

A new tropiduchid planthopper genus and species from China with descriptions of *in copula* genitalic structures (Hemiptera: Fulgoromorpha)

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Abstract. The new planthopper taxon, *Garummella bella* **gen.n., sp.n.**, from Xizang, China, is described and illustrated, including external morphology of adult and eggs and structures of the male and female genitalia. The new genus is compared with *Garumna* Melichar and *Paragarumna* Muir, resulting in *Paragarumna* (**syn.n.**) being placed as a junior synonym of *Garumna*, with two new combinations, i.e. *Garumna pseudolepida* (Muir) **comb.n.** and *Garumna melichari* Baker **comb.rev.** New locality records for *Garumna* species are given. The morphology of the genitalia and egg of a copulating pair of the new genus is investigated. The female has a ventrally sclerotized posterior vagina forming a torsion groove, an unusual long membranous anterior vagina and an enlarged common oviduct. During copulation both the aedeagus and the torsion groove appear tightly interlocked, which may help to maintain the copulatory position. The aedeagus is observed in the bursa copulatrix.

Introduction

Tropiduchidae (Hemiptera, Fulgoromorpha) is one of 21 planthopper families with approximately 350 species in 120 genera (Wilson & Malenovsky, 2007), found in all temperate and tropical areas of the world. Although variability of the male genitalia in the Fulgoromorpha is well documented, little information is available on the female genitalia or concerning the functionality of both sets of genitalia during copulation. With respect to the latter, the importance of functional morphology as a means of understanding the homologies of the genital structures and for phylogenetic interpretation of the observed differences has been noted, while those differences themselves may promote isolation of sympatric and synchronic species (Bourgoin & Huang, 1991). Similarly, although egg morphology is important to taxonomy and phylogeny in Hemiptera and insects in general (Cobben, 1965; Hinton, 1981), the eggs of Fulgor-

omorpha are known for relatively few species (see species description and discussion).

While sorting and identifying Chinese Tropiduchidae from material in the Institute of Zoology, Chinese Academy of Sciences, Beijing, a pair of specimens from China was found to represent a new genus and species similar to *Garumna* Melichar (from Sulawesi) and *Paragarumna* Muir (from southeast Thailand and Peninsula Malaysia). Furthermore, the specimens remained in copulation, offering a rare opportunity to examine the functional morphology of their genitalia.

Materials and methods

Dry pinned specimens were used for the descriptions and illustrations. External morphology was observed under a stereoscopic microscope and characters were measured with an ocular micrometer. For functional morphology, abdomina were removed from a copulating pair and placed still joined into 10% KOH overnight. After being transferred to distilled water, the genitalia were stained by

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methylrosanilinium chloride (a clinical solution, comprising methyl violet, ethanol and purified water) to highlight the internal thin and transparent membranous parts. Precise dissections and cleaning of genitalic structures were finished in distilled water. Observations and drawings were made in glycerine under a compound microscope. Photographs of the types were taken with a Nikon Coolpix 5400 digital camera. The digital images were then imported into Adobe Photoshop 8.0 for labelling and plate composition. Line figures were drawn with the aid of a camera lucida mounted on a Zeiss Stemi SV-11 stereomicroscope.

Specimens examined during the course of this study are deposited in the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (IZCAS), The Natural History Museum, London, U.K. (BMNH) and the Moravian Museum, Brno, Czech Republic (MMBC).

Morphology and terminology

The following structures of the male and female genitalia are apparent in Tropicuchidae. The terminology in this and following sections follows Bourgoïn & Huang (1990), Bourgoïn (1993) and Liang (2003).

Male

The male external genitalia (Fig. 3A, B) comprise the periandrium, aedeagus sensu stricto and gonostyli. With the internal corpus connectivi, they comprise a perfect set of articulated coupling structures, that together with the anal tube, are membranously attached to the body wall enabling their independent movement.

The corpus connectivi connects with the aedeagus dorsally and gonostyli ventrally. The endosoma is a membranous structure, which is situated at the apex of aedeagus (Fig. 3D). The periandrium is a strongly sclerotized tube, dorsally connected to the ventrobasal margin of the anal tube and ventrally connected to the gonostyli, with which they are connected. The periandrium surrounds the aedeagus in its basal part, providing stability and protection.

Female

Gonapophyses VIII (first valvulae) (Fig. 5B) are strongly sclerotized, whereas the endogonocoxal processes (Fig. 5B) remain semi-sclerotized, blade-like laminae, bearing several tiny apical teeth. The gonapophyses VIII perhaps have the function of protecting the endogonocoxal processes, whereas the latter probably assist the former in laying eggs into plant tissues.

