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Morphology of adult *Helopeltis bradyi* (Heteroptera: Miridae) of Java, resolving a longstanding species uncertainty

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Abstract. We conducted morphological studies on adult *Helopeltis* samples collected from 11 localities in Java, Indonesia, to resolve the locally longstanding ambiguity as to whether the species found is *H. antonii* or *H. bradyi*. Rigid body parts were measured, and external and genital morphology of both females and males pictured and described. Length of body, first antennal segment and its ratio to the posterior width of the pronotum all fall within the range of *H. bradyi*. All samples have a pale band on each femur including the hind one, which is the distinct external character to recognize *H. bradyi* and differentiate it from *H. antonii*. Internally, female and male genitals shapes match only one of two previously described genitals of the Javanese *H. bradyi*. These findings confirm that all collected samples from Java which resemble *H. antonii* are in fact *H. bradyi*, and thus *H. antonii* has not yet been found in this island.

Keywords: Species uncertainty, *Helopeltis antonii*, *Helopeltis bradyi*, Java, external morphology, genitalia.

Introduction

The heteropteran genus *Helopeltis*, commonly known as tea mosquito bug, is an important pest attacking a number of commercial perennial crops in Indonesia, for example cacao, tea, cashew, cinchona, cinnamon (Kalshoven 1981), camphor, acacia (Nair 2001, FAO 2007), and eucalyptus (Diabangouaya & Gillon 2001, Rustam et al. 2014). The earliest records of *Helopeltis* attack in Java date from the Dutch colonial era, and are mostly related to *H. antonii* and *H. bradyi* and their confused identity that has persisted until now (Table 1). The first description of the genus *Helopeltis* was published by Signoret (1858) who described *H. antonii* from an unknown number of samples collected in Sri Lanka. After receiving *Helopeltis* samples attacking Javanese tea plants, Westwood (1874) reported the observed symptoms and noted their similarity to those affecting Assamica tea plants in India as described by Peal (1873). As the same variety of tea plants had also been planted in Sri Lanka and Java, Westwood (1874) suspected that the *H. antonii* described by Signoret (1858) might have been introduced to Java with their host plants. Later, Waterhouse (1886) described insects found on Sri Lankan tea as *H. theivora*; he also noticed a difference between these samples and those described as *H. antonii* by Westwood (1874) on Javanese tea, and was therefore unsure whether the two species were identical. Waterhouse (1886) also described *H. bradyi* collected from Javanese cinchona, and *H. romundei* from the samples collected from Javanese tea in 1888. Despite the descriptions of both species, *H. antonii* dominated the report of *Helopeltis* attack in Java. Roepke (1909) suspected the different biological races of Javanese *H. antonii* from one population to the other, and Betrem (1953) suggested the name *H. antonii* subsp. *bradyi* for *H. antonii* from central Java that differ in life span from those of West Java. De Silva (1957) reported a new species that infested cacao in Sri Lanka which he called *H. ceylonesis,* this species along with *H. romundei* was then considered to be synonymous to *H. bradyi* (Stonedahl 1991).

Helopeltis antonii was the most studied and reported species of the genus *Helopeltis* represented in Java from the late 19th century until recently (e.g. Ferguson & Ferguson 1884, Bernard 1918, Mudjiono 1987, Kilin & Atmaja 2000, Atmadja 2003, 2008, 2009, Siswanto *et al*., 2008, 2009). However, in his review of oriental *Helopeltis*, which discovered nine species (*H. bradyi, H. cinchonae*, *H. clavifer, H. cuneata, H. fasciaticollis, H. insularis, H. sulawesi*, *H. sumatranus*, and *H. theivora*) in Indonesia, Stonedahl (1991) stated that this *H. antonii* had been mistakenly identified and should be consid-

Table 1. Chronological history of descriptions of *Helopeltis antonii* and *H. bradyi* in Java and elsewhere.

Year - Author	Event
1858 - Signoret	*H. antonii* was described from samples collected in Sri Lanka.
1873 - Peal	*H. antonii* symptoms on Assamica tea of India explained.
1874 - Westwood	*H. antonii* was suspected of being transported along with Indian tea to Java; given as explanation of similar destruction of tea in Javanese tea.
1886 - Waterhouse	- *H. theivora* was described from Sri Lankan tea. - Acknowledged the difference of *H. theivora* to samples found on Javanese tea. - *H. bradyi* was described from samples collected on Javanese cinchona.
1888 - Waterhouse	*H. romundei* was described on Javanese tea.
1909 - Roepke	Suspected the presence of biological races among different population of Javanese *H. antonii*.
1953 - Betrem	*H. antonii* subsp. *bradyi* was suggested for *Helopeltis* in central Java that differ in life span with that in West Java.
1957 - De Silva	*H. ceylonensis* was described from Sri Lankan samples.
1991 - Stonedahl	- *H. romundei* and *H. ceylonensis* were regarded as synonyms to *H. bradyi*. - Stated that *H. antonii* was only found in India, Sri Lanka, and Andaman Islands.
After 1991 until recently - local authors	Published reports and studies in Java mentioning *H. antonii*.

ered as *H. bradyi* because of differences in both the male and female genitalia. After examination of copious museum samples gathered from south India, Java, West Malaysia, Sabah, Singapore, Sri Lanka, Sumatra, and Timor, Stonedahl (1991), using four samples from Java, one from India, two from Sabah, and one from Sri Lanka, distinguished four female genital chambers and four male lobal sclerites which were specific to *H. bradyi*. He emphasized the high variability of these *H. bradyi* genitals as well as considering the possibility that insects with these four distinct genital features could belong to different species.

In spite of Stonedahl's (1991) review, there remains ambiguity as to whether the most commonly reported Javanese *Helopeltis* species is *H. antonii* or *H. bradyi* (e.g. Karmawati 2010, Atmaja 2012). This is probably due to the similarities in their external morphological characters, the limited taxonomic knowledge about their distinguishing genital features, and the absence of a thorough morphological investigation into the true identity of Javanese *Helopeltis* species.

