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Report of a rare ant species *Probolomyrmex procne* (Formicidae: Proceratiinae) from the Indian Institute of Science campus, with description of its dealate queen

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Abstract

A very rare ant, *Probolomyrmex procne*, belonging to the basal subfamily Proceratiinae, is discovered for the first time from the Indian Institute of Science campus, Bangalore, Karnataka. The worker caste of this species was first discovered and described from Palni hills in the year 1972, based on a single specimen, and was reported again from Mysore in 1990. This study describes the previously unknown queen and its 34-year rediscovery in the state of Karnataka. Due to their small size, cryptic appearance, and limited colony size, these tiny ants—which were discovered utilizing Winkler extraction method are rarely found. With this discovery, the number of specimens collected from India has increased from four to six. The vast array of sensilla on antennal segments, which play huge roles in various levels of communications, were studied in detail using scanning electron microscopy images.

Key words: Rare leaf litter ant, Proceratiinae, *Probolomyrmex*, dealate queen, Indian Institute of Science Campus

Introduction

The genus *Probolomyrmex* Mayr, 1901 distributed throughout the tropics and subtropics belongs to the subfamily Proceratiinae with about 30 valid species across the globe (AntWeb 2024). *Probolomyrmex* in the Indo-Australian and Oriental regions was divided by Eguchi et al. (2006) into two species groups: *P. longinodus* Terayama & Ogata, which has a reduced subpetiolar process and a low, long petiole, and *P. greavesi* Taylor, which has a stouter petiole and a very well developed subpetiolar process.

Probolomyrmex was first revised by Taylor (1965), who identified nine species. Since then, multiple publications have updated several regional faunas and supplied descriptions of isolated species. The South American *Probolomyrmex* was revised by Agosti (1994); the Northern Territory genus distribution was reported by Andersen (2003); the Oriental *Probolomyrmex* was revised by Eguchi et al. (2006) and the Colombian subfamily Proceratiinae was examined by Sosa-Calvo & Longino (2008). Yoshimura & Fisher (2009) revised the characters of male ants of the Malagasy region and provided a key to genera of the subfamily Proceratiinae. A general summary of the Vietnamese Formicidae was given by Eguchi et al. (2014). In Madagascar, Hita Garcia & Fisher (2014) conducted a taxonomic revision of the *Probolomyrmex* and reported two new species. In the Neotropical region, Oliveira & Feitosa (2019) revised the genus and described four new species.

Most species in this genus are known to have winged queens and males in the reproductive caste (Oliveira & Feitosa 2019). An ergatoid queen has been observed for one species, *P. guanacastensis* O'Keefe & Agosti (O'Keefe & Agosti 1997). *Probolomyrmex* may be specialist predators of polyxenid millipedes, according to Ito (1998). This was confirmed by a recent study (Ito & Hosokawa 2020), which also discovered that these ants exclusively attacked and consumed polyxenid millipedes. The nesting habits of *Probolomyrmex* are poorly understood, although it has been noted that colonies of up to 20 workers can be established in rotten logs, empty snail shells, and naturally occurring cavities in soil and leaf litter (Taylor 1965; Ito 1998; Kikuchi & Tsuji 2005). Surveys conducted between 180 and 2150 meters have revealed that colonies of this genus have been found in a wide range of environments, including lowland areas, xeric habitats, dry forests, grasslands, and montane rainforests (Fisher 2007; Shattuck et al. 2012). *Probolomyrmex* species in Oriental

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region were typically discovered in the soil and decaying wood remnants of mature forests (Eguchi et al. 2006). The habitats that the Australian species were discovered in included spinifex grasslands, eucalyptus woodlands, and rainforests (Shattuck et al. 2012). Furthermore, species from Madagascar were discovered in montane rainforest, lowland rainforest, coastal rainforest, and tropical dry forest (Hita Garcia & Fisher 2014).

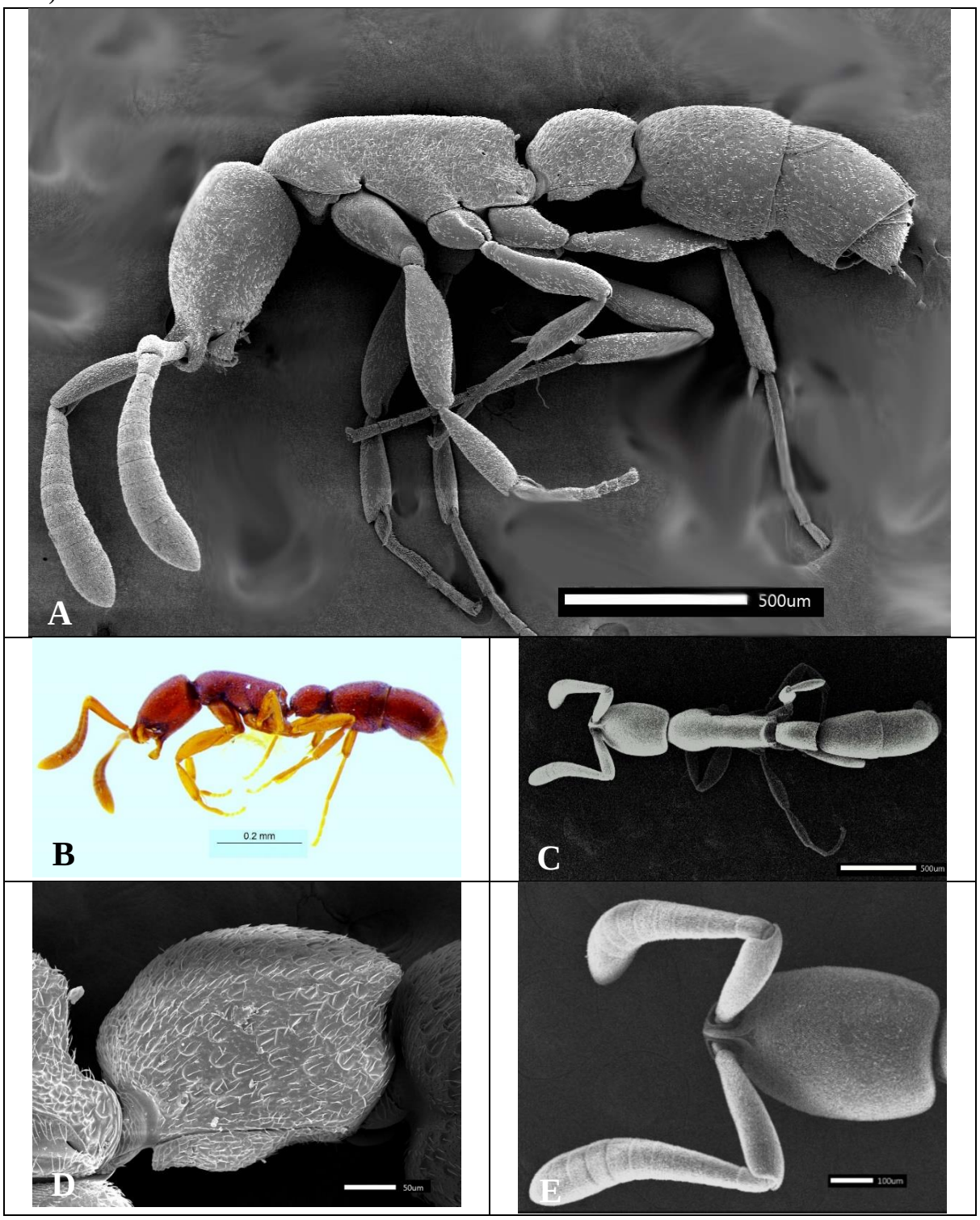

FIGURE 1. *Probolomyrmex procne*, worker. A– B. profile; C. dorsal view; D. petiole, lateral view, showing subpetiolar process; E. head, dorsal view.