In repose, the gonoplacs (third valvulae) (Fig. 5C) clasp the gonapophyses VIII with apical teeth, enabling them to hinge tightly together.

Gonopophyses IX (second valvulae) (Fig. 5B, C) are triangular, well-sclerotized sclerites. Along their anterobasal

margin they membranously fuse with the posterior vagina (Figs 4D, 5C), closing the latter posteriorly. They are connected to the gonoplacs (third valvulae) dorsally and articulate with the gonopophyses VIII ventrally via anterior and posterior fibula (Fig. 5B) interlocked on each side.

Taxonomy

Garummella gen.n.

Type species. Garummella bella sp.n.

Colour. Head and thorax yellow to dark brown; fore wings hyaline marked with brown in clavus and across wing sub-basally and on nodal line.

Head and thorax. Head (Figs 1C, 2A) slightly projecting before eyes; apex broadly convex in dorsal view, evenly and broadly rounded to base of frons; vertex and frons not separated, lateral carinae continuous. Frons (Figs 1D, 2C) without median carina, slightly longer in midline than greatest width, medial swollen area narrowing to frontoclypeal suture; lateral areas flat to lateral carinae, the latter attaining frontoclypeal suture; lateral margins distinctly convex adjacent clypeus; frontoclypeal suture slightly concave. Clypeus (Figs 1D, 2C) with distinct median ridge, uniting with median swollen area of frons. Rostrum long, reaching between hind coxae, apical segment distinctly longer than broad. Eyes oval. Ocelli distinct. Antennae (Figs 1D, 2B, C) with scape short, ring-like; pedicel globular, covered with many microsetae extending to base of pedicel. Vertex (Figs 1C, 2A) distinctly narrower than pronotum, more than twice as broad at base than length at midline and slightly shorter than pronotum at midline; lateral margins ridged and gently convex; posterior margin deeply concave; anterior part of vertex smoothly swollen, uniting with base of frons to form rounded surface; posterior part of vertex distinctly depressed, lateral margins of depression incurving anteriorly and meeting medially to form nearly semicircular arc; without median carina.

Pronotum (Figs 1C, 2A) shorter than half of length of mesonotum in midline; median carina ridged, lateral carinae converging anteriorly; disc arched anteriorly, deeply depressed between median and lateral carinae, with impression on each side; posterior margin obtuse-angled excavated. Mesonotum (Figs 1C, 2A) tricarinate, median carina straight, reaching to transverse suture, uniting with lateral carinae; lateral carinae curving anteriorly forming finely rounded parabola; pronotum and mesonotum together medially about four times as long as median length of vertex. Fore wings (Figs 1A, B, 2D) subhyaline, short, only slightly surpassing extremity of abdomen, 2.2 times as long as maximum breadth; corium without granulation, costal cell without cross veins; Sc + R forking before the nodal line; M forking at the nodal line; Cu forking after level of junction of claval veins, at middle of clavus; nodal line oblique, subapical line near apex; with five subapical and

