



A new subgenus and three new species of stingless bees (Hymenoptera: Apidae: Apinae: Meliponini) from India

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ABSTRACT: A new subgenus of stingless bees, *Flavotetragonula* Shanas, **subgen. n.** is established and three new species, *Tetragonula (Flavotetragonula) calophyllae* Shanas and Faseeh, **n. sp.**, *Tetragonula (Tetragonula) perlucipinnae* Faseeh and Shanas, **n. sp.** and *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, **n. sp.** are described from southern India, based on workers. It is established that *T. (Tetragonula) iridipennis* (Smith, 1854) does not occur in India. The most widespread species in peninsular India is *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, **n. sp.** Keys to the subgenera of *Tetragonula* Moure, 1961 and species of *Flavotetragonula* and *Tetragonula* of the Indian subcontinent are provided. Additional information on the geographic range of the north Indian species *T. ruficornis* Smith (1870) is given. The descriptions of the species are supplemented with the characters of foreleg and hind wing.

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KEY WORDS: *Flavotetragonula*, *Tetragonula*, systematics, new subgenus, new species

INTRODUCTION

Stingless bees are important pollinators in the tropics. They are more adapted to varying climatic conditions compared to other pollinators such as honey bees and bumble bees. Hence, they are promising candidates for crop production in the tropics. Among stingless bees, *Tetragonula* Moure, 1961 is the most complex genus, with 31 valid species worldwide (Engel *et al.*, 2017; Rasmussen *et al.*, 2017). The main difficulty in differentiating species of *Tetragonula* is the perceived absence of reliable structural characters in workers. Consequently, the classification mostly relied on

size, body proportions, coloration and pilosity, which makes the identification of individual specimens difficult or often impossible (Sakagami, 1978).

More than one hundred years ago, four names were proposed for four very similar specimens of *Tetragonula* from India and Sri Lanka (Rasmussen, 2013). Schwarz (1939) recognized *T. iridipennis* var. *iridipennis* as a very widespread form, extending from Ceylon (Sri Lanka) to Solomon Islands. Moure (1961) believed that, *Trigona iridipennis* is synonymous with *Trigona praeterita* Walker, 1860 from Sri Lanka and *Trigona ruficornis* Smith, 1870 from northern

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India. Critical study by Sakagami (1978) redefined *T. iridipennis* as confined to India and Sri Lanka.

Key to species of *Tetragonula* was provided by Bingham (1897), Schwarz (1939) and Sakagami (1978). However, these keys are not reliable (Rasmussen, 2013). Rasmussen provided a catalogue (Rasmussen, 2008) and a key to the workers of the “*iridipennis*” species group of the Indian subcontinent (Rasmussen, 2013). He tabulated the morphometric data based on the primary type specimens and differentiated four primary types viz., *Tetragonula iridipennis*, *T. praeterita*, *T. ruficornis* and *T. bengalensis*. The present study, although limited in geographic coverage, attempts to further streamline the taxonomy of *Tetragonula* of the Indian subcontinent.

MATERIALS AND METHODS

The study is based on an extensive collection of stingless bees in south India. Specimens were collected directly from live colonies and preserved in 98-100% ethyl alcohol. Permanent microscope slides of wings and legs were prepared. Legs were macerated in 10% KOH, washed in distilled water and passed through ethyl alcohol series (70-100 %) and then stained with acid fuchsin. The specimens were then dipped in clove oil and mounted in DPX. Microscope slides of wings were prepared without KOH treatment or staining. Images were processed using CombineZP, Zerene stacker and Adobe Photoshop. Species identifications were confirmed using morphological characters and published records. Morphological terminology (Figs. 1-3) is adapted and modified from Engel (2001), Huber and Sharkey (1993), Mason, (1986), Michener (2007) and Engel *et al.* (2018).

The characters of wings, especially the curvature of the median vein of hind wings, were clearly discernable only when the specimens were slide mounted. The measurements and photographs provided in Rasmussen (2013) alone were used to key out and classify the following three species mentioned in this work: *Tetragonula bengalensis* (Cameron, 1897), *Tetragonula iridipennis* (Smith, 1854) and *Tetragonula praeterita* (Walker, 1860).

Key to the species of *Tetragonula* of the Indian subcontinent is partially based on measurements and photographs of holotypes gathered from literature.

The conservation status mentioned in this work is an estimate based on the relative abundance of feral colonies and the colonies maintained by beekeepers in Kerala. The species are categorised as per annotation provided in the IUCN Red List Categories and Criteria (IUCN, 2019). The abbreviations used in this work are as follows: F3 - Length of 3rd Flagellomere; HTL - Hind Tibia Length; HW - Head width; IOD - Inter Ocellar Distance; OD - Ocellar diameter; OOD -Ocello Orbital Distance; WL2 - Wing diagonal.

The specimens are currently held in the collections of the Travancore Insect Collection, Department of Agricultural Entomology, Kerala Agricultural University (KAU), Vellayani, Thiruvananthapuram. The holotype of the new species will be permanently deposited in the National Pusa Collection, Indian Agricultural Research Institute (NPC) and the paratypes will be deposited in the Zoological Survey of India, Kolkata (ZSI) and the British Museum of Natural History (BMNH), London (UK).

RESULTS

SYSTEMATICS

Genus *Tetragonula* Moure, 1961

Flavotetragonula Shanas, **new subgenus**

LSID urn:lsid:zoobank.org:act:D68E8948-E4DC-4D84-BBF9-9B3112EB1CCC

Type species: *Tetragonula (Flavotetragonula) calophyllae* Shanas and Faseeh, new species.

Diagnosis: *Flavotetragonula* Shanas, **n. subgen.** can be distinguished from the related subgenus *Tetragonula* Moure, 1961 based on a combination of the following four characters: (i) the curvature of the median vein of hind wings (Fig. 2, 3) which is weakly curved and never bent (Fig.3) in *Flavotetragonula n. subgenus*, whereas it is distinctly bent or strongly curved in the nominotypical subgenus (Fig. 2); (ii) the absence or presence of unculus subapically on vein 4Rs of the forewing (Fig. 4B), (iii) presence of area beneath

costal notch without microtrichia (Fig. 5A), and (iv) presence or absence of microtrichia along apical margin of forewing (Fig. 5C).

Remarks: The weakly curved vein M on hindwing, which is never bent, is the only robust character which differentiates *Flavotetragonula* Shanas **n. subgen.** from the nominotypical subgenus of the Indian subcontinent. Unculus here, is defined as the raised pigmented projection at the subapical region of vein 4Rs on the forewing of certain species of *Tetragonula*. Unculus is mostly absent in *Flavotetragonula* Shanas, **subgen. n.**

Etymology: The subgeneric name is derived from *flavus* in Latin for yellow.

The new subgenus *Flavotetragonula* is proposed to contain the following three species.

1. *Tetragonula (Flavotetragonula) calophyllae* Shanas and Faseeh, new species.
2. *Tetragonula (Flavotetragonula) gressitti* (Sakagami, 1978)
3. *Tetragonula (Flavotetragonula) praeterita* (Walker, 1860)

Key to the subgenera of *Tetragonula* Moure, 1961

1. Scape shorter than torulocellar distance; about five distal hamuli; posterior contour of metatibia slightly convex, with distal angle subangulate; penicillus usually composed of soft setae (Indomalayan and Australasian) 2
- Scape at least as long as torulocellar distance; six distal hamuli; posterior contour of metatibia distinctly convex and distal angle rounded, almost without angulation; penicillus composed of stiff setae (Sumatra, Kalimantan)
.....*Tetragonilla* Moure.
2. Vein M on hindwing distinctly bent (Figs. 2A, 2B) or strongly curved (Fig. 2C); Unculus present (Figs. 4B, 7A, 9A) or absent (Fig. 8A) on vein 4Rs of forewing; microtrichia along forewing apical margin present (Fig. 4C); area beneath costal notch with microtrichia (Fig. 4A)

..... *Tetragonula* Moure.