In this study, we sampled and conducted external and genital morphological studies of Javanese *Helopeltis* collected from cacao, cashew, and tea orchards throughout Java Island to reconfirm their identity. Since none of the previous publications referred to above had presented detailed descriptions of the external morphology of both male and female *H. bradyi*, these were undertaken as part of this study.

Materials and methods

Helopeltis samples, which can easily be differentiated from other plant sucking bugs by their long, dorsal scutellar spine, were collected in 2013 from commercial cacao, cashew and tea crops located at 11 sites in Java (Table 2, Fig. 1). The external morphological features of 134 samples containing 61 females and 73 males were examined. Two male and female adults from each location were subjected to more detailed measurements and genital dissection. All samples were observed under a dissecting Leica KL 1500 LCD (Leica Microsystems GmbH, Wetzlar, Germany) microscope equipped with OptiLab Viewer v. 2.1 (PT. Miconos, Indonesia).

Following Stonedahl (1991), the selected adult pairs were checked for the characters that distinguish *Helopeltis* species viz the colour patterns of the head, thorax, legs, and abdomen. Segment IX of the male abdomen which contains the genital capsule was removed to extract the phallus; the female was dissected on sterna VII to take the genital chamber out without removing the ovipositor. The male lobal sclerite and the female genital chamber were placed in a 35-mm polystyrene petri dish containing 10% KOH and sealed with parafilm. After about 12 h the KOH had removed the fat without discolouring the melanized structures. The cleaned genitals were placed in a drop of glycerol on a depression slide; 1% chlorazol black was added for ca. 3 min to stain transparent sutures. The genitals were then examined with the dissecting microscope and photographed under an Olympus CX31 (Olympus Corporation, Tokyo, Japan) compound microscope. Stacked pictures were merged using Combine ZP (Hadley 2010).

Scanning electron microscopy (SEM, FEI Quanta 200) was then conducted to facilitate examination of the pretarsus and antennae. To prepare samples, antennae and wings were cut off prior to dehydration in a sequence of 70%, 90%, 96%, and 100% ethanol, critical-point-dried with carbon dioxide in a Balzer CPD 030, mounted on

Table 2. Collection sites, hosts, and number of sampled *Helopeltis*.
m asl = metre above sea level; S-E = South-East; M = male, F = female.

Collection site	Altitude (m asl)	Latitude and Longitude (S-E)	Host	No. of samples (M, F)
Serang, Banten	420	06°13'86" - 106°03'61"	Cacao	7, 8
Ciamis, West Java	27	07°29'06" - 108°35'53"	Cacao	5, 10
Bandung, West Java	1375	07°07'80" - 107°30'48"	Tea	8, 2
Batang, Central Java	113	06°56'76" - 109°48'31"	Cacao	2, 8
Kulonprogo, Yogyakarta	575	07°40'48" - 110°08'36"	Cacao	8, 6
Gunung Kidul, Yogyakarta	478	07°54'62" - 110°45'20"	Cacao	12, 2
Trenggalek, East Java	360	08°12'40" - 111°39'15"	Cacao	10, 3
Lumajang, East Java	6	08°16'12" - 113°03'92"	Cacao	15, 12
Banyuwangi, East Java	200	08°31'26" - 114°03'52"	Cacao	1, 2
Tuban, East Java	58	06°49'67" - 111°48'05"	Cashew	1, 3
Mojokerto, East Java	128	07°34'15" - 112°31'95"	Cashew	4, 5

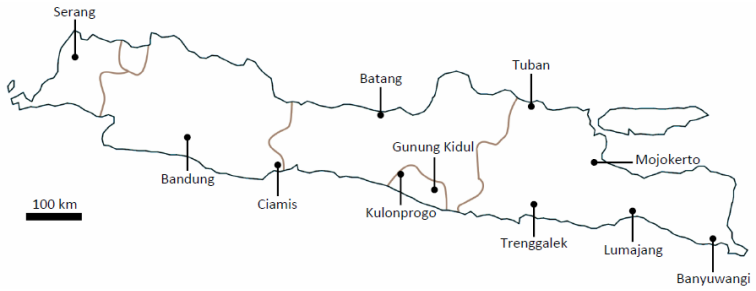

Figure 1. *Helopeltis* collection sites in Java Island.

aluminium stubs with adhesive tape, and then sputter coated with gold using a Balzer Union SCD040.

Results

The samples from different region in Java (Fig. 1, Table 1) shown the similarity in external morphological and genitals characters, therefore in this section there is only a single description for both sexes of these Javanese *Helopeltis* that depict a single species as discussed and concluded in the discussion section.

Abbreviations and measurement

The abbreviations used in the results and discussion sections are as follow: antennal segment one to four: AnI, AnII, AnIII, AnIV; labial segment one to four, LbI, LbII, LbIII, LbIV; abdominal segment I to IX, AbI, AbII, AbIII, AbIV, AbV, AbVI, AbVII, AbVIII, AbIX; F, female; M, male; Md, mandibular plate; Mx, maxillary plate; Fw, forewing; Hw, Hindwing; Ss, scutellar spine; Gc, genital chamber; Ls, lobal sclerite of aedeagus; Lp, left paramere; Rp, right paramere. Body length is measured in mm.

