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continued on the back inside cover

Cover: Green Bee-eater with colour pencils and watercolor wash by Elakshi Mahika Molur.



INTRODUCTION

Termites are widely spread group of insects that fall under the infra-order Isoptera and order Blattodea (Inward et al. 2007; Krishna et al. 2013a). Worldwide, around 2,933 living species of termites have been reported under 282 genera that belong to nine families (Krishna et al. 2013a). Family wise Termitidae is the largest among all the families and comprises of 2,077 species globally that belong to seven subfamilies. Among the subfamilies, Nasutitermitinae is the second largest with around 77 genera and 596 species reported from all over the seven biogeographic regions of the world (Krishna et al. 2013a). Nasutitermitinae group inhabits a variety of ecological conditions with diverse nesting and feeding habits (Eggleton 2000).

The genus *Bulbitermes* is the third largest genus (in species diversity) under the subfamily Nasutitermitinae and is endemic to the Oriental region (Chhotani 1997; Krishna et al. 2013a). It is a dead wood or plant material feeding nasutiform genus (Chuah 2005; Syaukani & Thompson 2011). This genus is similar to genus *Hospitalitermes* with constricted head behind antenna, mandibles with spine like processes and with more than 12 antennal segments in soldier castes. But the genus *Bulbitermes* differ from *Hospitalitermes* with comparatively less constricted head behind the antenna, mandibles with slightly shorter spine like processes and with hind legs not extending beyond the abdomen in soldiers (Chhotani 1997). The genus *Bulbitermes* comprises of 33 species. The Indian region (India, Bangladesh, Pakistan, Sri Lanka, Bhutan, Nepal, and Burma) houses four *Bulbitermes* species, viz., *B. pyriformis* Akhtar, 1975 (From Bangladesh), *B. prabhae*, Krishna, 1965 (From Burma), *B. bulbiceps* Maiti & Saha, 2000 (from Assam, India), and *B. parapusillus* Ahmad, 1965 (from Meghalaya, India) (Krishna et al. 2013b).

In this paper, we describe a new *Bulbitermes* species, *Bulbitermes debadiliporum* sp. nov., based on its monomorphic soldier and dimorphic worker (worker major and minor) castes from Meghalaya, India.

MATERIALS AND METHODS

The samples used in this study were collected from the betel nut plantation of Mawlynnong area, Pynursla, East Khasi Hills district and Nongkhrah village, Nongpoh, Ri-Bhoi district of Meghalaya, India. The collection was done using brush and forceps or handpicking and was preserved at 80% alcohol in the laboratory for further

studies. All the type specimens (Holotype & Paratypes) of this study are deposited in the national repository of Zoological Survey of India at the North Eastern Regional Centre, Shillong (ZSI, NERCS), Meghalaya, India. Voucher specimens are preserved in the research collection of entomology laboratory, Department of Zoology, North-Eastern Hill University (NEHU), Shillong, Meghalaya, India.

Leica Stereo Zoom microscope S8AP0 fitted with GT 5.0 camera and mosaic V.2 photographic software was used to take the micrographs of the samples. Measurements were taken on the micrographs using Image J software (2018 version) and were also cross checked with the ocular micrometer fitted with the microscope.

Morphological studies of the soldier and worker castes and also all measurements, terminologies and indices were based on Roonwal & Chhotani (1989). Identification of the species was done following the available literature of Ahmad (1965), Chhotani (1997), and Syaukani & Thompson (2011).

RESULTS

Taxonomic account

Infra-order: Isoptera Brullé, 1832

Family: Termitidae Latreille, 1802

Subfamily: Nasutitermitinae Hare, 1937

Genus: *Bulbitermes* Emerson, 1949

Bulbitermes debadiliporum sp. nov.