- Vein M on hindwing weakly curved, never bent (Figs. 3A, 3B); Unculus mostly absent (Fig. 5B) or weakly present on vein 4Rs of forewing; microtrichia along forewing apical margin absent (Fig. 5C); area beneath costal notch without microtrichia (Fig. 5A)
.....*Flavotetragonula* Shanas, **n. subgen.**

1. *Tetragonula (Flavotetragonula) calophyllae* Shanas & Faseeh, new species (Figs. 6 A-M) LSID urn:lsid:zoobank.org:act:B6CC2F5D-561A-46C7-B496-4E626798967E

Diagnosis: The new species is characterized by a yellow band on clypeus (Figs. 6F, 6G) and smooth, rotund wing hamuli (Fig. 6A). Two morphs exist, one with clear yellow band on the clypeus and lighter mandibles (Fig. 6F) and another with yellow band discontinuous in the middle and darker mandibles (Fig. 6G). This species has prominent plumose setae on infraepimeron unlike any other species (Fig. 6M).

Remarks: This new species resembles *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, **n. sp.**, by most diagnostic characters of the forewings, keirotrichial area in the inner surface of metatibia, curvature of strigillae of probasitarsus and erect dark brown setae on margin of mesoscutellum (Fig. 6H). However, they belong to the subgenera *Flavotetragonula* and *Tetragonula*, respectively, and can be easily differentiated. Yellow band on clypeus is absent in *T. travancorica*, while the same is present in *T. calophyllae*.

Description: Female (worker): Body length 3.4 mm (3.35–3.45 mm); forewing length, including tegula, 4.15 mm (4–4.15 mm); head length from anterior margin of clypeus to summit of vertex, in facial view 1.55 mm (1.52–1.85 mm); head width 1.77 mm (1.58–1.85 mm); length of scape 0.62 mm (0.62–0.64 mm); length of 2nd flagellomere 0.11 mm; length of 3rd flagellomere 0.12 mm; metatibia length 1.54 mm (1.49–1.59 mm); forewing diagonal from base of vein M to base of crossvein r-rs at margin of pterostigma 1.12 mm (1.01–1.12 mm).

Length of compound eye/length of scape ratio 1.9,

inter ocellar distance/ocellar diameter ratio 2.22-2.38. Ocellorobital distance/interocellar distance >0.5. Inter alveolar distance/ alveolar diameter ratio 1.1.

Length / width of head ratio 0.86-1.19, length / width of scape ratio 6.0-6.95, length / width of mandible ratio 3.13-3.33, length / width of 3rd tibia ratio 2.60-3.05, length of basitarsus / head width ratio 0.31-0.39, WL2/HW ratio 0.59-0.69, HTL/HW ratio 0.83-1, HTL/WL2 ratio 1.37-1.48, IOD/OOD ratio 1-1.73, malar space/F3 ratio 0.36-0.44, interalveolar distance / alveolar diameter ratio 1-1.3, alveolorobital distance/alveolar diameter ratio 1.45-2, IOD/OD ratio 2.22-2.38, length of mesoscutum/width of mesoscutum ratio 0.78-0.85, length of eye/ length of scape ratio 1.85-1.9. Clypeus with concave distal margin. Inner margin of mandible distinctly angulate proximal to middle. Strigillae on probasitarsus not uniformly curved.

Forewing with 2Rs, 1rs-m, 1m-cu, 3M, 4M, 1Cu, 2Cu, 3Cu, and 2cu-a (nebulous traces); wing membrane infuscate, highly fuscous in apical portion of radial cell; pterostigma length/width ratio 3.78 - 5.0; marginal cell narrowly open, Unculus absent on 4Rs; 3M tubular in basal half, then nebulous. Hind wing with 5 rotund hamuli; cubital cell nearly closed by weakly nebulous vein Cu-a; radial cell broadly open, r-sm faintly visible; median vein weakly curved and never bent (Figs. 3, 3A, 3B); proximal part of radial sector strongly nebulous and remaining weakly nebulous.

Metasoma broad, narrower than head; apex pointed, well telescoped into preceding segments; with setae on dorsal segments except on first two; first metasomal segment light brown; distal half of apical segment lighter.

Color: Integument, head black. Compound eyes orange brown. Clypeus black with yellow band apically. Labrum yellow brown. Mandibles golden yellow with black apex in light coloured morph; mandibles darker in darker morph. Ocelli light yellow to red. Scape dorsally dark brown to black, ventrally testaceous. Pedicel dark brown. First flagellomere yellow brown to dark brown dorsally, yellow brown ventrally. Flagellomeres with minute setae and pits,

dorsally dark, ventrally testaceous.

Thorax black. Plumose setae on thorax yellow brown, stout setae black. Tegula and wing sclerites dark brown, forewing veins, pterostigma dark brown. Wings hyaline. Trochanter yellow brown. Legs black; except tarsomeres brown, lighter towards apex. Penicillus, setae on tibia dark brown; plumose setae on tibia dull. Arolium black with white apex. Pleuron black with minute punctures. Mesoscutum, mesoscutellum, metanotum black. Propodeum black with punctures.

Pilosity: Head with dense plumose setae. Plumose setae denser below face and sparser on clypeus. Frons covered with sparse plumose setae. Labrum with long, short golden setae. Malar space black, without setae. Fine dull white setae on gena. Setae on vertex dark brown. Setae present on neck.

Setae on tegula dark brown. Mesoscutum with long stout black setae; with plumose setae forming indistinct hair bands. Anterior border of mesoscutum with plumose setae and stout setae. Mesoscutellum with dark stout setae along with yellow brown plumose setae on upper margin and light setae on lower margin. Anterior mesopleuron with plumose setae. Metapleuron with dense silvery setae. Infraepimeron with prominent plumose setae. Trochanter with white long spurs. Foretibia with short white, stout black setae on anterior side, posterior side with lamellate setae. Middle tibia with mixture of white setae, stout long black setae, yellow brown plumose setae. Hind tibia with long black stout setae, outer margin with brown plumose setae, keirotlichea on hind tibia silver white in color. Posterior region of hind basitarsus with yellow brown setae on medial line, basal seraceous area variable, less than half to more than half.

Male: Unknown

Material examined: Holotype: ♀ (worker): INDIA, KERALA, Kumbazha, P. Faseeh coll. 22-X-2017; **Paratypes:** 5 ♀ (worker): Same data as that for Holotype; 10 ♀ (worker): Attingal (nest inside hollow trunk of *Calophyllum inophyllum*), Shanas, S. coll. 21-III-2012; 6 ♀ (worker): Malayam. Shanas coll, 12-V-2016.

Distribution: INDIA (Kerala)

Conservation Status: Endangered (EN)

Remarks: The holotype was designated from type colony maintained by M.K.John, Manakkatumannil, Kumbazha, Pathanamthitta Dist., which had subsequently absconded, as reported by M. K. John. Type material was also collected from John's Beevalley and Anthuriums, Malayam (Thiruvananthapuram dist.) maintained by S. A. John and from a colony in existence for more than 30 years on a tree of *Calophyllum inophyllum* near the first authors residence at Attingal.

Etymology: The specific epithet is after the generic name of the endangered tree *Calophyllum inophyllum*, on which the first feral colony was observed.

Note on behavior and biology: The species displays more aggression than the common *T. travancorica* n. sp. when the colony is disturbed. Only very few surviving colonies were observed with beekeepers in Kerala. None of the beekeepers could succeed in splitting the colony of *T. calophyllae* n. sp. under captivity. Breeding behavior of this species still remains unknown. Their feral colonies are extremely rare in the wild. This species requires immediate attention for conservation.

Key to species of subgenus *Flavotetragonula* Shanás, subgen. n. of the Indian Subcontinent (based on workers)

1. Bodylengths less than 3.5mm.....2
— Bodylength greater than 6mm.....
Tetragonula (Flavotetragonula) gressitti
(Sakagami, 1978)
2. Erect setae on the margin of mesoscutellum dark brown (Fig. 6K); scape 6.45x longer than broad *Tetragonula (Flavotetragonula) calophyllae* Shanás and Faseeh, n. sp.
— Erect setae on the margin of mesoscutellum light brown; scape 7.38x longer than broad
Tetragonula (Flavotetragonula) praeterita
(Walker, 1860)

2. *Tetragonula (Tetragonula) perlucipinnae* Faseeh and Shanás, new species (Figs. 7 A-M)

LSID urn:lsid:zoobank.org:act:881821C5-157C-42D9-B5C2-919A9E9C2937

Diagnosis: The new species can be differentiated from all other species occurring in peninsular India and Sri Lanka by a comparatively more hyaline forewing without vein 2Rs (Fig. 7A); light brown erect setae on the margin of mesoscutellum (Fig. 7G) and uniformly curved strigillae on probasitarsus (Fig. 7F), when slide mounted, and evenly concave inner margin of mandible (Fig. 7M).

