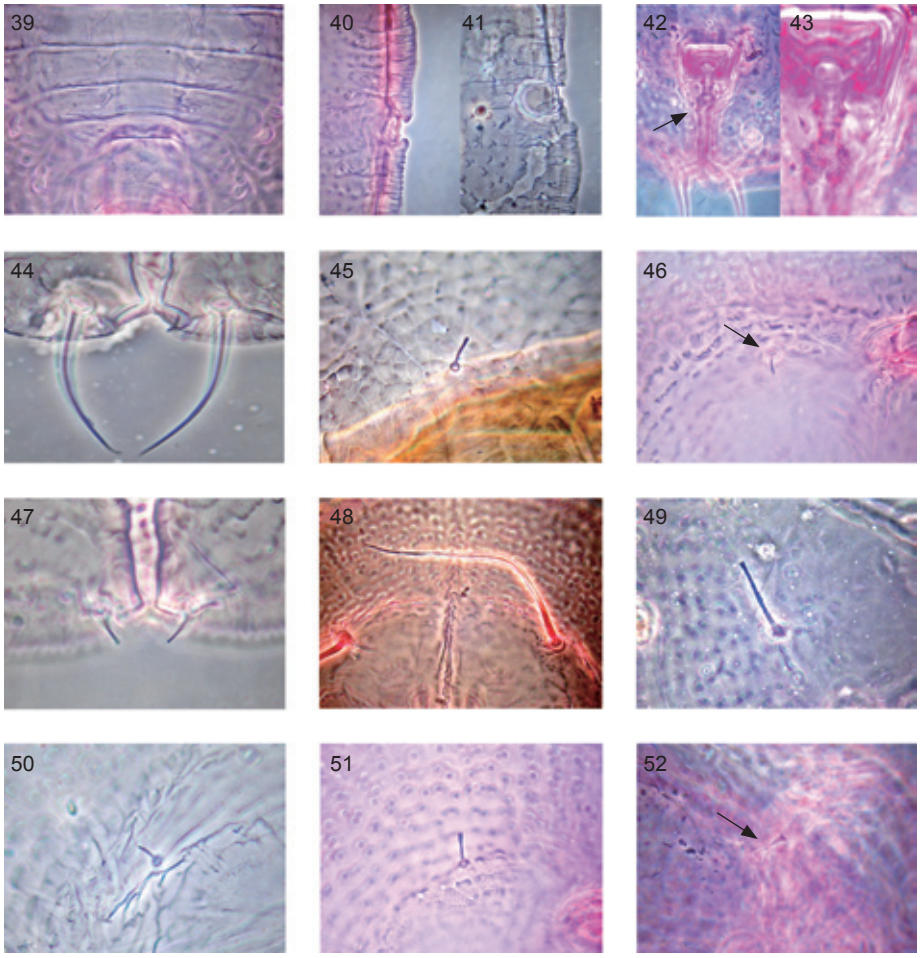
observed long setae on a euphorbiaceous host (*Breynia rhamnoides*). Corbett (1935) noted short setae puparia from *Hibiscus rosa-sinensis*, and long setae on those from *Baccaurea motleyana* and *Ficus elastica*. Takahashi (1932) referred to "two pairs on eighth abdominal segment laterad to and just above the vasiform orifice"; we consider that these were ventral setae. The length/apex of the caudal setae is variable, being capitate, fimbriate, or pointed.