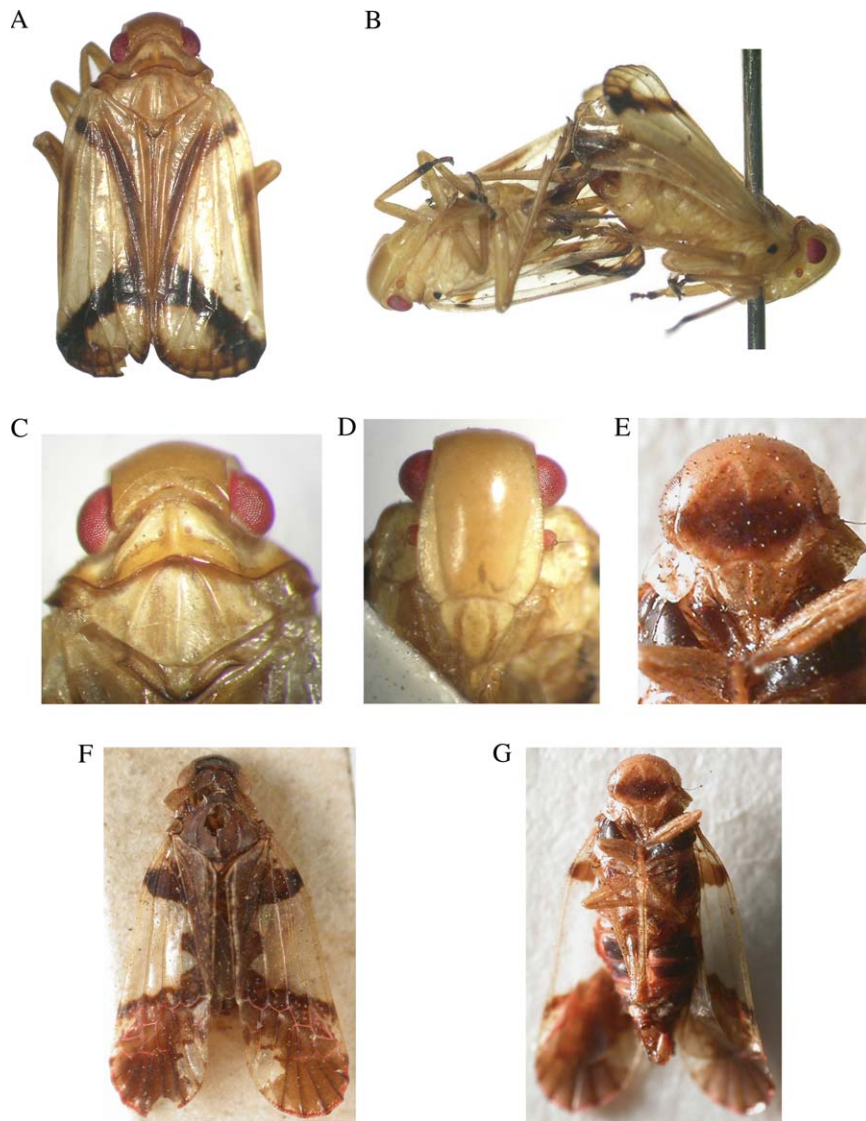


Fig. 1. *Garumnella* and *Garumna* species. (A–D) *Garumnella bella* sp.n.: (A) dorsal habitus; (B) male and female in copulation, lateral view; (C) head and thorax, dorsal view; (D) head, ventral view. (E–G) *Garumna lepida* Melichar (syntype): (E) head, ventral view; (F) dorsal habitus; (G) ventral habitus.

nine apical cells. Hind wings (Figs 1B, 2E) hyaline, posterior margin strongly sinuate, apical part with three forks. Legs elongate; hind tibiae (Fig. 1B) each with four distinct lateral spines; spinal formula of hind leg 6–6–2.

Male genitalia. Pygofer (Figs 3A, B, 5A) symmetrical, forming irregular rectangle, posterior margin gently produced caudad in lateral view; dorsal margin strongly excavated to accommodate anal tube. Xth segment (Figs 3A, B, 5A) relatively short, apical margin slightly concave in dorsal view, anal styles relatively short and small. Gonostylus (Figs 3A, E, F, 5A) elongate, bilaterally symmetrical, membranously fused with pygofer at base, dorsal edge with processes. Periandrium (Figs 3A, 5B, C) dorsally connected

with ventrobasal margin of anal tube, membranously fused with pygofer at ventral side, tube-like, distinctly sclerotized, surrounding aedeagus at basal part and visible in lateral view. Aedeagus (Figs 3A–D, 5B), asymmetrical, elongate, tubular, apical part abruptly curved through approximately 90°, directed to right, shaft of aedeagus (Figs 3A–D, 5B) with external sclerotization from base to turning point, endosoma membranous, with two spines (spI, spII) on outside and lacking spines on inside, phallotreme slit-like, running along the ventrolateral side of the aedeagus in a distinct longitudinal furrow.

Female genitalia. Anal tube (Figs 4A, D, 5A, C) short, apical margin convex in dorsal view, anal styles relatively

