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Research article

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Two new species of planthoppers from India (Hemiptera: Auchenorrhyncha: Delphacidae) in the genera *Parasogata* and *Eoerysa*

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Abstract. The genus *Parasogata* Zhou, Yang & Chen, 2018 is here reported from India represented by the new species *Parasogata sexpartita* sp. nov. collected in a recent exploration and survey of delphacids from Nagaland in northeastern India. A second species of *Eoerysa* Muir, 1913 from India, the new species *Eoerysa sagittaria* sp. nov., was found in Rampur, Una, Himachal Pradesh. Both new species are described with illustrations, and a molecular identification is given with the mtCOI gene sequence. A modified key to species of the genera is also provided.

Keywords. Planthopper, morphology, distribution, identification, taxonomy.

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Introduction

The delphacid fauna of India remains incompletely investigated. Delphacidae Leach, 1815 is the second most speciose family of Fulgoromorpha Evans, 1946 with 2214 extant described species worldwide (after Cixiidae Spinola, 1839, with 2520 species) (Bourgoin 2019). The Indian fauna of Delphacidae includes 52 published species records (Distant 1906; Muir 1921; Joseph 1961, 1964; Mammen & Menon 1972; Sharma & Singh 1980, 1982; Kalode 1983; Asche 1985, 1990; Rao & Chalam 2006; Nimisha 2008; Ramya & Meshram 2019), plus an additional 13 species published in a PhD thesis (Mammen 1971).

Here, we report on two new species of Delphacini Leach, 1815 (Delphacinae Leach, 1815) from the genera *Parasogata* Zhou, Yang & Chen, 2018 and *Eoerysa* Muir, 1913. Delphacini (Delphacinae) is the largest tribe of Delphacidae with 328 genera and 1631 species (Bourgoin 2019), including most of the economically important taxa (Wilson & O'Brien 1987; Wilson 2005). The genus *Parasogata* was described from China with two species *P. binaria* Zhou, Yang & Chen, 2018 and *P. furca* Zhou, Yang & Chen, 2018 (Zhou *et al.* 2018).

The genus *Eoerysa* was established with the type species *E. flavocapitata* Muir, 1913 described from the “Malay Peninsula and South China” (Muir 1913: 249), later reported from sugarcane in India (Chatterjee 1971; Chatterjee & Choudhuri 1979; Datta & Ghosh 1979). A second species *E. arudina* Kouh & Ding, 1980 from China (Yunnan) was subsequently added to the genus (Kuoh *et al.* 1980).

The molecular studies on delphacids gained a momentum with mitochondrial DNA nucleotide sequence data (mtCOI 504bp) generated by Dijkstra *et al.* (2003, 2006). These studies further paved the way for using different gene regions for the phylogenetic analyses of Delphacidae (Urban *et al.* 2010; Huang *et al.* 2017). MtCOI is one of the most promising genes for the species level identification and differentiation.

In this paper, we describe two new species of Delphacini, one species in the genus *Parasogata*, which also constitutes the first report of *Parasogata* from India, and another in the genus *Eoerysa*. Distribution map for the new species is given (Fig. 6). We also report the mtDNA from the COI barcode region from these species and report on the implications of these data.

Material and methods

Morphological terminology follows that of Asche (1985) and Bartlett (2009). In the descriptions, the header ‘male genitalia’ is understood to include segments IX–XI. Photographs were taken with a Leica DFC 425C digital camera on a Leica M205FA stereozoom automontage microscope. Male genitalia dissections were carried out as described by Oman (1949) and Knight (1965). Type specimens of both species were deposited in the National Pusa Collection, Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, India (NPC). Distribution map for new species has been prepared using maps.google.com.

DNA was extracted from whole specimen by crushing the entire body, according to the manufacturer protocol, DNAsure Tissue Mini Kit with slight modification in the procedure. The mitochondrial cytochrome oxidase subunit I (mtCOI) gene was amplified for PCR products, using universal primers LCO1490: 5'-ggtaacaatacataaagatattgg-3'; HCO2198: 5'-taaactcagggtgaccaaaaaatca-3' (Dietrich *et al.* 1997). The PCR protocol follows Hashmi *et al.* (2018). The polymerase chain reactions (PCR) were performed with 25 µl reaction volumes in Ventri® 96-well thermal cycler (Applied Biosystems® Life Technologies). Cycling protocol was: 4 min hot start at 94°C, 35 cycles of denaturation for 30 s at 94°C, annealing for 60 s at 47°C, elongation for 50 s at 72°C and a final extension at 72°C for 8 min in a C1000™ Thermal cycler. The products were examined on a 2% agarose gel and visualized under UV using Alphaview® software ver. 1.2.0.1. The amplified products were sequenced at AgriGenome Pvt. Ltd (Cochin India). The quality sequences were assembled with BioEdit ver. 7.0.0 and deposited in NCBI GenBank.

Results

Class Insecta Linnaeus, 1758
 Order Hemiptera Linnaeus, 1758
 Suborder Auchenorrhyncha Dumeril, 1806
 Infraorder Fulgoromorpha Evans, 1946
 Superfamily Fulgoroidea Latreille, 1807
 Family Delphacidae Leach, 1815
 Subfamily Delphacinae Leach, 1815
 Tribe Delphacini Leach, 1815

Genus *Parasogata* Zhou, Yang & Chen, 2018

Parasogata Zhou, Yang & Chen, 2018: 74. Type species *Parasogata binaria* Zhou, Yang & Chen, 2018 (by original designation).