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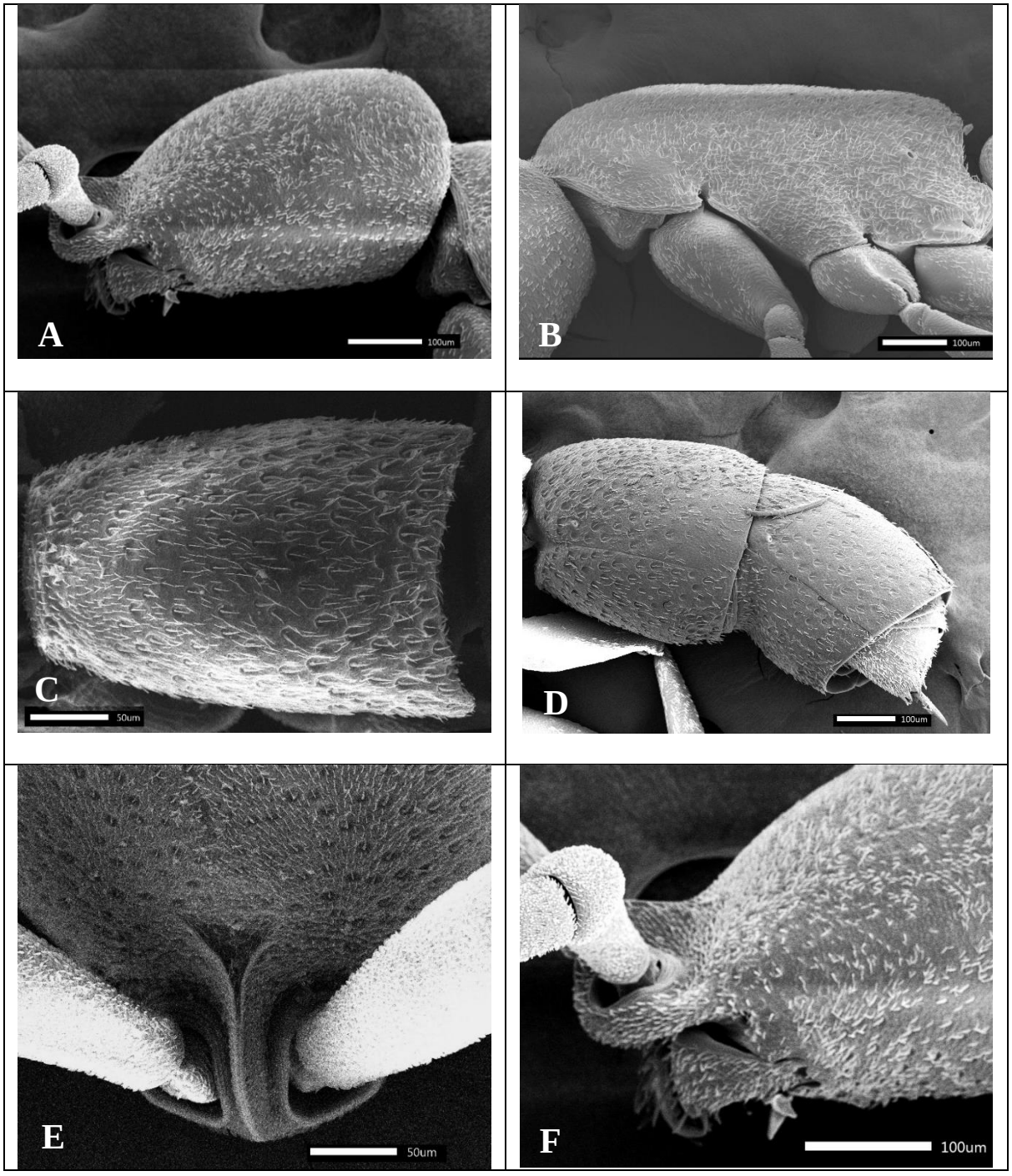

FIGURE 2. *Probolomyrmex procne*, worker. A. head lateral view; B. mesosoma, lateral view; C. petiole, dorsal view; D. gaster, lateral view; E–F. head, frontal view and lateral views showing clypeus and fronto-clypeal ridge.

To present, only two species, *P. bidens* and *P. procne*, as described by Brown in 1975, have been identified in India. *P. procne* was described by Brown (1975) based on a single worker specimen that was taken from the Palni Hills in 1972. John S. Noyes obtained an alate from Coimbatore in 1979, which Barry Bolton identified as *P. procne*. Two specimens of *P. procne* were collected by A. Tinaut from Mysore, Karnataka, in 1990 (AntWeb 2024). Two further unidentified specimen samples from India were made of

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specimens in this genus, according to information published in Antweb (2024): one by Lobl in 1979 from Uttarakhand and another by Besuchet and Löbl in 1978 from Darjeeling.

This work represents the new report of this genus and the subfamily Proceratiinae from the Indian Institute of Science campus, Bangalore, and presents the rediscovery of this rare ant genus, *P. procne*, from India. As was previously mentioned, this species has only been sampled three times from India, making this the fourth report of its occurrence on the Indian subcontinent. Despite being recorded and displayed on AntWeb, the female alate is not described, so a detailed account is provided here. A thorough explanation of the various sensilla types seen on the worker and dealate queen antennal segments of this species is also given because it has been noted that they are distinct, and have never been studied before.

Materials and methods

All observations and measurements were taken using a Leica S8APO stereoscope. All specimens of *P. procne* were obtained by Winkler extraction method. Voucher specimens (Female - CESM-1739/18; worker - CESM-1867/18) are deposited in the Museum at the Centre for Ecological Sciences, Indian Institute of Science, Bangalore. The images of *P. procne* were taken by the SEM facility at the Indian Institute of Science and Leica S8APO stereoscope.

The measurements and indices used in this study are described below:

HL	Head length: Length of head from the posterior margin of the head to the anterior extremity of the clypeus
HW	Head width: Maximum width of head in frontal view
SL	Scape length: Length of the first antennal segment, excluding the radicle
MSL	Mesosoma length: Maximum measurable length of mesosoma in dorsal view
WL	Weber's Length (Mesosoma length): Diagonal length of mesosoma in lateral view, from the anterodorsal pronotal margin to the posterior margin of propodeal lobe
MSW	Mesosoma width: Maximum measurable width of mesosoma in dorsal view
PRNW	Pronotum width: Maximum width of pronotum in dorsal view
PTL	Petiole length: Maximum length of petiole, measured in dorsal view
PTW	Petiole width: Maximum width of petiole, measured in dorsal view
PTH	Petiole height: Maximum height of petiole, measured in profile
GL	Gaster length: Maximum length of gaster measured in dorsal view
TL	Total length: Maximum measurable length in profile
CI	Cephalic index: HW/HL x 100
LPtI	Lateral petiolar index: Petiole node length x 100/Petiole height
SI	Scape index: SL/HW x 100

Results

Probolomyrmex Mayr, 1901

Probolomyrmex Mayr, 1901: 2. Type-species: *Probolomyrmex filiformis*, by monotypy.