Dimorphism and intraspecific variation: Puparia of *S. hibisci* from *Gardenia jasminoides* and *Paederia foetida* had short, capitate and/or pointed setae; specimens from *Euphorbia pulcherrima* and *Macaranga tanarius* had long, pointed setae; specimens from *Glochidion zeylanicum* and *Omalanthus fastuosus* had short, capitate setae; specimens from an unidentified plant had fimbriate and/or pointed setae. These observations suggest that the setal



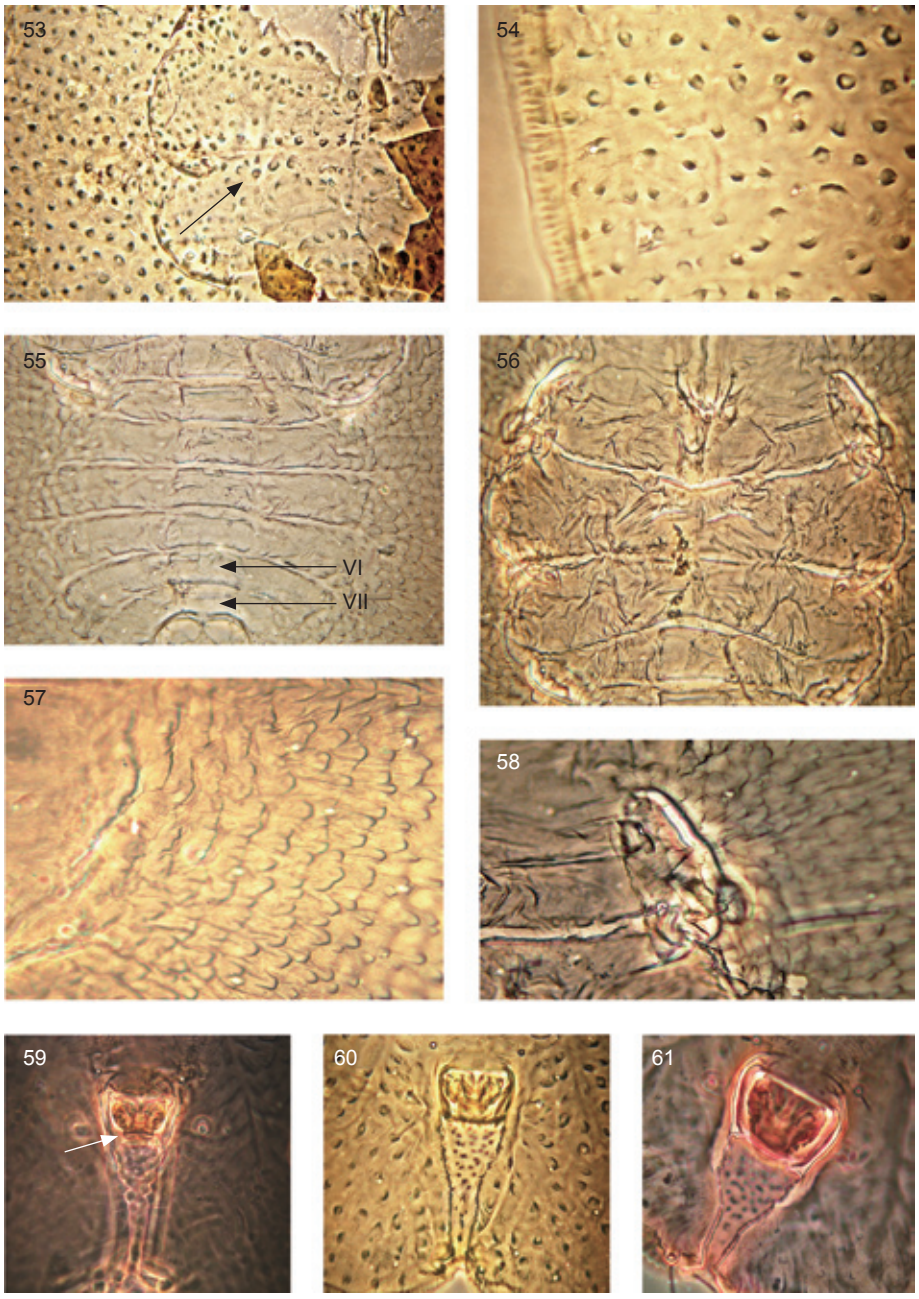
Figs. 29-38. Puparium. *Singhius hibisci* (India. Chennai: Porur). **29.** Same, dorsal and ventral view; **30.** same, thoracic tracheal pore; **31.** same, vasiform orifice; **32.** Holotype puparium, *Singhius morindae* (India. Tamil Nadu: Vellimalai), dorsal and ventral view; **33.** same, thoracic legs; **34.** same, thoracic tracheal pore; **35.** same, vasiform orifice. **36.** Holotype puparium, *Singhius russellae* (India. Tamil Nadu: Valparai), dorsal and ventral view; **37.** same, thoracic legs; **38.** same, posterior abdominal area.