Amended diagnosis

Yellowish white to brown (Fig. 1A). Vertex, pronotum and mesonotum with uninterrupted white fascia. Vertex, frons, face, antennae yellowish brown to yellowish white. Pronotum and mesonotum yellowish white (Fig. 1C–D). Forewings and hindwings hyaline with prominent veins (Fig. 1B). Legs yellowish white. Abdomen yellowish orange (Fig. 1B). Head including eyes narrower than pronotum (Fig. 1C). Vertex subquadrangular, weakly anteriorly projected; anterior margin arched, submedian carinae uniting at apex; Y-shaped carina feeble (Fig. 1C). Frons with lateral margins weakly diverging ventrad (widest near frontoclypeal suture); much longer in middle line than wide at widest part; median carina forked at fastigium (Fig. 1D). Antennae cylindrical, scape longer than wide, pedicle more than twice length of scape (Zhou *et al.* 2018: figs 13–16). Pronotum relatively broad, lateral carinae nearly attaining hind margin (Fig. 1C). Spinal formula of hind leg 5-7-4. Post-tibial spur with 29–32 fine teeth along hind margin. Pygofer in profile wider ventrally than dorsally, lateral quadrangular areas strongly sclerotized, medioventral process absent. Diaphragm well developed, dorsal margin broadly convex, armature very weak (Fig. 2D–F). Aedeagus long, tubular, weakly upturned, with row of dorsal subapical processes (Fig. 2B–C; Zhou *et al.* 2018: figs 26, 52). Parameres (=gonostyli) simple (basal and apical angles not developed), widely divergent apically (Fig. 2H; Zhou *et al.* 2018: figs 27–28, 53–54). Suspensorium elongate (Zhou *et al.* 2018: figs 29, 55). Segment 10 collar-shaped, lateroapical angles produced into 1–2 paired processes (widely separated at base in caudal view) (Fig. 2G; Zhou *et al.* 2018: figs 24–25, 51).

Remarks

This genus is readily recognized by its large size and vertex, pronotum and mesonotum bearing an uninterrupted white fascia. The genus was compared with four similar genera by Zhou *et al.* (2018) and considered most similar to *Sogata* Distant, 1906 but distinguished by the phallus being up-curved, bearing a dorsal row of subapical processes.

Key to the species of *Parasogata* Zhou, Yang & Chen, 2018 based on males (modified from Zhou *et al.* 2018)

1. Pronotum yellow (except median vitta); segment 10 bearing one pair of processes (Zhou *et al.* 2018: figs 50–51) *P. furca* Zhou *et al.*, 2018
 – Pronotum brown (except median vitta); segment 10 bearing two pairs of processes 2
2. Aedeagus with 10 subapical dorsal processes; segment 10 with two pairs of processes, ventral one about 2 × as long as dorsal one (Zhou *et al.* 2018, figs 24–25) *P. binaria* Zhou *et al.*, 2018
 – Aedeagus with 6 subapical dorsal processes; segment 10 with two pair of processes, ventral one about 4 × as long as dorsal one (Fig. 2A–C, G) *P. sexpartita* sp. nov.

Parasogata sexpartita sp. nov.

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Figs 1–2

Diagnosis

Parasogata sexpartita sp. nov. can be recognized by yellowish orange to stramineous habitus (Fig. 1A) with uninterrupted white vitta from frons to tip of scutellum (Fig. 1C) and aedeagus with 6 subapical dorsal processes (Fig. 2A–C), segment 10 with two pairs of processes (Fig. 2G).

Etymology

The species name is derived from the Latin term ‘sex’, meaning ‘six’, plus ‘partita’, meaning ‘parted’, a reference to the number of subapical spines on the aedeagus. The specific epithet is intended to be feminine in gender to match apparent gender.

Type material

Holotype

INDIA • ♂; Nagaland, Jharnapani; 25°75'58" N, 93°84'39" E; 23 Jun. 2019; Niranjana G.N. leg.; Hg light trap; NPC HEMT7.

Paratype

INDIA • 1 ♂; same collection data as for holotype; NPC HEMT8.

Description

MEASUREMENTS (mm). Male (holotype, NPC HEMT7) 4.6 long, 0.7 wide across eyes, 0.5 wide across hind margin of pronotum.

COLOURATION. Yellowish orange to stramineous. Vertex, pronotum and mesonotum with uninterrupted white vitta. Near-black bands follow lateral carinae from anterolateral compartments of vertex to frontoclypeal suture; median portion of frons white (continuation of dorsal vitta); clypeus pale medially, darker laterally. Genae orangish anteriorly, stramineous around (and including) antennae. Pronotum and mesonotum dark yellow. Forewings and hindwings yellow-hyaline with prominent black veins. Legs yellowish white. Abdomen yellowish orange (Fig. 1A–D).

MORPHOLOGY. Head including eyes $0.9 \times$ as wide as pronotum. Head weakly produced, vertex $0.3 \times$ as long as head width (including eyes) (Fig. 1A, C). Fastigium elliptical in lateral view (Fig. 1B). Frons longer than wide, lateral margins smoothly diverging to frontoclypeal suture, widest at apex; median carina forked at level of compound eyes. Clypeus as wide as frons basally, rostrum reaching mesocoxae. Antennae terete (Fig. 1D). Pronotum $3.2 \times$ as wide as long, anterior margin truncate behind vertex, posterior margin broadly convex; lateral carinae diverging, not reaching hind margin. Mesonotum $1.1 \times$ as wide as long; carina not conspicuous, obsolete before hind margin, lateral carinae weakly diverging (Fig. 1C). Forewings with R fork proximate to CuA fork; cell formed between fork of R and nodal line longer than that of cubitus; clavus long, reaching wing margin past basal $\frac{3}{4}$ of wing (approximately at nodal line); fork of Pcu+1A in basal $\frac{1}{3}$ of wing; branching pattern: RA unbranched, RP 2-branched (RP₁₊₂, RP₃₊₄), MP unbranched, CuA 2-branched.