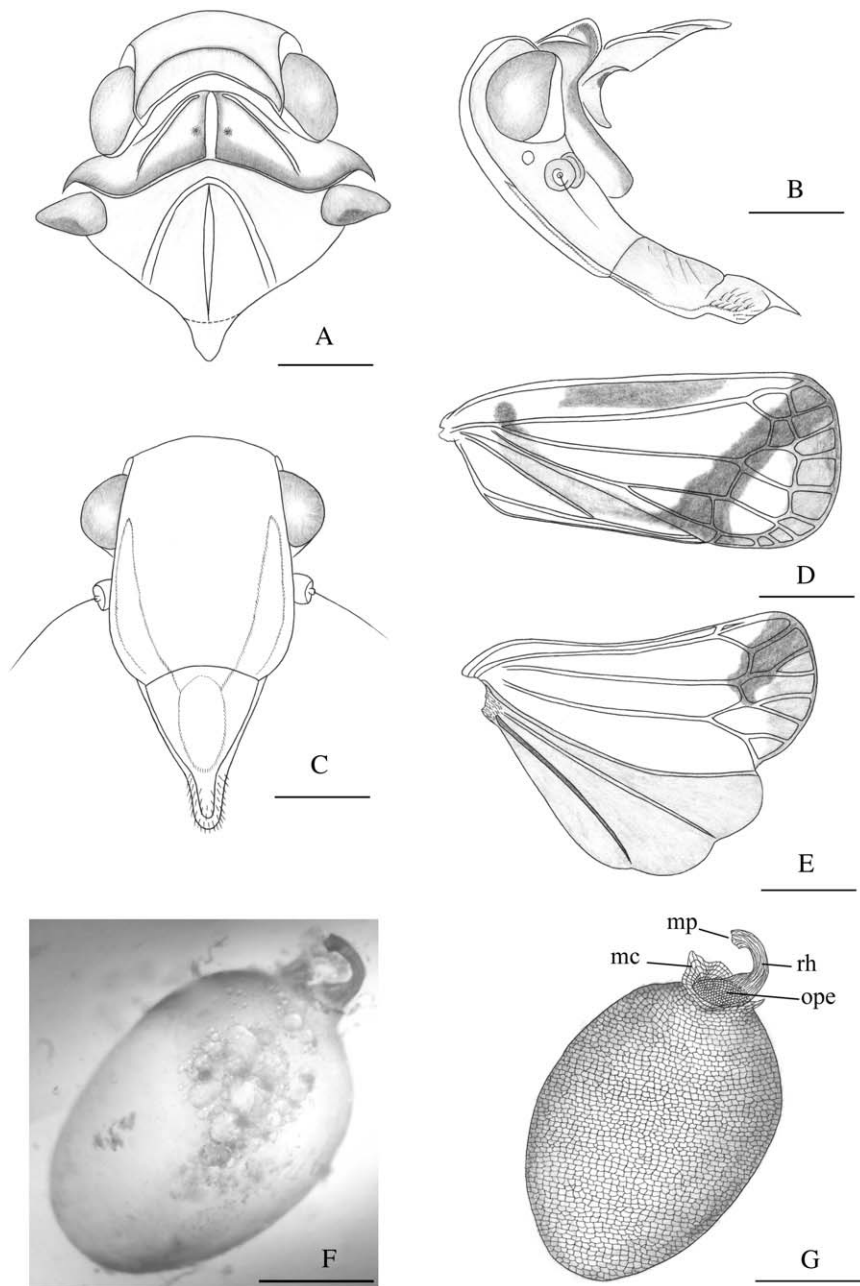


Fig. 2. *Garumnella bella* sp.n. external morphology. (A) Head, pronotum and mesonotum, dorsal view; (B) head, pronotum and mesonotum, lateral view; (C) head, ventral view; (D) right fore wing; (E) right hind wing; (F) egg, lateral view; (G) egg, lateral view. Scale bars: A–C = 0.5 mm; D, E = 1 mm; F, G = 0.3 mm. Abbreviations: mc, marginal collar; mp, micropylar pore; ope, operculum; rh, respiratory horn.

short and small. Gonopophyses VIII (first valvulae) (Fig. 5 A, B) strongly sclerotized with eight blunt teeth on dorsal margin, several minute teeth arranged in three oblique rows and two blunt apical teeth on ventral margin. Gonopophyses IX (second valvulae) (Figs 4C, D, 5B, C) triangular, fused together on inner-lateral margin and strongly reduced but well-sclerotized, apical ends not confluent; gonopospiculum (Figs 4C, 5B) as long as median length of triangular

part, flattened laterally and blunt at apex. Gonoplares (third valvulae) (Figs 4A, B, D, 5A, C) with several teeth at apical part, directed mesad. Gonocoxae VIII (Figs 4D, 5A, C) almost rectangular sclerotized plates with a distinct black spot on the caudadorsal edge. Genital opening singular (monotrysian) occurring between gonopophyses VIII and IX (Figs 4D, 5B, C). Posterior vagina strikingly sclerotized except in its dorsal part, forming a torsion groove (Figs 4D,