Diagnosis. The worker caste of *Probolomyrmex* is easily distinguished from that of the other genera of the subfamily by a combination of the following features: frontal lobes fused to each other and forming a vertical plate; antennal socket located in shelf-like fronto-clypeal region that overhangs mandibles; mandible small, elongate-triangular, with acute apical tooth followed by a series of small denticles; outer surface of mandible with several thick and short setae; promesonotal suture and metanotal groove absent; gaster not down-curved; body covered with extremely fine pubescence, without standing hairs. In general, the queen caste is similar in colour and morphology to the worker caste. But the queen differs majorly from workers in having well developed eyes, ocelli and wings in addition to other differences in morphology and physiology (Taylor 1965; Agosti 1994; Eguchi et al. 2006; Keller 2011; Oliveira & Feitosa 2019).

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Indian species of the genus *Probolomyrmex*

***Probolomyrmex bidens* Brown, 1975**

Probolomyrmex bidens Brown, 1975: 56. Holotype worker. Type-locality: Palni Hills, 10 km NW Kodaikanal, Tamil Nadu [Madras] India [MHNG].

Worker diagnosis. Posterior borders of head more pronounced, more nearly rectangular than in related species; posterior border straight or even feebly convex in full-face view. No eyes detected at 50 ×. Propodeal teeth fairly prominent, subrectangular. Petiolar node special in form with the sides ending behind in prominent triangular teeth. In dorsal view, the sharp posterior border is broadly excavated. The subpetiolar process is like that of *P. greavesi*, but is even deeper, with the posteroventral corner a little less sharply angled. Postpetiolar segment robust, rounded in front as seen from above. Larger punctures more numerous and more than usually distinct on head, mesosoma, and petiole; appressed pubescence also fairly distinct over most of body. Colour dark ferruginous, legs and antennae a bit lighter, more yellowish." The queen and male castes of this species are unknown. *P. bidens* is relatively larger than the only other known Indian species *P. procne* with the following morphometric data in mm: TL 2.7, HL 0.62, HW 0.41, SL 0.41, WL 0.80, PRNW 0.33, PTL 0.31, PTW 0.23, CI 66, LPtI 83 (Brown 1975).

***Probolomyrmex procne* Brown, 1975** (Figs. 1–2).

Probolomyrmex procne Brown, 1975: 56. Holotype worker. Type-locality: Palni Hills, 39 km. E Kodaikanal, Tamil Nadu [Madras] India [MHNG].

Worker diagnosis. *P. procne* clearly fits in the *longinodus* group by the following characters: petiole clearly longer than high (Fig. 1D) and subpetiolar process is low with poorly developed postero-ventral portion (Eguchi et al. 2006). Since the worker caste was thoroughly described by Brown (1975), only the most important characters are included here. Head narrow, sides convex, no eyes; mesosoma very feebly but evenly convex from front to rear in side-view outline, propodeal teeth or angles almost rectangular. Lateral petiolar index about 136; dorsal surface convex behind as well as in front; seen from above with almost perfectly straight sides diverging caudad and ending in a pair of acute angles, with the posterior border broadly and rather deeply concave. Erect pilosity restricted to a few hairs on the mandibles; pubescence of the very fine, opaque "pruinose" kind, overlaid by larger punctures of foveolate that are particularly distinct on the 2 main gastric segments, where the integument is slightly more shining; larger punctures are a little larger and more distinct on node. Colour medium ferruginous with more yellowish antennae and legs (Brown 1975). The specimen in this study agrees with the above description as well. It agrees well with the other diagnostic features as mentioned earlier: frontal lobes fused to each other and forming a vertical plate; antennal socket located in shelf-like fronto-clypeal region that overhangs mandibles; mandible small, elongate-triangular, with acute apical tooth followed by a series of small denticles; outer surface of mandible with several thick and short setae as seen above. Morphometric data provided by Brown (1975) in parenthesis () mostly agrees with the fresh data: HL 0.58 (0.58), HW 0.36 (0.375), SL 0.37 (0.40), WL 0.66 (0.75), PRNW 0.27 (0.29), PTL 0.28 (0.32), PTW 0.18 (0.21), PTH 0.22, TL 2.36 (2.40), CI 63 (65), SI 103, LPtI 133 (136).

Antennal sensilla. The nature and arrangement of sensory hairs throughout the body are distinctive and those on antennae are remarkably diverse. The antennal scape, pedicel, and especially the antennal funiculi are with abundant pubescence, sensory hairs of varying shapes and sizes in addition to varying number of pits (Fig. 3A–B). The last flagellar segment shows the most diversity and the following composition of antennal sensilla (Fig. 3C). A unique shaped, very long appressed hairs, which are exceptionally longer and thicker than all other hairs, set in deep longitudinal grooves, are present in quite abundant numbers on flagellum of *P. procne* as seen in Fig. 3C, 1 (inside markings). Those in longitudinal grooves are in two different shapes and sizes, the second type is distinctly long, thin and ridged and is similar to sensilla chaetica (Fig. 3C, 2) and this type of sensilla are most commonly seen in almost all species of ants' flagellar segments.

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The long and thin appressed hairs are present from first funicular segment onwards, whereas the very long and exceptionally thick appressed hairs are present from the second funicular segment onwards only. The long appressed hairs resemble the "LAH" reported in many species of *Probolomyrmex* in the study by Oliveira & Feitosa (2019), though they are not classified into any of the known sensillum types.

The long, dagger like basiconica seems to be very diverse as shown in the image (Fig. 3C, 3a, 3b). The most prominent, long, and thick basiconica, which are broader at base and uniformly narrowing towards the tip are abundant and uniformly distributed on the ventral surface of the last flagellar segment, whereas they are absent on dorsal surface. The second type of basiconica, which are narrow at the base and tip, with a broader middle portion like a spearhead are at least in three subtypes, one long, thick and seen inclined at an angle to the antennal surface, whereas the second type is very short, but are of the same shape, seen at similar angles. The third possible subtype, which are scarce are placed vertically on the surface as seen in Fig. 3C.

There are varying number of antennal pits on the surface of different flagellar segments as seen in Fig. 4. Additionally, there observed a few remarkably thicker and larger sensilla towards the border of the last flagellar segment, both inside and outside surface, with a very broad base and narrowed rounded tip, which projects beyond all other sensilla (Fig. 3C, 5) and might belong to the basiconica type of sensilla. The sensilla of this shape were not reported in any other ant species.

The most abundant and diverse type of sensilla noticed on the last flagellum are trichodea (Fig. 3C, 6, 6a, 6b), both on the dorsal and ventral surface. The first type is long, thin and straight, whereas the second type is curved, and this type seems to be of two types, one thin, curved and quite abundant. These type of sensilla are present throughout the surface and form a pattern surrounding the LAP hair, as if it protects the LAP sensilla. The second curved type, trichodea curvata is flattened, broad from base and very curved and fewer in number compared to other two types of trichodea curvata sensilla. Another not so abundant type of sensilla, similar to companiformia in other species of ants are observed at the joints (Fig. 4A, 7).

