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Taxonomic insight on some newly recorded species of the springtails (Hexapoda: Collembola) from North Eastern and Eastern states of India

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ABSTRACT. Six Collembola species from five families and two orders are for the first time recorded from India. All the described new records are mainly from two states, West Bengal and Arunachal Pradesh and collected from the surveys conducted in the Eastern Himalayan Region. *Sphyrotheca multifasciata* (Reuter, 1881) (Sminthuridae), *Sminthurinus bimaculatus* Axelson, 1902 (Katiannidae), *Dicranocentrus nepalensis* Mari Mutt & Bhattacharjee, 1980 (Orchesellidae), *Isotomurus plumosus* Bagnall, 1940 (Isotomidae), *Isotomurus pseudopalustris* Carapelli, Frati, Fanciulli & Dallai, 2001, (Isotomidae), *Willowsia jacobsoni* (Börner, 1913) (Entomobryidae), are the Collembola species whose occurrence is first time observed in India. As a result of the present work Collembola fauna of India reached up to 348 species. Material examined, a brief description and microscopic images of the new records are provided in the present study.

Key words: Springtails, soil micro-arthropods, new record, biodiversity, taxonomy

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INTRODUCTION

Collembola, one of the ancient organisms harbours a diverse range of habitats from polar caps to deserts and forest floors to marshy sea shores (Hopkin, 1997). These minute, wingless, entognathous organisms are one of the main reformers of the soil structure, important as prey and interact with the soil microbes to help in their spore dispersal (Larink, 1997). They sometimes indicate soil fertility, quality and ecosystem by occurring in a high number and act as a potent bioindicator (Stork & Eggleton, 1992; Chahartaghi et al., 2005; Greenslade, 2007). The first Indian species of collembola was reported and

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documented from Malabar hill region by Ritter (1910). After that Imms (1912) made an elaborate study, Carpenter (1917) worked on the Entomobridae species from North-Eastern regions, Salmon (1949, 1957, 1970), Choudhuri (1958a, 1958b), Yosii (1966), Mitra (1966, 1967, 1972, 1973, 1974, 1975, 1976a, 1976b, 1977, 1986, 1990, 1992), Mitra et al. (1981), Prabhoo (1970, 1971), Gupta and Mukherjee (1976), Hazra (1984, 1995), Mandal (2013), Mandal et al. (2004, 2005), Mandal and Hazra (2006, 2009) contributed a lot on the ecology and described a large number of species in the field of Indian Collembola. The study of Indian Collembola is not extended, though, the tropical forest hot and humid climate of India is a favourable habitat for a large number of springtail species. Most of the ecological as well as taxonomic works on Collembola are mainly studied in European countries (Potapov et al., 2020).

India encompasses only 3.63% of the total Collembola fauna of the world, so a large number of springtails still need to be discovered from this country (Mandal, 2018). Presently India has a total of 342 Collembola species (Mandal, 2018), after the present study additional six species have been newly added to the list. This manuscript holds a few Collembola new records not only from India; they are also the first time recorded from the Asian region (Bellinger et al., 1996–2024).

MATERIAL AND METHODS

To extend the studies of the Collembola fauna in India, several samples of the plant (like *Pinus roxburghii*, *Rhododendron arboreum*, *Musa acuminata* etc.) leaf-litter and soil samples were collected from different ecosystems of West Bengal, Arunachal Pradesh and Eastern Himalayan Region during 2022–2023 (Fig. 1).