Female of *Helopeltis bradyi*

Surface. Body smooth (Fig. 2), covers with setae of various lengths. *Head* (Fig. 3A-C). Ecdysial groove is apparent; Mx rugose; a distinct, long seta is under the eyes, near Md; more setae found on frons (shorter) and clypeus (longer). *Labrum and labium* (Fig. 2, 3C). Labrum cloths with short abundant setae; labium covers by long, scarce sub erect setae. *Antennae* (Fig. 4A-D). Antennae cover with simple suberect setae, groups of very short and fine setae cover antennal pores, adpressed setae at distal end. *Thorax* (Fig. 3A, 3D-F). Pronotum and scutellum without punctures. Mid part of scutellum ascends to form the base of Ss. The shaft of Ss covers by sutures that circle it; the round tip rugose. Simple, very short, rare setae cover the pronotum, scutellum, and Ss; setae more abundant on the round tip of Ss, groups of fine setae cover the pores on Ss' shaft and round tip. Ventrally, coxae and mesepisternum cloth with setae, more abundant on mesepisternum. *Wings* (Fig. 4E). Fw and Hw semitransparent, corium with shallow costal fracture. Fw covers by very short suberect setae,

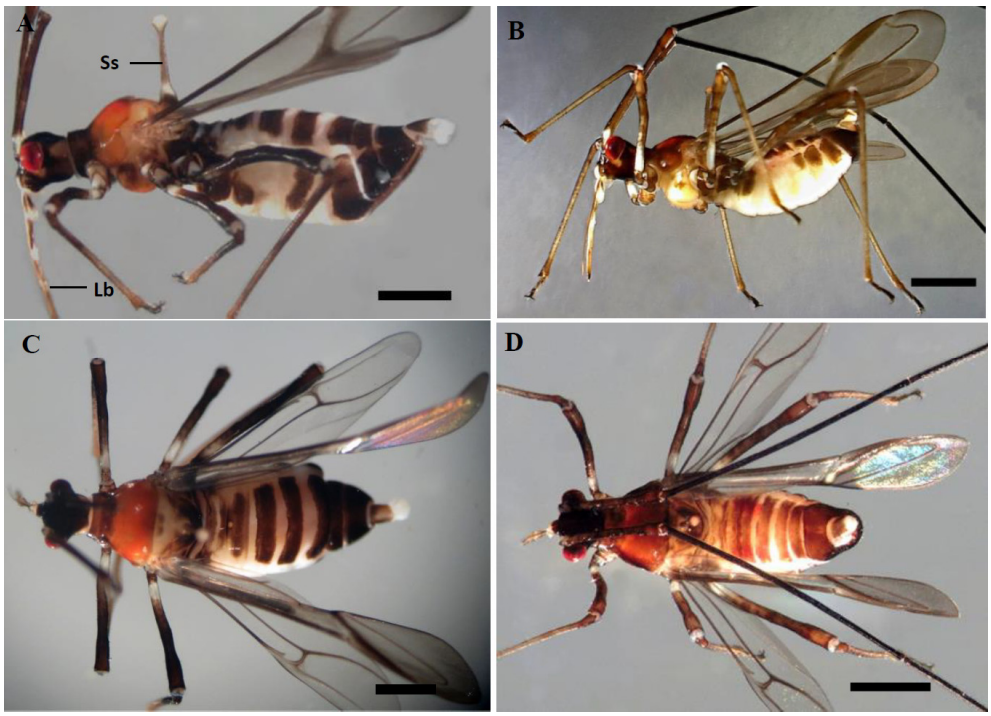

Figure 2. Lateral and dorsal habitus of female (A, C) and male (B, D) *Helopeltis bradyi*. Lb = labium, Ss = scutellar spine. As the study found that all specimens were *H. bradyi*, this name is linked to the features illustrated in this and subsequent Figures. Bars = 1 mm.

more abundant on the membranous than leathery part; setae on Hw more or less equally spread and less abundant than those on Fw membrane. *Legs* (Fig. 4F-G). Femora nodulous, arch ventrally; cover with short, abundant sub erect setae dorsally and very scarce and long trichobothria ventrally. Tibiae, tarsi, and pretarsi arm with long setae; the setae became longer on the distal part of tibia down to the pretarsus. Tarsi and pretarsi cloth with fine setae that adhere to the surface; dorsal surface of parempodia and claw grooved. *Abdomen* (Fig. 3G-H). Ab I-VI smooth, Ab VII-IX cover with setae especially on its mid-ventral side up to anal tube.

Coloration. Dark brown to fuscous with colourful pronotum. *Head* (Fig. 3A-C). Dark brown to fuscous; posterior part lighter than anterior part. Three spots found laterally; a white one ventrad the eyes, a light brown one near the collar, and sometimes a brown spot just below the previous. Tip of clypeus and buccula white; upper part of clypeus, the rest of buccula, Mx, Md, and gula are dark brown to fuscous. Eyes pinkish red or brownish red. *Antennae* (Fig. 2, 3B-C). Brown to fuscous; the base of AI pale, the rest light brown; AII-AIV darker than AI. *Labrum and labium* (Fig. 2A-B). Labrum pale, labium light brown. Basal and distal parts of LbI, distal part of LbII, and base of LbIII pale. Anterior part of LbI and distal part of LbIV dark brown to fuscous. *Collar and pronotum* (Fig. 2, 3A) Collar and pronotum patternless; between yellow, yellow-orange, reddish orange, reddish brown, and dark brown to fuscous; sometimes light fuscous tinge is found at the anterior edge of collar and posterior edge of pronotum. *Mesoscutum, scutellum, and scutellar spine* (Fig. 2, 3D). Mesoscutum pale to light brown. Scutellum dark brown to fuscous. Base of Ss pale, the shaft light brown, and the round tip pale to light brown. *Pleura and sterna* (Fig. 3E-F). Propleuron colour similar to pronotum; mesopleuron dark brown to fuscous; mesepisternum, mesepimeron, and ostiolar peritreme dark brown to fuscous. Mesosternum light brown, pro- and metasternum dark brown to fuscous; a white spot is found on the middle of metasternum, caused by the rubbing of labial tip. *Wings* (Fig. 4E). Fw and Hw semitransparent with light brown to fuscous venations.