In addition, there are some unique types of sensilla at the basal segments of the antennae in *P. procne* (these are present only on the basal segments, lesser or absent on 12th flagellar segment), which are broad with transverse ridges, but the tips are narrowed and rounded mostly. These types may be classified into at least six types (Fig. 4A, 8, 8a, 8b, 8c, 8d, 8e). Some of these are narrow at base, medially broad, uniformly narrowing towards the tip, more or less lanceolate in shape and are upright (Fig. 4A, 8), whereas a few other sensilla are of the same shape and size but are slanted (Fig. 4A, 8a). A further little narrower form than this slanted subtype is also seen abundantly (Fig. 4A, 8b). Another subtype has a similar narrow base, but medially very broad and attenuated distally with an oblique tip (Fig. 4, 8c). While a few are similarly shaped, attenuated, but much shorter and narrower (Fig. 4, 8d). However, some others are of the same shape, but larger than the above mentioned two types (Fig. 4A, 8e). These type of sensilla are very abundant at the basal segments (Fig. 4B–C), but the number decreases towards the tip (Fig. 4D–E, 5A) and visibly, they are overlaid by the generous array of trichodea sensilla.

The sensilla coeloconica are deep, wider and conspicuous with distinct peg in the middle as seen in earlier Fig. 4A, 9. Another not so abundant types of sensilla are possibly sensilla ampullacea as showed in earlier Fig. 4A, 9a. Among the abundant, diverse sensilla on surface of basal antennal segments, some are similar to previously described types (Fig. 4A, 8–8e) but longer and narrower than most of them are also there as seen in Figure 4A, 10–10a). Furthermore, there are a few clusters of Böhm bristles at the basal segment, which are very thin and short (Fig. 5B, 11). The most common and abundant types of sensilla are those types described above and many of them are known in other species of ants and other insects as well.

Distribution. Karnataka (Mysore) and Tamil Nadu (Coimbatore, Palni hills) (Brown 1975; AntWeb 2024).

Differential diagnosis. As per Eguchi et al. (2006), *P. procne* is similar to *P. dammermani* Wheeler and *P. longinodus* Terayama & Ogata but differs from them by the nature of the petiolar node and by the differences in morphometry. SEM images of *P. procne*, further signify body sculpturing, hairs, spines, spurs, teeth, and claws of the worker and dealate queen. The whole body is furnished with abundant hairs, including the metapleural gland and legs, most of which are in foveae and micropits (Fig. 5C–E). Tip of the gaster possess a small number of teeth as in many species of ponerinae and cerapachyinae (Fig. 5F). Also, tibial

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spurs are pectinate, whereas hairs on legs are abundant, long, thin, flattened and greatly pointed like a knife, towards the tip (Fig. 5G–H).

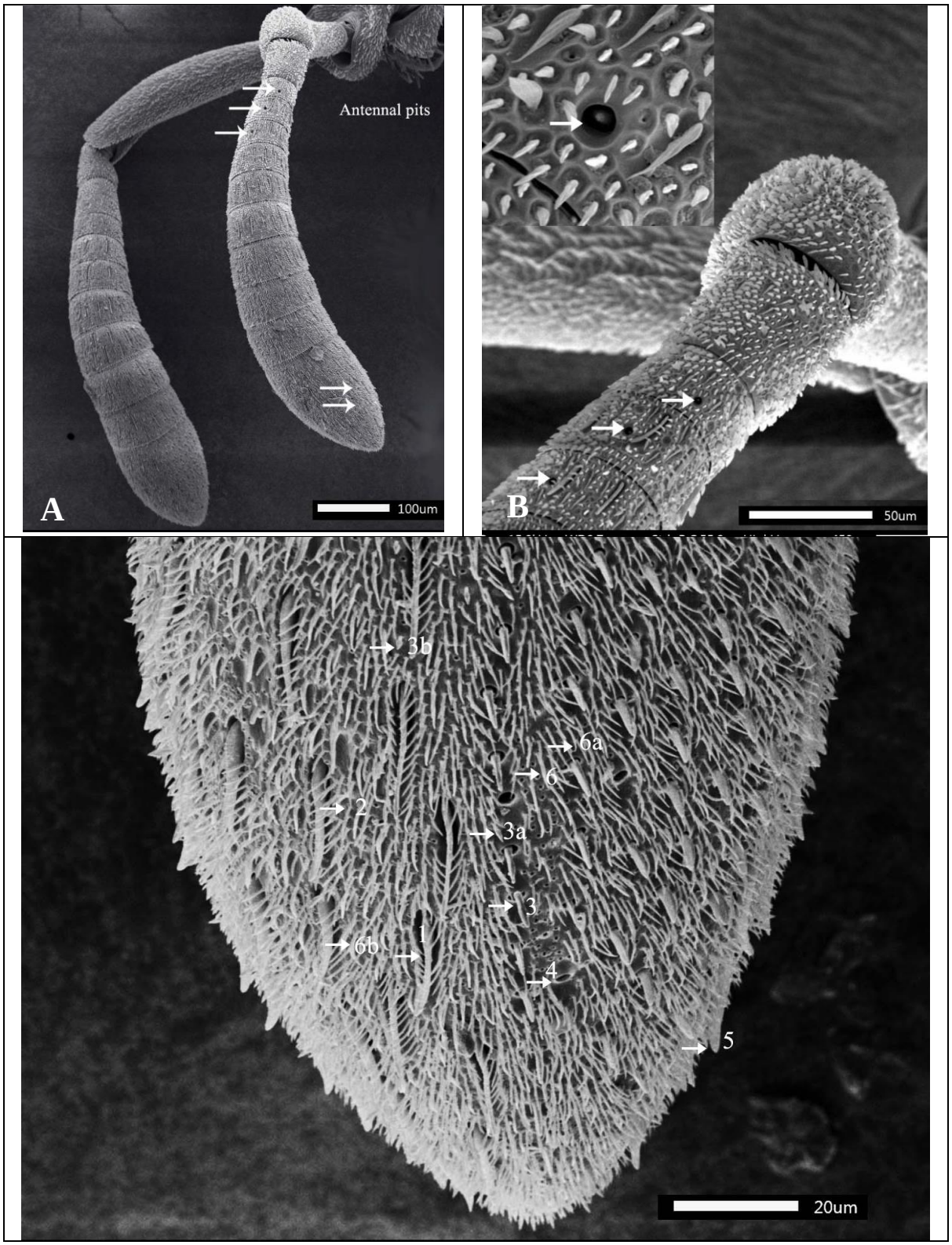

FIGURE 3. *Probolomyrmex procne*, worker. A–B. antennae showing antennal pits; C. tip of the last flagellar segment showing different types of sensilla; numbers inside figure shows its subtypes: 1. thick, long, appressed hairs in grooves; 2. thin, long, appressed hairs in grooves; 3. sensilla basiconia and subtypes; 4. antennal pits; 5. very large sensilla at the side; 6. sensilla trichodea and its subtypes.