morphology varies considerably in *S. hibisci*, and the setae are not therefore regarded as useful for species discrimination. Puparium subelliptical to oval, widest at metathoracic region, and may be more or less constricted or not at all in the tracheal pore area, usually abundant on the lower surface of leaves. Puparial dimorphism is clear, ♂ 0.62-0.65 mm long, 0.45-0.46 mm wide; ♀ 0.75-0.78 mm long, 0.55-0.58 mm wide. Thoracic and caudal tracheal pore area indicated by C-shaped emargination. Anterior and posterior marginal setae 2.75 and 3.25 μm long, respectively. In less-bleached specimens, submedian area often with brown shading. Dorsal setae pointed, usually broken and appearing capitate, fimbriate in a few specimens, and may be long or small. Generally, cephalic and 1st abdominal setae 2.75 μm long, 8th abdominal setae 1.50 μm long, and caudal setae 2.75 μm long, length always varying within a population of the same colony. Submarginal lines usually appearing as papillae in well-stained specimens. Submedian tubercles arranged longitudinally in a row on abdomen, near termination of segment sutures. Lacking minute tubercles along sutures of thoracic and abdominal segments. Geminate pores and porettes scattered throughout dorsum. Vasiform orifice: rectangular, length ♂ and ♀, 3.00-4.00 μm, width ♂ 4.50-4.88 μm, ♀ 5.50-5.75 μm; operculum subcordate, length ♂ and ♀, 2.75-3.60 μm, width ♂ 3.00-3.25 μm, ♀ 3.50-4.00. Caudal furrow funnel-shaped entirely connecting posterior end of vasiform orifice (♂ 5.00-5.12 μm long, 2.75-3.25 μm



Figs. 39-52. Variation in *Singhius hibisci*. **39.** Seventh abdominal segment; **40.** thoracic tracheal pore on *Glochidion zeylanicum*; **41.** thoracic tracheal pore on *Euphorbia pulcherimma*; **42.** vasiform orifice with excluded lingula on unidentified plant; **43.** same, enlarged view of lingula; **44.** long, pointed caudal setae on *Euphorbia pulcherrima*; **45.** small, capitate dorsal seta on *Gardenia jasminoides*; **46.** small, capitate dorsal seta on *Glochidion zeylanicum*; **47.** small, capitate caudal setae on *Paederia foetida*; **48.** long, pointed dorsal seta on *Mallotus japonicus*; **49.** long, capitate dorsal seta on *Macaranga tanarius*; **50.** small, capitate seta on *Paederia foetida*; **51.** small, capitate dorsal seta on *Omalanthus fastuosus*; **52.** small, fimbriate dorsal seta on unidentified plant.

wide; ♀ 6.87-7.25 μm long, 3.37-3.50 μm wide), filled with minute tubercles. Lingula mostly obscured by operculum, in a few specimens lingula reaching middle of caudal furrow, apically lobulate and little divided in middle, posteriorly long and slender. *Venter*. A pair of ventral abdominal setae, anterior to vasiform orifice 0.62-1.75 μm long, 2.12-3.75 μm apart. Antennae reaching base of prothoracic legs, apical end keel-like. Leg apices with prominent pads. Adhesive sacs and spiracles visible. Thoracic and caudal tracheal folds slightly indicated.