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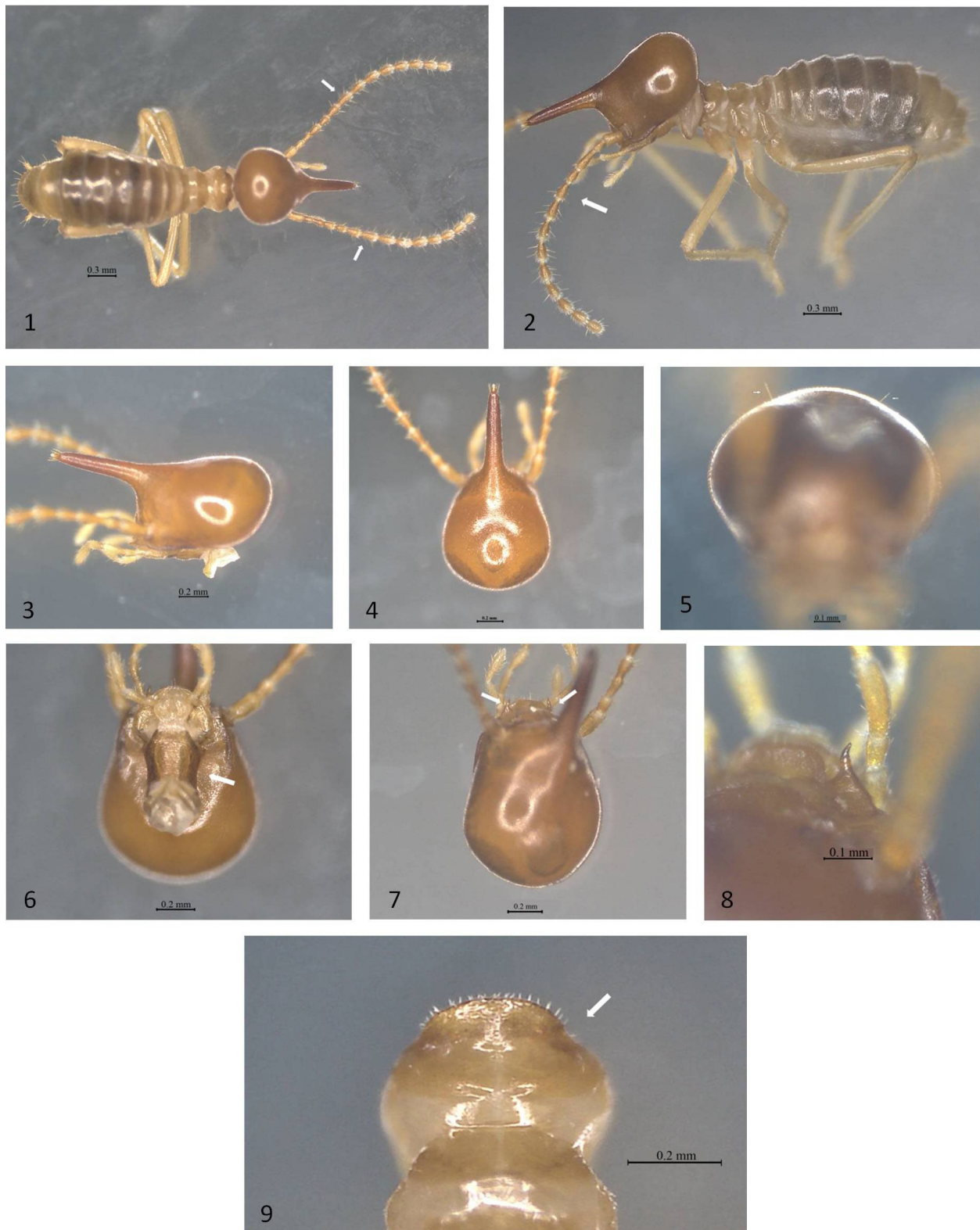
(Images 1–9)

TYPE MATERIALS

Holotype: I/ISOP/ERS/4431, Soldier, 20.xii.2018. The holotype was collected from a carton nest from the betelnut plantation of Mawlynnong area of Pynursla, East Khasi Hills District of Meghalaya, India (25.2047°N, 91.9112°E; elevation 530 m), coll. K.S. Das; deposited in ZSI, NERCS.

Paratypes: I/ISOP/ERS/4432: 17 soldiers and 7 workers (5 workers major and 2 workers minor), same data as holotype.

Other materials studied: ISOP/ZOO/NEHU/100: 18 soldiers and 3 workers major, 20.vi.2018. Collected from dry bamboo plant, Nongkhrah village, Nongpoh, Ri-Bhoi district, Meghalaya, India (25.9270°N, 91.8917°E; elevation 587 m), coll. K.S. Das and party; preserved in the Department of Zoology NEHU, Shillong. ISOP/ZOO/



Images 1–9. Soldier of *Bulbitermes debadiliporum* sp. nov. (Holotype—1,3,4,6,7,9; Paratypes—2,5,8): | 1—soldier with 14 segmented antenna (marked) in dorsal view | 2—soldier with 13 segmented antenna (marked) in lateral view | 3—Head in lateral view | 4—Head in dorsal view | 5—long bristles posteriorly on head capsule (marked) | 6—postmentum (marked) | 7—left and right mandibular apical processes (marked) | 8—right mandibular apical process in higher magnification | 9—pronotum (marked). © Khirad Sankar Das.