Description: Female (worker): Body length 3.25 mm (3.2–3.25 mm); forewing length, including tegula, 3.6 mm (3.4–3.65 mm); head length from anterior margin of clypeus to summit of vertex, in facial view 1.35 mm (1.29–1.39 mm); head width 1.48 mm (1.46–1.62 mm); length of scape 0.58 mm (0.56–0.58 mm); length of 2nd flagellomere 0.12 mm; length of 3rd flagellomere 0.12 mm; meta tibia length 1.41 mm (1.38–1.44 mm); forewing diagonal from base of vein M to base of cross vein r-rs at margin of pterostigma 1.02 mm (0.92–1.02 mm).

Length of compound eye / length of scape ratio 2, inter ocellar distance / ocellar diameter ratio 2.43–2.57. Ocello orbital distance / interocellar distance >0.5. Inter alveolar distance / alveolar diameter < or =1. Length/width ratio of head 1.1–1.26; length/width of scape ratio 6.24–7.49; length/width of mandible ratio 2.76–3.0, length/width of pterostigma 3.67–4.57, length/width ratio of 3rd tibia 2.75–3.11, length/width ratio of basitarsus 1.78–2, length of basitarsus / head width ratio 0.31–0.33, WL2/HW ratio 0.57–0.69, HTL/HW ratio 0.87–0.95, HTL/WL2 ratio 1.38–1.53, IOD/OD ratio 1.55–1.89, malar space / F3 ratio 0.25–0.3, Inter alveolar distance / alveolar diameter ratio 0.9–1, alveolar orbital distance / alveolar diameter ratio 1.6–1.89, IOD/OD ratio 2.43–2.57, length/width of mesoscutum ratio 0.78–0.85, length of eye/scape length ratio 1.94–2.01.

Distal margin of clypeus straight. Inner margin of mandible evenly concave. Strigillae on probasitarsus uniformly curved. Forewing with 1rs-m, 1m-cu, 3M, 4M, 1Cu, 2Cu, 3Cu, and 2cu-a (nebulous traces); 2Rs absent; wing membrane hyaline, lightly

infusate in apical portion of radial cell; pterostigma length/width ratio 3.67 - 4.57; marginal cell narrowly open, Unculus present on 4Rs; 3M tubular in basal half, then nebulous. Hind wing with 5 distal hamuli; cubital cell nearly closed by nebulous vein Cu-a; radial cell broadly open; vein r-m faintly visible; median vein distinctly angled (Figs. 7A); radial sector weakly nebulous.

Metasoma slightly flattened, narrower than head, tapering towards apex beyond first two segments.

Color: Head black, except, clypeus red brown. Compound eyes brown. Ocelli yellow brown. Scape dark brown, pedicel dorsally dark brown, ventrally ferruginous. First flagellomere yellow, remaining antennomeres brown dorsally and ferruginous ventrally, with minute setae and pits. Labrum brown. Mandibles amber colored with apical dark border. Malar space light brown. Gena black. Neck light brown.

Mesoscutum black, mesoscutellum light brown. Tegula, wing sclerites brown. Metanotum yellow brown. Pleuron red brown with minute punctures. Costal vein, pterostigma dark brown. Wing hyaline. Legs brown anteriorly, yellow brown posteriorly. Basitarsus brown, lighter towards apex of tarsomeres. Penicillium yellow brown. Arolium, black with white apex.

Propodeum red brown. First abdominal segment light brown, rest dark brown. Apical terga brown. All tergal segments with light border. Last abdominal terga yellow brown.

Pilosity: Labrum with long yellow brown setae and white short setae. Clypeus densely covered with plumose setae, frons sparsely covered with plumose setae, which do not obscure integument. Setae on vertex long, light brown. Gena with simple silvery setae. Neck with white simple setae.

Pronotal knobs with dense white plumose setae. Mesoscutum with bands of plumose setae, intermixed with a few light brown stout setae. Setae on mesoscutellum brown along upper margin, white in lower margin, both intermixed with dull white plumose setae. Pleura with silver white setae. Metapleuron with dense long silvered setae.

Anterior portion of mesopleuron with dense plumose setae, posterior part with less branched plumose setae. Infraepimeron with faintly plumose setae. Trochanter with white spurs. Keirotrichea white brown. Foretibia with white setae on anterior side, posterior side with lamellate setae. All setae on antenna comb of fore tibia, clearly visible. Middle tibia with mixture of both white and brown stout hairs along with white plumose hairs. Hindtibia with long stout brown setae, outer margin with white plumose setae. White setae anteriorly on median line of basitarsus. Basal seraceous area more than half length of basitarsus. Abdominal terga with setae except first two.

Male: Unknown

Material examined: Holotype: ♀ (worker): INDIA, KERALA, Ayarote, P. Faseeh, coll. 31-X-2017. **Paratypes:** 8 ♀ (worker): Same data as that for Holotype.

Remarks: The type material was collected from M.J. Beefarm of M.J. Kurian, Ayarote, Kasaragod. It is currently known only from the Type locality. The original 'Type colony' absconded, as reported by M.J. Kurian.

Distribution: INDIA (Kerala: Kasaragod)

Conservation status: Data Deficient (DD)

Etymology: The specific epithet is based on the latin words *perlucidulus* and *pinna*, alludes to the transparent wing.

3. *Tetragonula (Tetragonula) ruficornis* (Smith, 1870) (Figs. 8 A-G)

Notes on distribution: *Tetragonula (Tetragonula) ruficornis* is widespread in the north Indian plains, from Varanasi to Punjab. They are particularly well adapted to cold weather and probably this is the only species occurring in Northern Uttar Pradesh, Uttarakand, Haryana, Punjab and Delhi. Feral colonies were observed on trees near parks and undisturbed foreign embassy areas in south Delhi.

Remarks: This species can be easily visually distinguished from others by the presence of yellow tinge on antennae and yellow first abdominal

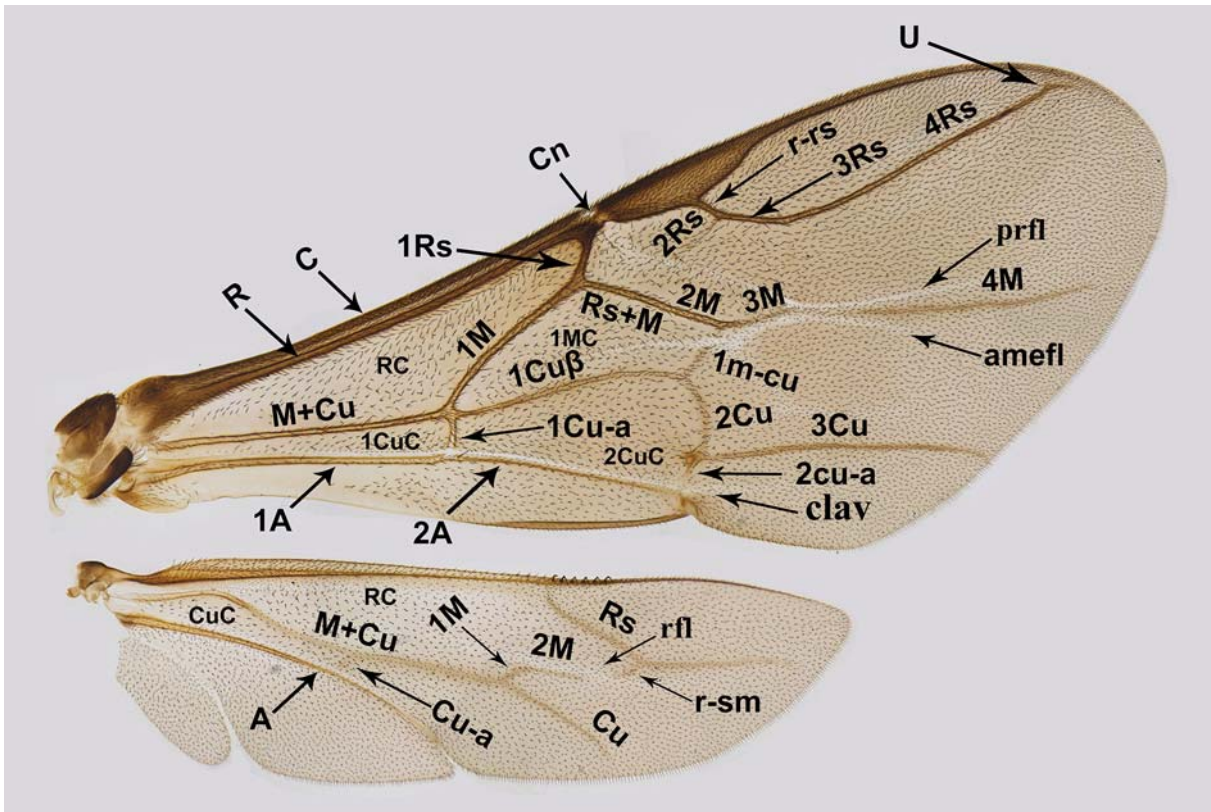


Fig. 1. *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, n. sp., fore- and hind wings illustrating wing veins and terminology. A - anal cross vein, amefl, anterior medial; C - Costa; Clav, clava; Cu - Cubitus; Cu-a - Cubito-anal; CuC - Cubital Cell; Cn - Costal notch; M - media; MC - Medial Cell; prfl, posterior radial flexion line; pmeffl, posterior medial flexion line; R - radius; RC - Radial Cell; rfl - radial flexion line; Rs - Radial sector; r-sm - radio-sub medial; U - Unculus.

segment (Figs. 8B, 8E). From the photographs given by Preeti *et al.* (2014) and Makkar *et al.* (2018), it is clear that they misidentified *T. ruficornis* as *T. iridipennis*.