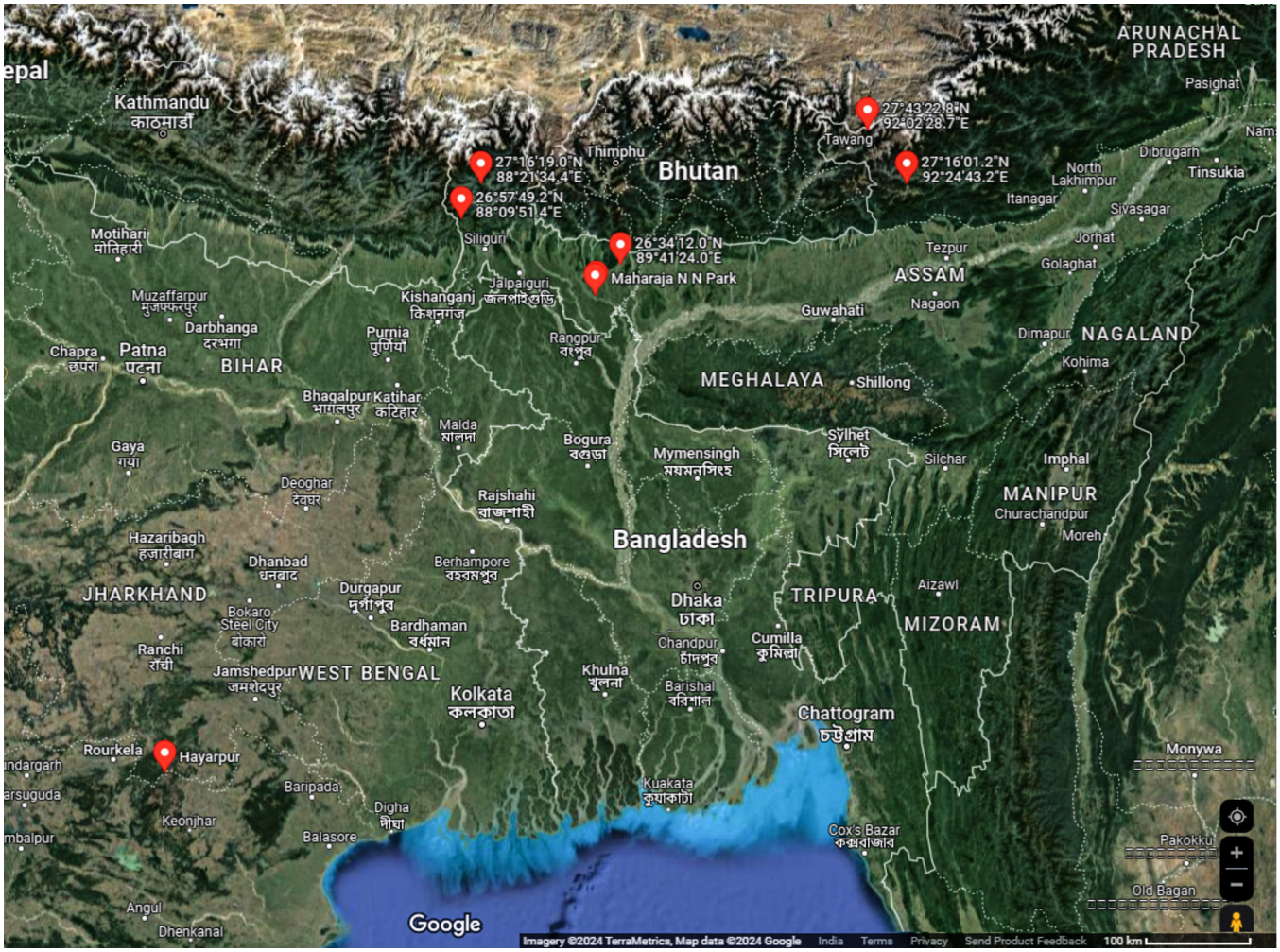

Figure 1. The map of localities of India (red bulbs), where the new records of Collembola were reported.

Collembola specimens were collected from the field using an aspirator and stored directly in 70% ethyl alcohol. A few specimens were also extracted from the soil samples collected from the field using Tullgren-Berlese funnels. Photographs of the specimens were taken using a Leica M205A stereomicroscope attached to a Leica DMC 6200. Image stacking and measurements were done using the Leica application suite V3.80. Morphological identification of specimens was carried out using specimens mounted in Hoyer's medium on the slides under a Leica DM2500 microscope attached to an image-capturing device Leica DFC 295. Identification was done following the standard dichotomous key of Bellinger et al. (1996–2024), and species were identified following the description of Potapov (2001) (Isotomidae), and Bretfeld (1999) (Symphypleona). Geocoordinate data were measured using a GPS Navigator- GARMIN GPS 72H. All the materials are registered and deposited in the National Zoological Collections of ZSI.

***Abbreviation*: Ant. I–II:** Antennal segment I–II, **Abd. I–II:** Abdominal segment I–IV, **App. an.**: Appendices anales, **a.s.l.:** Above sea level, **Emp.:** Empodium/ia, **Md:** Mandible/-ae, **Mx:** Maxilla/-ae, **PAO:** Postantennal organ, **Th. I–III:** Thoracic terga I–III, **Tita:** Tibiotarsus, **VT:** Ventral Tube, **ZSI:** Zoological Survey of India.

RESULTS

The results of the study included six Collembola species belonging to five families and two orders are for the first time recorded from India.

Taxonomic hierarchy

Phylum Arthropoda Latreille, 1829

Class Collembola Lubbock, 1871

Order Entomobryomorpha Börner, 1913

Family Orchesellidae Börner, 1906

Subfamily Heteromurinae Absolon & Kseneman, 1942

Genus *Dicranocentrus* Schött, 1893

Dicranocentrus nepalensis Mari Mutt & Bhattacharjee, 1980 (Fig. 2)

Material examined. 81 specimens, India, Sikkim, South Sikkim district, 4 km from Ravangla, collected from leaf litter, 27°16'19.0"N, E88°21'34.4"E, 2218 m a.s.l., 12-IX-2022, leg. G.P. Mandal, reg. no- 3428/H14.; 3 specimens, India, Darjeeling district, 4 km from Mukhia Nursery, Pokhrabong, collected from leaf litter, 26°57'49.2"N, E88°09'51.4"E, 2179 m a.s.l., 14-IX-2022, leg. G.P. Mandal, reg. no- 3429/H14.

Diagnosis. Body length average 2.9 mm. General colour light yellow without any trace of pigment in body, except a median blue spot in middle of the antennae and coxa with diffuse blue pigment (Fig. 2A). Tergal margins of Th. II-III, legs upto subcoxa, tita and apex of the head with diffused blue pigment patches. Ant. V–VI broken in all. Ratio of Ant. I: II: III: IV– 1: 5.9: 2.2: 7. Ant. I & III smaller than others. All labral chaetae are smooth and not bifurcated, formula as 4/5, 5, 4. Labial triangle with 5 basal ciliated and 4 smooth chaetae. Unguis slender curved with a basal paired, two inner unpaired, one external and outer teeth, Emp. lanceolate with an external tooth, tenent hair absent (Fig. 2B). A single row of 4 chaetae laterally present on the basis of each coxa. Trochanteral organ with about 28–30 spinous setae on it. Fore, mid and hind tita with 6, 6, 7 spinous smooth chaetae respectively. VT anteriorly with 3+3 long ciliated chaetae, lateral flap with 55–60 short smooth chaetae. Ratio of manubrium: dens–1: 1.33. Bidentated mucro with a basal spine (Fig. 2C).

Distribution in India. Sikkim (South Sikkim), West Bengal (Darjeeling).

General distribution. Himalayan Region (Bellinger et al., 1996–2024).

Remarks. In our specimens, the terminal unpaired tooth is not visible clearly. Most of the specimens have broken antennae, pin chaetae were not observed. Chaetotaxy same as the original description, in addition, Abd. IV with 10+10 lateral chaetae.