NEHU/120: 21 soldiers and 8 workers major, 17.x.2018 and ISOP/ZOO/NEHU/121: 12 soldiers, 17.x.2018, samples collected from the same area as mentioned above by same collector and preserved in Department of Zoology, NEHU, Shillong.

DESCRIPTION

Imago: Unknown

Soldier (Images 1–9, Table 1): Monomorphic. Head is pear shaped without rostrum and slightly constricted behind antennae. In colouration, head brown to rusty brown (in middle & posterior portion) to dark smoky brown (in anterior portion and lateral posterior ends). In dorsal profile, head weakly depressed behind rostrum, faintly concave, posterior margin roundly convex, two long bristles present on posterior end of head capsule. Fontanelle gland and tube visible. Rostrum cylindrical and darker than head with reddish-brown (proximal portion) to dark reddish-brown (distal portion) in colour. Tip portion with four long bristles and somewhat hyaline at end. Rostrum length usually more than the half of head length without rostrum and in some cases less than or equal to $\frac{3}{4}$ of head length without rostrum. Mandible vestigial with prominent long apical processes. Length of spine like apical processes slightly varies among the soldiers and right mandible without any minute tooth. Antennae generally 14 segmented (sometimes 13 segmented) and yellowish-brown to brown in colour. Segments vary in length. In 13 segmented ones, 2nd shortest, 3rd twice as long as 2nd, 3rd longer than 4th and 5th, 5th longer than 4th. In 14 segmented ones, 2nd shortest or subequal to 3rd, 4th longer than 3rd (sometimes 3rd longer than 4th). Pronotum saddle shaped, indistinctly emarginated anteriorly and posteriorly. In colour, pale brown to brown. Anterior lobe darker than posterior and minute hairs present on anterior margin. Legs pale brown to straw in colour. Abdominal tergites pale brown in colour with long bristles on posterior tergites; sternites brownish-yellow in colour with long and short bristles.

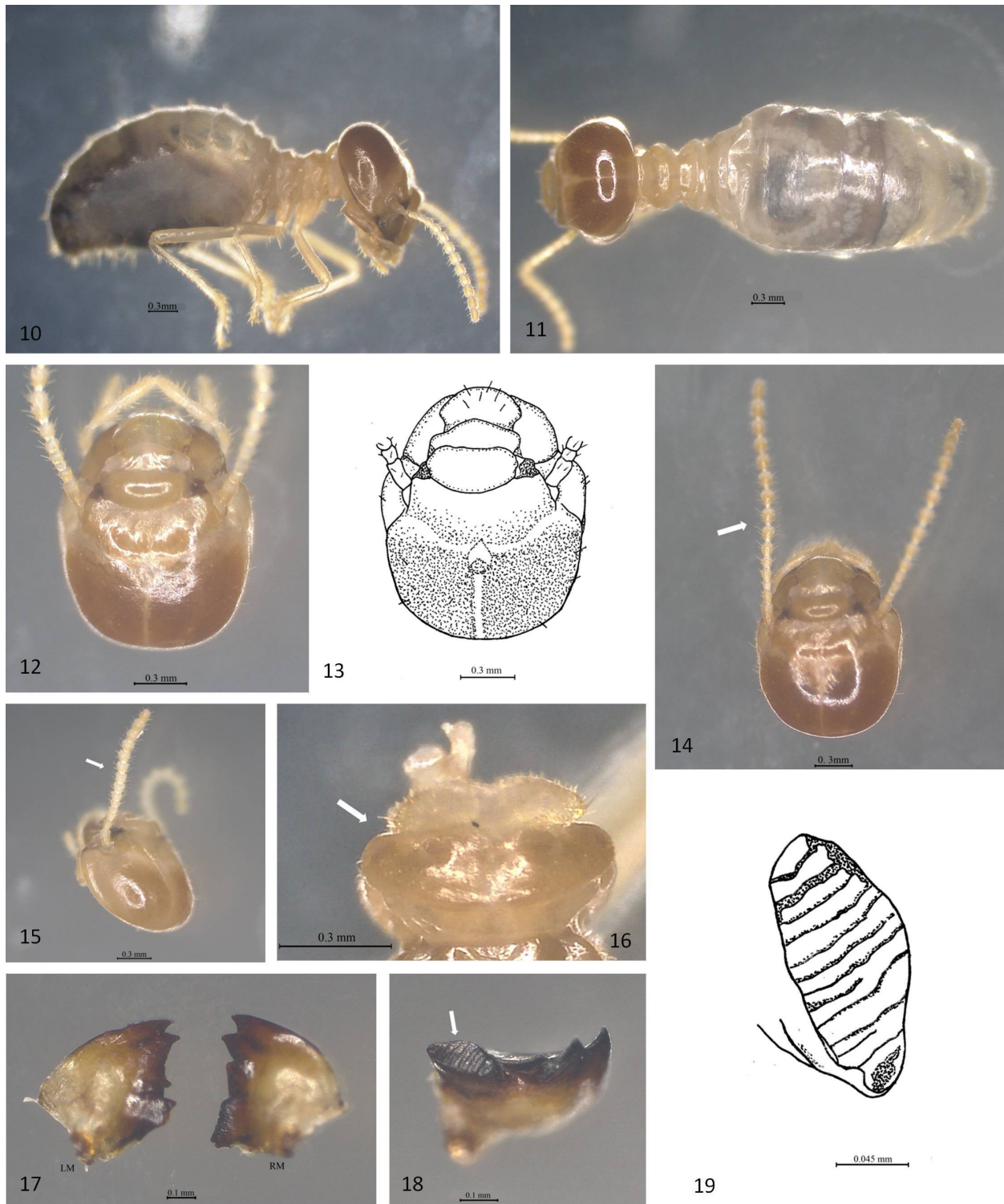
Worker: Dimorphic. Worker major (Images 10–19; Table 2): Head subsquarish in shape; light brown with yellowish tinge to dark brown in colour and fairly pilose. Epicranial Y-suture distinct. Fontanelle plate prominent, oval. Postclypeus swollen, hairy and divided into two equal halves by the median suture. In length, less than half of its width. Antennae pale yellow to pale yellowish brown in colour and 14–15 segmented. In 14 segmented ones, 4th shortest, 2nd subequal to 3rd or longer than 2nd and 3rd. In 15 segmented ones, 3rd shortest or subequal to 4th, 2nd longer or subequal to 4th. Mandibles with