Material examined: 10 ♀ (worker): INDIA, DELHI, R. K. Puram, Shanas. S, coll. 25-III-2018; 8 ♀ (worker): VARANASI, IIVR campus, Singh. N., 8-II-2019.

Distribution: INDIA (Uttarpradesh, Uttarakand, Haryana, Punjab, Delhi).

Conservation status: Near threatened (NT).

4. *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, new species (Figs. 9 A-J)

LSID urn:lsid:zoobank.org:act:10D7DD1A-D311-4B65-9961-65B6D2F88091

Diagnosis: The new species is distinguished from other Indian species of the subgenus by a strongly

nebulous radial vein on the hind wings (Fig. 9A) and dark brown erect setae on the margin of mesoscutellum (Fig. 9C). This species exhibits extreme phenotypic plasticity, however, they can be distinguished from *T. iridipennis* (Smith, 1854) by a comparatively longer (0.11-0.12mm) 2nd antennal flagellomere and other features given in the key to species.

Remarks: These are small to medium sized bees which exhibit varying number of wing hamuli (4 to 6) in symmetric or asymmetric pattern on either wing to the extent of >10 % variation in the population from the normal pattern of 5 hamuli each on both wings. This species is often confused with *T. iridipennis* (Smith, 1854) which is restricted to Sri Lanka. This species is easy to manage and widely multiplied as well as traded by the beekeepers of southern India.

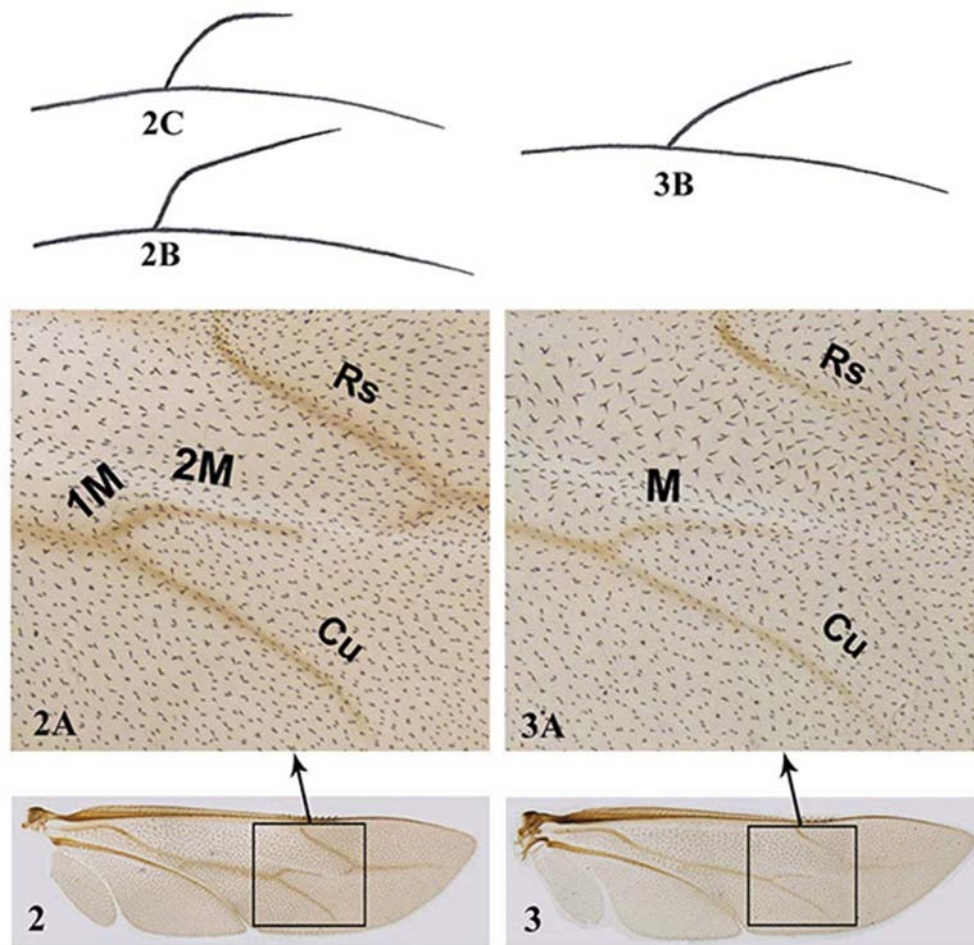


Fig. 2 & 3. Representative characters of the subgenera *Tetragonula* and *Flavotetragonula*. Fig. 2. Hindwing of *Tetragonula* (*Tetragonula*) *travancorica* Shanas and Faseeh, *n. sp.* 2A & 2B. Distinctly bent median vein in *T. travancorica* *n. sp.*; Fig. 2C. Strongly curved median vein in *T. ruficornis* (Smith, 1870). Fig. 3. Hindwing of *Tetragonula* (*Flavotetragonula*) *calophyllae* Shanas and Faseeh, *n. sp.* 3A & 3B. Weakly curved and never bent median vein in *T. calophyllae* *n. sp.*

Description: Female (worker): Body length 3.55–4.1 mm; forewing length, including tegula 3–4.25 mm; head length 1.29–1.52 mm; head width 1.62–1.82 mm; length of scape 0.53–0.64 mm; length of 2nd flagellomere 0.11–0.12 mm, length of 3rd flagellomere 0.13; metatibia length 1.4–1.9 mm; forewing diagonal from base of vein M to base of crossvein r-rs at margin of pterostigma 0.91–1.2 mm.

Length of compound eye/length of scape ratio 2, inter ocellar distance/ocellar diameter ratio 1.5–2.6. Ocellar orbital distance/inter ocellar distance ratio >0.5. interalveolar distance/alveolar diameter ratio 1.1.

Length/width of head ratio 0.82–1.2; length/width of scape ratio 5.14–6.95; length/width of mandible ratio 3.2–4.45; length/width of pterostigma ratio 4–5.7; length/width of 3rd tibia ratio 2.80–3.1, length of basitarsus / head width ratio 0.26–0.32; WL2/ HW ratio 0.57–0.63; HTL/HW ratio 0.86–1.05; HTL/WL2 ratio 1.43–1.67; IOD/OOD ratio 1.5–1.8; malar space/F3 ratio 0.27–0.33; interalveolar distance/alveolar diameter ratio 1.0–1.2; alveolorbital distance/alveolar diameter ratio 1.8–2; IOD/OD ratio 1.8–2.5; length /width of mesoscutum ratio 0.83–0.86; length of eye/scape length ratio 1.82–2.0.