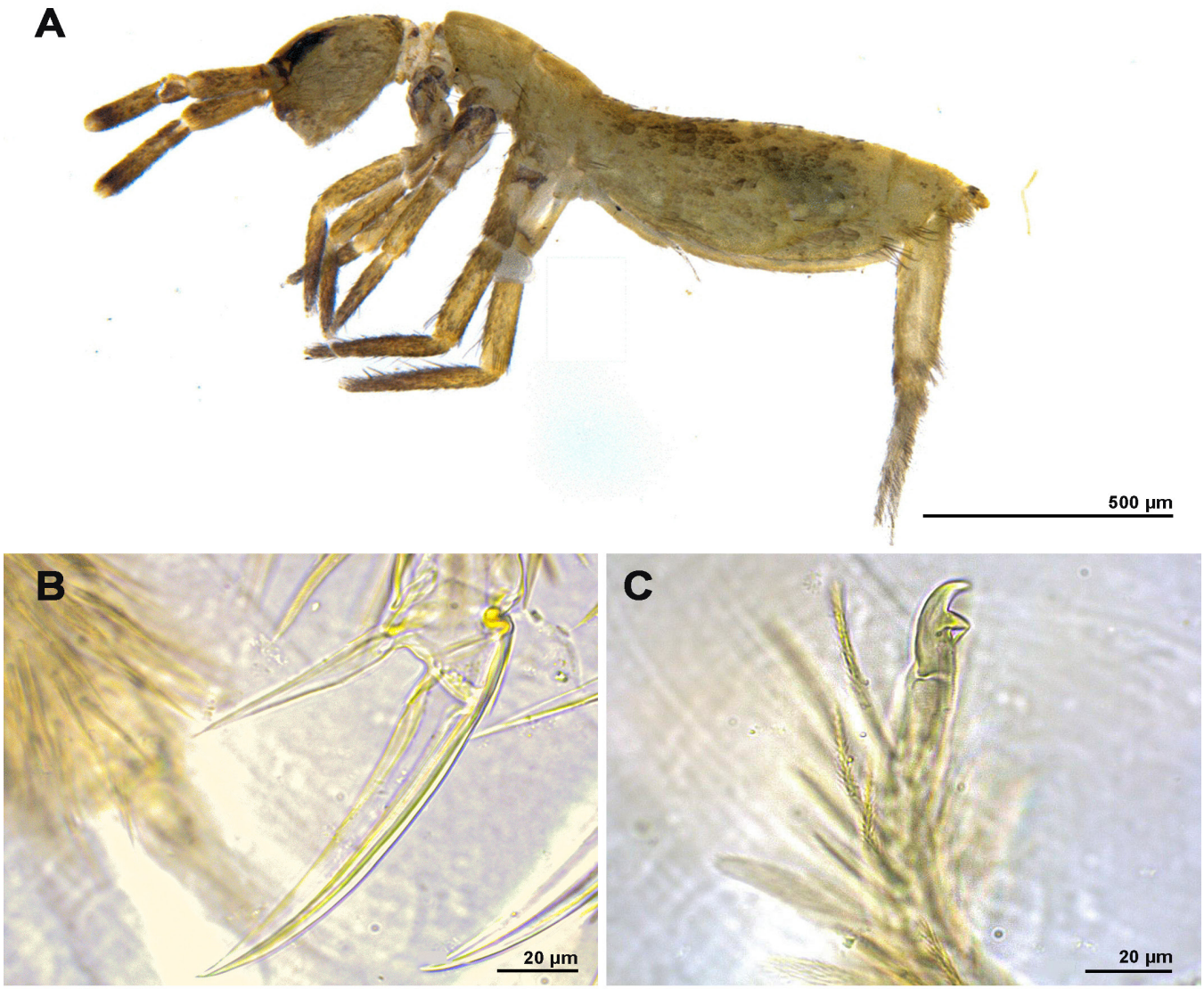

Figure 2. *Dicranocentrus nepalensis* Mari Mutt & Bhattacharjee, 1980. **A.** Habitus; **B.** Unguis of fore claw; **C.** Apex of dens with mucro.

Family Isotomidae Schäffer, 1896

Subfamily Isotominae Schäffer, 1896

Isotomurus plumosus Bagnall, 1940 (Fig. 3)

Material examined. One specimen, India, Arunachal Pradesh, West Kameng district, 2.9 km away from Kunzang choekhor ling Monastery, collected from leaf litter, 27°15'31.1"N, E92°24'26.5"E, 2340 m a.s.l., 27-III-2023, leg. G. P. Mandal, reg no.- 3426/H14.

Diagnosis. Adult body length about 1.92 mm. Antennae: head diagonal- 1.24: 1. Ground colour pale yellow, with dorso-median line of dark purple pigmentation; in our specimen, the lateral longitudinal lines are faintly coloured on Abd.I–IV. Lateral black patch prominent on the Abd. VI. Head with median blue patch and basal blue diffused pigment. Antennae become gradually darker to the apex. Legs with differential pigment patches (Fig. 3A). Antennal segment ratio as I: II: III: IV- 1: 1.7: 1.8: 2.5. A prominent pin chaeta at tip of Ant. IV (Fig. 3B), Ant. III organ with two curve rods, base of Ant. I with four smooth chaetae. PAO bean shaped, 0.5 times of nearer omma. Lateral process of the labial palp not reaching the base, Md and Mx well developed. Unguis with a lateral and without any internal teeth, Emp. unarmed (Fig. 3C). VT not clearly visible. Ventral side of manubrium near dens with 3+3 conspicuous spinous chaetae. Dens: mucro ratio- 18.5: 1. Mucro quadridentate with chaetae.

