European Journal of Taxonomy 935: 101–121
https://doi.org/10.5852/ejt.2024.935.2549

ISSN 2118-9773
www.europeanjournaloftaxonomy.eu
2024 · Mandal P. *et al.*

Research article

urn:lsid:zoobank.org:pub:C4364351-09E6-4934-AF52-9EC6704E353F

Two new species and one new record of *Willowsia* Shoebotham, 1917 (Collembola: Entomobryidae) from the Eastern Himalayan region of India

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Abstract. Two species new to science *Willowsia sikkimensis* sp. nov. and *W. arunachalensis* sp. nov., and one new record of the genus *Willowsia* Shoebotham, 1917 are described and illustrated here. The new species are mainly distinguished from the others on the basis of pigment pattern, scale type and chaetotaxy. The species were collected from the states of Arunachal Pradesh and Sikkim (India). *Willowsia shiae* Pan, Zhang & Chen, 2006 is recorded for the first time from India (Arunachal Pradesh) and redescribed with detailed chaetotaxic nomenclature. A key to the Indian species of *Willowsia* and a comparison table of related species are also provided.

Keywords. *Willowsia,* key, colour pattern, sexual dimorphism.

Mandal P, Mandal G.P., Suman K.K. & Bhattacharya K.K. 2024. Two new species and one new record of *Willowsia* Shoebotham, 1917 (Collembola: Entomobryidae) from the Eastern Himalayan region of India. *European Journal of Taxonomy* 935: 101–121. https://doi.org/10.5852/ejt.2024.935.2549

Introduction

Seira nigromaculata Lubbock, 1873 was separated from the genus *Seira* Lubbock, 1869 and a new genus *Willowsia* Shoebotham, 1917 was erected by Shoebotham (1917) as it differs from *Seira* in having a bidented mucro with a basal spine, dens without scales and some species with sexual dimorphism. The variable body colour pattern remains an important taxonomic character for species discrimination among *Willowsia*, although sexual dimorphism in a Puerto Rican population of *Willowsia jacobsoni* (Börner, 1913) showed colour variation (Mari-Mutt 1981). In addition, pointed scales with distinguished

ribs, dens without scales, bidented mucro with basal spine and inner teeth of unguis also bear taxonomic characters for the genus (Zhang *et al.* 2011). *Willowsia* with 42 described species worldwide belongs to the tribe Willowsiinae Yoshii & Suhardjono, 1989 under the largest Collembola family Entomobryidae Schäffer, 1896 (Bellinger *et al.* 1996–2024) and the largest diversity of *Willowsia* occurs in temperate and sub-tropical Asia (Zhang *et al.* 2011). Based on the latest Indian checklist of Collembola Lubbock, 1873, only two species – *W. nigromaculata* (Lubbock, 1873) and *W. kalatopensis* Baquero, Jordana & Mandal, 2015 – have been reported from India (Mandal 2018). In this study, *W. shiae* Pan, Zhang, & Chen, 2006 is reported for the first time from India and two new species of *Willowsia* are described from Sikkim and Arunachal Pradesh, the eastern part of the Himalayan region, India.

Material and methods

The Eastern Himalayan region belongs to a biodiversity hotspot area as it encompasses large numbers of endemic species as well as threatened taxa. Arunachal Pradesh, the largest mountainous state of the Eastern Himalayan region, is also part of the Himalaya biodiversity hotspot and a globally important eco-region (Saikia *et al.* 2017). The eastern part of Himalaya exhibits a mixed tropical, wet temperate, conifer to sub-alpine vegetation with limited human intervention which favours the occurrence of a varied collembolan fauna. The collection localities of Arunachal Pradesh (27°15.957′ N, 92°25.520′ E; 8405.5 ft a.s.l.) and Sikkim (27°42.565′ N, 88°33.723′ E; 7824.80 ft a.s.l.) are enriched mainly with the leaf litter of deodar (*Cedrus deodara* (Roxb. ex D.Don) G.Don, pine (*Pinus roxburghii* Sarg.) and other trees of alpine forest.

The specimens for this study were collected using an entomological aspirator and stored in vials with 70% ethyl alcohol. Sorting up to family level was done with a Leica M205A stereo microscope attached to a Leica DMC6200 camera. A few entire specimens were mounted dorso-laterally on slides using Hoyer's medium (Krantz 1978) and dried on hot plate. Depigmentation was performed using Nesbitt's solution (Krantz 1978) for chaetotaxy study. Taxonomical identification was carried out with a Leica DM2500 microscope attached to a Leica DFC 295 camera following the standard key (Bellinger *et al.* 1996–2024). Morphological taxonomic characters were digitally drawn using CorelDRAW Suite 2021 ver. 23.1.0.389. Scale morphology is described following Zhang *et al.* (2011). Head and ocular setae are designated following Jordana & Baquero (2005) and Mari-Mutt (1981). Labial chaetae are named following Gisin (1967). Nomenclature of tergal chaetae follows Szeptycki (1979), Jordana & Baquero (2005) and Zhang *et al.* (2019). All the specimens were deposited at the National Zoological Collection (NZC) of the Zoological Survey of India (ZSI).