Figure 3. Main body parts of *Helopeltis bradyi*. Dorsal view of head and pronotum (A), lateral and frontal view of head (B, C); thorax (D-F); dorsal and lateral view of female (G-H) and male abdomen (I-J). Bu = buccula, Cl = clypeus, Co = collar, Cx = coxa, Gu = gula, Lb = labium, Lr = labrum, Mc = mesoscutum, Md = mandibular plate, Me1 = mesepimeron, Me2 = mesosternum, Mt1 = mesepisternum, Mt2 = metasternum, Mx = maxillary plate, Og = orifice of lateral glands, Pn = pronotum, Pt = peritreme, Sc = scutellum, Sr = spiracle, Ss = scutellar spine. Bar on abdominal pictures = 500 µm. Roman numeric indicated the number of segment.

Legs (Fig. 2, 4F, G). Base of each femur covers with a pale band, the rest of the femur light brown or dark brown to fuscous; lighter coloured femora show dark brown spots scattered on them; tibiae lighter than femora, with basal part darker than distal. Tarsus dark brown basally, fuscous distally. Foreleg lighter in coloration than mid or hind legs. *Abdomen* (Fig. 3G-H). Dorsal side of each segment marks by a fuscous band; the last four segments fully covered by the band, the bands on AbV anteriorly to AbIII gradually shortened and slightly less fuscous. A small pale dot, the point where the scent gland was located during the nymphal stage presents at the anterior end of AbIV. Posterior edge of AbI and anterior edge of AbII with a thin band; together the bands form two triangle-like patches to both lateral side and a fusiform patch medially. Each latero-abdominal segments mark with a fuscous patch, sometimes only AbV pale, AbVIII-IX fully fuscous, AbVII is pale on the point

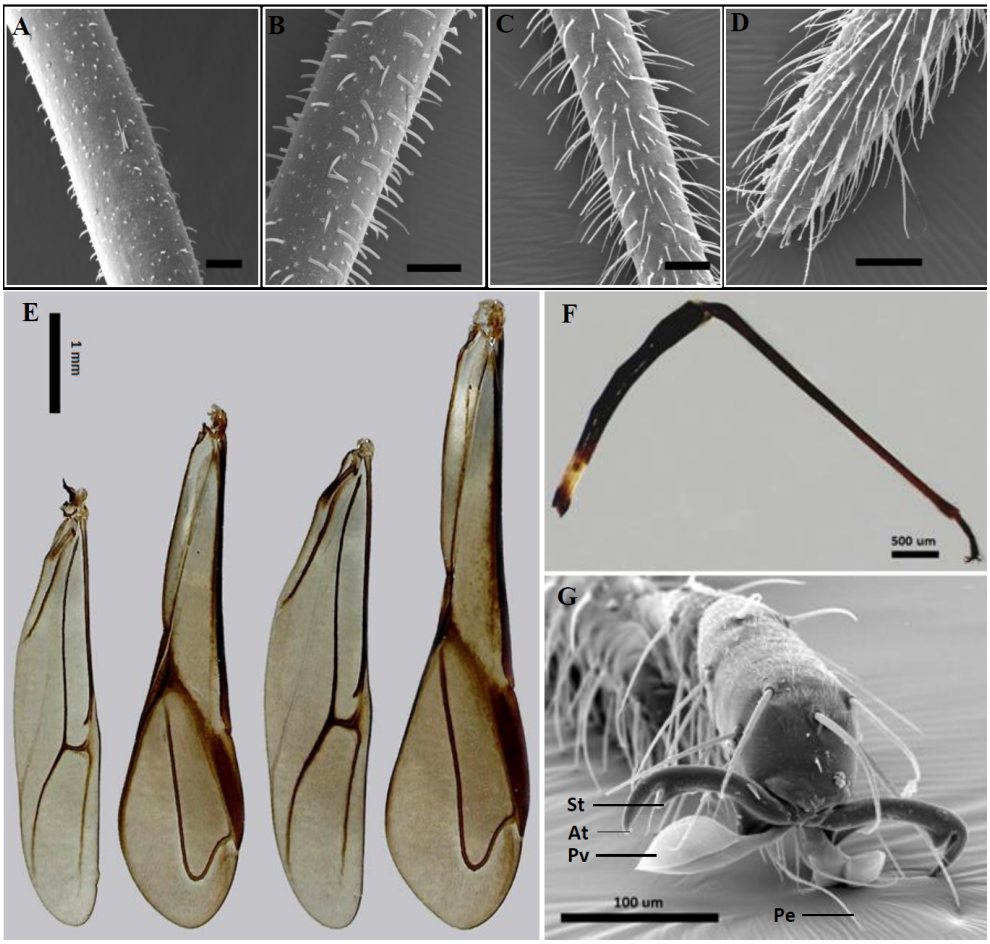

Figure 4. The appendages of *Helopeltis bradyi*. SEM of male antennal segment I-IV (A-D); the pair of right wings of male (left) and female (right) (E); hindleg of female (F); and pretarsal of female (G). At = apical tooth, St = sub apical tooth, Pe = parempodium, Pv = pseudopulvillus. Bar on antennal pictures = 50 µm.

where Gc is found, AbV has the shortest and thinnest patch. Base of abdomen pale.

Size and structure. Body length 4.2-4.9× pronotum width. *Head* (Fig. 3A-C). Head triangular frontally, square laterally, rather swollen dorsally, and more or less flat ventrally. Eyes slightly protruding, but not stalked, oval in shape with unapparent curve at the lower latero-posterior side. Frons more or less flat from lateral view, slightly swollen dorsally. Vertex 3× as wide as eyes; distance between antennal fossa 1.3× eye diameter; distance from eye to collar 0.5-0.6× eye diameter dorsally; longitudinal depression dorsally as long as or slightly longer than eye diameter; transverse depression indistinct; clypeus swollen, its base is more or less levelled with antennal fossae base; buccula shorter than the distance between buccula and collar (0.8×). *Antennae* (Fig. 2, 3B-C, 4A-D). AI shorter than AII and AIII, but longer than AIV (Table 3); AIV is the shortest. AI thicker than the rest, its distal end swollen; 2.08-2.23× head width + eyes and 1.47-1.7× pronotum width. AII 3.17-3.23× head width + eyes and 2.24-2.47× pronotum width. Antennal setae lengthened gradually from basal to distal part. AI setae very short, AII setae about half AII diameter. By the distal part of AIII, setae length equal to AIII diameter, but on AIV is longer. *Labrum and labium* (Fig. 2, 3C). Labrum shorter than LI. Labium extended to the middle of metasternum; LIV > LII >LIII > LI; LI more or less equal to the distance between buccula and collar. *Collar and pronotum* (Fig. 4A-B). Collar flat; calli

Table 3. Measurement (mm) of body parts of *Helopeltis* (n = 22).