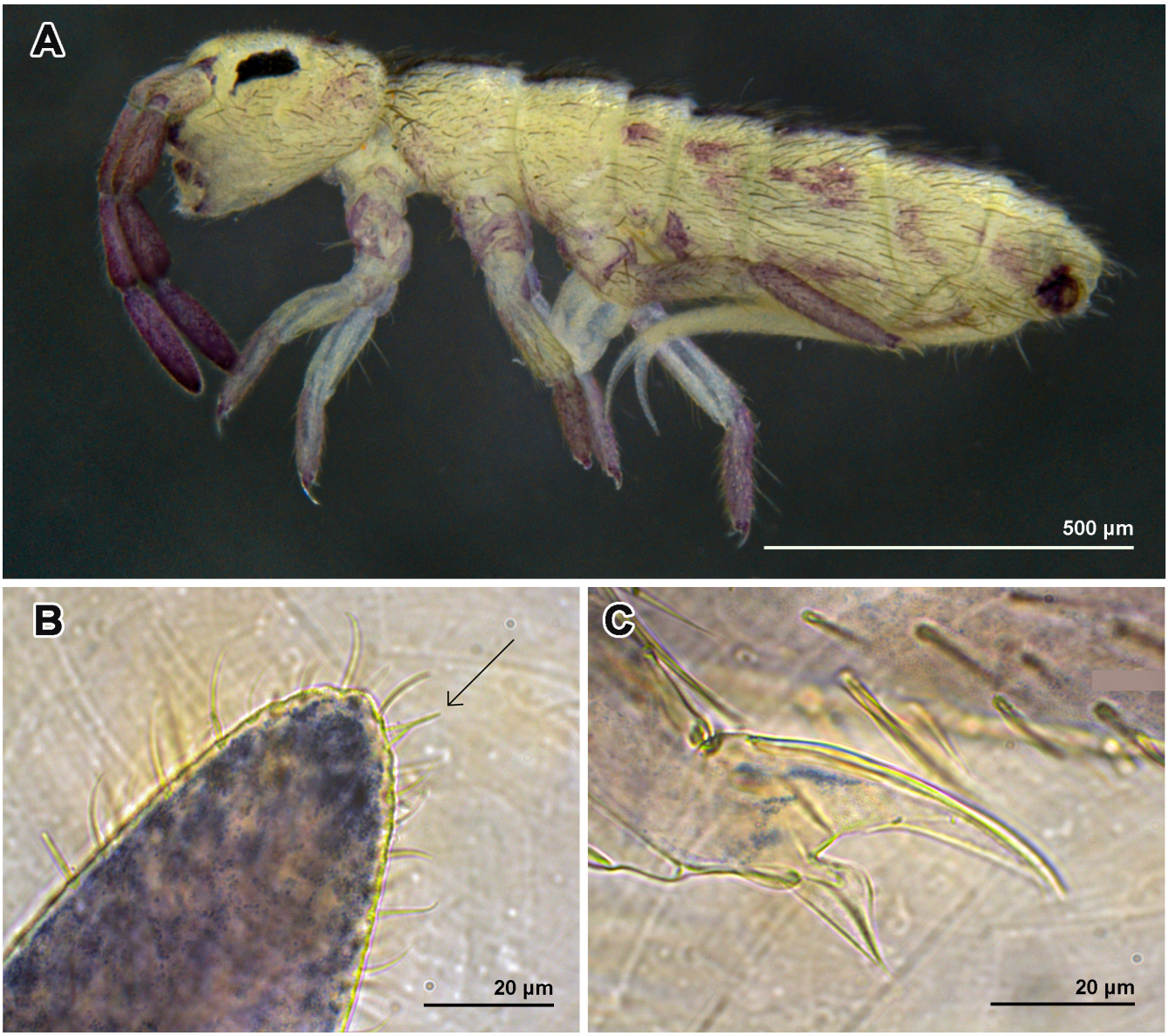

Figure 3. *Isotomurus plumosus* Bagnall, 1940. **A.** Habitus; **B.** Pin setae of Ant. IV; **C.** Hind claw.

Distribution in India. Arunachal Pradesh (West Kameng)

General distribution. Arctic, Sub-arctic, Europe, West & Central Asia, Mediterranean, North America, and New Zealand (Bellinger et al., 1996–2024).

Remarks. This species is quite similar to *I. palustris* (Muller, 1776) in colour pattern and mucro shape, unlike *I. plumosus* has a lighter lateral colouration, and a more prominent middle dark blue band and a distinct chaeta present at the base of mucro.

Isotomurus pseudopalustris Carapelli, Frati, Fanciulli & Dallai, 2001 (Fig. 4).

Material examined. 51 specimens, India, Arunachal Pradesh, West Kameng district, 4 km away from Bomdila towards Pedung, collected from leaf litter, 27°16'01.2"N 92°24'43.2"E, 2561 m a.s.l., 27-III-2023, leg. G. P. Mandal, reg no.- 3435/H14.

Diagnosis. Average body length about 1.9 mm (three specimens). Antennae: head diagonal 1.4: 1. Body colour dirty white with differential pigment patches mainly on the lateral portion of the body, dark uninterrupted dorso-median black band conspicuous. Antennae, coxa and tita uniformly brown pigmented (Fig. 4A).