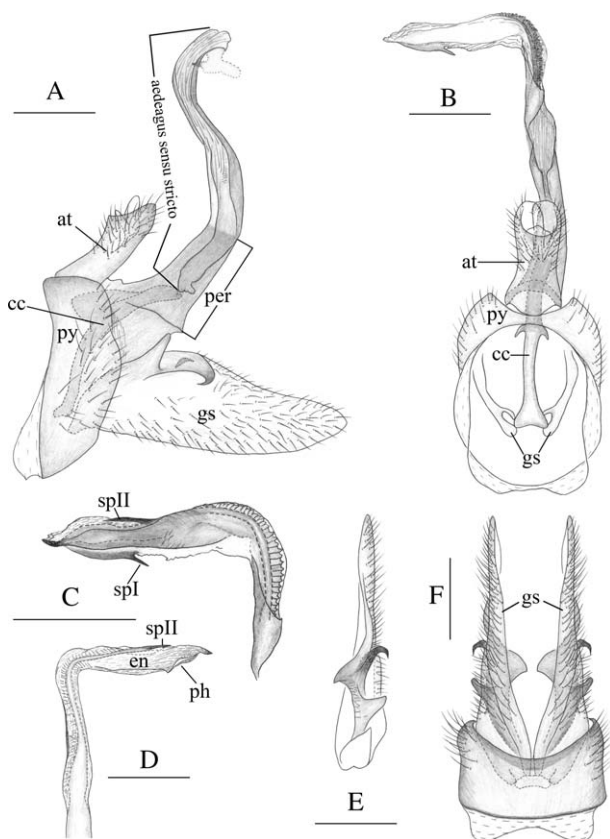


Fig. 3. *Garumnella bella* sp.n., male genitalia: (A) genitalia, lateral view; (B) genitalia, dorsal view; (C) apex of aedeagus, dorsal view; (D) apex of aedeagus, ventral view; (E) gonostylus, dorsal view; (F) genital capsule, ventral view. Scale bars = 0.5 mm. Abbreviations: at, anal tube; cc, corpus connectivi; en, endosoma; gs, gonostylus; ph, phallotrema; py, pygofer; per, periandrium; spI, sclerotized process 1; spII, sclerotized process 2.

5B–D). Dorsally, a large bursa copulatrix (Figs 4D, 5C, D) opens directly into vagina and an enlarged common oviduct and spermatheca (Figs 4D, 5C, D) open apically into anterior vagina.

Remarks. The new genus is similar to *Garumna* (Fig. 1E, G), but differs in having the face (Figs 1D, 2C) longer, without a median carina and with a medial swollen area narrowing to frontoclypeal suture and uniting with median ridge of clypeus, the fore wing (Fig. 2D) with the distance between the wing margin and Sc becoming narrower from base towards apex, Sc forked before the nodal line, apical cells short, and the corium near nodal line without granulation (in *Garumna*, the corium near the nodal line has several granules, see Fig. 1F).

Etymology. The new genus name is a combination of the similar *Garumna* plus the diminutive suffix 'ella', gender: feminine.

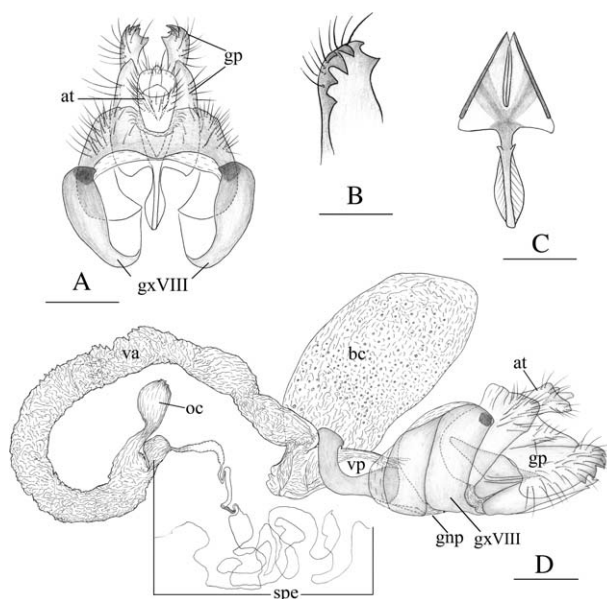


Fig. 4. *Garumnella bella* sp.n., female genitalia: (A) genitalia, dorsal view; (B) gonoplac tip, ventrolateral view; (C) gonopophyses IX, ventral view; (D) female genitalia, right view, showing inner components of female. Scale bars = 0.5 mm. Abbreviations: at, anal tube; bc, bursa copulatrix; gnp, gonoporus; gp, gonoplac; gxVIII, gonocoxae VIII; oc, common oviduct; spe, spermatheca; va, anterior vagina; vp, posterior vagina.

Garumnella bella sp.n. (Figs 1–5)

Types. Holotype ♂, CHINA: Xizang, Mêdog County, Hanmi, 2120 m, 11.viii.2006 (Z.-S. Song). Paratype. 1♀, same data as holotype. Types deposited in IZCAS.

Length (from apex of vertex to tip of genitalia): ♂, 5.55 mm; ♀, 5.75 mm.

Colour. General colour yellow; apex of rostrum black; eyes and ocelli red; pronotum with posterior portion and tegulae all suffused with reddish yellow; mesopleura with black spot; legs and abdomen yellow, apex of fore and medial tibiae, protarsus and mesotarsus all suffused with black, apex of all spines black; fore wings (Figs 1A, B, 2D) dark brown on clavus adjacent claval suture, and across wing sub-basally and on nodal line, costal cell with middle portion and all apical cells suffused with dark brown. Hind wings (Fig. 2E) with anal area suffused with fuscous, apical part dark fuscous.