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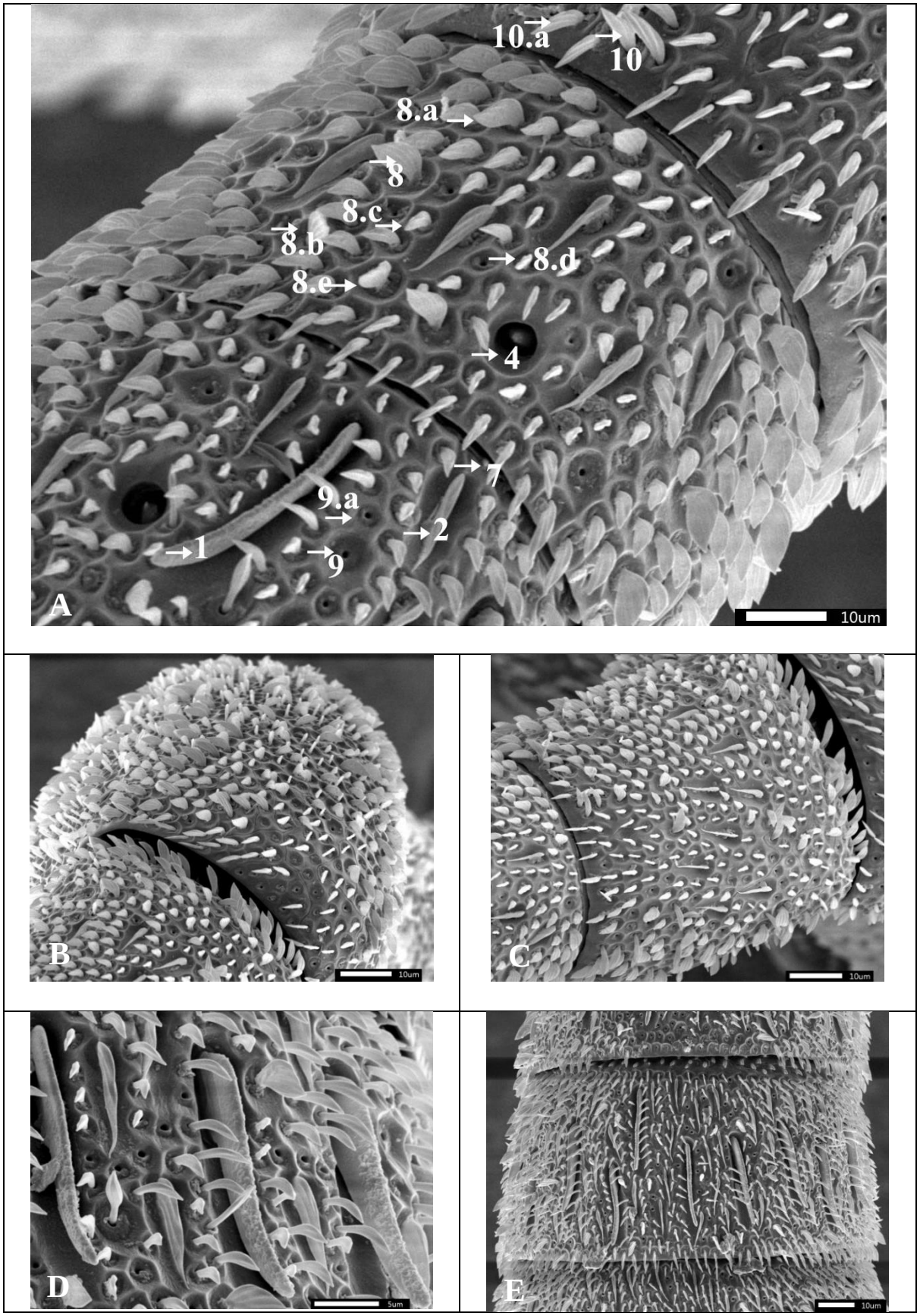

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FIGURE 4. *Probolomyrmex procne*, worker. Numbers inside figure A: 7. sensilla companiformia; 8–8e. unique sensilla and its subtypes; 8. lanceolate shaped and upright; 8a. lanceolate shaped and slanted; 8b. lanceolate, narrower and slanted; 8c. sensilla with narrow base, medially very broad and attenuated distally with an oblique tip; 8d. similar in shape as above, attenuated, but much shorter and narrower; 8e. similar in shape as above, but larger than the above two subtypes; 9. sensilla coeloconica; 9a. sensilla ampullacea; 10–10a. longer and thicker than previously described sensilla; B. diversity and abundance of sensilla on scape; C. diversity and abundance of sensilla on pedicel; D. distribution of sensilla on 6th flagellar segment; E. distribution of sensilla on 9th flagellar segment.

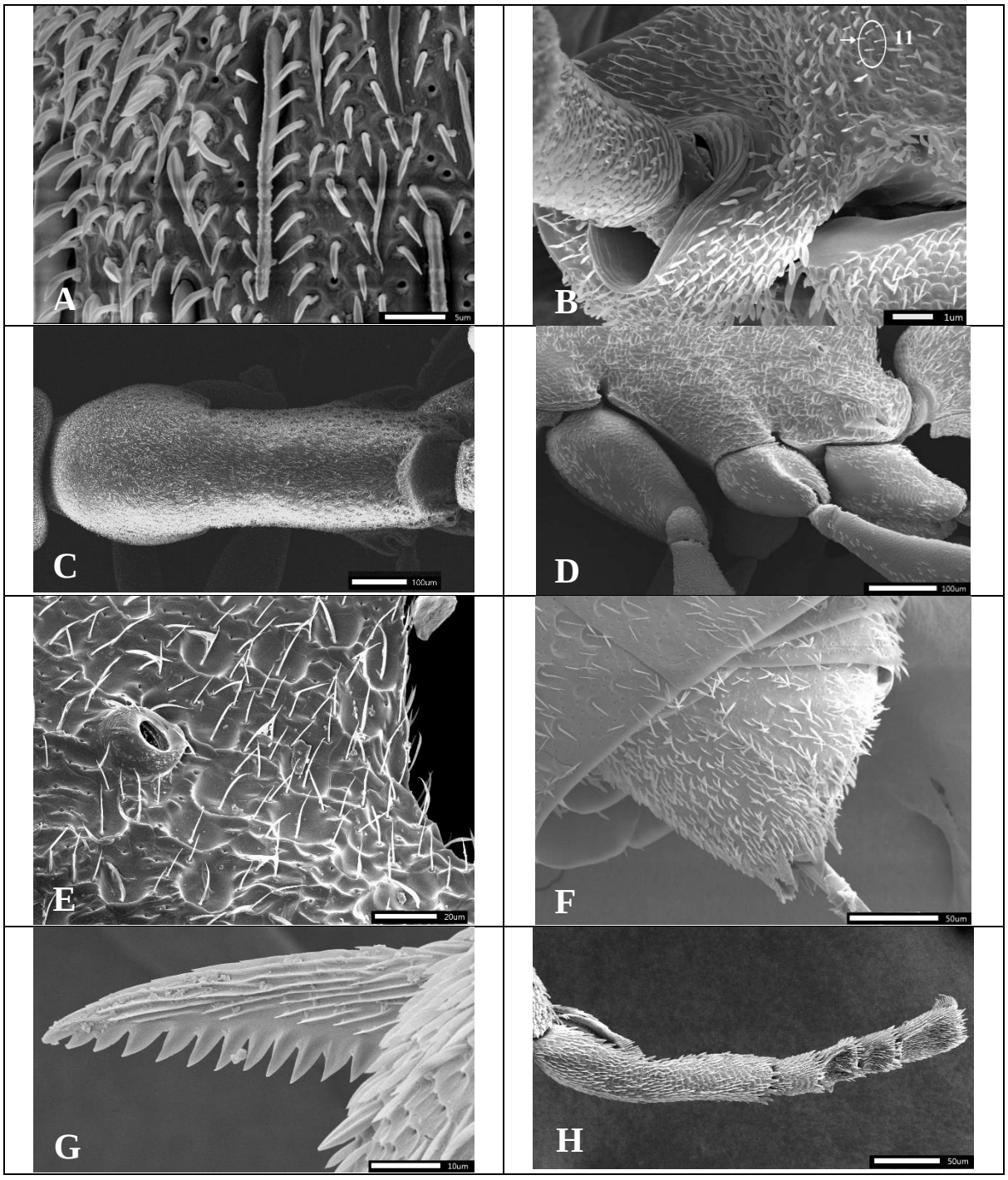

FIGURE 5. *Probolomyrmex procne*, worker. A. close up view of the sensilla on 9th flagellar segment; B, 11. Böhm bristles on head; C. thorax, dorsal view; D. thorax, lateral view showing abundance of hairs around propodeal spiracle

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and metapleural gland; E. close up view of propodeal spiracle; F. gaster tip showing teeth; G. pectinate tibial spur; H. distribution and abundance of hairs and setae on leg.