MALE GENITALIA (Fig. 2). Pygofer in lateral view approximately quadrangular (Fig. 2F), anterior margin nearly truncate, caudal margin convexly rounded (in lateral view), $1.2 \times$ as long as wide; margins of opening rounded (not carinate). Diaphragm well developed, dorsal margin concave, armature weak (Fig. 2D). Parameres diverging, rather sinuate, $6.1 \times$ as long as wide; widest subapically, apically acute (Fig. 2H). Aedeagus $8 \times$ as long as wide; shallow tubular, dorso-basally concave, subapically ornamented

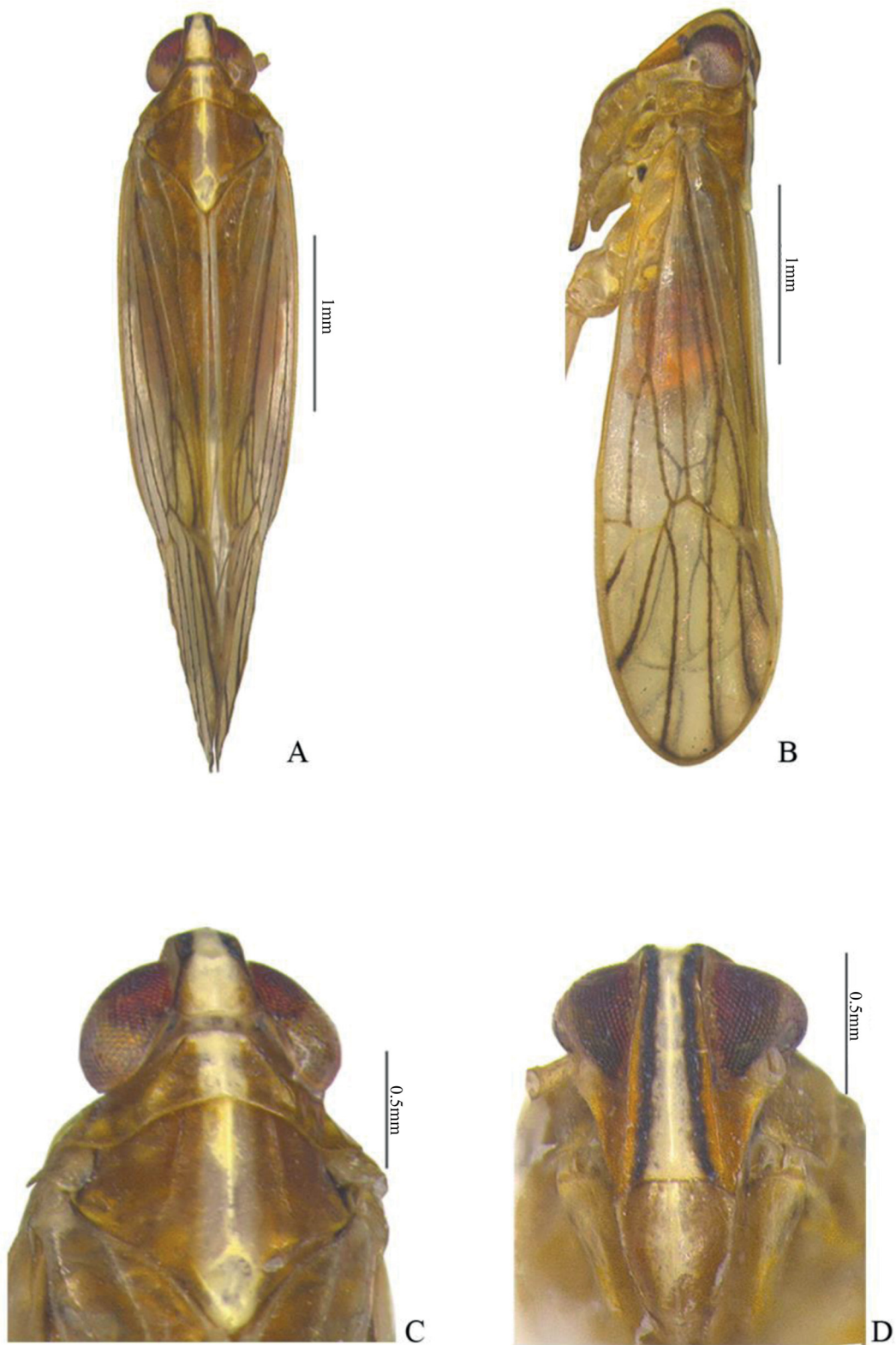


Fig. 1. *Parasogata sexpartita* sp. nov., holotype ♂ (NPC HEMT7). **A.** Habitus, dorsal view. **B.** Habitus, lateral view. **C.** Head, pro- and mesonotum, dorsal view. **D.** Head, ventral view.