Body part	Male			Female		
	Mean	Range	SE	Mean	Range	SE
Body length	6.2	5.7 – 6.6	0.13	7.9	7.2 – 8.4	0.17
First antennal segment	2.6	2.5 – 2.7	0.03	2.7	2.5 – 2.9	0.08
Second antennal segment	4.2	3.8 – 4.8	0.12	4.1	3.8 – 4.2	0.06
Head width + eyes	1.2	1.1 – 1.2	0.02	1.2	1.2 – 1.3	0.02
Collar width (dorsally)	0.7	0.6 – 0.7	0.02	0.8	0.7 – 0.8	0.02
Collar + pronotum length	1.0	0.9 – 1.2	0.04	1.2	1.1 – 1.2	0.02
Pronotum (posterior width)	1.4	1.4 – 1.5	0.02	1.7	1.7 – 1.7	0.00
Right forewing	5.1	4.9 – 5.2	0.07	6.2	6.0 – 6.5	0.03
Right hindwing	4.1	3.9 – 4.2	0.06	5.0	4.7 – 5.2	0.03
Fore femur	1.9	1.6 – 2.1	0.07	2.0	1.9 – 2.0	0.02
Fore tibia	2.6	2.5 – 2.7	0.03	2.8	2.6 – 2.9	0.04
Hind femur	2.5	2.5 – 2.7	0.03	2.6	2.6 – 2.7	0.02
Hind tibia	3.3	3.2 – 3.4	0.03	3.5	3.5 – 3.7	0.03
Ratio 1st antenna/posterior width of pronotum	1.8	1.7 – 1.9	0.04	1.6	1.5 – 1.7	0.04

unapparent; posterior width of pronotum to collar width 1.42×. *Scutellum and scutellar spine* (Fig. 2, 3D). Scutellum 'U' shaped, anterior part 2.5× posterior part; the posterior bends upright. Ss more or less straight; the length of the shaft 4× the diameter of the round tip. *Pleura and sterna* (Fig. 3E-F). Peritreme lays on anterior region of metepisternum. Mesosternum 1.5× width and 2× length metasternum. *Wings* (Fig. 4E). Leathery part of Fw 1.2× length of membranous part; average Fw length 1.24× Hw. *Legs* (Fig. 2, 4F-G). Fore femora on average 0.77× fore tibia; hind femora to hind tibia is 0.8×. First segment of tarsi is the longest, about 2× segment II. Claw arms with apical and subapical tooth. *Abdomen* (Fig. 3G-H). Narrow anteriorly, wide medially, pointed distally; the widest is AbVII. Terga II-VIII equip with seven abdominal spiracles.

Genitalia (Fig. 5A-D). Gc surrounds by two sclerotized rings that fused posteriorly. Medially, a medial sclerite separates the chamber into more or less equal parts; the medial sclerite is heavily twisted, extends from the posterior end of Gc anteriorly, splits into two ridges, and form a 'Y' shaped junction with the anterior lobe. Anterior lobe heavily twisted, arches laterally toward sclerotized rings. Two transfer sclerites arch parallel to anterior lobe. To the left and right of medial sclerite arch parallel ribs, distally fused with lateral oviduct.

Male of *Helopeltis bradyi*

Surface. As in female.

Coloration. Similar to females, often darker (Fig. 2). Collar and pronotum dark brown to fuscous. Laterally, fuscous patch present on AbI-III and AbVI-VIII; AbIV-V pale (Fig. 3I, J).

Size and structure. Similar to female, smaller on average (Table 3). Body length 4.1-4.4× pronotum width; vertex 3.4× as wide as eyes. Distance between antennal fossa 1.4× eye diameter; distance from eye to collar 0.79× eye diameter dorsally. Buccula 0.53× shorter than the distance between buccula and collar. *Thorax*. Collar + pronotum length 0.82-1.0× as long as the width of head including the eyes, 0.64-0.8x pronotum width. *Antennae*. AII equal to or slightly longer than in females. AI 2.25-2.27× head width + eyes, 1.78-1.80× pronotum width; AII 3.45-4.0× head width including eyes, 2.71-3.20× pronotum width. *Abdomen* (Fig. 3I, J). Dorsally, abdomen flat medially and pointed distally; laterally it swollen medially.

Genitalia (Fig. 5E-J). Aedeagus pear-shaped. Rp and Lp asymmetrical; Rp very small, Lp large with a pointed hook (Lp is 3× length of Rp). Ls knife-shaped; two thirds of the lower part arch laterally to form the blade; one third of anterior part is curved to resemble a knife holder; curve part 0.4-0.5× blade length. Apex of Ls is covered with short setae.