Queen diagnosis. The queen is similar in colour and morphology to the worker caste, but the queen differs majorly from workers in having well developed eyes, ocelli, and wings (Fig. 6A).

Description. *Dealate measurements:* HL 0.58, HW 0.41, SL 0.43, WL 0.78, PRNW 0.31, PTL 0.28, PTW 0.23, PTH 0.22, GL 1.03, TL 2.68, CI 71, SI 104, LPtI 127.

Body ferruginous. The body sculpturing, structure of head, appendages, and metasoma are as in workers. Additionally, dealate queen possess well-developed eyes, three ocelli of similar size. Head 1.41 × longer than wide, sides broadly convex, sclerites of frons and clypeus are fused and form shelf-like projection (Fig. 6B–D), which overhangs mandibles as in worker castes. Antennae 12-segmented; inserted on a shelf-like projection; antennal insertions are fully open as in workers; their bases are separated by narrow, vertical carinae. Antennal scape short, extending a little beyond the level of posterior margin of median ocellus. Mandibles short and triangular, with acute apical teeth followed by 6–7 undefined teeth. Pronotum subtriangular in lateral view. Metanotum convex (Fig. 6E). Petiole little longer than its height with well-developed subpetiolar process (Fig. 7A).

Antennal sensilla. The diversity and abundance of sensilla showed variations across scape, pedicel and flagellar segments as observed in worker antennae (Figs. 7–8). Evidently, the density and diversity of sensilla across the whole antennae were significantly reduced compared to those in worker antennae. Those very thick LAP sensilla were observed from 3rd funicular segment onwards, whereas the thin, LAP sensilla were observed from first funicular segment onwards as in workers, though in very few numbers on all segments. Additionally, three variants of possibly, trichodea and basiconica, were also observed in fewer numbers and there are a few probably queen specific sensilla (Figs. 8H, 9A–C), which are present from 7th segment onwards. As described above, the shape, size, abundance, and distribution of these sensilla differs between the antennae of dealate queen and worker as well. As observed in the case of sensilla on antennal flagellar segments, sensory hairs are lesser on the cuticular surface of dealate queen as well.

Worker-based key to the Indian species *Probolomyrmex* Mayr, 1901 (based on Brown 1975)

1. Slightly larger species with total length 2.70 mm; CI 66; petiole wider than the other species with width 0.23 mm; petiole with subrectangular subpetiolar process----------***P. bidens***

– Slightly smaller species with total length 2.40 mm; CI 65; petiole narrower and longer than the other species with width 0.21 mm; petiole with narrow subpetiolar process----------***P. procne***

Discussion

Taylor (1965) pointed out that due to extreme structural reduction in *Probolomyrmex,* measurements such as dimensions and proportions of head, antennae, petiole, are widely used along with surface sculpture in distinguishing closely related species. The holotype and the specimen included in this study had a few slight measurement discrepancies, however these could be an indication of intraspecific variation. The situation can however, only be clarified by conducting additional in-depth examinations of the intraspecific differences within this species. The measurements come closer to the holotype of *P. procne*, as mentioned earlier and differ clearly from all other known species as mentioned in the key to Oriental species (Eguchi et al. 2006). Only 3 workers (1 Palni hills; 2 Mysore) and a single alate of this species are known so far. Hita Garcia & Fisher (2014) observed noticeable metanotal grooves in two of the Malagasy species, though complete absence of this feature is characteristic of this genus.

The detailed scanning electron microscopic observations revealed a diverse and abundant array of sensilla on the scape, pedicel and flagellar segments of the antennae in worker and dealate queen of this ant species. Ants, being social are known to utilize complex and diverse chemical signals to maintain higher levels of organization in their colonies. They are known to perceive diverse chemical substances at lower

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concentrations than other insects (Wilson 1971). Oliveira & Feitosa (2019) observed abundant pubescence and long appressed hairs set in longitudinal grooves on antennal funiculi of many species of *Probolomyrmex*.

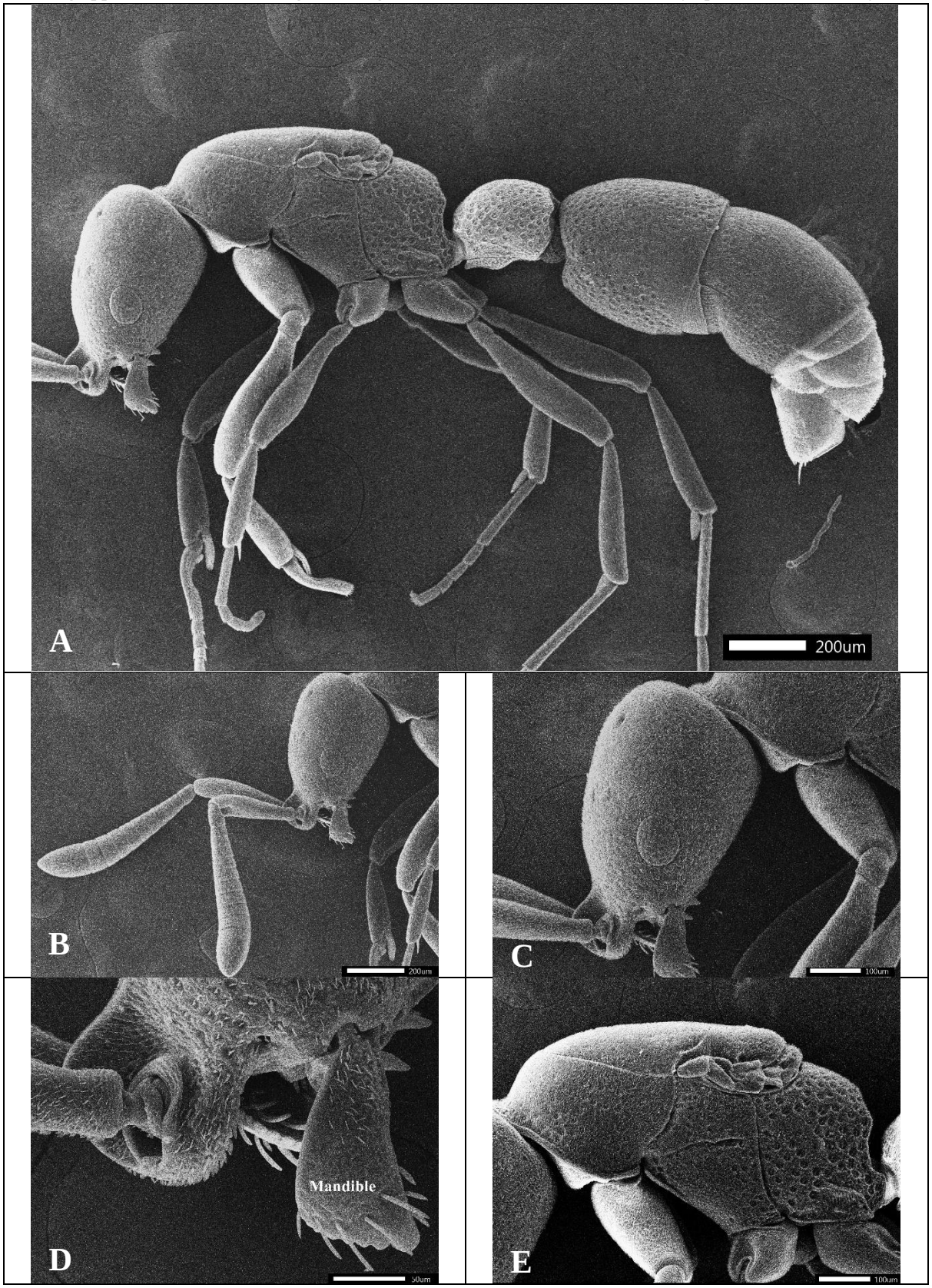

FIGURE 6. *Probolomyrmex procne*, dealate queen. A. lateral view; B. head, lateral view showing antenna; C. head, lateral view, showing frons, mandible, eyes and ocelli; D. mandible showing its teeth and stiff hairs; E. mesosoma, lateral view.