Head and thorax. Head (Figs 1C, 2A) projecting before eyes approximately one-third length of eye; vertex (Figs 1C, 2A) broader at base than long at midline (1 : 0.43), slightly shorter than pronotum at midline (0.94 : 1); frons (Figs 1D, 2C) slightly longer medially than greatest width (1 : 0.97). Pronotum (Figs 1C, 2A) distinctly shorter than mesonotum in midline (0.35 : 1); pronotum and mesonotum together medially 4.06 times as long as median length of vertex.

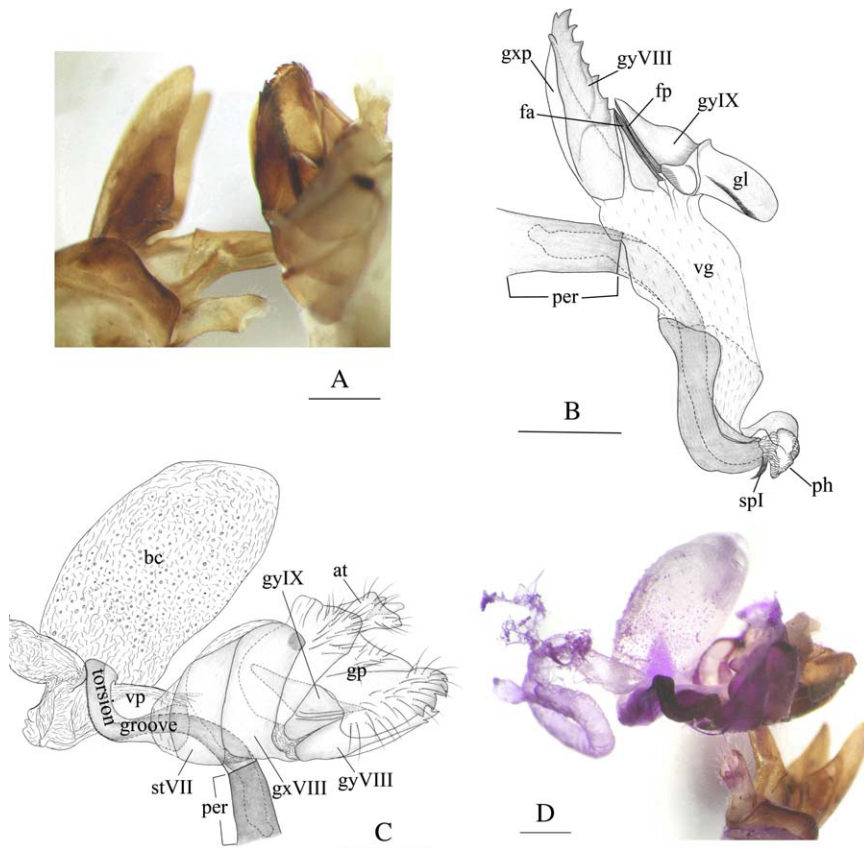


Fig. 5. *Garumnella bella* sp.n. (A) Male and female genitalia, lateral view, in copula; (B) right gonopophyses VIII, gonopophyses IX and vagina, right view, showing the aedeagus inserting into vagina of female; (C) aedeagus and female genitalia, left view, showing aedeagus and torsion groove tightly interlocked; (D) male and female genitalia, left view. Scale bars = 0.5 mm. Abbreviations: at, anal tube; bc, bursa copulatrix; fa, anterior fibula; fp, posterior fibula; gl, gonospiculum; gp, gonoplac; gxp, endogonocoxal process; gxVIII, gonocoxae VIII; gyVIII, gonopophyses VIII; gyIX, gonopophyses IX; ph, phallotrema; per, perianthrium; spl, sclerotized process I; stVII, sternite VII; vg, vagina; vp, posterior vagina.

Male genitalia. See generic description, with gonostylus (Figs 3A, E, F, 5A) approximately three times as long as broad in lateral view, tapering to apex in distal half, dorsal edge with a basal angular, dorsoposteriorly directed process, followed by two hook-like processes, directed inward and outward, respectively (see Figs 3A–F, 5A, B).

Female genitalia. See generic description, with gonopophyses VIII (first valvulae) (Figs 4A–D, 5A–D) with eight blunt teeth on dorsal margin, several minute teeth arranged in three oblique rows and two blunt apical teeth on ventral margin. Gonoplacs (third valvulae) (Figs 4A, B, D, 5A, C) with seven teeth at apical part, directed mesad.