Institutional abbreviations

NZC = National Zoological Collection
ZSI = Zoological Survey of India

Abbreviations for morphological terms

Abd. I–VI = abdominal segment I–VI
Ant. I–IV = antennal segment I–IV
mac = macrochaeta, -ae
man = manubrium
mi = microchaeta, -ae
ms = S-microchaeta,-ae (microsensillum, -a)
psp = pseudopore
sens = ordinary S-chaeta, -ae on terga
Th. I–III = thoracic segments I–III

Results

Taxonomy

Class Collembola Lubbock, 1873
Order Entomobryomorpha Börner, 1913
Family Entomobryidae Schäffer, 1896
Subfamily Willowsiinae Yoshii & Suhardjono, 1989

Genus ***Willowsia*** Shoebotham, 1917

Diagnosis

Body length ranges from 1–2 mm; 8+8 eyes within dark patches; four segmented antennae, unilobed or bilobed apical bulb; scales broad and apically pointed with various rib length from spinulate to uninterrupted type, present on body and frequently on appendages also; elongated terminal scales absent on body segments; unguis with one or two unpaired teeth; dens without scales and spines; bidented mucro with basal spine.

Willowsia sikkimensis sp. nov.
urn:lsid:zoobank.org:act:CFAA8B12-FD08-4A58-A42D-728210F73FA7
Figs 1–3, Tables 1–3

Diagnosis

Blue pigment present on Abd. III–V and as patches on lateral side of head, Th. III, Abd. II; pigment sometimes deep on Th. III. Head with 9+9 antennal and 9+9 sutural mac. Th. II with 5+5 medio-sublateral and 19–21 posterior mac; Abd. I–IV with 3, 5, 3, 13 central mac on each side respectively and Abd. IV with 23 lateral mac.

Etymology

The specific epithet is given after the type specimen collection state Sikkim (India).

Type material

Holotype

INDIA • ♀ (on slide); collected from Sikkim, North Sikkim District, Lachen Village; 27°42.565′ N, 88°33.723′ E; 7824.80 ft a.s.l.; 9 Sep. 2022; G.P. Mandal leg.; in leaf litter; reg. no. 3287/H14; NZC.

Paratypes

INDIA • 3 ♀♀ (on slides), 25 specs in ethyl alcohol; same collection data as for holotype; reg. no. 3388/H14; NZC.

Description

Measurements. Body length up to 2.4 mm without appendages (Fig. 1A–C).

Colouration. General body colour pale yellow; deep blue pigment present on Abd. III–V and diffusely on Th. III, Abd. II (Fig. 1A–B), sometimes Th. III deeply pigmented (Fig. 1C). Coxa and distal part of hind femur with blue patch. Eye patches dark blue, transverse band present between two eyepatches, little blue ting present behind eyes.

Scales. Spinulate type of scales present all over body (Fig. 2A), Ant. I–II, legs up to femur. Ventral side of manubrium with slender scales.

Table 1 (continued on next page). Comparison of morphological characters between the new species and related world species of *Willowsia* Shoebotham, 1917.

species	colouration	scale type	scales present (P) or absent (A)			apical bulb	trochanteral organ spine	posterior mac on labral triangle
			Ant	legs	man			
W. arunachalensis sp. nov.	legs, Ant. uniformly pigmented; Abd. III, V–VI totally pigmented. All segments are laterally pigmented	long basal rib	A	A	P	bilobed	16–18	5 ciliate
W. bartkei Stach, 1965	transverse blue band on Abd. II–III, posterior Abd. II and IV	spinulate	A	A	A	unilobed	30	?
W. buski (Lubbock, 1870)	uniformly blue colour pigment present across body	long basal rib	A	A	A	bilobed	10	5 ciliate
W. cassagnaui Zhang, 2015	irregular lateral pigment patches on Th. II–Abd. VI.	long basal rib	A	A	P	bilobed	14	5 ciliate
W. christianseni Chang & Ma, 2018	anterior of Th. II, lateral margin of Th. II–III and posterior part of Abd. III–V with blue pigment	spinulate	P	P	P	bilobed	21	5 ciliate
W. fascia Pan & Zhang, 2016	transverse pigment bands on Abd. II–III	very long rib	A	A	A	?	8–13	5 ciliate
W. guangdongensis Zhang, Xu & Chen, 2007a	scattered blue pigment on lateral side from thorax to Abd. III, posterior margin of Abd. IV–V	long basal rib	P	P	P	unilobed	20–29	5 ciliate
W. guangxiensis Shi & Chen, 2004	Abd. II–III entirely dark blue pigmented	spinulate	P	P	P	bilobed	38–41	8 ciliate
W. ieti Yosii 1971	Abd. II with two pairs of minute spots, Abd. III with narrow transverse band and Abd. IV lateral band; Abd. V with pigment patch	long basal rib	P	A	P	bilobed	20–30	?
W. jacobsoni (Börner, 1913)	Th. II and Abd. III are fully pigmented and ⅓ of Abd. IV and II	long basal rib	?	?	P	unilobed	16	3–5 ciliated
W. japonica (Folsom, 1898)	lateral patches on Thorax, Abd. I–II and IV; transverse bands on posterior Abd. III and V	short rib	A	A	A	lobed		unknown

Table 1 (continued).