apical and 2–3 marginal teeth. Left mandible with prominent apical and 3 marginal teeth. Apical tooth and 1st marginal tooth form an acute angle between them. Posterior margin of 1st marginal slightly sinuate. Second and third marginal teeth small and prominent. Third marginal slightly longer than second and separated by wide U-shaped gap from molar prominence. Molar plate with four prominent ridges. Right mandible with 1 apical and 2 marginal teeth. Apical and first marginal teeth slightly boarder than left mandible ones. Apical tooth and 1st marginal tooth form an obtuse angle between them. Second marginal tooth small, with a blunt apex, posterior edge nearly straight. Molar plate with 10 well developed prominent ridges. Inner layer of molar plate undeveloped and proximal notch of molar plate weakly developed. Thorax pale yellowish in colour. Pronotum saddle shaped, faintly emarginated at anterior and indistinctly emarginated at posterior. In colouration, light brown to brown and slightly lighter than colour of head. Anterior lobe darker than posterior and minute hairs present on anterior margin along with two long bristles on lateral sides each. Legs straw in colour. Abdominal tergites pale brown in colour with long bristles only on posterior tergites; sternites brownish-yellow in colour with long and short bristles.

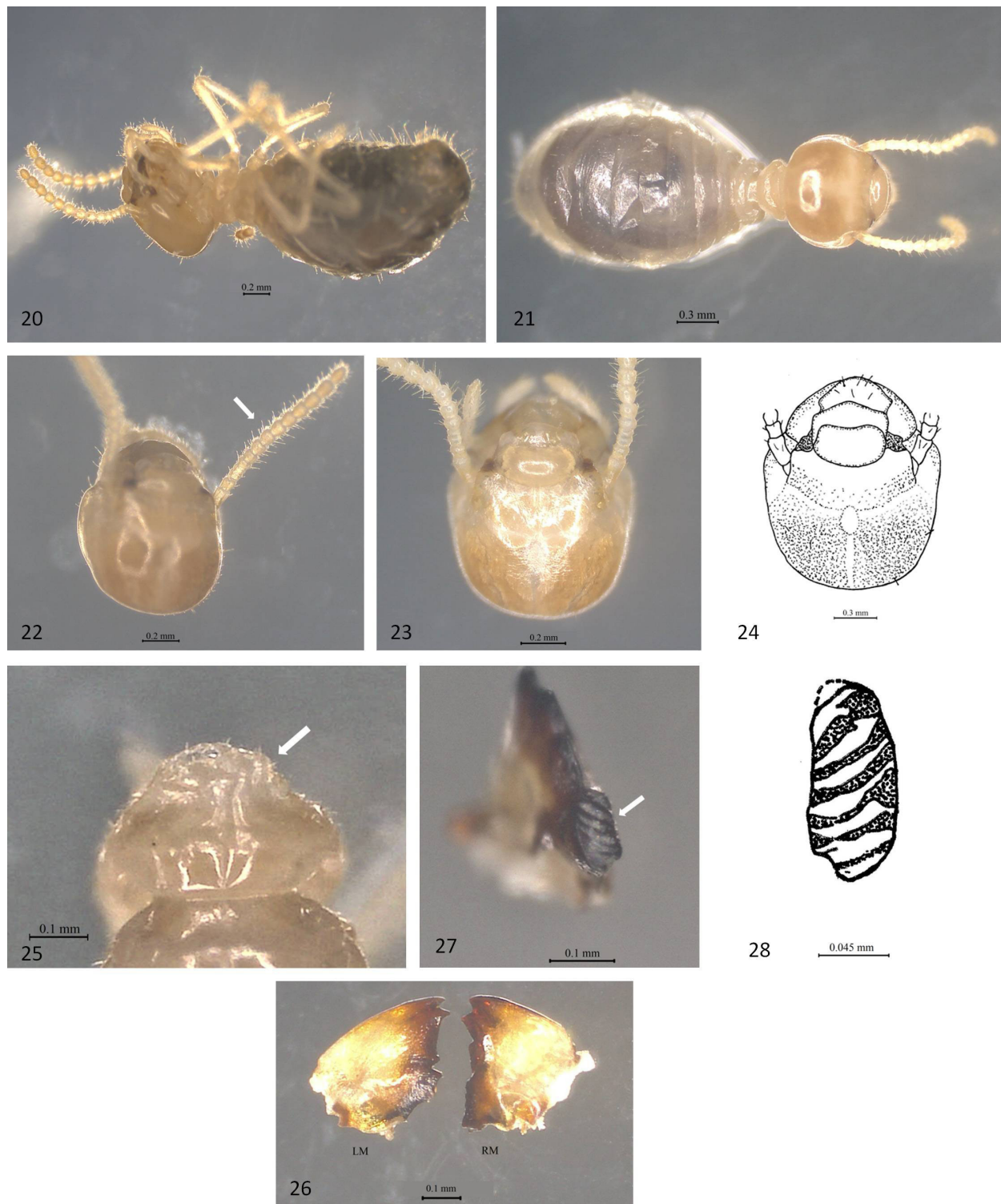
Worker minor (Images 20–28; Table 2): Similar with worker major but smaller in size. Antenna only 14 segmented, 4 shortest, 2 subequal to 3 or longer than 3. Mandibles with apical and 2–3 marginal teeth, smaller in size than worker major. Apical and first marginal teeth less pointed than in worker major. Left mandible with apical and 3 marginal teeth, prominent. Apical tooth slightly shorter than 1st marginal tooth with an acute angle between them. Posterior margin of 1st marginal slightly sinuate. Second and