Discussion

This new morphological study provides the most detailed examination to date of the most common *Helopeltis* species occurring in Java. In this discussion we will use this information to demonstrate that this species is *H. bradyi* and not *H. antonii* as used to be reported locally, or the other three spe-

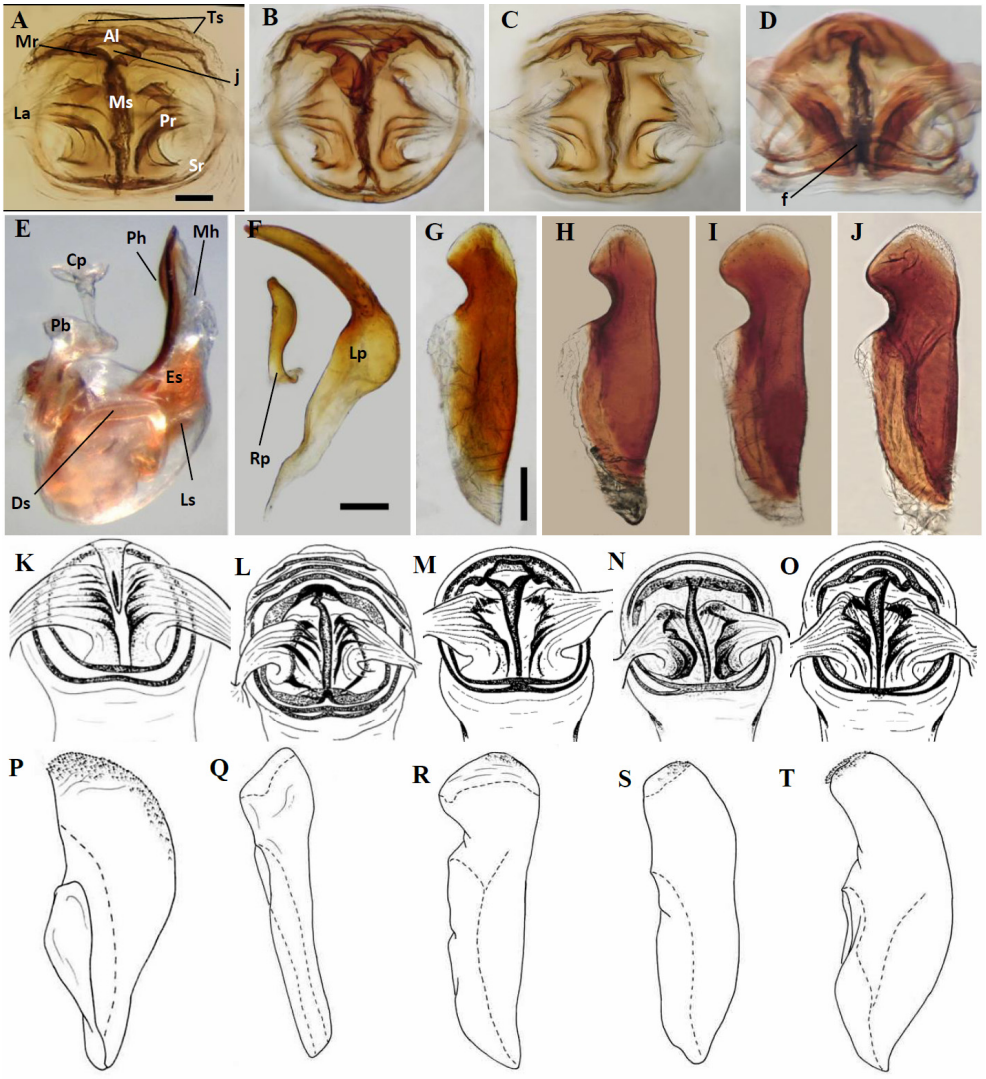

Figure 5. Variations of Javanese *Helopeltis* genital chamber; female genital chamber (A-D) characterized by 'Y' junction (j) and fused posterior of sclerotized rings (f); male aedeagus (E), parameres (F), and lobal sclerites (G-J); the sketches of female genital chambers of *H. antonii* (K) and the four *H. bradyi* of Sabah (L), Java (M, N), and South India (O); and the sketches of male lobal sclerites of *H. antonii* (P) and the four *H. bradyi* of Sabah (Q), Java (R, S), Sri Lanka (T). Al = anterior lobe, Cp = capitate process, Ds = ductus seminis, Es = eversible sac of endosoma, La = lateral oviduct, Lp = left paramere, Ls = lobal sclerite, Mh = membranous sheath, Mr = medial ridge, Ms = medial sclerite, Pb = phallobase, Ph = phallotecha, Rp = right paramere, Sr = sclerotized rings, Ts = transverse sclerite. Bar = 100 µm. All sketches were after Stonedahl (1991) with the permission from Cambridge University Press.

cies recorded in Java viz. *H. theivora* (Waterhouse, 1886); *H. cinchonae* (Mann 1907); and *H. cuneata* (Distant 1903) or *H. elegans* (Poppius 1914), which was found in a small island close to Central Java called Nusa Kambangan in 1911 and synonymized to *H. cuneata* (Stonedahl 1991). This finding therefore supports Stonedahl's (1991) view that reports of *H. antonii* in Indonesia, particularly in a Javanese context, actually refer to *H. bradyi*. Thus *H. antonii* appears to be confined to India, the Andaman Islands (Stonedahl 1991, Srikumar et al. 2013), and Sri Lanka (Stonedahl 1991, Basnagala et al. 2002).

Javanese *H. bradyi*, described *H. bradyi*, and *H. antonii*

The coloration on the head of Javanese *Helopeltis* showed some characteristics that are common to *H. antonii* and *H. bradyi* (Stonedahl 1991). The pale spots anterior to the eyes and near the collar, the pale base of segment I of the antennae, and the patternless collar and pronotum that could be of yellow-orange, reddish brown, or dark brown colours were also indicative of both species. While the pattern on the head was similar to the Stonedahl (1991) description, the colour of the head matched the picture of *H. bradyi* when compared to pictures of *H. bradyi* and *H. antonii* taken in India, all sent to us by courtesy of K.B. Rebijith of IIHR, Bangalore. In these pictures, the head of *H. antonii* is bi-coloured; the half from the top to mid lateral is dark brown to fuscous and the other half down to the gula reddish brown. The spot ventrad eyes of *H. antonii* were smaller than that of *H. bradyi*. The pronotum monotone, which in our study ranged from reddish brown to fuscous, was similar to the Indian *H. antonii* and *H. bradyi* and to those found in other studies (Srikumar & Bhat 2012, Srikumar et al. 2013).