species	colouration	scale type	scales present			apical bulb	trochanteral organ spine	posterior mac on labral triangle
			Ant	legs	man			
W. nigromaculata (Lubbock, 1873)	lateral margins of Th. II–Abd. II with blue pigment, Abd. III with one transverse band and Abd. IV with one lateral spot on each side	long basal rib	A	A	A	bilobed	42–49	5 ciliate
W. platani (Nicolet 1842)	Th. III, Abd. II–IV, Abd. V posteriorly and Abd. VI with dark transverse bands	long basal rib	A	A	A	?	?	5 ciliate
W. pseudobuskii Pan & Zhang, 2016	transverse bands on Th.III, posterior margin of Abd. II–III	long basal rib	A	A	A	unilobed	10–17	5 ciliate
W. pseudoplatani Pan & Zhang, 2016	metathorax and Abd. II–IV dark blue, Abd. V with a posterior dark band	long basal rib	A	A	A	?	11–16	5 ciliate
W. pseudoshi Ma, 2016	head dark blue with a median yellow patch; blue pigment along the lateral margin of the body	spinulate	P	P	P	bilobed	52–68	7 ciliate
W. shiae Pan, Zhang & Chen, 2006	blue pigment patches scattered all over the body, Abd. III–V completely pigmented	spinulate	P	A	P	bilobed	37–40	5 ciliate
W. sikkimensis sp. nov.	blue pigment present on Th. III and Abd. III–V, as patches on head and Abd. II	spinulate	P	P	P	bilobed	53–55	5 ciliate
W. variabilis Ma, 2016	blue pigment present on head and body, deeper on lateral sides	spinulate	P	P	P	bilobed	49–52	7 ciliate
W. zhaotongensis Chai & Ma, 2017	blue pigment on Abd. III, V, ⅔ of Abd. IV, patches on Abd. II and coxa of leg	spinulate	P	P	P	bilobed	36–38	6 ciliate

Fig. 1. *Willowsia sikkimensis* sp. nov., habitus. **A**. Holotype, ♀ (reg. no. 3287/H14). **B–C**. Paratype, ♀ (reg. no. 3388/H14.). Scale bars: A–B = 1 mm; C = 500 µm.

Head. Eyes 8+8, G and H smaller. Antennae 2.47 × as long as head diagonal. Ratio of antennal segments I: II: III: IV = 1: 1.56: 1.57: 2.45. Ant. IV with many sensory setae and bilobed bulb distally. Dorsal cephalic region with nine antennal (An), four median (M_1–M_4) and nine sutural (S_0–S_6, S_{4i}, S_{5i}) mac (Fig. 2B). Interocular setae as p, s, t. Labral setae formula as 4/5, 5, 4; pre-labral setae ciliated, others