Eggs. Egg oval (Fig. 2F, G), length 750–900 μm ; the widest breadth 525–600 μm . Surface with two main regions: a specialized area and an unspecialized egg capsule (Fig. 2F, G). Specialized area characterized by large respiratory plate containing operculum and respiratory horn in apical part (Fig. 2F, G). Operculum (Fig. 2F, G) ellipsoidal in shape with clear marginal collar (Fig. 2F, G) and many surface

respiratory pores; follicle cell impressions in concentric rings around operculum, separating latter from surrounding egg surface, perhaps to facilitate larval eclosion (Guglielmino *et al.*, 1997) (Fig. 2F, G). Respiratory horn (Fig. 2F, G) long (approximately 225–270 μm in length), narrowing gradually towards its apex. Chorionic surface bearing polygonal impressions (readily visible in reflected light under medium to high magnification).

Etymology. This new species name is derived from the Latin, ‘bella’, meaning beautiful.

Distribution. China (Xizang).

Synonymy of *Garumna* and *Paragarumna*

The new genus is similar externally to *Garumna* Melichar and *Paragarumna* Muir based on the proportions of the head and thorax in dorsal view and the fore wing venation and marking. However, it differs in some important aspects

(see remarks under genus description). With respect to the identity of *Garumna*, there has been some confusion following Muir's (1931) interpretation of its original description. Muir stated that *Garumna* could be distinguished by the swollen condition of the base and sides of the frons, the median carina of the frons, the presence of the median carina of the pronotum and the Sc + R vein in the fore wing forking before the nodal line. This latter feature probably derived from Melichar (1914: 97): 'Von den drei Sektoren ist der äussere vor der Queraderlinie kurz gegabelt'. However, after receiving images of the types (see below) of the type species of *Garumna* (*G. lepida* Melichar), Sc + R clearly forks on the nodal line (Fig. 1F) and the face (Fig. 1E) is identical to that of *Paragarumna*. Furthermore, examination of specimens of *Paragarumna* indicates a certain degree of variation in the median carina of the frons. Therefore, the main difference between *Garumna* and *Paragarumna* is the presence or absence of the pronotal medial carina, which we consider insufficient to separate the two genera, and which are therefore synonymized. The nomenclatorial changes resulting from this action are summarized below, together with the material examined.

Garumna Melichar

Garumna Melichar, 1914: 97. Type species: *G. lepida* Melichar

Paragarumna Muir, 1931: 303 (**syn.n.**). Type species: *P. pseudolepida* Muir

Garumna lepida Melichar (Fig. 1E–G)

Garumna lepida Melichar, 1914: 98, fig. 26.

Material examined. Indonesia, Sulawesi: 5♂, 2♀, Domoga-Bone Nat. Park, ii–viii. 1985, Royal Entomological Society Project Wallace Expedition (BMNH).

Remarks. Identified by comparison with images of the types (MMBC). Details of the type series, described from 'Celebes' (=Sulawesi), is as follows (from Wilson & Malenovsky, 2007): 1♀ (Fig. 1E–G) and one sex unknown (abdomen damaged) (MMBC), 1♂ (Budapest). There is one additional male in MMBC, collected by Baker from P. Princessa, Palawan, which is not part of the type series and is probably a different species (I. Malenovsky, MMBC, personal communication).

Garumna melichari Baker **comb.rev.**

Garumna melichari Baker, 1927: 409, fig. 13a–e.

Paragarumna melichari (Baker) Muir, 1931: 305.

Material examined. Syntype, sex unknown (abdomen missing), W. Indonesia, Mentawai Is, Sipora, 11.x.1924 (*H.H. Karny*) (BMNH).

Garumna pseudolepida (Muir) **comb.n.**

Paragarumna pseudolepida Muir, 1931: 304, figs 5, 6.

Material examined. Syntype ♀, 'Bulsit Besar, Siam, Malay States' (see below); 1♀, Peninsula

Malaysia, Selangor; 1♂, 2♀, Peninsula Malaysia, Palau (BMNH).

Remarks. As noted above, the type of *P. pseudolepida* is labelled from 'Bulsit Besar, Siam'. The previously uncertain whereabouts of Bukit (for Bulsit) Besar (meaning a large hill, and a common locality on specimens bearing a 'Siam Malay States' label in the BMNH) was clarified by Zhang *et al.* (2004) as Khao Sai Nam Tok National Park, southeast Thailand, of which the modern name in English was found to be the White Sand Water Falls National Park.

Garumna n.sp.?

Material examined. 1♂, 2♀, Sabah, Tawau, on Cocoa; 1♂, 1♀, Sarawak, on *Piper nigrum* (black pepper) (BMNH).