third marginal small and prominent. Second marginal tooth broader than the left mandible ones of worker major. Third marginal slightly longer than second and separated by V-shaped gap from molar prominence. Molar plate with four prominent ridges. Right mandible with 1 apical and 2 marginal tooth. Apical tooth shorter and pointed than the 1st marginal and form an obtuse angle between them. Second marginal tooth small with a blunt apex, posterior edge nearly straight. Molar plate with six well developed prominent ridges.

Comparison

The termite species *Bulbitermes debadiliporum* sp. nov., in its morphological characteristics and morphometrics (Table 1 and 2) of the soldier and worker castes, shows slight similarity with other *Bulbitermes*



Images 10–19. Worker major of *Bulbitermes debadiliporum* sp. nov. (Paratypes): 10—whole body in lateral view | 11—whole body in dorsal view | 12—head in dorsal view | 13—head in dorsal view (line diagram) | 14—worker with 15 segmented antenna (marked) | 15—worker with 14 segmented antenna (marked) | 16—pronotum (marked) | 17—right mandible (RM) and left mandibles (LM) | 18—right mandible molar plate ridges (marked) | 19—right mandible molar plate ridges (line diagram). © Khirud Sankar Das.



Images 20–28. Worker minor of *Bulbitermes debadiliporum* sp. nov. (Paratypes): 20—whole body lateral view | 21—whole body dorsal view | 22—Antenna (marked) | 23—Head dorsal view | 24—head dorsal view (line diagram) | 25—pronotum (marked) | 26—right mandible (RM) and left mandibles (LM) | 27—right mandible molar plate ridges (marked) | 28—right mandible molar plate ridges (line diagram). © Khirod Sankar Das.

species of Indian region (Chhotani 1997), Thailand (Ahmad 1965) and Sumatra (Syaukani & Thompson 2011) but differ significantly in the key taxonomic characteristics which separate this species from the rest as a new *Bulbitermes* species.