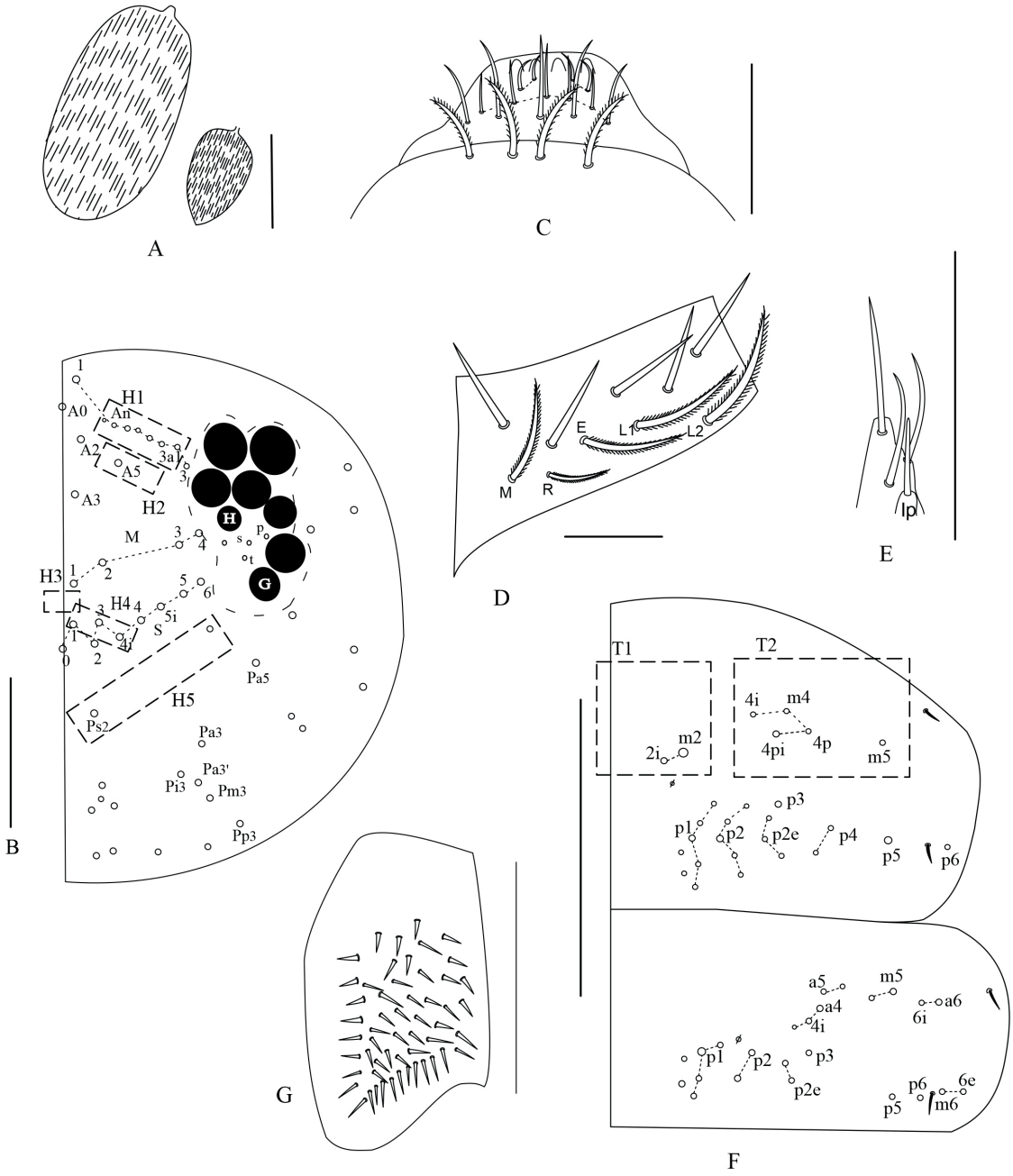

Fig. 2. *Willowsia sikkimensis* sp. nov., paratype, ♀ (reg. no. 3388/H14). **A**. Body scale type. **B**. Dorsal chaetotaxy of head. **C**. Labrum. **D**. Labial triangle (right side). **E**. Lateral process of labial papilla E (right side). **F**. Chaetotaxy of Th. II–III. **G**. Trochanteral organ. Scale bars: A, D = 20 μm; C, E, G = 50 μm; B = 100 μm; F = 200 μm.

smooth; labral papillae conical (Fig. 2C). Labial triangle with five ciliated ($MREL_1L_2$) and five smooth setae (Fig. 2D), tip of lateral process of labial papilla reaching apex of labial papilla (Fig. 2E).