Distal margin of clypeus very slightly concave. Inner

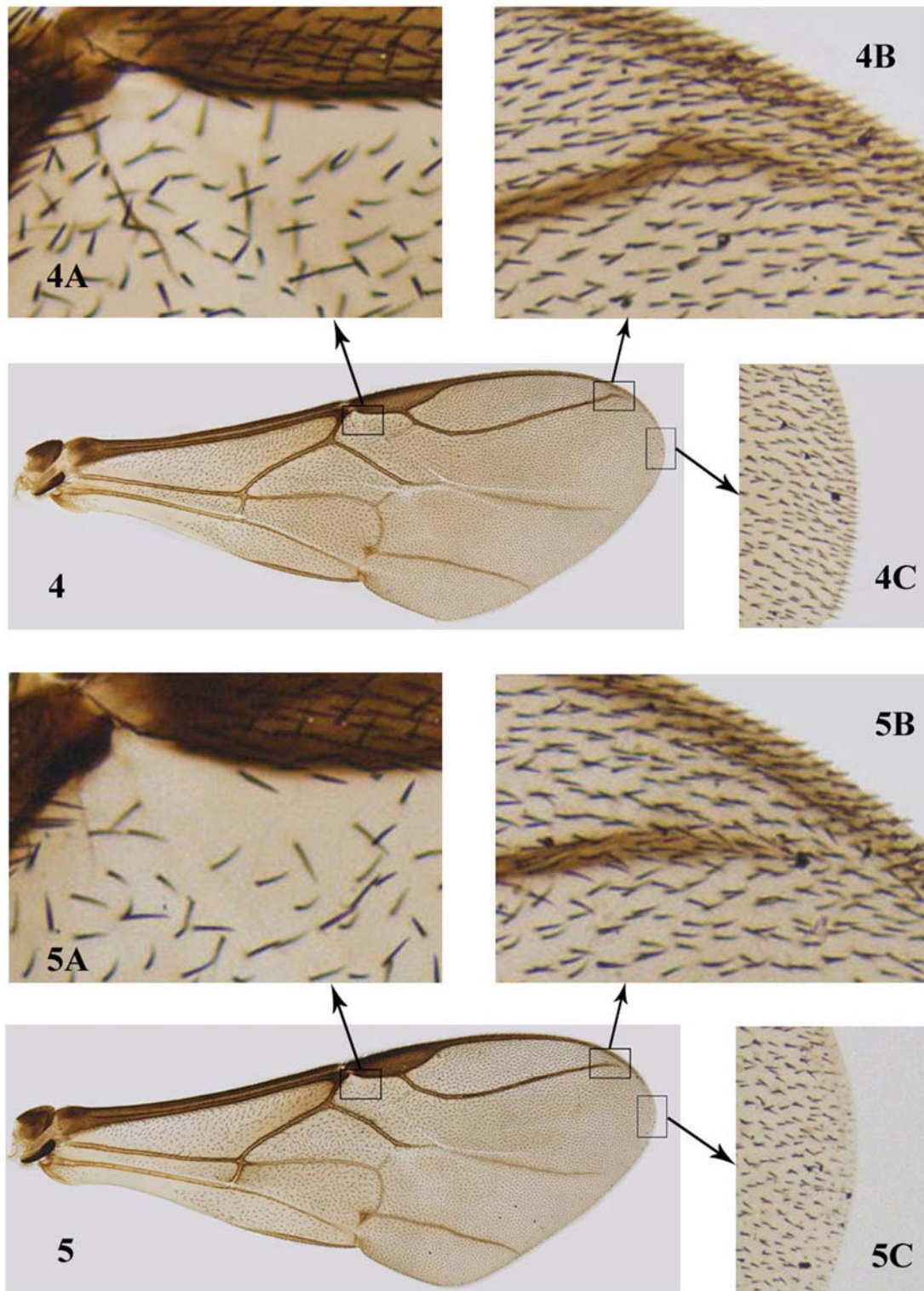


Fig. 4 & 5. Representative characters of the subgenera *Tetragonula* and *Flavotetragonula*. Fig. 4. forewing of *Tetragonula (Tetragonula) travancorica* n. sp. 4A - area beneath costal notch with microtrichia; 4B - unculus; 4C. wing apex; Fig. 5. forewing of *Tetragonula (Flavotetragonula) calophyllae* n. sp. 5A. area beneath costal notch without microtrichia; 5B - unculus. 5C - wing apex.

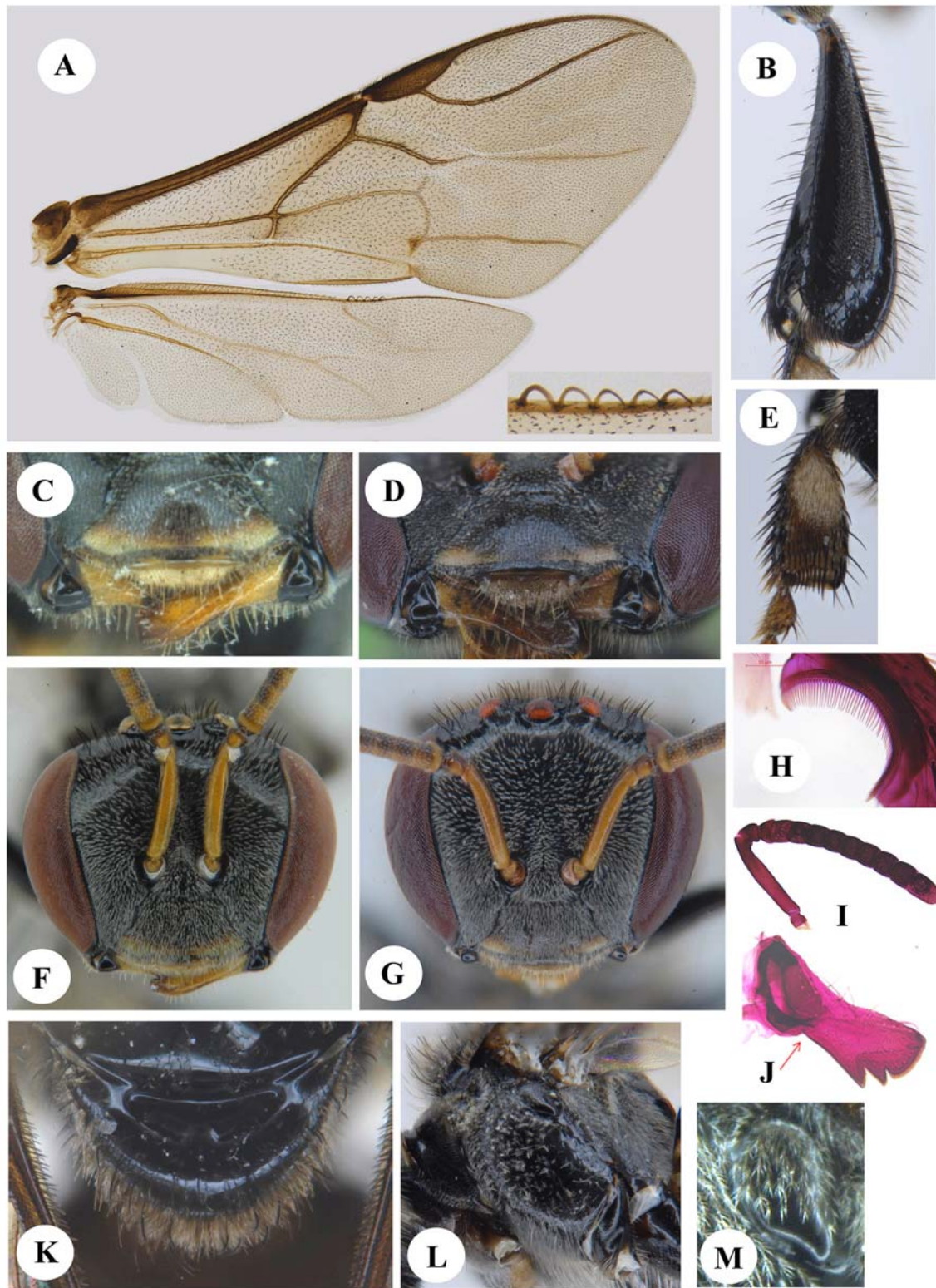


Fig. 6. Workers of *Tetragonula (Flavotetragonula) calophyllae* n. sp.. A. forewing, hindwing and hamuli; B. inner view of hind leg; C, D. lower frontal view of clypeus and mandible; E. inner surface of hind basitarsus; F, G. frontal view of head; H. strigillar concavity of the probasitarsus; I. antenna; J. mandible; K. dorsal view of mesoscutellum; L. mesepisternum; M. infraepimeron.