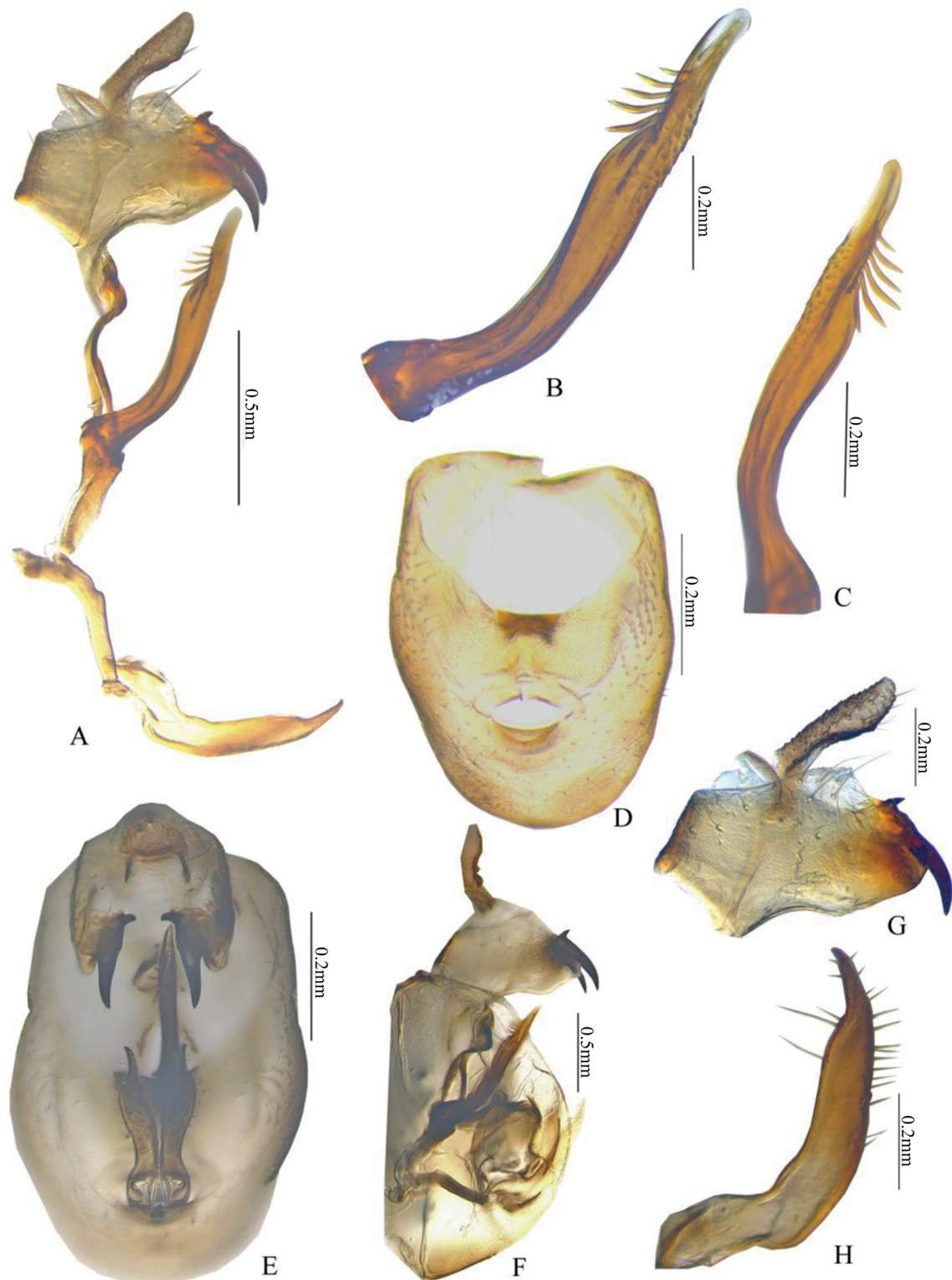


Fig. 2. *Parasogata sexpartita* sp. nov., male genitalia, holotype (NPC HEMT7). A. Aedeagal complex. B. Aedeagus, left view. C. Aedeagus, right view. D. Pygofer, caudal view. E. Male genitalia, caudal view. F. Male genitalia, lateral view. G. Segments 10 and 11. H. Paramere, lateral view.

with six radiating spines dorsally; apically recurved with dorsal gonopore (Fig. 2A–C). Segment 10, including segment 11, $0.7\times$ as long as wide (in lateral view) with two pairs of latero-apical pointed processes (dorsal tooth-like, ventral more elongate and directed ventrad); segment 11 long (Fig. 2G).

Molecular data

The DNA barcode fragment (mtCOI ~650bp) sequence was submitted to NCBI GenBank with accession number MN787519.

Remarks

This species is similar to *P. binaria* and can be distinguished by an aedeagus with six radiating spines (Fig. 2B–C) (vs ten in *binaria*) subapically and dorsal gonopore.

A peculiar aspect of the forewing venation is that the MP vein bends sharply at the nodal line, and it is not entirely clear whether it is angled toward the leading or trailing portion of the wing, a matter that could change the interpretation of the vein branches. Both previously described species of *Parasogata* appear to have the RP 3-branched (RP₁₊₂, RP₃, RP₄).

There are no host associations reported for any species of *Parasogata*.

Genus *Eoerysa* Muir, 1913

Eoerysa Muir, 1913: 249. Type species *Eoerysa flavocapitata* Muir, 1913 (by monotypy).

Amended diagnosis

Habitus colouration varies from near black (in male *E. flavocapitata*) to near white. Body distinctly dorsoventrally flattened (Fig. 3A–C). Head including eyes narrower than pronotum, projecting slightly in front of eyes. Vertex broad, narrowed anteriorly, as long as wide at base, Y-shaped carina distinct, apically converging at fastigium (Fig. 3D); fastigium rather angled (Fig. 3C) (appearing carinae when viewed from ventral aspect). Frons broad, lateral margins arched, slightly longer in middle line than wide at widest part, widest somewhat above frontoclypeal suture, median carina prominent and forked at fastigium. Basally clypeus as wide as apex of frons on dorsal margin. Rostrum reaching to mesocoxae (Fig. 3E). Ocelli present. Antennae terete, scape about as long as wide, pedicel exceeding $2\times$ scape; surpassing frontoclypeal suture (Fig. 3D–E). Pronotum broad, lateral carinae attaining hind margin (Fig. 3D). Spinal formula of hind leg 5-7-4. Post-tibial spur with 17–19 fine teeth. Pygofer with laterodorsal angles not produced, in posterior view with opening rather quadrangular, appearing wider than long, medioventral process absent; diaphragm relatively weak, moderately wide, dorsal margin convex, protruding into a plate (Fig. 4B, D, G). Phallus tubular, approximately straight (Fig. 4C). Suspensorium elongate quadrangular, circular at ventral half. Segment 10 (anal segment) ring-like with short latero-apical processes (Fig. 4A).