One of the key external morphological characters of *H. bradyi* that differs from *H. antonii* is the presence of a pale band at the base of each fore-, middle, and hind femora of *H. bradyi*; *H. antonii* only has this band on its fore- and middle femora (Stonedahl 1991). This band was found at the base of the hind femur of the Javanese *Helopeltis* samples in this study as well as being in the picture of *H. bradyi* sent by Rebijith, and reported in both Srikumar & Bhat (2012) and Srikumar et al. (2013). In these two last studies, the band on the *H. antonii* femora was observed at the base of the fore and mid femora and just below the clubbed distal end of the hind femur (see Srikumar et al. 2013). By carefully comparing the descriptions of Stonedahl (1991) and the pictures in Srikumar & Bhat (2012), Srikumar et al. (2013) and Rebijiths', it can be seen that the femora of Indian *H. antonii* are lighter in coloration than those of the Indian *H. bradyi* and our Javanese *Helopeltis*. The fore and mid femora of *H. antonii*'s are pale at the base and light brown with brown mottles in the middle. The base of hind femur is darker than its middle part, and that of fore and mid femora. The pale middle part of hind femur is then regarded as the pale band on hind femur in contrast to the darker base and the brown fuscous distal end (Stonedahl 1991; see also Srikumar et al 2013). The coloration of the legs of the Indian *H. bradyi* and our Javanese *Helopeltis* were more or less homogenous dark brown to fuscous. The legs of the teneral adults of Javanese *Helopeltis* were lighter than that of matured adults, their mottled legs turning a uniform dark brown to fuscous as they aged. There is no information about changes in colour of *H. antonii* with maturity in the literature.

Stonedahl (1991) noted that the colour pattern on the lateral side of abdominal sterna of *H. antonii* was similar to that of *H. bradyi*. On both sexes of both species, a fuscous patch was found on sterna I-III. In the Javanese samples, except for the last three genital segments (VII-IX), all lateral segments of mature female adults were marked with a fuscous patch including segment VI, or on all but segment V. The patch was confined to the first three segments in the teneral female adults. It is important to note that a long and obvious patch was found on segment VI of all studied Javanese *Helopeltis*. Stonedahl (1991) wrote that both *H. antonii* male and female adults have a fuscous patch on sterna I-III of their abdomen, but in his key indicated the possibility of the patch to extend to segment IV and V. On the male Javanese *Helopeltis* beside on the genital capsule (segment IX), a fuscous patch was observed on segments I-III and segments VI-VIII; segments IV and V were pale.

In previously published studies on *H. bradyi* and *H. antonii*, only two structures, body and antennal length could be compared directly to those of our samples. The body length of male Javanese samples (5.7–6.6) fell within the range previously found for *H. bradyi* (5.5–6.9) but slightly smaller than the range of *H. antonii* (5.9–6.9); female body length was 7.2–8.4 which was also within the range previously found for *H. bradyi* (6.6-8.6), but longer than that for *H. antonii* (7.2-8.0) (Stonedahl 1991; Ambika & Abraham 1979). Like *H. bradyi* as previously reported, the Javanese samples differed from *H. antonii* by their longer first antennal segment. This segment was also longer than the posterior width of the pronotum, with the ratio for males and females being 1.7–1.9 : 1 and 1.5–1.7 : 1, respectively, compared to 1.5–1.85 : 1 and 1.45–1.6 : 1 for *H. bradyi* and 1.20–1.45 : 1 and 1.05–1.30 : 1 for *H. antonii* (Stonedahl 1991).

The genital chamber of female Javanese *Helopeltis* was distinct to one illustrated previously for *H. antonii* by Stonedahl (1991) who described that of *H. antonii* as having unfused sclerotized rings (Fig. 5K). The medial sclerite of *H. antonii* genital chamber was straight, very short and

small, anteriorly fused with undeveloped anterior lobe, while posteriorly it did not reach the sclerotize ring of the chamber. Behind the undeveloped anterior lobe no transverse sclerite(s) was found. Stonedahl (1991) showed four types of *H. bradyi* genital chamber (Fig. 5L-O), including two (Fig. 5M, N) from Java which had a rigid medial sclerite expanding from the fused posterior ring anteriorly. Just before reaching anterior lobe, it divided into two ridges to form a 'Y' shaped junction between the medial sclerite and the lobe (Fig. 5M), but sometimes not (Fig. 5N). The anterior lobe was well developed, with one transverse sclerite immediately behind it. In the current Javanese samples, all chambers possessed this 'Y' shaped junction, but with two transverse sclerites directly behind the lobe (Fig. 5A-D). These represented only one type of genital chamber, and were similar to *H. bradyi* in Fig. 5M.

The male lobal sclerite of Javanese *Helopeltis* also resembled that previously described for *H. bradyi* by Stonedahl (1991) using samples from Java. One type was knife-shaped and the other rather straight from base to apex; both possessed limited setae on the apex. For *H. antonii* he described the lobal sclerite as being 'D' shaped, wider anteriorly with a straight pointed tip posteriorly, and with abundant setae from the apex and covering almost half of the lobed side of the sclerite (Fig. 5P). The current Javanese samples best resembled those of *H. bradyi* in Fig. 5R, knife-shaped with limited apex setae, but with slight variations, especially in the shape of the knife handle and the width of the sclerite (Fig. 5G-J).

The above demonstrates that evidence from external characters, white bands on all femora, body length, and the ratio of the first antennal segment to the posterior width of the pronotum, point to the Javanese *Helopeltis* being *H. bradyi* as described by Stonedahl (1991). This is similarly the case for genital structure; none of the female genital chambers and male lobal sclerites of Javanese *Helopeltis* resembled that of *H. antonii*, but they were similar to one described as *H. bradyi*.