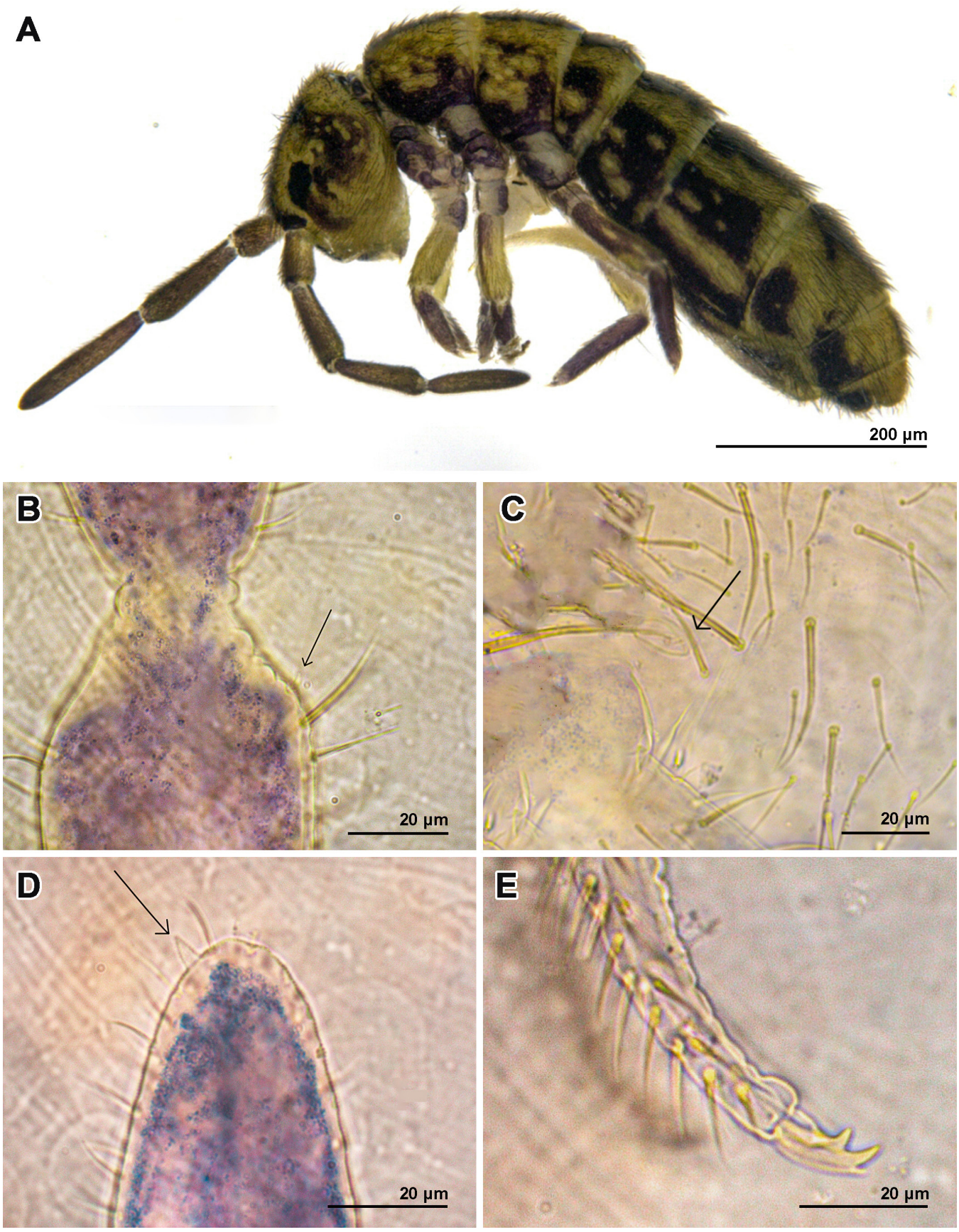

Figure 4. *Isotomurus pseudopalustris* Carapelli, Frati, Fanciulli & Dallai, 2001. **A.** Habitus; **B.** Ant. III organ; **C.** PAO, **D.** Pin chaeta on Ant. IV; **E.** Apex of dens with mucro.

Antennal segment ration I: II: III: IV- 1: 1.4: 1.5: 2.1. Ant. IV with a prominent pin chaeta (Fig. 4D) and Ant. III with two small curved sense rods (Fig. 4B). Base of Ant. I with 8–9 small smooth chaetae. PAO oval shaped 0.5 times to nearer omma (Fig. 4C). Md. with four basal as well as rear teeth. Unguis with one inner and outer tooth, Emp. lanceolate with corner edge. Hind tita with 5 large ciliated chaetae. VT with 4+4 chaetae. Tenaculum quadridentate. Manubrium: dens- 1: 2.27, covered with numerous smooth setae. Mucro with four teeth, without chaeta (Fig. 4E).

Distribution in India. Arunachal Pradesh.

General distribution. Mediterranean region (Bellinger et al., 1996–2024).

Remarks. This species was first reported not only from India but also from the Asian continent. The species is similar to *I. palustris* -in most aspects expect some differences in the colour pattern, the latter one has relatively less pigmentation in the lateral portion and the median longitudinal band becomes lighter in the last few segments (Potapov, 2001).

Family Entomobryidae Schäffer, 1896

Subfamily Willowsiinae Yoshi and Suhardjono, 1989

Genus *Willowsia* Shoebotham, 1917

Willowsia jacobsoni (Börner, 1913) (Fig. 5).

Material examined. 5 specimens, India, West Bengal, Alipurduar district, Dhowla Jhora Tea Garden, N26°34'12'', E89°41'24'', 64.9 m a.s.l., 06-II-2023, leg. P. Mandal., reg. no- 3395/H14.

Diagnosis. Average adult body length 1.7 mm (two specimens). General body colour dull white to pale yellow with dark blue bands on Th. II, Abd. III and posterior 1/4 of Abd. II & Abd. IV. Antennae become gradually darker from apex of Ant. II. Blue-brown pigment patch present on all tita. No other pigment patches observed in our specimens (Fig. 5A). Body scales are with long basal rib type, manubrial scales elongated. Ant. IV with a unilobed apical bulb. Antennal segment ratio I: II: III: IV- 1: 2.4: 1.3: 2.6. Ant. III sensorial organ with two rods. Antennae: head diagonal- 1: 2. Labral chaetae formula as 4/5, 5, 4, pre-labral chaetae ciliated. Labral intrusion with more than one denticles. Tip of lateral process of the labial palp reaching the apex. Head chaetotaxy same as per Katz (2017) (Fig. 5B). Unguis with internal basal paired, two unpaired teeth, tenet hair clavate, larger than the unguis (Fig. 5C). Trochanteral organ with 18–20 spines. Retinaculum quadridented (Fig. 5D). Dens crenulated and without spines, smooth part 2 times as mucro in length. Mucro bidentate with a basal spine, reaching sub-apical tooth (Fig. 5E).

Distribution in India. West Bengal (Darjeeling).

General distribution. West Africa, Madagascar, Continental South East Asia, Malaysia, Hawaii, Melanesia & Micronesia, Antillean & South Florida, Caribbean Mainland, Australia (Bellinger et al., 1996–2024).

Remarks. The previous distribution of *Willowsia* in India from Himachal Pradesh and Jammu & Kashmir (Mandal, 2018) was wrongly interpreted. After rechecking the slides, it becomes obvious that they were another species of *Willowsia* which were misidentified. Here we are providing an updated distribution of *Willowsia jacobsoni* from West Bengal, India. The specimens were collected from the ant nest of *Caesalpinia pulcherrima* plant.

Order Symphypleona Börner, 1901

Family Katiannidae Börner, 1913

Genus *Sminthurinus* Börner, 1901

Sminthurinus bimaculatus Axelson, 1902 (Fig. 6)

Material examined. 4 specimens, India, Arunachal Pradesh, Tawang district, 500 m from Cona County Crossing, collected from leaf litter, 27°34'34.0"N, 91°52'37.7"E, 2552.7 m a.s.l., 02-IV-2023, leg. G. P. Mandal, reg no.-3391/H14; 11 specimens, Odisha, Kendujhar district, Bolani, Hayarpur, 22°7'22.8"N, 85°20'24"E, 2876 m a.s.l., 17-VII-2021, leg. A. Rameshkumar., reg no.-3402/H14.