Remarks

The genus can be distinguished by the depressed shape of the body (reminiscent of *Eumetopina* Breddin, 1896), and the broad, apically converging vertex. *Eoerysa* is similar to *Eumetopina*, although the latter genus has a broader frons and displays processes on the medioventral portion of the pygofer opening.

Biology

Host associations of the genus are giant cane (*Arundo donax* L.) for *Eoerysa arundina* Kuoh & Ding, 1980 (Kuoh *et al.* 1980) and sugarcane (*Saccharum sinense* Roxb. and *S. officinarum* L.) for *Eoerysa flavocapitata* (Chatterjee 1971; Wilson 1987; Wilson *et al.* 1992; Ding 2006).

Key to the species of *Eoeurysa* Muir, 1913 (revised from Yang 1989)

1. General colouration mostly dark brown; vertex nearly as broad as long on midline (Yang 1989: fig. 110A); males with parameres nearly parallel-sided (not expanded medially, Yang 1989: fig. 110E); aedeagus lacking basal process (bearing flattened projection near midlength (Yang 1989: fig. 110J) *E. flavocapitata* Muir, 2013
- General colouration pale (except clypeus and adjacent parts); vertex longer in midline than broad; male with parameres expanded medially; aedeagus with elongate process off dorso-basal portion 2
2. Clypeus dark (Yang 1989: fig. 111B); parameres very broad medially; aedeagus with 7–8 dorsal teeth (Yang 1989: fig. 111E, H) *E. arundina* Kuoh & Ding, 1980
- Clypeus pale yellowish (Fig. 3E); parameres modestly expanded medially, in lateral view with mediolateral process (Fig. 4E–F); apex of aedeagus sagittate, lacking dorsal teeth (Fig. 4C)
..... *E. sagittaria* sp. nov.

Eoeurysa sagittaria sp. nov.

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Figs 3–5

Diagnosis

Body dorsoventrally flattened, colouration creamy white to pale yellow, without dark markings (Fig. 3A). Vertex longer than broad (Fig. 3D). Male with parameres simple, sinuate, weakly expanded medially (Fig. 4E), in lateral view with mediolateral process (Fig. 4F). Aedeagus tubular, approximately straight, with strong, elongate, dorso-basal process, apex sagittate (Fig. 4C). Segment 10 with single caudal process (Fig. 4D).

Etymology

The species name comes from the Latin word ‘*sagittaria*’, meaning ‘arrow’, in reference to the arrowhead shape of the apex of the aedeagus. The specific epithet is feminine in gender to match the apparent gender of the genus.

Type material

Holotype

INDIA • ♂; Himachal Pradesh, Rampur Una; 31°44'92" N, 77°62'92" E; 22 Sep. 2018; Sunil and G.N. Niranjana leg; light trap; NPC HEMT9.

Paratypes

INDIA • 4 ♂; same collection data as for holotype; NPC HEMT10 to HEMT13 • 7 ♀; same collection data as for holotype; NPC HEMT14 to HEMT20.

Description

MEASUREMENTS (mm). Male (holotype, NPC HEMT9) 3.7 long, 0.6 wide across eyes, 0.5 wide across hind margin of pronotum. Female (paratype, NPC HEMT14) 3.9 long, 0.6 wide across eyes, 0.5 wide across hind margin of pronotum.

COLOURATION. Creamy white to pale yellow. Head concolorous with thorax; thorax creamy white with light yellow carina; tegulae concolorous with thoracic notum. Forewings hyaline, veins pale, apical margin bordered with black. Abdomen creamy white near base, near black distally (Fig. 3A–E).