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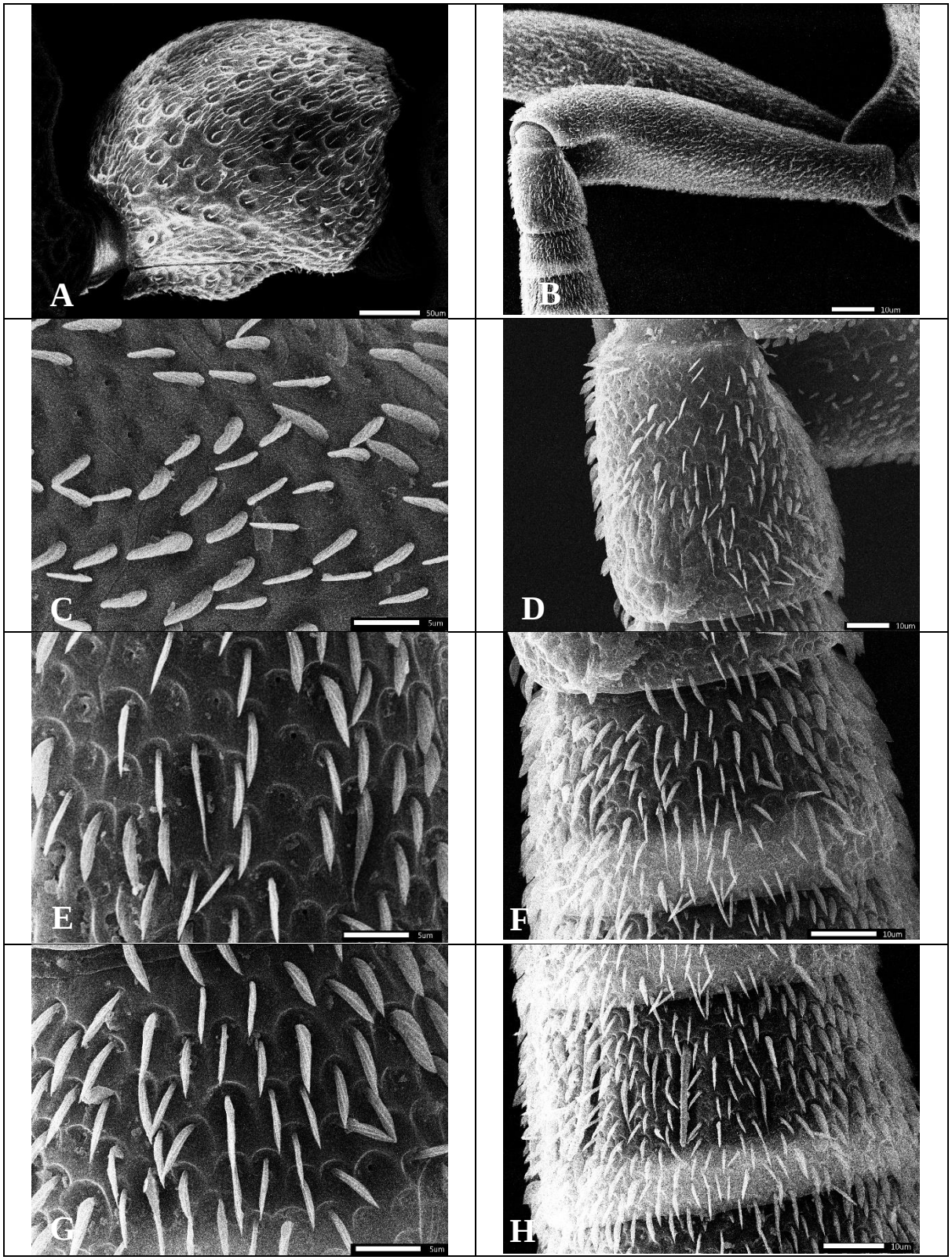

FIGURE 7. *Probolomyrmex procne*, dealate queen. A. petiole, lateral view showing subpetiolar process; B–C. sensilla on antennal scape; D–E. sensilla on antennal pedicel; F–G. 3rd flagellar segment; H. 4th flagellar segment.

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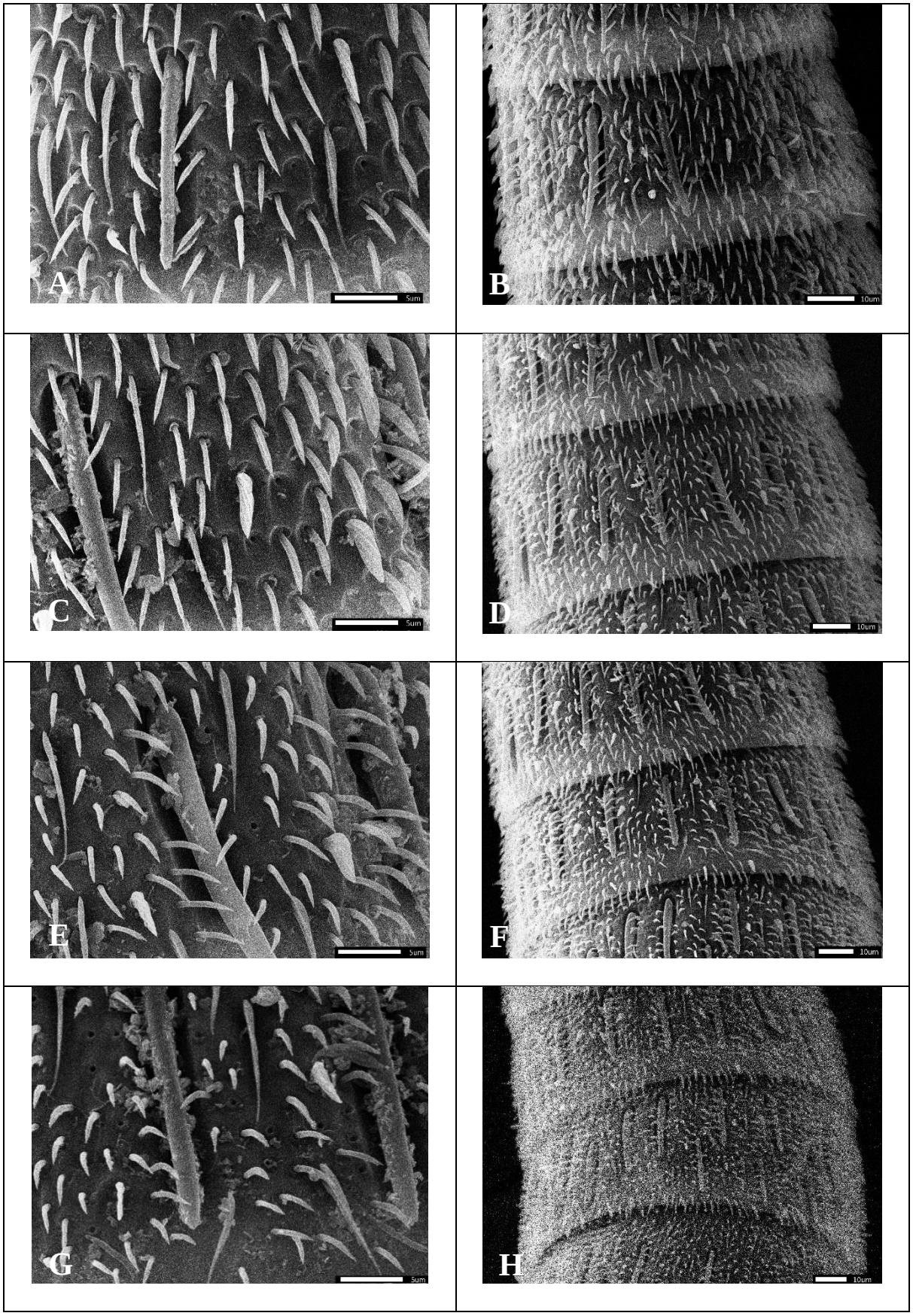