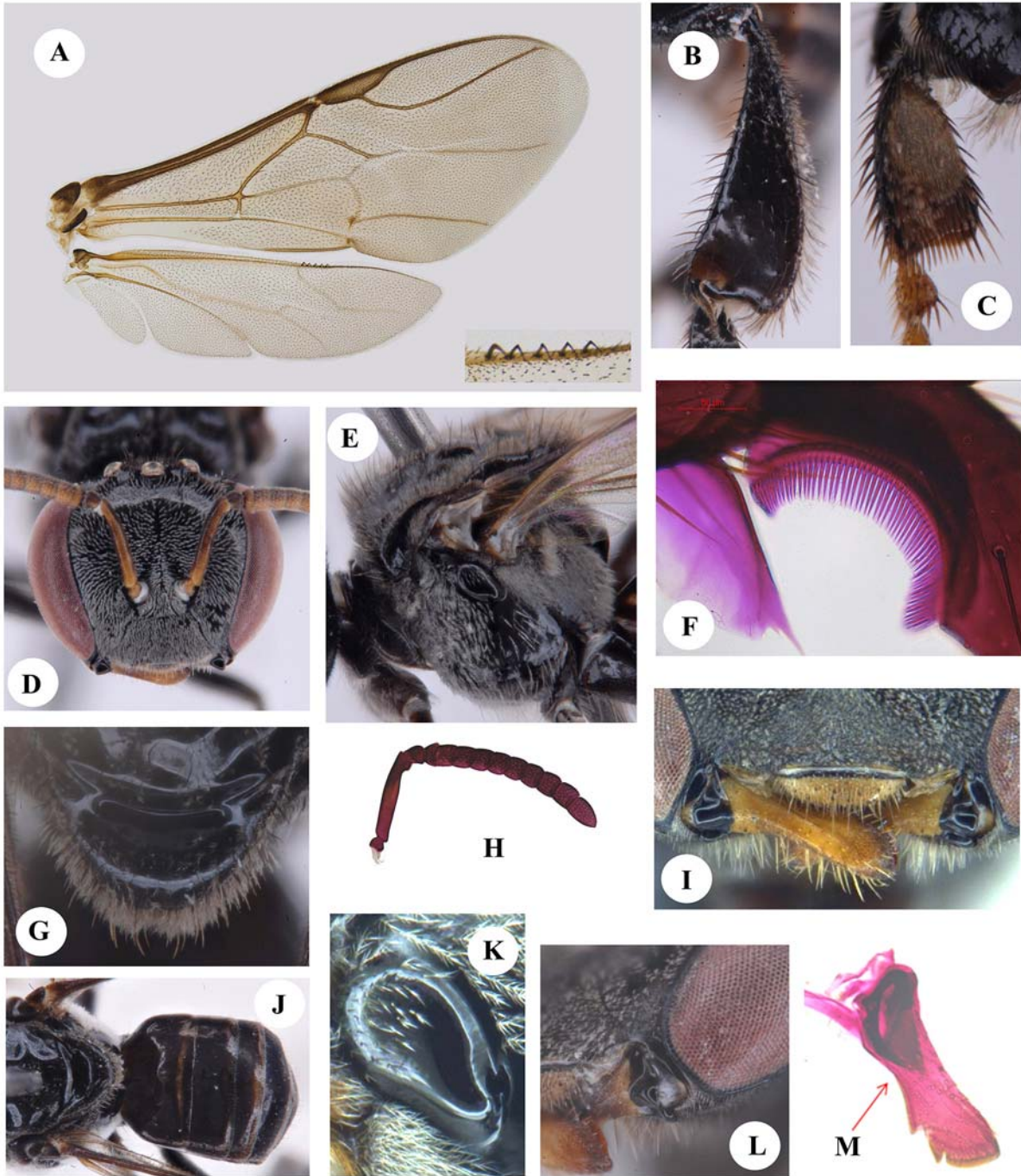


Fig. 7. Workers of *Tetragonula (Tetragonula) perlucipinnae* Faseeh and Shanas, **n. sp.** A. forewing, hindwing and hamuli; B. outer view of hind leg; C. inner surface of hind basitarsus; D. frontal view of head; E. mesepisternum; F. strigillar concavity of the probasitarsus; G. dorsal view of mesoscutellum; H. antenna; I. lower frontal view of clypeus and mandible; J. dorsal view of metasoma; K. infraepimeron; L. malar area; M. mandible.

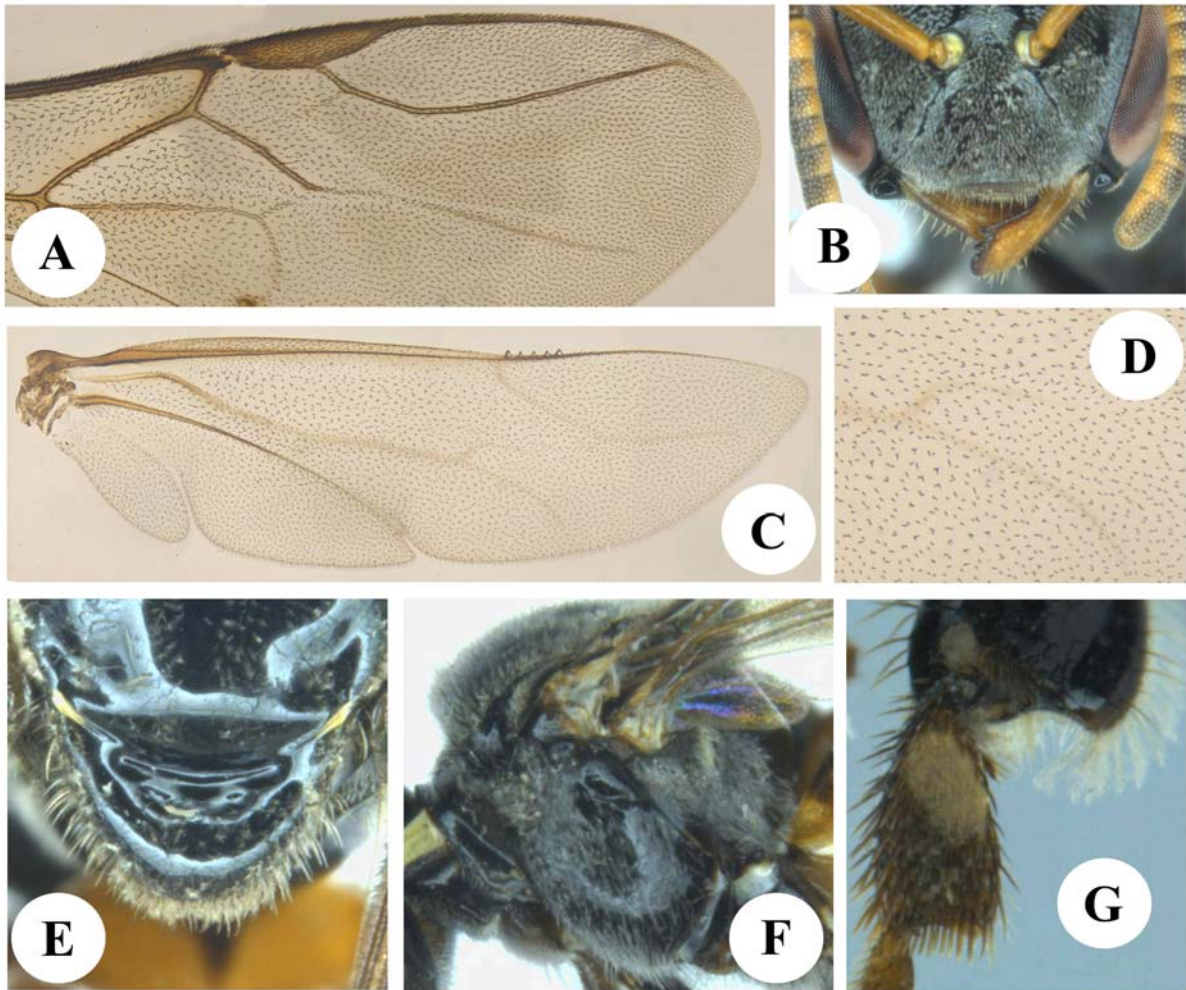


Fig. 8. Workers of *Tetragonula ruficornis* (Smith): A. forewing. B. lower frontal view of head. C. hindwing. D. media of hindwing. E. dorsal view of mesoscutellum F. mesepisternum. G. inner surface of hind basitarsus with sericeous area.

margin of mandible distinctly angulate proximal to middle. Strigillae on probasitarsus not uniformly curved.