Copulation in Fulgoromorpha with reference to a preserved copulating pair

Surprisingly little information is available on the mating position and copulatory mechanism in Fulgoromorpha. Most pairs probably initially adopt a side-by-side position facing the same way and then move end-to-end, as in most other Auchenorrhyncha (see bugguide.net image no. 145807: *Orgerius*). However, at least some adopt a side-by-side position facing the opposite way (Santini & Lucchi, 1974; Sforza & Bourgoin, 1998) or end-to-end with the male upside down (see Weber, 1930: fig. 232a; bugguide.net image no. 121549: *Cedusa*). Regardless of their position, the female genitalia is always above, which requires some twisting of the male abdomen. However, such twisting may be lost when joined specimens are killed (Sforza & Bourgoin, 1998: 67), as may be the case with the pair described here, in which the male is upside down (Fig. 1B). Such mating positions may explain the widespread occurrence of asymmetry in Fulgoromorpha and in insects in general (Huber *et al.*, 2007). In Tropicuchidae, asymmetry is found in the male aedeagus, perianthrium, pygofer and gonostylus, and in the female gonocoxae VIII and sternite VIII. However, in the new genus, asymmetry is found only in the aedeagus (Fig. 3A–D).

During copulation, hooks of the male gonostyli, anal tube and pygofer all assist in holding the partners together [see figures showing internal structures during copulation by Weber (1930: fig. 233), Hoch & Remane (1985: fig. 7a) and Sforza & Bourgoin (1998: fig. 3)], whereas in the tropiduchid *Trypetimorpha* Costa, the gonostyli grip the female gonapophyses VIII by their outer edges while inflation of the endosoma and the anteroventrally directed endosomal processes may also play a role (Bourgoin & Huang, 1991). In the new species, assistance in maintaining the mating

position could be provided by the tightly fitting and strongly curved apical part of the aedeagus within the strikingly sclerotized vagina (Figs 4D, 5B–D). This condition is also found in *Trypetimorpha* (T. Bourgoïn, personal communication), but here there are two hooks of the gonostylus for gripping the female gonapophyses VIII, rather than the perhaps less-effective single hook in the new species. The effectiveness of the hold, which must be maintained throughout insemination, determines the length of time for copulation, e.g. in different species of the planthopper family Delphacidae copulation ranges from 1 to 33 min (Soulier-Perkins & Bourgoïn, 1998); the longer the period of time the less likely another male will be able to supplant its sperm before fertilization takes place. Of the three methods used to deposit sperm in Fulgoromorpha (see Soulier-Perkins & Bourgoïn, 1998), depositing sperm in the bursa copulatrix is the most probable for *G. bella*, as the aedeagus is observed within this structure (Figs 4D, 5B–D). By contrast, in the cixiid genus *Hyalesthes obsoletus* Signoret, the aedeagus reaches only to the anterior vagina (Sforza & Bourgoïn, 1998: 67).

Some other differences in the genitalia are apparent in *G. bella*. In many tropiduchids, the female common oviduct is a narrow tube and the length of the anterior vagina is moderate, e.g. in *Sogana clara* Liang & Wang, *S. hopponis* Matsumura, *S. robustocarina* Liang & Wang, *Elithiyya singaporensis* Wang & Liang (Isporisini) and *Trypetimorpha biermani* (Dammerman in Bierman) and *Ommatissus* sp. (Trypetimorphini), but in *G. bella* the common oviduct is a thin-walled, inflated (oval ball-like) structure (Figs 4D, 5C, D) and the anterior vagina is unusually long (Fig. 4D). In addition, compared with some other tropiduchids studied (see Bourgoïn & Huang, 1991), *G. bella* has several teeth on the gonoplac (Figs 4A, B, 5A, C) and the endosoma has two spines on its outside and lacks spines on the inside (Figs 3B–D, 5B).

Eggs

Information on the eggs of Tropiduchidae is very limited, with the exception of *Ommatissus lybicus* Bergevin (Alfieri, 1934; Hussain, 1963; Gharib, 1966), *O. binotatus* Fieber (Guglielmino, 1997; Guglielmino *et al.*, 1997), *Kallitambinia australis* Muir (Fletcher, 1979, 1981), *Tambinia rubrolineata* Liang (Liang & Jiang, 2003) and *Paricanoides dalatensis* Liang (Liang, 2003). The egg of *G. bella* is generally similar to that of *P. dalatensis*, but differs in the ratio of its length to its widest breadth and its respiratory horn being very much longer. This structure in *O. binotatus* consists of a hollow tube with an internal cone-shaped projection, housing a micropylar canal with a micropylar pore at its apex (Guglielmino *et al.*, 1997).

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