Bulbitermes debadiliporum is closely related to *B. prabhae* in its morphological characteristics. But, the soldiers of *B. debadiliporum* have two long hairs on the head posteriorly whereas *B. prabhae* without hairs. Antennae are 14 segmented in *B. prabhae* where segment 3rd is longer than 4th whereas 13–14 segmented in *B. debadiliporum* with segment 3rd shorter than 4th in 14 segmented antennae. No minute inconspicuous tooth observed below the tip of the apical process of the right mandibles in *B. debadiliporum* unlike *B. prabhae*. Morphometrics of soldier such as head length with and without rostrum, head width and rostrum length etc. are also vary slightly between the species.

In comparison to *B. parapusillus*, the head length with rostrum (1.17–1.52 mm), without rostrum (0.78–1.08 mm), head width (0.67–0.88 mm), and rostrum length (0.53–0.60 mm) of *B. parapusillus* are less than *B. debadiliporum*. Antennae with only 13 segments in *B. parapusillus* whereas 13–14 segmented in *B. debadiliporum*. Workers monomorphic in *B. parapusillus* with only 14 segmented antenna whereas dimorphic (with worker major and minor) in *B. debadiliporum* and with 14–15 segmented antenna.

In case of *B. pyriformis*, the head length with rostrum (1.28–1.59 mm), head length without rostrum (0.78–0.98 mm) and head width (0.64–0.85 mm) are less in both the upper and lower range values than *B. debadiliporum*. Antennae with 12–13 segments in *B. pyriformis* whereas 13–14 segmented in *B. debadiliporum*. Pronotum not notched or emarginated at the anterior and posterior margins in *B. pyriformis* whereas in *B. debadiliporum* indistinctly emarginated.

In contrast to *B. bulbiceps*, the soldier of *B. debadiliporum* is larger in size than *B. bulbiceps* (2.90–3.15 mm). Antennae are with only 12 segments in *B. bulbiceps* whereas in *B. debadiliporum* antennae are 13–14 segmented. Rostrum is shorter in length in *B. bulbiceps* (0.42–0.46 mm) than *B. debadiliporum*. Mandible without any apical process or tooth in *B. bulbiceps* in contrast to the long spine like apical processes of *B. debadiliporum*. Head length with rostrum (1.10–1.26 mm), head width at constriction (0.43–0.48 mm), head height (0.46–0.54 mm), head width a constriction/ Head width index (0.58–0.60), postmentum length (0.18–0.21 mm), postmentum width (0.24–0.26 mm), pronotum width (0.30–0.34 mm), pronotum length (0.11–0.12

Table 1. Morphometrics (in mm) of soldiers of the termite species *Bulbitermes debadiliporum* sp. nov.

Characteristics	Holotype	Range (n = 18)
Total body length	3.69	3.14–4.70
Head length with rostrum	1.60	1.51–2.00
Head length without rostrum	0.93	0.87–1.25
Head width	0.85	0.75–1.22
Head width / Head length without rostrum	0.91	0.86–0.98
Rostrum length	0.67	0.61–0.80
Rostrum length / Head length without rostrum	0.72	0.55–0.78
Head width at constriction	0.58	0.57–0.69
Head width at constriction / Head width	0.68	0.58–0.78
Head Height	0.66	0.55–0.81
Pronotum length	0.22	0.18–0.28
Pronotum width	0.46	0.42–0.55
Postmentum length	0.35	0.27–0.35
Postmentum width	0.31	0.28–0.36

Table 2. Morphometrics (in mm) of worker major and worker minor of the termite species *Bulbitermes debadiliporum* sp. nov.

Characteristics	Worker major (n = 5)	Worker minor (n = 2)
Total body length	3.20–5.90	2.65–2.78
Head length	0.87–1.25	0.68–0.74
Head width	1.04–1.40	0.74–0.81
Pronotum Length	0.21–0.43	0.18–0.27
Pronotum width	0.51–0.77	0.41–0.44
Postclypeus length	0.20–0.25	0.18–0.20
Postclypeus width	0.50–0.60	0.38–0.40

mm) and head length (0.76–0.80 mm) of *B. bulbiceps* are less than *B. debadiliporum*. Workers are monomorphic with 14 segmented antennae in *B. bulbiceps* whereas dimorphic (workers major and minor) in *B. debadiliporum* with 14–15 segmented antennae. Total body length, head length and width, pronotum length and width of workers also vary significantly between the species.

Etymology

The name of this species is given in the honor of the first authors' mother Mrs. Deba Das and father Mr. Dilip Das.