Genital morphology has been the more reliable character for species determination (Schmitz 1968, Stonedahl 1991, Stonedahl et al. 1995). However, unlike *H. antonii*, the female genital chamber and male lobal sclerite of *H. bradyi* from different locations is highly variable (Stonedahl 1991). A comparison between four types of *H. bradyi* female genital chambers (Fig. 5L-O) and Rebijith's picture of Indian *H. bradyi*, show that the differences are in the anterior shape of the chamber. The common feature is the fused posterior of sclerotized rings; Stonedahl (1991) acknowledged this as a species character of *H. bradyi*. The male lobal sclerite of *H. bradyi* also differs within the species: for example, the one from Sabah has no setae and is narrow (Fig. 5Q); the one from Sri Lanka has setae on the apex and is bent dorsally (Fig. 5T). Stonedahl (1991) indicated the possibility that the four variants may represent different species, however, the remarkable similarity of their external features led to their description as four variants of *H. bradyi*.

Javanese *H. bradyi* vs. other *Helopeltis* species recorded from Java

Morphological and genitals differences between Javanese samples, which are similar to and proven as *H. bradyi,* with the other three species found in Java are clearer than the uncertainty between *H. bradyi* and *H. antonii*. Historically, no reports related to the ambiguity of the external morphological characters between *H. bradyi* and *H. theivora*, *H. cinchonae*, or *H. cuneata*, had been published, while the latest study on their genitals anatomy (Stonedahl 1991) have shown a very big distinction among them.

The size of *H. theivora*, *H. cinchonae*, and *H. cuneata* is variable, with the males smaller than the females like other *Helopeltis* species. The size of *H. cinchonae* (male, 5.3-6.6; female, 6.6-8.9) is around those of Javanese *H. bradyi* (male ; female: 5.7-6.6; 7.2-8.4) or *H. bradyi* (male ; female: 5.5-6.9; 6.6-8.6) as described in Stonedahl (1991). The male *H. theivora* is as big as *H. bradyi* (5.7-6.6), but the female is rather smaller (6.4-7.6 to 7.2-8.4); while *H. cuneata* (female, 5.9-6.4) is significantly smaller than the other mentions species (Stonedahl 1991).

Helopeltis theivora is generally brown to dark brown in coloration (Stonedahl 1991). Unlike the mono-coloured pronotum of Javanese *H. bradyi*, the pronotum of *H. theivora* is usually bi-coloured with at least the posterior part dark brown to fuscous, while the mid and sometimes anterior parts green, yellow, orange, brown, or the combination of these colours (Roy et al. 2009, Sarmah & Bandyopadhyay 2009). The head is dorsally brown to fuscous like in Javanese *H. bradyi*; laterally it does not have the pale spots, but characterized by the wide pale band that extended from below the eyes posteriorly to the anterior part of collar (Stonedahl 1991). The abdominal sterna I-III is also pale, not marked with dark patch (Stonedahl 1991). No pale band is found on the basal of the

femora; both the femora and tibia are brown and covered with darker specks (Waterhouse 1886). The male Ls is asymmetrical 'D' shaped, with a smaller, pointed, and twisted posterior part, and a broader anterior part and pointed apex; the female Gc is rather similar to *H. antonii*'s, but differ only in the medial sclerite which is bigger and extended from the base of Gc more than halfway anteriorly, and the membrane that extended from the anterior part to the base of the chamber (see Stonedahl 1991).

The general coloration of *H. cinchonae* is dark brown; the head is fuscous with pale spot near collar and narrow pale spot at the dorsal margin of eye; the pronotum is mono-coloured, sometimes bi-coloured, with the anterior part darker than the posterior (Stonedahl 1991). The cuneus is red (Poppius 1915, see Plate II in Miller 1941), while that of Javanese *H. bradyi* is brown. The Javanese *H. bradyi* has a longer AI, which is around 2× the width of the head + eyes, the AI of *H. cinchonae* is profoundly short, only as long as or slightly longer than the width of the head + eyes (Stonedahl 1991), and stouter than the other mentioned species (see Plate II in Miller 1941). The male aedeagus has no Ls; the female Gc is simple; without medial sclerite, parallel ribs, or anterior lobe, only covered with a membrane that laterally connected to the lateral oviduct (see Stonedahl 1991).

Helopeltis cuneata is very distinct from Javanese *H. bradyi* by the generally yellow red (Poppius 1914) or pale brownish yellow colour (Stonedahl 1991). The fuscous parts are only the AIII-IV, scutellum, apical angle of corium, and the last two abdominal segments (Stonedahl 1991). If the Javanese *H. bradyi*'s legs are dark brown with darker mottles and an obvious pale band on each femur, the legs of *H. cuneate* are yellow (Distant 1903, Poppius 1914), or pale brownish yellow with vague fuscous mottles on femora (Distant 1903, Stonedahl 1991). The Ls of aedeagus is club-shaped, blunt on both ends, two third of the posterior part is gradually widened, while the one third anterior part is abruptly enlarged with the setae restricted to the apex; female Gc is with an inverted 'U' shaped, slightly twisted medial sclerite that extended from posterior to the anterior part of the chamber, while anterior lobe is absent (see Stonedahl 1991).

The evidences of external morphology and genital anatomy have verified that the Javanese *Helopeltis* is not belong to *H. theivora*, *H. cinchonae*, and *H. cuneata* that are also recorded from Java, nor does it fit the characters of *H. antonii* as used to be reported. The subtle external morphological differences between *H. bradyi* and *H. antonii*, and among the variants of *H. bradyi* itself have made these species very difficult to differenciate. Based on our study of the Javanese samples, we furthermore suspect that some variants of *H. bradyi* and one of the described *H. bradyi* from Java that are all have different genital structures are a cryptic species that externally similar to *H. bradyi* but actually are different from this species. We strongly suggest the need for molecular studies to further delimit *Helopeltis* species. This would further test Stonedahls' hypothesis of the existence of more than one species within oriental *H. bradyi*, and perhaps others previously described as *Helopeltis*.

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