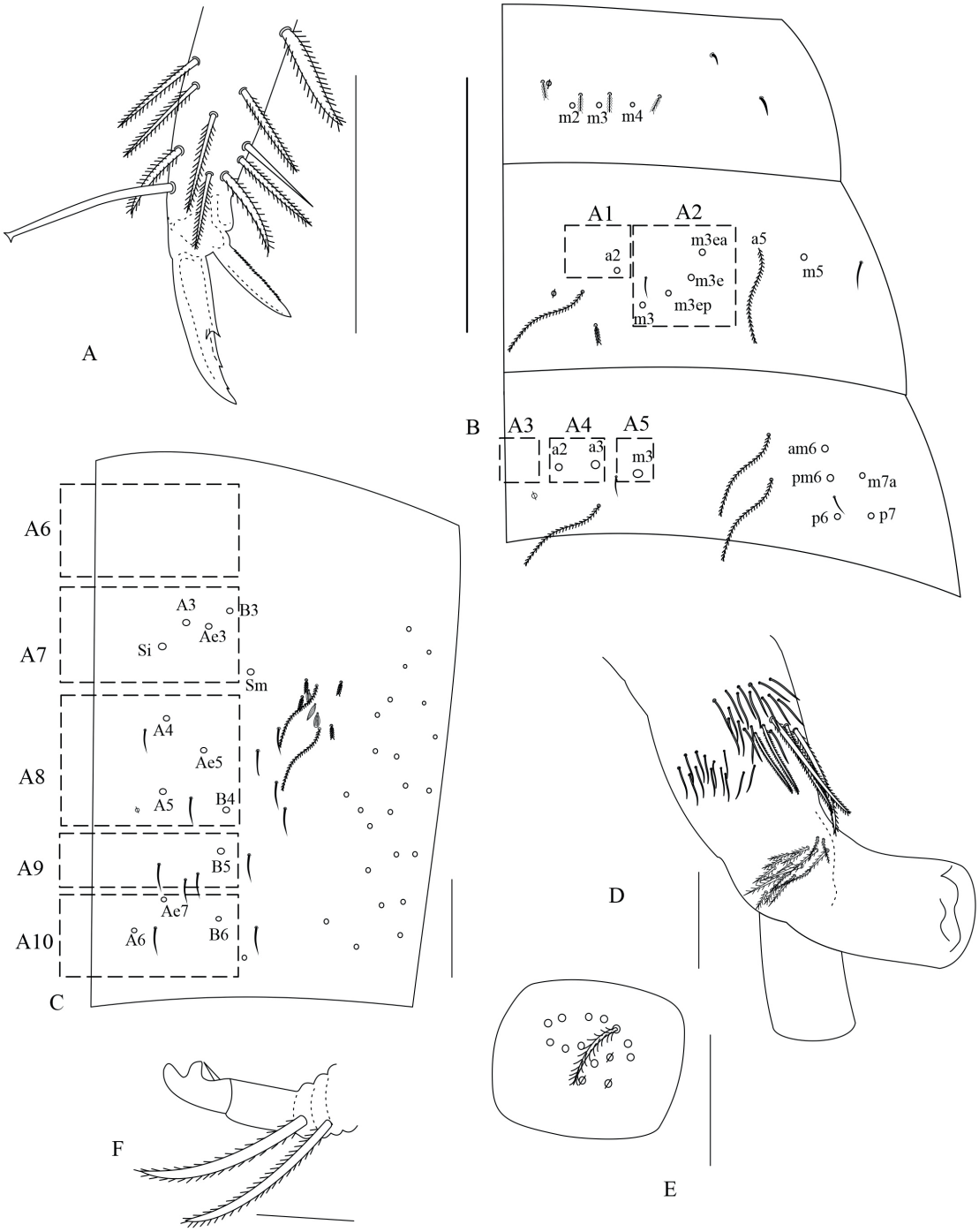

Fig. 3. *Willowsia sikkimensis* sp. nov., holotype, ♀ (reg. no. 3287/H14). **A**. Hind foot complex. **B**. Chaetotaxy of Abd. I–III (right side). **C**. Chaetotaxy of Abd IV (right side). **D**. Anterior face of ventral tube. **E**. Manubrial plaque (left side). **F**. Mucro. Scale bars: A, D = 100 µm; B = 200 µm; C, E = 50 µm; F = 25 µm.

Table 2. Chaetotaxy comparison between the closely related world species of *Willowsia* Shoebotham, 1917.

species	Th. II (mac)			Th. III (mac)	Abd. I (mac)	Abd. II (mac)	Abd. III		Abd. IV
	medio median	sub lateral	posterior			central	central	lateral	central
W. arunachalensis sp. nov.	0	2	9	13	2	4	2	4	8
W. bartkei Stach, 1965	2	3	15	18	3	3	2	4	7
W. buski (Lubbock, 1870)	0	2	8	12	2	4	2	3	4
W. cassagnaui Zhang, 2015	0	1	10	11	3	4	2	3	7
W. christianseni Chang & Ma, 2018	2	2	18	19	4	4	3	4	10–12
W. fascia Pan & Zhang, 2016	1	2	11	16	3	3	3	3	7
W. guangdongensis Zhang, Xu & Chen, 2007a	0	1	3	9	2	3	2	3	7
W. guangxiensis Shi & Chen, 2004	2	4	19	13	4	5	2	4	13
W. ieti Yosii 1971	0	1	10	11	2	4	2	3	7–8
W. jacobsoni (Börner, 1913)	0	1	5	–	8	2	2	5	5
W. japonica (Folsom, 1898)	1	1	11	13–14	3	3	2	3	7
W. kalatopensis Baquero, Jordana & Mandal 2015	0	3	0	11	2	3	2	–	6–7
W. nigromaculata (Lubbock, 1873)	0	1	7	10	3	3	3	3	7
W. platani (Nicolet 1842)	0	1	7	10	2–3	3	3	3	7
W. pseudobuskii Pan & Zhang, 2016	1	2	12	15	3	3	2	3	5
W. pseudoplatani Pan & Zhang, 2016	0	1	6	13	3	3	2	3	7
W. pseudoshi Ma, 2016	2	2	17–19	22–23	4	4	2	5	16–19
W. shiae Pan, Zhang & Chen, 2006	3	4	19	24	4	5–6	3	5	9
W. sikkimensis sp. nov.	2	4	20–21	24	3	5	3	5	13
W. variabilis Ma, 2016	2	2	23–25	27–28	7–8	5	2	3–4	10–13
W. zhaotongensis Chai & Ma, 2017	2	3	16–18	22–23	4	4–5	3	5	10–12

Thorax. Tergal mac as shown in Fig. 2F. Th. II with two medio-median (m2, m2i) (in Figure T1), five medio-sublateral (m4, m4i, m4p, m4pi, m5) (in Figure T2), 20–21 posterior mac (p5i sometimes absent), two sens present. Th. III with 18 median and six lateral mac (a6, a6i, p5, p6, m6, m6e), two sens present on lateral side. Trochanteral organ with 53–55 smooth setae arranged in square (Fig. 2G). Unguis with basal paired, two unpaired inner teeth each located 22 µm, 36 µm and 46 µm distance from unguis base respectively, 13µm distance between two inner unpaired teeth (hind claw); unguiculus

Table 3. Comparison of *Willowsia sikkimensis* sp. nov. and *W. zhaotongensis* Chai & Ma, 2017.

characters	***W. sikkimensis*** sp. nov.	***W. zhaotongensis*** Chai & Ma, 2017
colouration	pigment patch on Th. II and Abd. II present or sometimes reduced	deep pigment band on Abd. II present, Th. II not pigmented
labial triangle seate formula	$MREL_1L_2$	$M_1M_2REL_1L_2$
antennal (An) setae no.	9	7
Th. II setae	m1 absent, 4pi present, posterior setae: 19–21	m1 present, 4pi absent posterior setae: 16–18
Abd. I central mac	3 (m4p absent)	4 (m4p present)
Abd. II central mac	a3 absent, 3ea present	a3 present, 3ea absent
Abd. IV mac	central: 13 (Ae3 absent) lateral: 25	central: 10–12 lateral: 17–20
uncrenulated dens: mucro	1.26: 1	1.4–1.7: 1

lanceolate with outer edge serrate. Thick, smooth clavate tenent hair present, slightly longer than inner side of unguis (Fig. 3A).