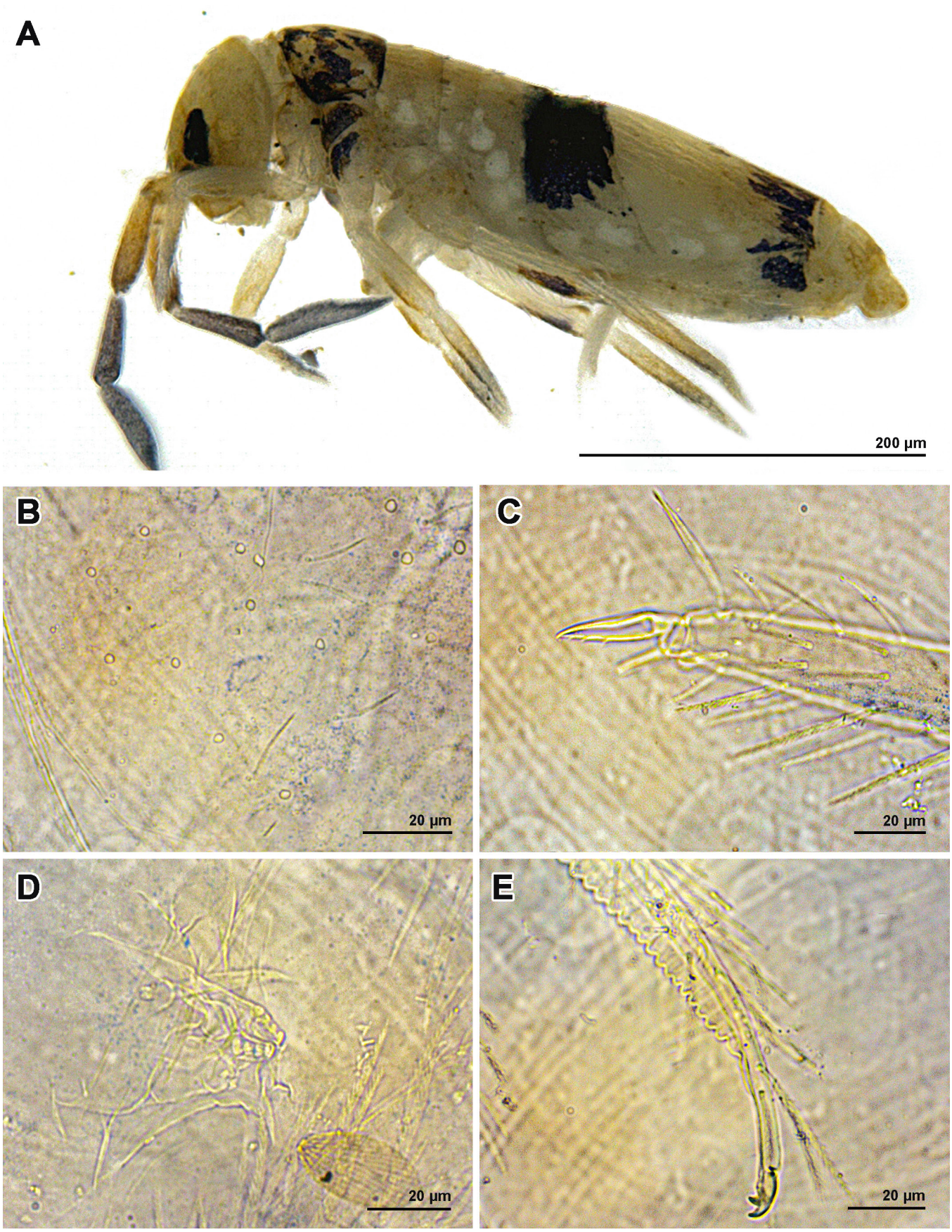

Figure 5. *Willowsia jacobsoni* (Borner, 1913). **A.** Habitus; **B.** Cephalic chaetotaxy; **C.** Fore leg; **D.** Retinaculum; **E.** Distal part of dens with mucro.