Forewing with 2Rs, 1rs-m, 1m-cu, 3M, 4M, 1Cu, 2Cu, 3Cu, and 2cu-a (nebulous traces); wing membrane infusate (lightly infusate over most of membrane, darker in apical portion of radial cell); pterostigma length/width ratio 4 - 5.7; marginal cell narrowly open, Unculus present on 4Rs; 3M tubular in basal half, then nebulous. Hind wing with mostly 5 but sometimes variable distal hamuli (4-6) symmetric or asymmetric; radial and cubital cells nearly closed by nebulous veins; median vein distinctly angled (Figs. 2, 2A, 2B); radial vein entire and strongly nebulous. Metasoma broad, pointed

at apex and well telescoped in to preceding segments.

Color: Integument, head, neck, gena, clypeus, thorax black. Labrum yellow; mandibles golden brown with black apex; compound eyes red brown; ocelli brown; area between compound eyes and mandible slightly brown; malar area black; antenna brown to dark brown; depression on each flagellomere darker except on first. First flagellomere lighter; scape brown.

Tegula, wing sclerites brown; wing veins, pterostigma brown; wings hyaline. Legs red-dark brown with brown tarsomeres and penicillus; trochanter brown; mesotibial spur yellow. Arolium

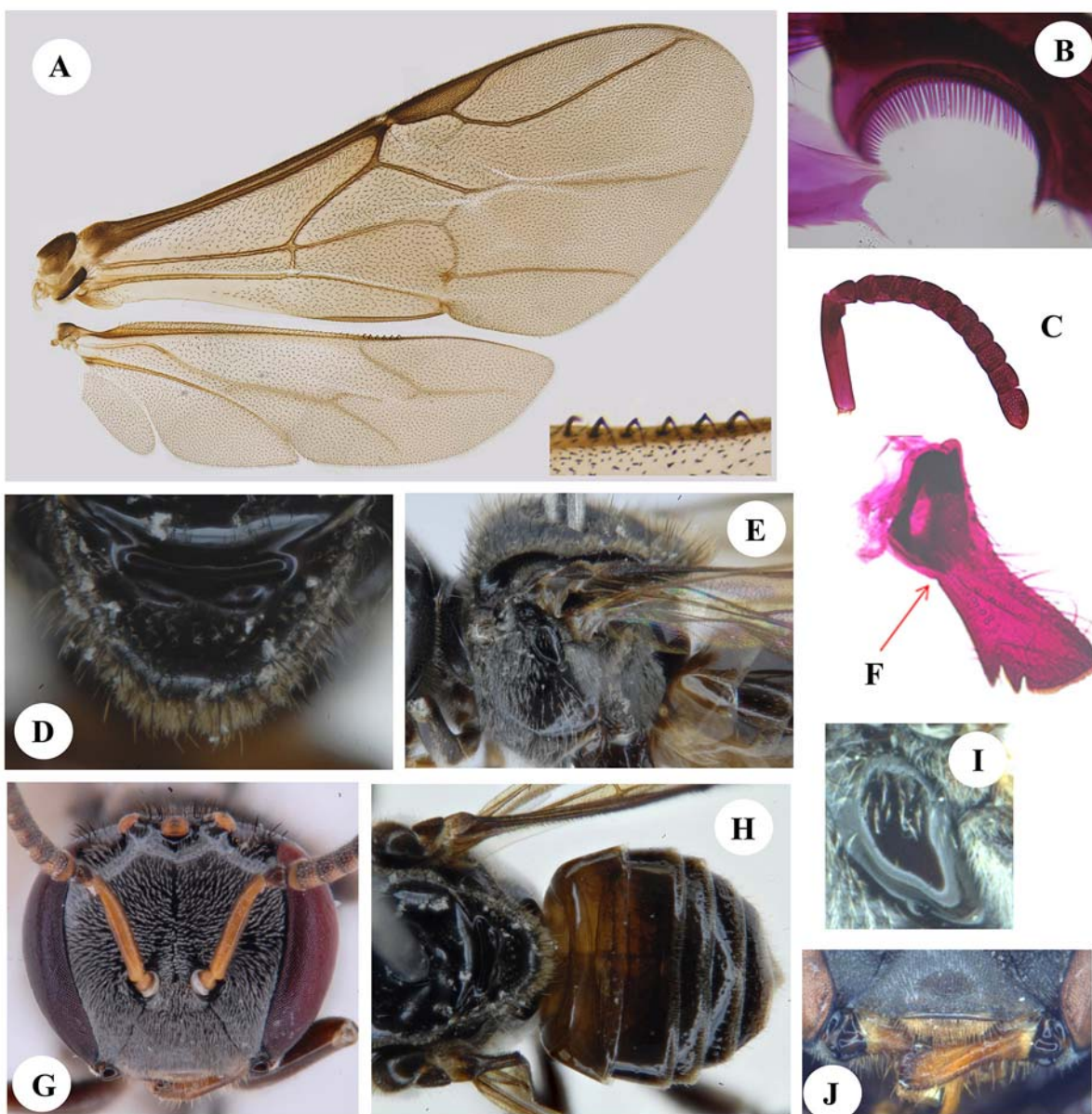


Fig. 9. Workers of *Tetragnula (Tetragnula) travancorica* Shanas and Faseeh, **n. sp.** A. forewing, hindwing and hamuli; B. strigillar concavity of the probasitarsus; C. antenna; D. dorsal view of mesoscutellum; E. mesepisternum; F. mandible; G. frontal view of head; H. dorsal view of metasoma; I. infraepimeron; J. lower frontal view of clypeus and mandible.

golden brown. Mesoscutellum, propodeum brown to black, metanotum lighter.

Metasoma darker towards apex; first two abdominal segments red brown, remaining ones darker; apical segment yellow to brown at apex, dark brown basally.

Pilosity: Head with dense plumose setae except on vertex. Setae on vertex stout and brown. Labrum

with brown to golden brown simple setae. Gena with light brown, fine setae. Neck with simple white setae.

Mesoscutum with white plumose setae. Seta bands very distinct with glabrous interspaces. Mesoscutellum with both dark brown simple and plumose setae. Setae on mesoscutellum and mesoscutum are almost similar in size. Metanotum

with short and dull brown setae. Anterior mesopleuron with white plumose setae. Plumose setae at the base of hind wing (metapleuron) is more denser than setae on anterior region. Infraepimeron with faintly plumose setae.

Lamellate setae present on posterior foretibia. Trochanter with white spurs. Femur and tibia with brown simple and white plumose setae. Seraceous area variable, less than half to more than half. Posterior region of hind basitarsus with simple brown setae on medial line. Setae absent on first two abdominal segments.

Males: Unknown

Material examined: Holotype: ♀ (worker): INDIA, KERALA, Kollam, Ambanad Estate. Faseeh P coll, 10-ii-2018; **Paratypes:** 20♀ (worker): Same data as that of Holotype; 20♀ (worker): Vellayani. Shanas, S. coll, 15-II-2015. 10♀ (worker): Attingal, Shanas, S. coll, 27-VI-2016; 12♀ (worker): KARNATAKA, Madikeri, Shanas, S. coll. 05-X-2004; 5♀ (worker): TAMIL NADU, Coimbatore, Shanas, S. coll. 20-V-2007.

Distribution: INDIA (Karnataka, Kerala and Tamil Nadu).

Conservation Status: Least concern (LC)

Etymology: This species is named after the erstwhile kingdom of Travancore.

Key to species of subgenus *Tetragonula* Moure, 1961 of the Indian Subcontinent (based on workers)

1. Vein M on hindwing distinctly bent (Figs. 2A, 2B); Unculus present (Figs. 4B, 7A, 9A) or indistinct on vein 4Rs of forewing.3
 - Vein M on hindwing strongly curved (Figs. 2C, 8D); Unculus absent (Figs. 8A) or indistinct on vein 4Rs of forewing2
2. Mesoscutellum 2.82x wider than long; basal sericeous area of hind basitarsus more than half of the length of basitarsus
 -*T. bengalensis* (Cameron, 1897)

- Mesoscutellum 2.09x wider than long; basal sericeous area of hind basitarsus less than half of the length of basitarsus (Fig. 8G)
 -*T. ruficornis* (Smith, 1870)
- 3. Vein 2Rs present on forewings (Fig. 9A); erect setae on margin of mesoscutellum dark brown, distal part of radial cell of forewing infuscate (Fig. 6A)..... 4.
 - Vein 2Rs absent on forewings (Fig. 7A); erect setae on margin of mesoscutellum light brown (Fig. 7G), distal part of radial cell of forewing very lightly infuscate (Fig. 7A); strigillae of probasitarsus uniformly curved when slide mounted (Fig. 7F)
 - ...*T. perlucipinnae* Faseeh and Shanas, **n. sp.**
- 4. Length of 2nd flagellomere 0.07 mm; width of mesoscutellum (0.57mm) 1.73x length of mesoscutellum (0.33mm); mandible uniformly coloured, without black apical area
 -*T. iridipennis* (Smith, 1854)
- Length of 2nd flagellomere (0.11-0.12) mm; width of mesoscutellum (0.74-0.91mm) 2.37-2.67x length of mesoscutellum (0.31-0.34mm); mandible with black apical area
 - ...*T. travancorica* Shanas and Faseeh, **n. sp.**