Distribution

India, Meghalaya, East Khasi Hills District, Pynursla area, Mawlynnong; Ri-Bhoi District, Nongpoh area.

Keys to *Bulbitermes* species of Indian region based on the soldier caste (modified from Chhotani (1997))

1. Smaller species (Head length with rostrum 1.10–1.59 mm) 2
 - Larger species (Head length with rostrum 1.37–2.00 mm) 4
2. Antennae with only 13 segments. Rostrum length 0.53–0.60 mm. Head straight behind rostrum and with a faint hump in profile. Mandibles with short, spine like process *B. parapusillus* (Ahmad)
 - Antennae with 12–13 segments. Spine like process present or absent 3
3. Antennae with 12–13 segments. Rostrum length 0.70 mm. Head weakly depressed behind rostrum and with weak hump. Mandibles with long spine like process *B. pyriformis* (Akhtar)
 - Antennae with 12 segments; head length with rostrum 1.10–1.26 mm. Rostrum length 0.42–0.46 mm. Head weakly depressed behind rostrum and with a weak hump. Mandibles without any spine like process *B. bulbiceps* (Maiti and Saha)
4. Antennae with 14 segments, 3rd longer than 4th. In profile head depressed behind rostrum appreciably. Right mandible with a minute tooth near the tip *B. prabhae* (Krishna)
 - Antennae 13–14 segmented; in 14 segmented antennae, segment 4th longer than 3rd. Head weakly depressed behind rostrum. Right mandible without a minute tooth near the tip *Bulbitermes debadiliporum* sp. nov.

Bioecology

Bulbitermes is primarily an arboreal nester genus that build stercoral carton nest of round or elongate shapes on the tree trunks, branches or in bushes (Weesner 1965; Lommen et al. 2004). They also live in wood nest (Arumugam et al. 2018). In case of the species *B. debadiliporum*, studied samples were collected from stercoral carton nest found inside the trunk of dead standing betelnut and dry bamboo. The trunk of the betelnut plant was eaten up completely from inside where the carton nest was located and it was somewhat elongated in shape. In dry bamboo tree, soldiers and workers were found foraging, but could not locate their nest. Due to their preference to feed on dead wood materials, *B. debadiliporum* may fall under the feeding group II.

DISCUSSION

Bulbitermes debadiliporum sp. nov. stands as a separate species from other *Bulbitermes* species due to its distinct morphological features. The soldier castes of the species have 13–14 segmented antennae along with significant variations in other morphological characteristics such as total body length, head length with and without rostrum, head width, rostrum length, rostrum length and head length index, head width at constriction, head width at constriction and head width index, head height, pronotum length and width etc. with other related *Bulbitermes* species from Indian and other Oriental regions. On the other hand, the worker caste of the species also shows distinct morphological features with 14–15 segmented antennae along with its dimorphic occurrence (workers major and minor). With the differences in number of antennal segments

and morphometrics, workers major, and minor also differ in their molar plate ridges (10 molar ridges in workers major and 6 in workers minor) of the left mandibles. Dimorphism among the soldier and worker castes of *Nastutitermitinae* is not uncommon as many genera comprise of dimorphic soldier and worker caste (Chhotani 1997). *Bulbitermes* species with dimorphic workers also were reported from Malayasia earlier. But, among the *Bulbitermes* species from Indian region, the dimorphic worker caste is reported for the first time in *B. debadiliporum*. Besides, other morphological characters in worker caste such as head length and width, pronotum length and width etc. of *B. debadiliporum* also vary significantly with other related *Bulbitermes* species as discussed above. Thus, we propose this species *Bulbitermes debadiliporum* as a new *Bulbitermes* species from Meghalaya, India.

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Article

Documenting butterflies with the help of citizen science in Darjeeling-Sikkim Himalaya, India

– Aditya Pradhan, Rohit George & Sailendra Dewan, Pp. 22771–22790

Communications

Determinants of diet selection by Blackbuck *Antelope cervicapra* at Point Calimere, southern India: quality also matters

– Selvarasu Sathishkumar, Subhasish Arandhara & Nagarajan Baskaran, Pp. 22791–22802

An update on the conservation status of Tibetan Argali *Ovis ammon hodgsoni* (Mammalia: Bovidae) in India

– Munib Khanyari, Rigzen Dorjay, Sherab Lobzang, Karma Sonam & Kulbhushansingh Ramesh Suryawanshi, Pp. 22803–22812

An annotated checklist of the avifauna of Karangadu mangrove forest, Ramanathapuram, Tamil Nadu, with notes on the site's importance for waterbird conservation