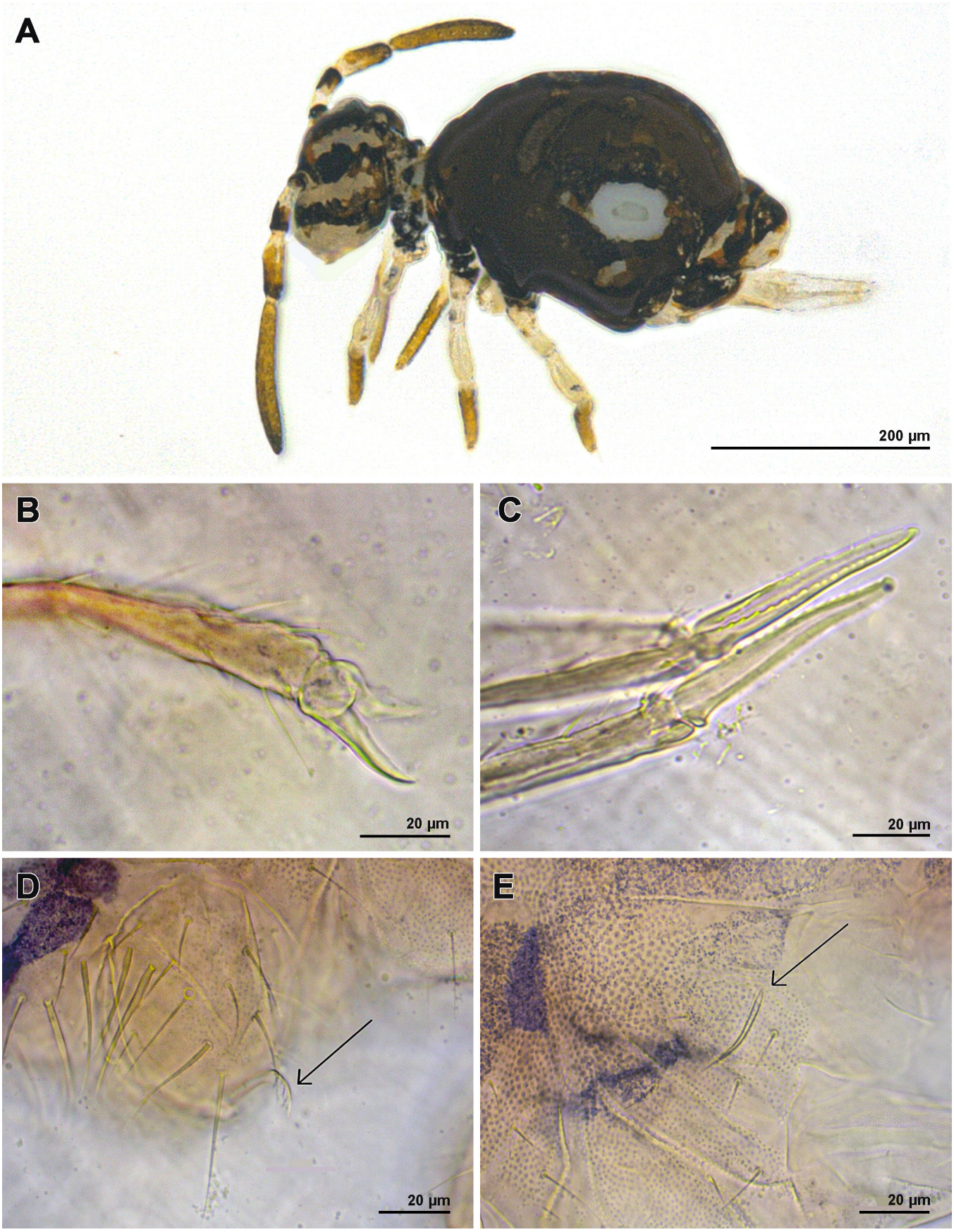

Figure 6. *Sminthurinus bimaculatus* Axelson, 1902. **A.** Habitus; **B.** Hind claw; **C.** Mucro; **D.** App. an. organ; **E.** Neosminthuroid setae.

Diagnosis. General body length 0.85 mm. Body colour deep brown with differential black pathches. A white patch present postero-laterally on both sides of the globular abdomen. Head with brown-black lateral transverse bands (Fig. 6A). Apex of Ant. I–II and Ant. III–IV completely deep brown pigmented. Tita of each leg covered with brown pigment. Trochanter and femur of leg and furcula are pale. Antennal segment ratio as Ant. I: Ant. II: Ant. III: Ant. IV-1: 1.72: 2.4: 6.2; fourth antennal segment annulated. 8+8 ommatidia with two chaetae on each side, C and D smaller ones. Unguis with basal teeth, an internal tooth and a lateral tooth; Emp. I larger, Emp. II–III broader than Emp. I (Fig. 6B). Tita of each leg with 2–4 spatulate chaetae. App. an. with 3–4 hair-like branches (Fig. 6D). Abd. V fused with other Abd. segments and with Bothriotrichum D. Neosminthuroid chaetae present near the furca (Fig. 6E). VT smooth with 1+1 anterior setae. Manubrium with 12 chaetae, dens dorsally with 12+12 chaetae. Ratio of Manubrium: dens: mucro- 2.13: 2.27: 1. Mucro elongated, lamellate, inner side with serrated edges (Fig. 6C).

Distribution in India. Arunachal Pradesh (Tawang), Odisha (Bolani).

General distribution. Arctic and Subarctic region, Europe, West and Central Asia, Mediterranean region (Bellinger et al., 1996–2024).

Remarks. The examined species has a small inner tooth in unguis, however Bretfeld (1999) mentioned that teeth may or may not be present in some examples. This species is collected from leaf litter mainly of pine and rhododendron forest.

Family Sminthuridae Lubbock, 1862

Genus *Sphyrotheca* Börner, 1906

Sphyrotheca multifasciata (Reuter, 1881) (Fig. 7)

Material examined. 4 specimens, India, West Bengal, Coochbehar district, Torsha river embankment, collected from Banana garden soil, 26°18'15.48''N, 89°26'48.12''E, 32.9 m a.s.l., 07-II-2023, leg. P. Mandal., reg. no.- 3389/H14; 2 specimens, West Bengal, Coochbehar district, Cooch Behar Rajbari Park, 26°19'41.88''N, 89°26'22.56''E, 45.11 m a.s.l., 07-II-2023, leg. P. Mandal, reg. no.- 3440/H14.

Diagnosis. Adult body length up to 0.87 mm. Head diagonal 0.34 mm. Body colour pale yellow with deep violet-blue patches present all over the body and head, darker on the ventral side. Legs with diffused pigment patches and a horizontal blue band present near the fore part of each tibia. Furcula uniformly pigmented (Fig. 7A). Antennal segment ratio I: II: III: IV– 1: 1.4: 2: 3.7. Head with 4+4 frontal spine-like chaetae and 4+4 median thick chaetae (Fig. 7B), 8+8 ommatidia present in a circle patch. Labial chaetotaxy is 4,5,5. Md with 5 apical teeth. Most dorsal abdominal chaeta are modified thick and rough, numerous on the posterior part, thin smooth chaetae scattered sparsely. Trochanter with a strong spine (Fig. 7C). Unguis with a median internal and a small external tooth with pseudonychia, Emp. with a thin filament and small spine, hind leg Emp. smaller than the others (Fig. 7D). Bothriotricha B, C, D clearly visible. App. an. elongated, apically curved towards the anus. Mucro: dens ratio as–1: 2.36. Dens dorsally with 18 smooth chaetae in 3 rows. Mucro elongated, lamellate with basal serrations (Fig. 7E).

Distribution in India. West Bengal (Coochbehar).

General distribution. North Eurasia, Sino-Japanese, Mediterranean countries, North America, and South-West Australia (Bellinger et al., 1996–2024).

Remarks. This species is collected from the soil samples extracted from those specific locations, covered in a layer of moss along with leaf litter. It is the first time this species recorded from India.