FIGURE 8. *Probolomyrmex procne*, dealate queen. A. 4th flagellar segment; B–C. 6th flagellar segment; D–E. 9th flagellar segment; F–G. 10th flagellar segment; H. 11th flagellar segment.

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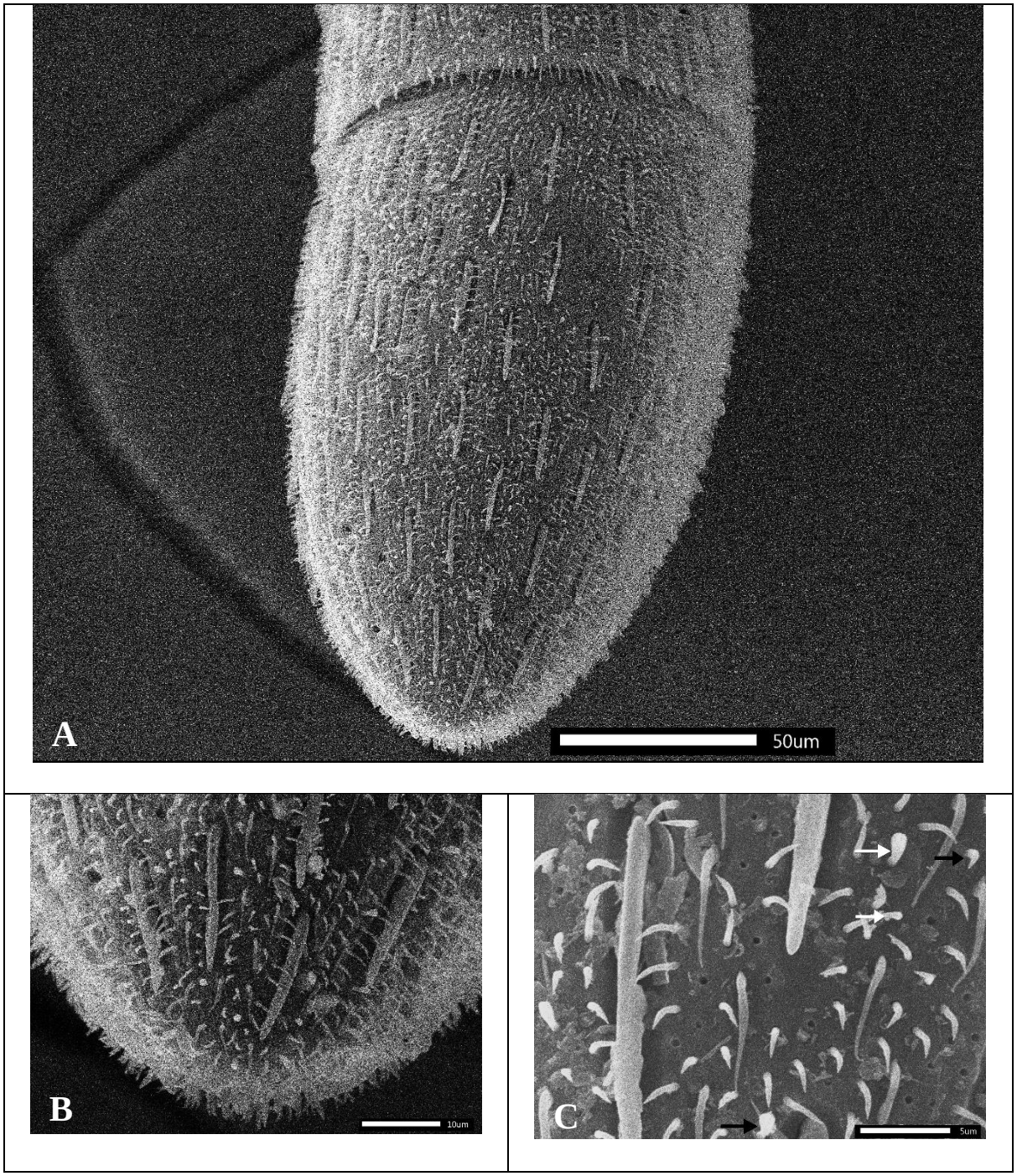

FIGURE 9. *Probolomyrmex procne*, dealate queen. A–C. Last flagellar segment.

In *P. boliviensis* Mann, only the antennal pits of varying sizes are evident. *P. brujitae* Agosti shows abundant long appressed hairs in longitudinal grooves and very short basiconica hairs in a line. *P. cegua* Oliveira & Feitosa also shows abundant long appressed hairs. *P. dentinodis* Oliveira & Feitosa shows abundant LAP and short hairs in many rows, which are in broad, oval depressions. *P. kelleri* Oliveira & Feitosa, *P. lamellatus* Oliveira & Feitosa and *P. petiolatus* Weber also show similar antennal sensilla and pits, except for lesser dense short hairs. As observed in above mentioned species, *P. procne* also has LAP hairs in abundance. This, long appressed hairs are seemingly abundant in *P. procne*, compared to other *Probolomyrmex* species. Furthermore, seemingly queen specific sensilla observed in *P. procne* looks similar to the short hairs, basiconica type, described in *P. lamellatus* in the earlier study.

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The distribution and abundance of different types of sensilla on different antennal segments and between antennae of dealate queen and workers differ considerably. In this species, the last segment of the antennae in dealate queen shows lesser number of sensilla compared to that in worker ants, especially, basiconica, trichoid and other smaller hairs. Variability of sensory hairs between queen and workers might be correlated with their role in the colony. Eyes and antennae are two major important sensory organs for ants. Workers lack eyes, whereas dealate queen possess well developed eyes. As observed in many studies mentioned above, understandings about the patterns of antennal sensilla may be useful for phylogenetic studies of ants. It may be assumed that as the shape, size, structure and distribution of these diverse sensilla varies across scape and flagellum of antennae, their function also might be different in accordance with the structure of the sensilla type.

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