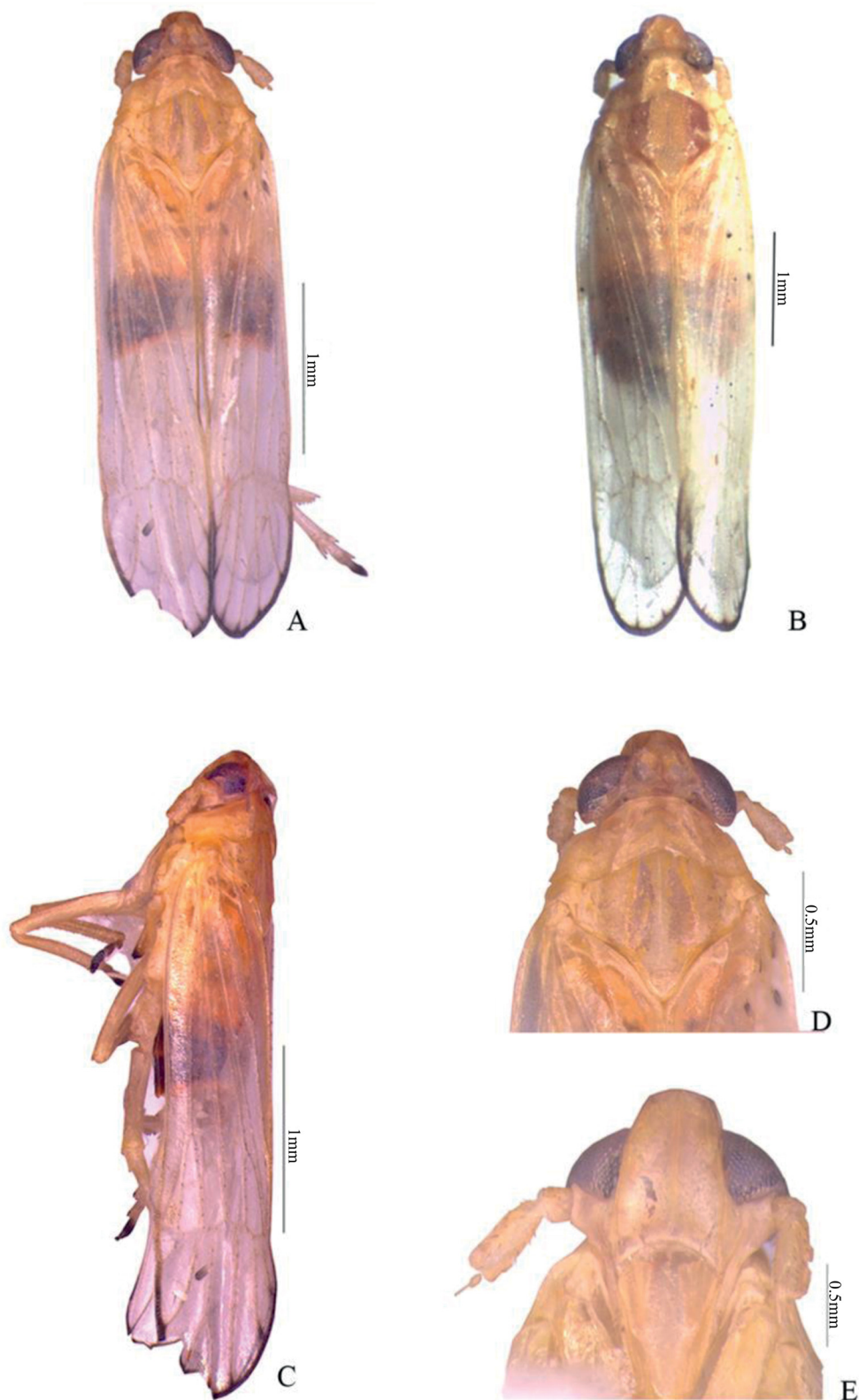


Fig. 3. *Eoerysa sagittaria* sp. nov., habitus. **A, C–D.** Holotype ♂ (NPC HEMT9). **B.** Paratype ♀ (NPC HEMT14). **A.** Male habitus, dorsal view. **B.** Female habitus, dorsal view. **C.** Habitus, lateral view. **D.** Head, pro- and mesonotum, dorsal view. **E.** Head, ventral view.