DISCUSSION

The hind wing venation has been consistently neglected by every major worker of the genus (Bingham, Engel, Moure, Rasmussen, Sakagami and Schwarz). The scattered mention to hindwing in most publications are, on the number of hamuli and size. Hind wing venation is vaguely referred to as ‘radial and cubital cells closed by nebulous veins’ (Engel and Rasmussen, 2017; Rasmussen *et al.*, 2017; Engel *et al.*, 2018). The “*laeviceps*” species group referred to by Sakagami, 1978, Rasmussen, 2010, 2013 (Neotype designated by Rasmussen and Michener, 2010) may contain a complex assemblage of species, mostly falling under the *Tetragonula* Moure, *Flavotetragonula* **n. subgen.**, and probably yet another undescribed new subgenus. A comprehensive classification of *Tetragonula*, Moure, 1961 can be attempted only

after proper study of each valid species based on hind wing venation.

The present study introduces three new species of stingless bees to the existing bee fauna of the Indian subcontinent, taking the total species of *Tetragonula* present in the Indian subcontinent to eight and in India to six viz., *Tetragonula (Flavotetragonula) calophyllae* Shanas and Faseeh, **n. sp.**; *Tetragonula (Flavotetragonula) gressitti* (Sakagami, 1978); *Tetragonula (Tetragonula) bengalensis* (Cameron, 1897); *Tetragonula (Tetragonula) perlucipinnae* Faseeh and Shanas, **n. sp.**; *Tetragonula (Tetragonula) ruficornis* (Smith, 1870) and *Tetragonula (Tetragonula) travancorica* Shanas and Faseeh, **n. sp.** The stingless bees of the Indian subcontinent are poorly explored unlike the Neotropical and Indomalayan fauna. Misinterpretation of stingless bee species is widespread in most publications from India, either by mentioning the wrong species name or by referring to species from outside the Indian subcontinent, which are not present in India. The studies conducted by several workers as well as most publications from India (reviewed by Rasmussen, 2013) indicates the presence of *Tetragonula iridipennis*, which probably refers to *T. travancorica* Shanas and Faseeh **n. sp.**, (in South India); *T. ruficornis* (Smith, 1870) in the North Indian plains (from Varanasi to Punjab) and many other known and unknown species (elsewhere in India). A thorough and critical review of all publications from India is necessary to assign the proper species name to all published works till date in-order to streamline the research on stingless bees in India.

Stingless bees exhibit varied biology and extremely divergent breeding habits. Proper studies on biology can be conducted only after proper identification of the species involved. Surveys carried out all over India by the first author has revealed the presence of stingless bees in most regions including higher elevations and drier interior regions in India.

Melponine species seem highly diverse in their ecological preferences. The restricted geographic

distribution observed among several species in the group may be attributed to their possible narrow range of temperature and floral preference. They are most speciose in the Indomalayan region where, several known and unknown species are probably facing the threat of extinction due to climate change. In India (except north east), several Meliponine species (described and undescribed), well adapted to harsh drier environment, do not seem to face an immediate threat due to climate change. Nevertheless, their distribution range may have been severely restricted due to landscape changes, burgeoning human population and lack of awareness among the general population regarding the identity of meliponines and their importance as pollinators. Transnational collaborative research, focused on systematics, ecology and biology of the species is essential for conservation and sustainable geographic re-deployment of these enigmatic pollinators.

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REFERENCES

- Bingham C. T. (1897) Hymenoptera. Vol. I. Wasps and bees. In: Blandford, W.T. (Ed.), The fauna of British India, including Ceylon and Burma. Taylor and Francis, London, XXIX + 579 pp. + 4 pls.
- Cameron P. (1897) Hymenoptera orientalia, or contributions to a knowledge of the Hymenoptera of the Oriental zoological realm. Part 5. Memoirs and Proceedings of the Manchester

- Literary and Philosophical Society 41 (4): 1–144, +2 pls.
- Engel M. S. (2001) A monograph of the Baltic amber bees and evolution of the Apoidea (Hymenoptera). *Bulletin of the American Museum of Natural History* 259: 1–192.
- Engel M. S. and Rasmussen, C. (2017) A new subgenus of Heterotrigona from New Guinea (Hymenoptera: Apidae). *Journal of Melittology* 73: 1–16.
- Engel M. S., Kahono S. and Pegg D. (2018) A key to the genera and subgenera of stingless bees in Indonesia (Hymenoptera: Apidae). *Treubia* 45: 65–84.
- Engel M. S., Michener C. D. and Boontop Y. (2017) Notes on Southeast Asian stingless bees of the genus *Tetragonula* (Hymenoptera: Apidae), with the description of a new species from Thailand. *American Museum Novitates* 3886: 1–17.
- Huber J. T. and Sharkey M. J. (1993) Structure, pp. 13–59. In Goulet, H. and Huber, J.T. (eds.). *Hymenoptera of the World: An Identification Guide to Families*. Research Branch, Agriculture Canada, Ottawa, Publication 1894/E, 668 pp.
- IUCN (2019) IUCN Red List Categories and Criteria version. <https://www.iucnredlist.org/>
- Makkar G. S., Chhuneja P. K and Singh J. (2018) Stingless Bee, *Tetragonula iridipennis* Smith, 1854 (Hymenoptera: Apidae: Meliponini): Molecular and Morphological Characterization. *Proceedings of National Academy of Science, India, Section B Biological Science* 88(1): 285–291.
- Mason W. R. M. (1986) Standard drawing conventions and definitions for venational and other features of wings of Hymenoptera. *Proceedings of the Entomological Society of Washington* 88(1): 1–7.
- Michener C. D. (2007) *The bees of the world* [2nd ed.]. Baltimore: Johns Hopkins University Press, xvi + [i] + 953 pp., +20 pls.
- Moure J. S. (1961) A preliminary supra-specific classification of the Old World meliponine bees (Hymenoptera, Apoidea). *Studia Entomologica* 4 (1–4): 181–242.
- Preeti S. V., Shivam S. and Uniyal V. P. (2014) Building Walkways: Observation on Nest Duplication of Stingless Bee *Trigona iridipennins* Smith (1854). *Ambient Science* 1(1): 38–40.
- Rasmussen C. (2008) Catalog of the Indo-Malayan / Australasian stingless bees (Hymenoptera: Apidae: Meliponini). *Zootaxa* 1935: 1–80.
- Rasmussen C. (2013) Stingless Bees (Hymenoptera: Apidae: Meliponini) of the Indian subcontinent: Diversity, taxonomy and current status of knowledge. *Zootaxa* 3647(3): 401–428
- Rasmussen C. and Michener C. D. (2010) The identity and neotype of *Trigona laeviceps* Smith (Hymenoptera: Apidae). *Journal of the Kansas Entomological Society* 83: 129–133.
- Rasmussen C., Thomas J. C. and Engel M. S. (2017) A new genus of Eastern Hemisphere stingless bees (Hymenoptera: Apidae), with a key to the supraspecific groups of Indomalayan and Australasian Meliponini. *American Museum Novitates* 3888: 1–33.
- Rathor V. S., Rasmussen C. and Saini M. S. (2013) New record of the Stingless Bee *Tetragonula gressitti* from India (Hymenoptera: Apidae: Meliponini). *Journal of Melittology* 7: 1–5.
- Sakagami S. F. (1978) *Tetragonula* stingless bees of the continental Asia and Sri Lanka (Hymenoptera, Apidae). *Journal of the Faculty of Science, Hokkaido University, Series 6, Zoology* 21 (2): 165–247, +1 pl. [pl. v].
- Smith F. (1854) Catalogue of the Hymenopterous insects in the collection of the British Museum. Part II, Apidae. British Museum (Natural History), London, pp. 199–465 + pls. 7–8.
- Walker F. (1860) Characters of some apparently undescribed Ceylon insects. *Annals and Magazine of Natural History* (3) 5 (28): 304–311.