Figs. 53-61. Micrographs. **53.** Holotype puparium, *Singhius russellae* (India. Tamil Nadu: Valparai), submedian and subdorsal area of cephalothorax; **54.** same, margin and tubercles; **55.** Holotype puparium, *Singhius morindae* (India. Tamil Nadu: Vellimalai), abdominal segments, median and submedian area; **56.** same, cephalothorax, median and submedian area; **57.** same, subdorsal tubercles; **58.** same, proleg and tubercle; **59.** same, vasiform orifice and caudal furrow; **60.** Holotype puparium, *Singhius russellae* (India. Tamil Nadu: Valparai), vasiform orifice and caudal furrow; **61.** *Singhius hibisci* (India. Chennai: Porur), vasiform orifice and caudal furrow.

Singhius morindae Sundararaj and David
(Figs. 32-35, 55-59)

Singhius morindae Sundararaj and David 1993: 103-104.
Material examined: Holotype, India. Tamil Nadu, Vellimalai, 1 puparium on *Morinda tinctoria*, 3 Aug. 1987, R. Sundararaj (IDAV).

A full description is available in Sundararaj and David (1993).

Host plant: *Morinda tinctoria* (Sundararaj and David 1993). Record of *S. morindae* from *Phyllanthus reticulata* by David and Dubey (2006) based on a misidentification of *S. hibisci*.

Distribution: India: Tamil Nadu (Sundararaj and David 1993); Waynad Wildlife Sanctuary, Kerala.

Remarks: This species differs from *S. hibisci* in the median length of abdominal segment VII which is > 1/2 or equal to segment VI. It differs from *S. russellae* in its shape and the absence of tubercles on the submedian area. The subdorsal tubercles appear to be made up of minute granules (Figs. 32, 57), whereas in *S. hibisci* and *S. russellae*, the tubercles are more chitinized and not made up of granules (Figs. 2, 54). The geminate pores and porettes are abundant in this species and scattered irregularly on the subdorsum and submargin. Of these geminate pores, 1 minute pore is always placed on white shading on the dorsum and other nearby at distance of its own diameter. A pair of faint tubercles laterad of pro- and metalegs. A minute seta located in middle of each puparial leg.

Singhius russellae (David and Subramaniam)
(Figs. 36-38, 53, 54, 60)

Aleurotuberculatus russellae David and Subramaniam 1976: 172.
Singhius russellae: Jesudasan and David 1990: 1-16.

Material examined: Holotype, India. Tamil Nadu: Valparai, 2 puparia on 1 slide, on unidentified tree, 16 Apr. 1967, B.V. David (IDAV).

Diagnosis, drawings, and illustrations are given to benefit identification key.

Host plant: Unidentified tree.

Distribution: India: Tamil Nadu (David and Subramaniam 1976).

Remarks: The holotype slide bears 2 puparia; 1 is parasitized but is in better condition than the other of which nearly 60% of the dorsum is lost. In the parasitized puparium, the characters of taxonomic importance are clear, and hence it is fixed here as the holotype. All of the dorsal setae are broken in both specimens; the original description by David and Subramaniam (1976) states that they are capitate. The caudal tracheal pore is deeply invaginated with a comb of fine teeth. It differs from *S. morindae* by the presence of tubercles on the submedian area of the cephalothorax and abdomen, and from *S. hibisci* in having the median length of abdominal segment VII > 1/2 or equal to segment VI, and the tuberculated submedian area. It differs from both *S. hibisci* and *S. morindae* in the absence of a C-shaped thoracic tracheal pore and in having a tuberculated submedian area.