– H. Byju, N. Raveendran, S. Ravichandran & R. Kishore, Pp. 22813–22822

Habitats and nesting habits of Streaked Weaver *Ploceus manyar* in select wetlands in the northern districts of Tamil Nadu, India

– M. Pandian, Pp. 22823–22833

Genetic evidence on the occurrence of *Channa harcourtbutleri* (Annandale, 1918) in Eastern Ghats, India: first report from mainland India

– Boni Amin Laskar, Harikumar Adimalla, Shantanu Kundu, Deepa Jaiswal & Kailash Chandra, Pp. 22834–22840

Redefining *Pallisentis ophiocephali* (Thapar, 1930) Baylis, 1933 from two freshwater fishes of Channidae family of Hooghly District, West Bengal, India

– Prabir Banerjee & Biplob Kumar Modak, Pp. 22841–22849

A new termite species of the genus *Bulbitermes* (Blattodea: Isoptera: Termitidae) from Meghalaya, India

– Khired Sankar Das & Sudipta Choudhury, Pp. 22850–22858

First report of the beetle *Henosepilachna nana* (Kapur, 1950) (Coleoptera: Coccinellidae) from Maharashtra with special reference to molecular phylogeny and host plants

– Priyanka B. Patil & Sunil M. Gaikwad, Pp. 22859–22865

Assessment of population, habitat, and threats to *Cycas pectinata* Buch.-Ham. (Cycadaceae), a vulnerable cycad in Bhutan

– Sonam Tobgay, Tenjur Wangdi, Karma Wangchuck, Jamyang Dolkar & Tshering Nidup, Pp. 22866–22873

Ecological niche modeling to find potential habitats of *Vanda thwaitesii*, a notified endangered orchid of Western Ghats, India

– S. William Decruse, Pp. 22874–22882

Occurrence of opportunistic invasive macroalgal genus *Caulerpa* and *Halimeda opuntia* in coral reefs of Gulf of Mannar

– Chatragadda Ramesh, Koushik Sadhukhan, T. Shunmugaraj & M.V. Ramana Murthy, Pp. 22883–22888

Short Communications

Diversity of bees in two crops in an agroforestry ecosystem in Kangsabati South Forest Division, Purulia, West Bengal, India

– Pallabi Das & V.P. Uniyal, Pp. 22889–22893

An extended distribution and rediscovery of *Rhynchosia suaveolens* (L.f.) DC. (Fabaceae) for Maharashtra, India

– Ajay K. Mishra, Vedhika Gupta, Ajay V. Rajurkar, Pankaj A. Dhole & Vijay V. Wagh, Pp. 22894–22899

Notes

New distribution records of two uncommon microhylid frogs, *Melanobatrachus indicus* Beddome, 1878 and *Mysticellus franki* Garg & Biju, 2019 from Nelliampathy, Kerala, India

– Madhura Agashe, Avrajjal Ghosh, K. Dilshad, Maitreya Sil & Aniruddha Datta-Roy, Pp. 22900–22904

First record of Brilliant Flash *Rapala melida nicevillei* (Swinhoe, 1911) (Lepidoptera: Lycaenidae: Theclinae) to Meghalaya, India

– Suman Bhowmik, Atanu Bose, Jayant Ghanshyam Bhoir, Atanu Bora, Suraj Das, Shyamal Kumar Laha & Ngangom Aomoa, Pp. 22905–22907

A note on the occurrence of *Cremnorchonchus conicus* (Blanford, 1870) in Mumbai, India

– Naman Kaji & Shubham Yadav, Pp. 22908–22910

***Jasminum angustifolium* (L.) Willd. var. *angustifolium* (Oleaceae): a new distribution record for West Bengal, India**

– Keya Modak & Monoranjan Chowdhury, Pp. 22911–22915

***Cyrtosia falconeri* (Hook.f.) Aver. (Orchidaceae): an addition to the flora of Jammu & Kashmir, India**

– Mushtaq Ahmed & Manjul Dhiman, Pp. 22916–22919

New distribution record of *Roridomyces* cf. *phyllostachydis* (Agaricales: Mycenaceae), a bioluminescent fungus from Namdapha National Park, Arunachal Pradesh, India

– Arijit Dutta, Sourav Gupta, Jayanta K. Roy & M. Firoz Ahmed, Pp. 22920–22923

Photographic evidence of bioluminescent mushroom *Mycena chlorophos* (Mycenaceae) from Goa, India

– Swanand R. Patil, Mirjoy M. Mathew, Abhijeet V. Patil, Ramesh N. Zarmekar, Pankaj R. Lad & Grenville Dcosta, Pp. 22924–22926

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