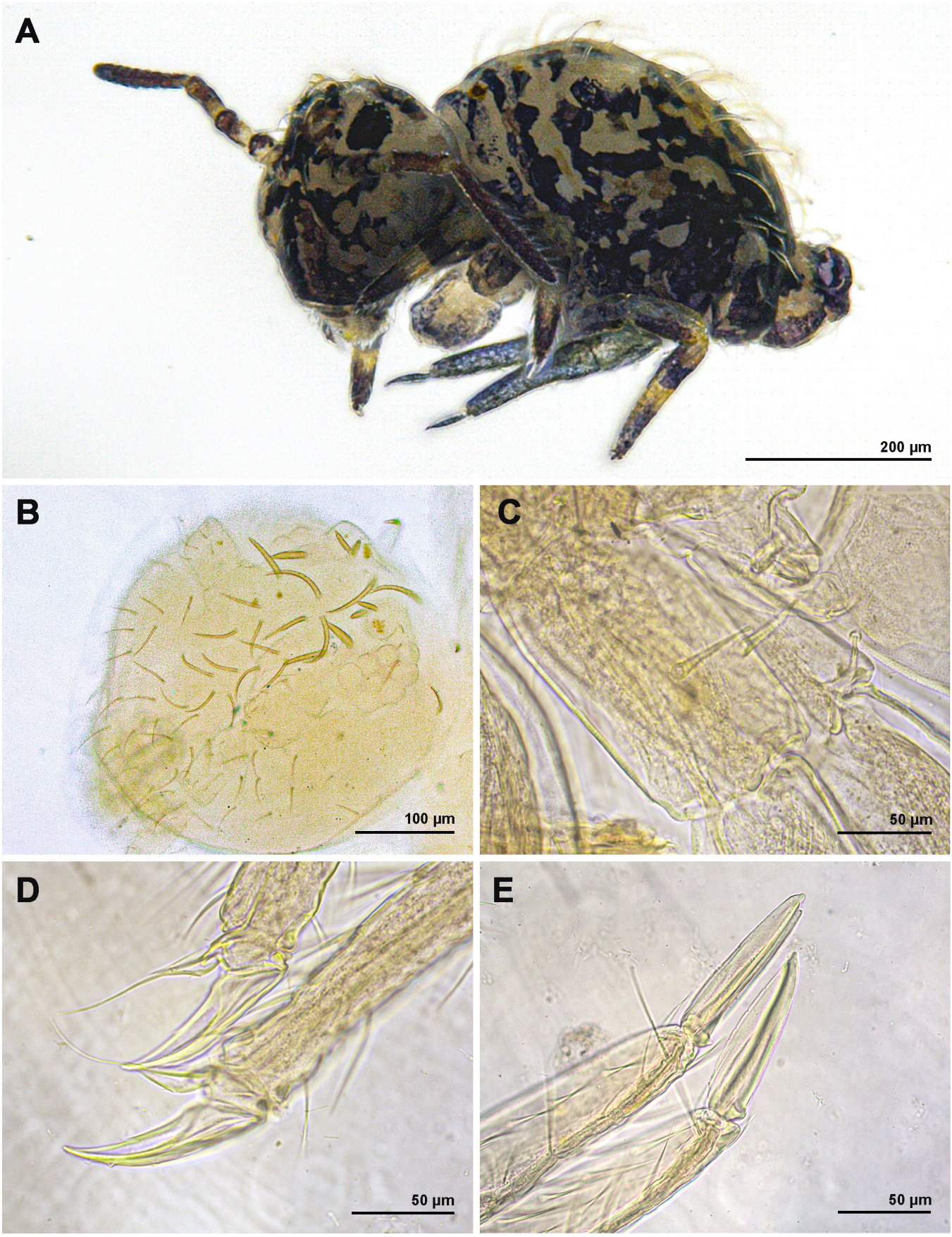

Figure 7. *Sphyrotheca multifasciata* (Reuter, 1881). **A.** Habitus; **B.** Spinous setae on head; **C.** Trochanteral organ; **D.** Fore and mid claw; **E.** Mucro.

DISCUSSION

The mountainous and terai region of Eastern Himalayan region, Darjeeling and Arunachal Pradesh is among one of the most bio-diverse regions and comes under the world hotspot zone, regardless very little study of the lower invertebrates has been done here (Chettri et al., 2010). Previously, Mitra (1976a) described a new species *Seira arunachala* Mitra, 1976 and two new records *Homidia cingula* (Börner, 1906) and *Salina (Salina) yosii* Salmon, 1964 first time from Arunachal Pradesh. Later, Mandal and Hazra (2009) studied the Collembola faunal diversity of the eastern and North-Eastern part of India and reported a total of 76 species of which 64 are from the order Entomobryomorpha, 11 are from Poduromorpha, no species from order Symphypleona recorded. In the checklist of Collembola from India, published by Mandal (2018), only one species was reported from each of the genera of *Sminthurinus* and *Sphyrotheca*, after this study one more species to each of the genera is added.

This study also clarifies the conflict regarding the distribution of *Willowsia jacobsoni* in India. In addition, two more *Isotomurus* species are added to the past seven species of which four are endemic to India. Large areas of India and diverse ecosystems probably harbour a large number of the Collembola species as they inhabit various habitats. This study is mainly based on the materials from the collections made during the Eastern Himalayan Region survey, 2022–2023. Therefore, different sampling methods, ecosystem exploration and more extensive study should be done to conquer proper knowledge about Indian Collembola fauna.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: P. Mandal: Collected and identified specimens, written the original manuscript; G.P. Mandal: Survey and project supervisor, reviewer, identifier; K.K. Suman: Specimen collection and reviewing; K.K. Bhattacharya: Review and editing; S. Kumari: Specimen collection and Identification. All authors approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in the National Collections of ZSI (Zoological Survey of India) and are available from the curator, upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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اطلاعات تاکسونومیک گونه‌های به تازگی گزارش شدهٔ دم‌فنری‌ها (Hexapoda: Collembola) از ایالات شرقی و شمال شرق هند

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چکیـــده: شش گونه از دم‌فنری‌ها، متعلق به پنج خانواده و دو راسته، برای اولین بار از هند گزارش شدند. کل گونه‌های ثبت شده جدید به طور عمده در طول برنامه مطالعاتی نواحی هیمالایای شرقی و از دو ایالت بنگال غربی و آروناچال پرادش، جمع‌آوری شده‌اند و شامل *Sphyrotheca multifasciata* (Reuter, 1881) (Sminthuridae)، *Sminthurinus bimaculatus* Axelson, 1902 (Katiannidae)، *Dicranocentrus nepalensis* Mari Mutt & Bhattacharjee, 1980 (Orchesellidae)، *Isotomurus plumosus* Bagnall, 1940 (Isotomidae)، *Isotomurus pseudopalustris* Carapelli, Frati, Fanciulli & Dallai, 2001 (Isotomidae) و *Willowsia jacobsoni* (Börner, 1913) (Entomobryidae) بودند. با در نظر گرفتن نتایج این تحقیق تعداد دم‌فنری‌های ثبت شده در هند به ۳۴۸ گونه رسید. فهرست نمونه‌های مورد بررسی، توصیف افتراقی و تصاویر میکروسکوپی گونه‌های ثبت شده جدید ارایه شد.

واژگـان کلیدی: دم‌فنری‌ها، ریزبندپایان خاکزی، گزارش جدید، تنوع زیستی، رده‌بندی