DISCUSSION

Examinations of the holotype (by the senior author) and a paratype (by Jon Martin, BMNH, UK) of *S. ehretiae* revealed that the thoracic tracheal openings and median length of abdominal segment VII were similar to those of *S. hibisci*, and no further differences could be observed. Thus, *S. ehretiae* is considered a junior synonym of *S. hibisci*. Currently, the genus includes 3 valid species of *S. hibisci*, *S. morindae*, and *S. russellae*. Of the 3 species now recognized in the genus, *S. russellae* is unique in having undefined thoracic tracheal pores, and the entire subdorsum tuberculated. *Singhius hibisci* and *S. morindae* are similar in having C-shaped thoracic tracheal pore openings, and in the structure of the vasiform orifice. However, *S. morindae* is distinguishable from *S. hibisci* by the median length of abdominal segment VII that is equal to segment VI (in *S. hibisci* the median length of abdominal segment VII is equal to ≤ 1/2 of segment VI). Observations of a large number of specimens of *S. hibisci* suggest the puparium shape and tuberculation pattern vary in this species. Sundararaj and David (1993) differentiated *S. morindae* as a new species differing from *S. hibisci*, only in having capitate dorsal setae. In the *S. morindae* holotype the 1st abdominal setae are broken; however, the cephalic setae are capitate. The capitate nature of the setae is also seen in *S. hibisci*, but the apex was larger in *S. morindae*. Examination of the holotype of *S. morindae* showed that it is over-bleached, which probably caused the very fine appearance of the dorsal tubercles (Figs. 32, 52). Our observations suggest that the only difference between *S. hibisci* and *S. morindae* is the median length of the 7th abdominal segment, which is

equal to the 6th in the latter species. In *S. hibisci* specimens examined, we found no abdominal segment VII which was equal to VI; therefore, *S. morindae* is treated here as a valid species.

The morphology of adult *S. hibisci* was compared to that of *Dialeurodes* species. Adults of *S. hibisci* lack the sensorial plaques, but the sensorial cones are present, and reach the apical end of their respective antennal segments. In *D. citri*, *D. agalmae*, *D. daphniphylli*, and *D. kirkaldyi*, the sensorial plaques are present and sensorial cones are absent. It is believed that in the *Dialeurodes*-group, sensorial cones are modified into flat plaques covering much of the antennal segment on which they occur. In adult males and females of *S. hibisci*, the upper and lower lobes of the compound eyes are joined by 3 ommatidia, whereas in *D. citri* by a single ommatidium, in *D. agalmae* by 2 ommatidia, and in *D. daphniphylli* by 3 ommatidia. In the *Dialeurodes* species examined and *S. hibisci*, the wing vein subcosta, radius, and cubitus are present; however, the wing expanse and length of the subcosta were smaller in *S. hibisci*. There were 2 mesotibial brushes in *D. citri* and *S. hibisci*. Based on considerable morphological differences in puparia and adults, we believe that *Singhius* is a monophyletic genus.

Acknowledgments: We thank Jon Martin, BMNH, London, UK for examination of paratype of *S. ehretiae* and reconfirming its synonym status. This publication was supported by a postdoctoral grant (NTU 95R0044) from National Taiwan Univ. and a grant (NSC95-2621-B-002-012) from the National Science Council, Republic of China.

REFERENCES

Cohic F. 1959. Aleyrodidae actuellement connus de Nouvelle-Calédonie et dépendances. L'Agron. Trop. **14:** 242-243.

Corbett GH. 1935. Malayan Aleurodidae. J. Fed. Malay St. Mus. **17:** 772-773.

David BV, AK Dubey. 2006. Whitefly (Hemiptera: Aleyrodidae) fauna of Andaman and Nicobar Islands, India with description of a new species. Entomon **23:** 191-205.

David BV, TR Subramaniam. 1976. Studies on some Indian Aleyrodidae. Rec. Zool. Surv. India **70:** 133-233.

Evans GA. 2007. The whiteflies (Hemiptera: Aleyrodidae) of the world and their host plants and natural enemies. Available at http://www.sel.barc.usda.gov:591/1WF/whitefly_catalog.htm (version 6 Septe. 2007).