Abdomen. Dorsal chaetotaxy as Fig. 3B–C. Abd. I with three central mac (m2–m4), one ms and one sens. Abd. II with five central mac (a2, m3, m3ep, m3e, m3ea), two sens and one ms, m5 present. Abd. III with three dorso-central (a2, a3, m3), five lateral mac (am6, pm6, p6, m7a, p7) and two sens. Abd. IV 13 central (A3–A6, Ae3, Ae5, Ae7, B3–B6, Si, Sm) and 23 lateral mac and with 12 S-setae as Figure 3C. Ventral tube with 5+5 long and 17–19 median ciliated setae on each side of anterior face, about 17–20 lateral flap setae, posterior side with 1+1 smooth and 1+1 ciliated setae (Fig. 3D). Manubrial plaque with 11 ciliated setae, three pseudopores clearly visible (Fig. 3E). Uncrenulated part of dens 1.26 × as long as mucro. Bidented mucro with sub-equal teeth, basal spine tip reaching subapical tooth (Fig. 3F).

Remarks

This new species is greatly different from the species of *Willowsia* described from India and the world both in chaetotaxy and colour pattern (Tables 1–2). *Willowsia sikkimensis* sp. nov. is similar to the Chinese species *W. zhaotongensis* in head chaetotaxy, scale morphology and its position on body (Chai & Ma 2017). However, the two species are noticeably dissimilar in antennal and body chaetotaxy, a labial triangle with a different posterior row formula and a few other characters listed in Table 3.

Willowsia arunachalensis sp. nov.
urn:lsid:zoobank.org:act:8AEC0266-A90C-40E2-B23C-B82C9A363BD4
Figs 4–6, Tables 1–2, 4

Diagnosis

Body segments with distinct pigment patches, intensely coloured laterally; Abd. III pigmented; Scales of long basal rib type, absent on legs and antennae, present on manubrium; labral papilla with 2–4 denticles; Abd. I–IV with 2, 4, 2, 8 central mac on each side respectively, Abd. IV with 13 lateral mac.

Etymology

The specific epithet was given after the type collection state Arunachal Pradesh (India).

Type material

Holotype

INDIA • ♀ (on slide); Arunachal Pradesh, West Kameng district, Bomdila town, Bomdila Forest Inspection Bungalow; 27°15.957′ N, 92°25.520′ E; 8337 ft a.s.l.; 29 Mar. 2023; G.P. Mandal leg., reg. no. 3386/H14; NZC.

Paratypes

INDIA • 4 ♀♀ (on slides), 18 specs in alcohol; same collection data as for holotype; reg. no. 3387/H14; NZC.

Description

Measurements. Average body length in adult up to 3 mm (Fig. 4A–B).

Colour. Ground colour pale yellow, blue pigment scattered as distinct patches all over body, especially on lateral side. Eye patches dark blue; blue transverse band between eyes; ventral side of head blue pigmented. Antennae pigmented, darker towards tip. Legs with blue pigment, furcula unpigmented (Fig. 4A–B).

Scales. Scales of long basal rib type (Figs 4D, 5A); present on body and ventral manubrium. Antennae and legs devoid of scales.

Head. Eyes 8+8, G and H smaller. Antenna 2.57 × as long as cephalic diagonal. Antennal segment ratio as I: II: III: IV = 1: 2.42: 2.26: 3.1. Ant. IV with bilobed apical bulb, many sensory setae and normal ciliated setae (Fig. 5B). Dorsal cephalic chaetotaxy as Fig. 5C, with four antennal (An), four median (M_1–M_4) and seven sutural (S_0, S_2–S_5, S_{4i}, S_{5i}) mac. Labral formula 4/5, 5, 5, prelabral setae ciliated and other smooth, four labral papillae each with 2–4 denticles (Figs 4C, 5D). Labial palp with a thick lateral process, tip not reaching at apex of labial papilla (Fig. 5E). Labial triangular setae as $MREL_1L_2$, all ciliated (Fig. 5F).

Thorax. Thoracic mac as Fig. 5G; Th. II with two medio-sublateral (in figure T2), nine posterior mac, Th. III with 13 mac on each side. Trochanteral organ with 15–17 smooth spiny setae, 11–12 in 'L' arrangement and five present in inner area (Fig. 5H). Unguis with 4 inner teeth,1 paired basal and 2 unpaired, one external basolateral tooth present. Hind leg paired and two unpaired teeth distance from unguis base 21 µm, 32 µm, 40 µm respectively, between two unpaired teeth 8 µm. Unguiculus lanceolate with outer edge serrate, tenent hair thick and serrated with clavate tip (Figs 4E, 6A).