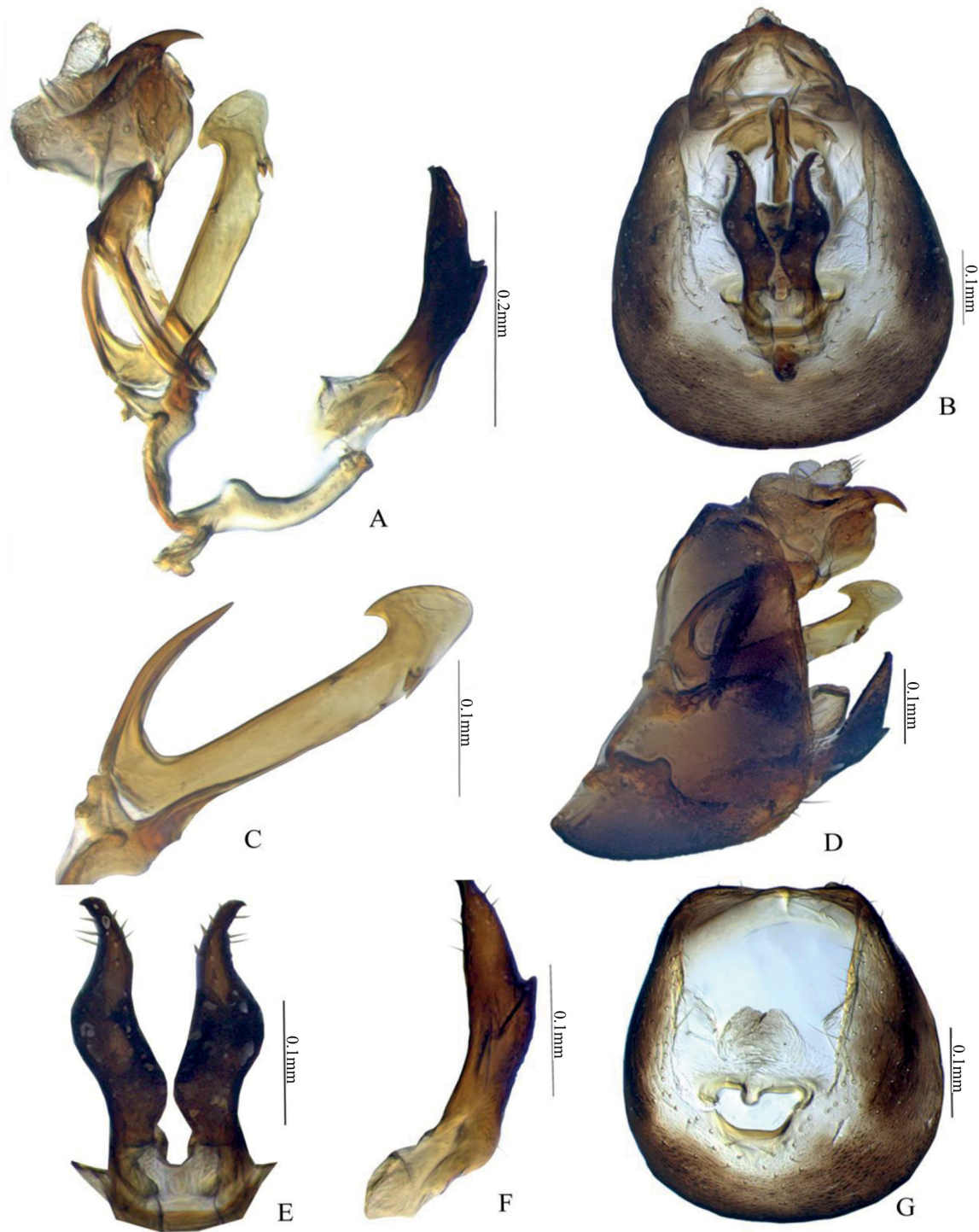


Fig. 4. *Eoerysa sagittaria* sp. nov., male genitalia, holotype (NPC HEMT9). **A.** Aedeagal complex. **B.** Male genitalia, caudal view. **C.** Aedeagus. **D.** Male genitalia, lateral view. **E.** Parameres, caudal view. **F.** Paramere, lateral view. **G.** Pygofer, caudal view.

MORPHOLOGY. Body dorsoventrally depressed. Head including eyes $0.9\times$ as wide as pronotum. Vertex broad, widest at base, tapering distally to broad apex; length $0.4\times$ width across eyes, Y-shaped carina distinct, forked near distal margin of eyes (Fig. 3A, D). Anterior margin of head weakly convex (from dorsal or ventral view), fastigium sharply angled (from lateral view) (Fig. 3C). Frons moderately broad, longer than wide, lateral margins weakly arched, widest subapically; median carina forked near fastigium. Carina of frons and clypeus prominent. Clypeus base as wide as apex of frons, rostrum reaching mesocoxae (Fig. 3E). Antennae terete, scape about as wide as long; pedicel approximately $3\times$ as long as scape. Pronotum broad, $3.1\times$ as wide as long; carinae distinct, lateral carinae reaching posterior margin. Mesonotum $1.1\times$ as wide as long (Fig. 3D), with carinae not reaching posterior margin, lateral carinae weakly diverging posteriorly.

MALE GENITALIA (Fig. 4). Pygofer in lateral view roughly triangular (much wider ventrally than dorsally, dorsocaudal margins not expanded); in caudal view $1.2\times$ as long as wide, medioventral processes of opening absent, diaphragm weakly sclerotized, moderately wide, dorsal margin convexly produced (Fig. 4D, G). Parameres simple (in caudal view), $8\times$ as long as wide; sinuate with sharp, dorsolaterally directed apices (Fig. 4E); in lateral view with mediolateral process (Fig. 4F). Aedeagus tubular, straight, mostly of uniform width; $7.2\times$ as long as wide; base with elongate caudally curved spine; apex abruptly broadened and decurved round sagittate apex, basally ornamented with long curved spinose process. Suspensorium elongate, ventral two-thirds ring-like (Fig. 4A, C). Segment 10 quadrangular, $1\times$ as long as wide, ring-like, bearing short, curved processes on dorsocaudal surface; segment 11 moderately long (Fig. 4A, D).

FEMALE GENITALIA (Fig. 5). Valvulae I in lateral view (Fig. 5A), dorsally concave, dorsal and ventral margin with smoothly sculptured area extending from base to apex. Valvulae II (Fig. 5B), in lateral view, distal half of dorsal margin with 17–18 large, quadrangular, distantly placed serrations decreasing in size gradually towards the apex; apex acute with small serrations; ventral margin translucent, tip with few serrations.

Molecular data

The DNA barcode fragment (mtCOI ~650bp) sequence was submitted to NCBI GenBank with accession numbers MN787520 and MN787521.

Remarks

Eoerysa sagittaria sp. nov. is closely related to *E. arundina*, especially based on the basal process of aedeagus (Fig. 4C). This species can easily be identified by the flattened body (Fig. 3A), the progressively broadening frons (Fig. 3D) and the structure of the male genitalia (Fig. 4) (aedeagus apically sagittate, lacking the dorsal teeth of *E. arundina*).

Discussion

Including the species described here, there are now 54 species of Delphacidae reported from India. Additionally, Mammen (1971) described 13 additional taxa in a thesis on Indian Delphacidae, but these names are not considered published in the sense of the *International Code of Zoological Nomenclature* (viz., ICZN 1999, online version article 9.12). This number undoubtedly underestimates the true diversity of delphacid species. In comparison, Costa Rica has 57 reported delphacid species (Bartlett 2019), nearly the same number reported from India, despite India being approximately $64\times$ the size of Costa Rica. Additionally, the Indomalayan region has 467 known delphacid species, compared with 266 in the Neotropical region (Bartlett *et al.* 2018), further suggesting that the known delphacid fauna of India is greatly underestimated.