Gill RJ. 1990. The morphology of whiteflies. *In* D Derling, ed. Whiteflies: their bionomics, pest status and management. Anthenaeum Press, UK, XVIII International Congress Entomology: Intercept, pp. 13-46.

Jesudasan RWA, BV David. 1991. Taxonomic studies on Indian Aleyrodidae (Insecta: Homoptera). Oriental Ins. **25:** 231-434.

Ko CC, AK Dubey. 2007. *Aleurocyperus humus* gen. et sp. n. (Hemiptera: Aleyrodidae) from Taiwan, with interesting feeding behaviour. Zootaxa **1443:** 37-54.

Kotinsky J. 1907. Aleyrodidae of Hawaii and Fiji with descriptions of new species. Bull. Brd. Comm. Agric. For Hawaii Div. Ent. **2:** 93-102.

Martin JH. 1987. An identification guide to common whitefly pest species of the world (Homoptera: Aleyrodidae). Trop. Pest Manage. **33:** 298-322.

Martin JH, LA Mound. 2007. An annotated checklist of world's whiteflies (Insecta: Hemiptera: Aleyrodidae). Zootaxa **1492:** 1-84.

Mound LA, SH Halsey. 1978. Whitefly of the world. A systematic catalogue of the Aleyrodidae (Homoptera) with host plant and natural enemy data. Chichester, UK: British Museum (Natural History) and J Wiley, 340 pp.

Quaintance AL, AC Baker. 1914. Classification of the Aleyrodidae, Part II. Bur. Entom. Tech. Ser. US **27:** 95-109.

Singh K. 1931. A contribution towards our knowledge of the Aleyrodidae (whiteflies) of India. Mem. Dept. Agric. India. Entomol. Ser. **12:** 1-98.

Sundararaj R, BV David. 1993. On a new species of *Singhius* Takahashi (Aleyrodidae: Homoptera) with a key to Indian species. J. Bombay Nat. Hist. Soc. **89:** 103-104.

Takahashi R. 1932. Aleyrodidae of Formosa, Part I. Rep. Dep. Agric. Govt. Res. Inst. Formosa **59:** 1-57.

Takahashi R. 1935. Aleyrodidae of Formosa, Part IV. Rep. Dep. Agric. Govt. Res. Inst. Formosa **66:** 39-65.

APPENDIX 1. *Dialeurodes* species studied. (Specimens from the NTU collections are available for experts to study).

1. *Dialeurodes agalmae* Takahashi
Material examined: Taiwan. Taipei, 3 ♂♂, 3 ♀♀ adults on *Schefflera taiwaniana*, 13 Mar. 2002, C.C. Ko; Yangmingshan, 2 puparia on *Schefflera taiwaniana*, 15 Apr. 1994, K.C. Chou (NTU).

2. *Dialeurodes citri* (Cockerell)
Material examined: Taiwan. Tainan, Paiho, 4 ♂♂, 12 ♀♀ adults on *Citrus* sp., 12 May 2003, C.C. Ko; Meifeng, 21 puparia on *Turpinia formosana* (Staphyleaceae), 6 Sept. 1986, C.C. Ko (NTU).

3. *Dialeurodes daphniphylli* Takahashi
Material examined: Taiwan. Taipei: Tienmu, 3 ♂♂, 2 ♀♀ adults; 48 puparia on *Daphniphyllum* sp. (Daphniphyllaceae), 23 Jan. 2003, C.H. Hsien; Sungkang, 8 ♂♂, 10 ♀♀ adults, 48 puparia on *Fatsia polycarpa* (Araliaceae), 26 Apr. 2002, C.C. Ko (NTU).

4. *Dialeurodes kirkaldyi* (Kotinsky)
Material examined: Taiwan. Taipei, 23 ♂♂, 9 ♀♀ adults on *Jasminum sambac* (Oleaceae), 21 Mar. 2001, C.C. Ko; Taichung, 38 puparia on *Jasminum sambac* (Oleaceae), 8 Dec. 1985, C.C. Ko (NTU).