Abdomen. Abd. IV 2.6 × as long as Abd. III along dorsal midline. Dorsal chaetotaxy of Abd. I–IV as shown in Fig. 6B–C. Abd. I with two central mac (m3, m4) and two sens. Abd. II with four central mac (a2, m3, m3e, m5) and 6–7 lateral mesochaete, two sens. Abd. III with two central (a2, m3), four lateral mac (am6, pm6, p6, m7a) and two two sens (Fig 6B). Abd. IV with 8 central mac (A4, A6, A6e, A7e, B4–B6, Si, Sm), 13 lateral mac and 7 S-setae (Fig. 6C). Ventral tube with 4+4 anterior long and other 10+10 ciliated setae, 8+8–10+10 smooth lateral flap setae, posterior side with 1+1 smooth setae (Fig. 6D). Tenaculum quadridentate with a stout single seta. Manubrial plaque with five ciliated seate, two pseudopores visible (Fig. 6E). Basal part of dens a little thick, uncrenulated dens 2.45 × as long as mucro. Mucro bidented with single basal spine (Fig. 6F).

Remarks

Willowsia arunachalensis sp. nov. is similar to *W. ieti* Yosii, 1971 in chaetotaxy pattern, although differs from the latter in having lanceolate hind unguiculus, spine number of trochanteral organ and absence of scale on antennae, details given in Table 4. The new species is closest to *W. cassagnaui* Zhang, 2015 for both species have no scales on Ant. I and legs. However, the latter has 3+3 mac on Abd. I and rounded labral papillae. *Willowsia buski* (Lubbock, 1870) and the new species share a similar body chaetotaxy though they differ in colour pattern, Abd. IV chaetotaxy, labral papillae structure, trochanteral setae number etc. (Table 4). A detailed comparison of all the related species of *Willowsia* with *W. arunachalensis* is given in Table 1 along with chaetotaxic comparison of the same (Table 2).

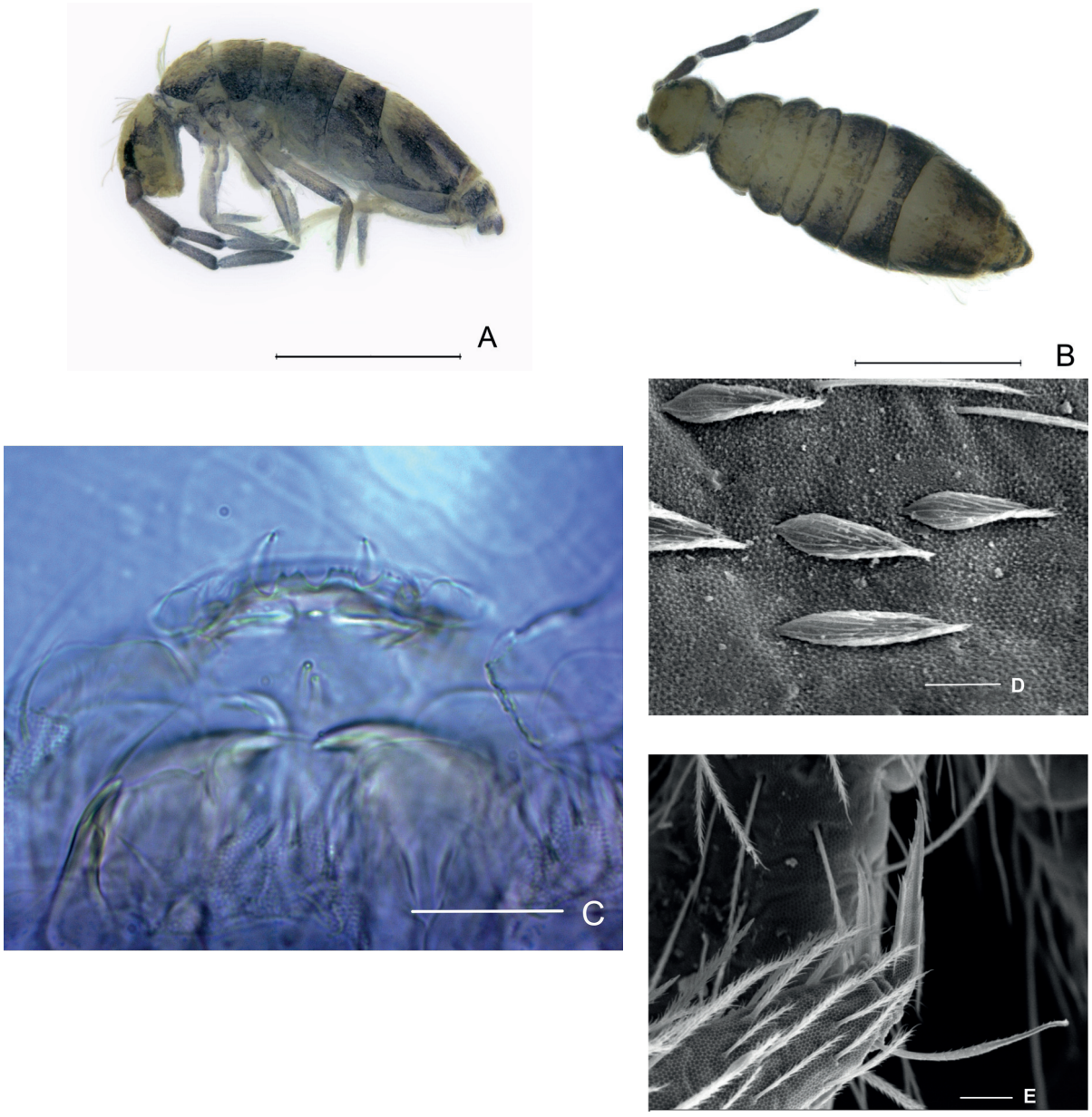

Fig. 4. *Willowsia arunachalensis* sp. nov. **A**. Holotype, ♀ (reg. no. 3386/H14), habitus, dorso-lateral view. **B**. Paratype, ♀ (reg. no. 3387/H14), habitus, dorsal view. **C–E**. Paratype, ♀ (reg. no. 3387/H14). **C**. Labral papillae. **D**. SEM of body scales. **E**. Fore claw (SEM image). Scale bars: A–B = 500 µm; C = 20 µm; D–E = 10 µm.