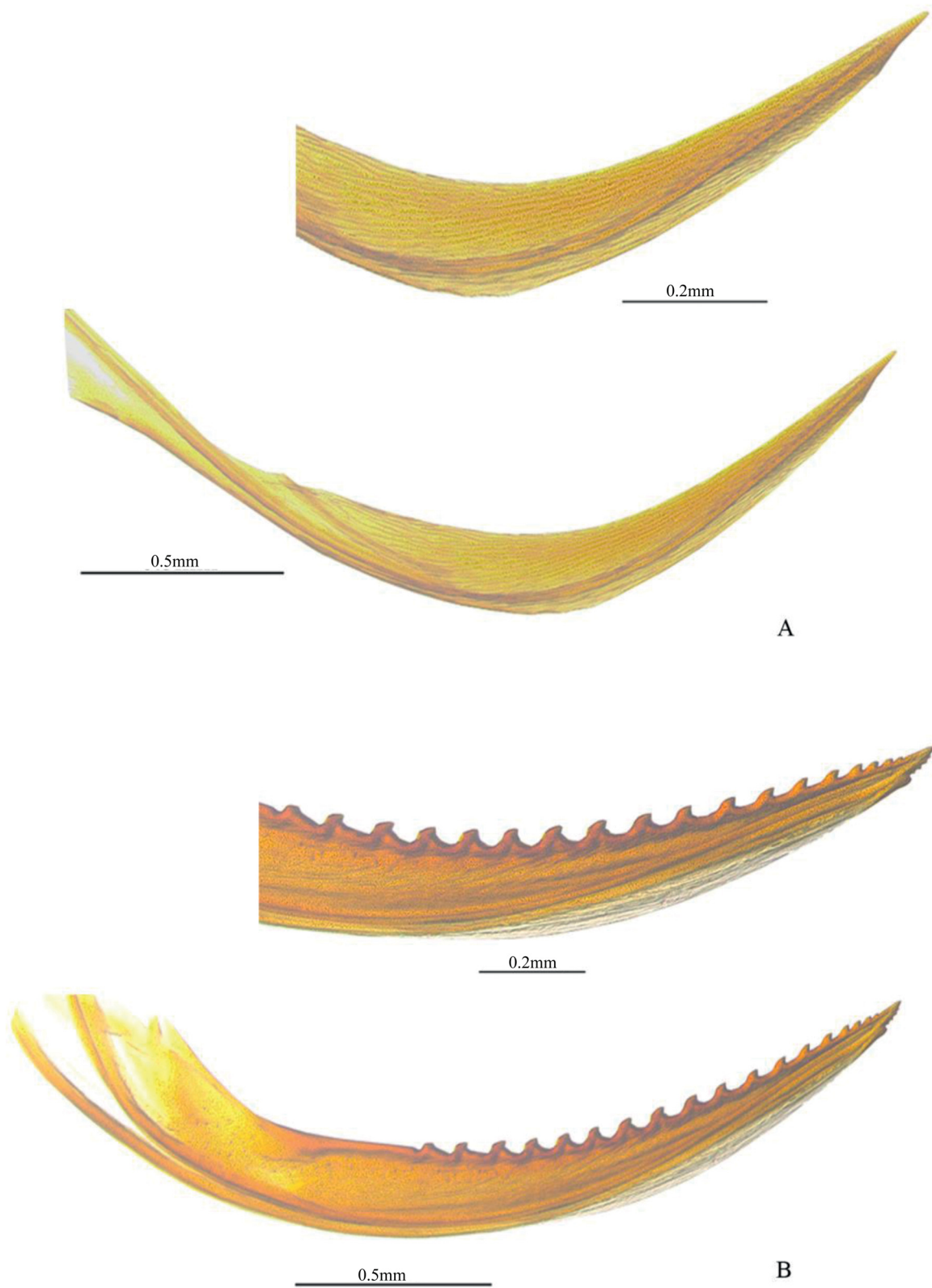


Fig. 5. *Eoeurysa sagittaria* sp. nov., female genitalia, paratype (NPC HEMT14). **A.** Valvulae I. **B.** Valvulae II.

Here, we provide mitochondrial cytochrome oxidase subunit I (mtCOI) gene sequences for the new species, which act as reference sequences for the taxa and allow further molecular studies. This represents the first molecular data for the genus *Parasogata*. Additional data from mtCOI is needed to compare the species within *Parasogata* and *Eoerysa*, and additional genes will be needed to comment on the evolutionary lineage and relationships of these with other genera within Delphacini. Blast searches of these mtCOI data for both species on both GenBank and Barcode of Life databases suggest that there is no similar data for closely allied delphacids available. Collection of additional delphacid species and mtCOI data from a variety of Delphacini would be desirable to improve DNA barcoding identification results.

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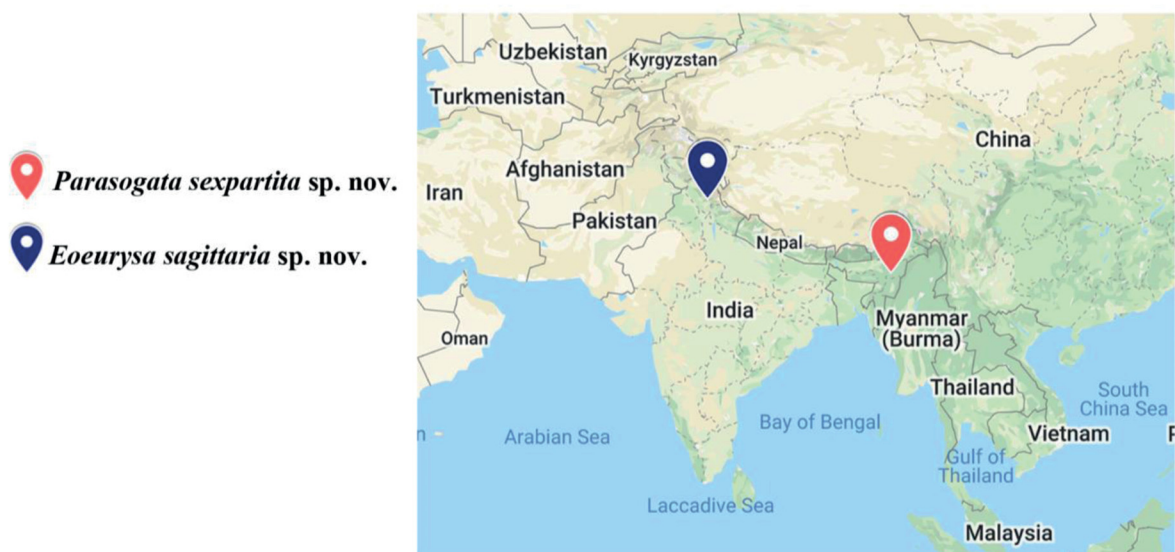


Fig. 6. Distribution map of the new species.

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