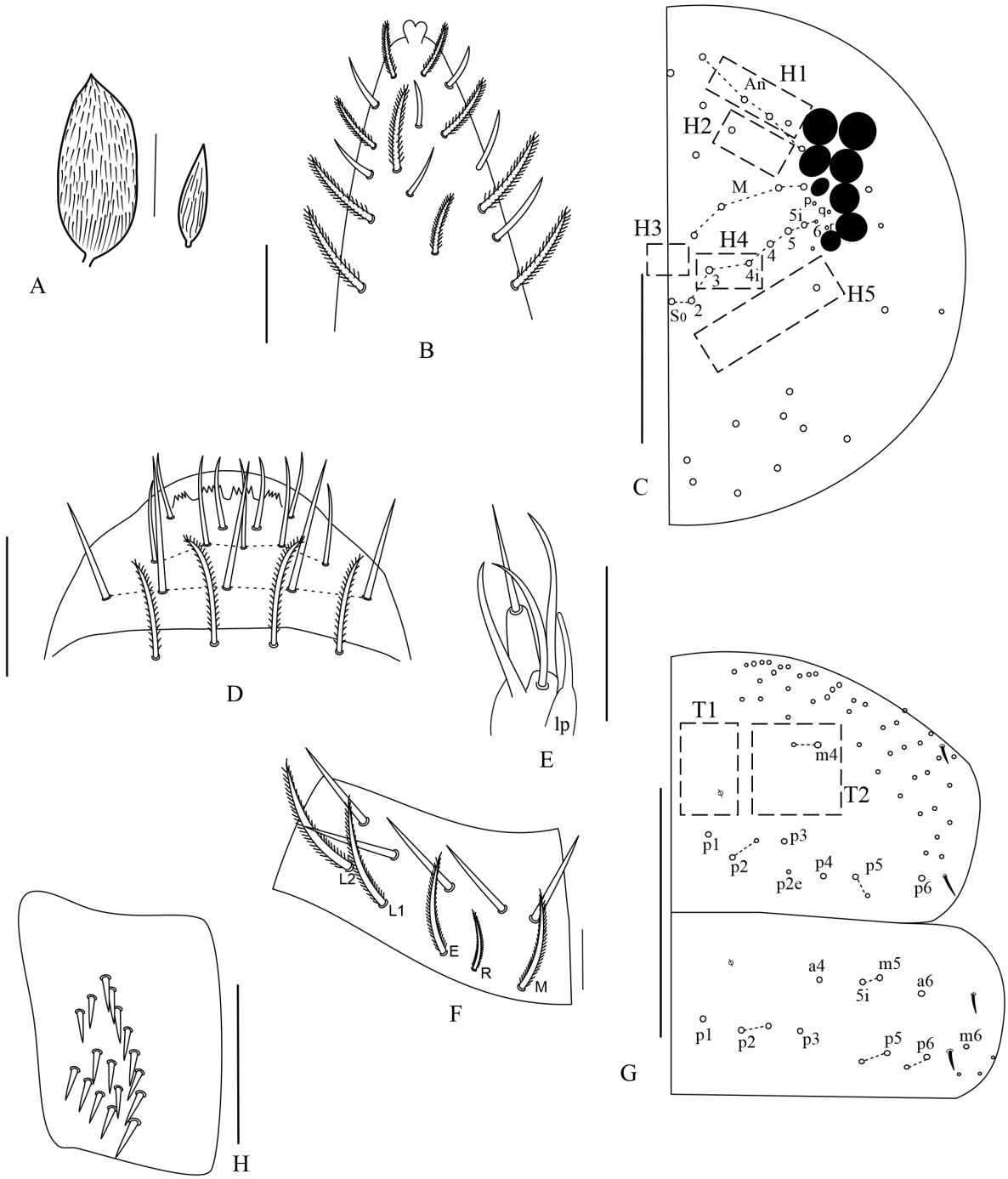

Fig. 5. *Willowsia arunachalensis* sp. nov., paratype, ♀ (reg. no. 3387/H14). **A**. Body scale. **B**. Apex of Ant IV. **C**.Dorsal head chaetotaxy (right side). **D**. Labium. **E**. Lateral process of labial palp (right side). **F**. Labial triangle (left side). **G**. Dorsal chaetotaxy of Th II-III. **H**. Trochanteral organ. Scale bars: A–B, D–F = 20 μm; C = 100 μm; G = 200 μm; H = 50 μm.

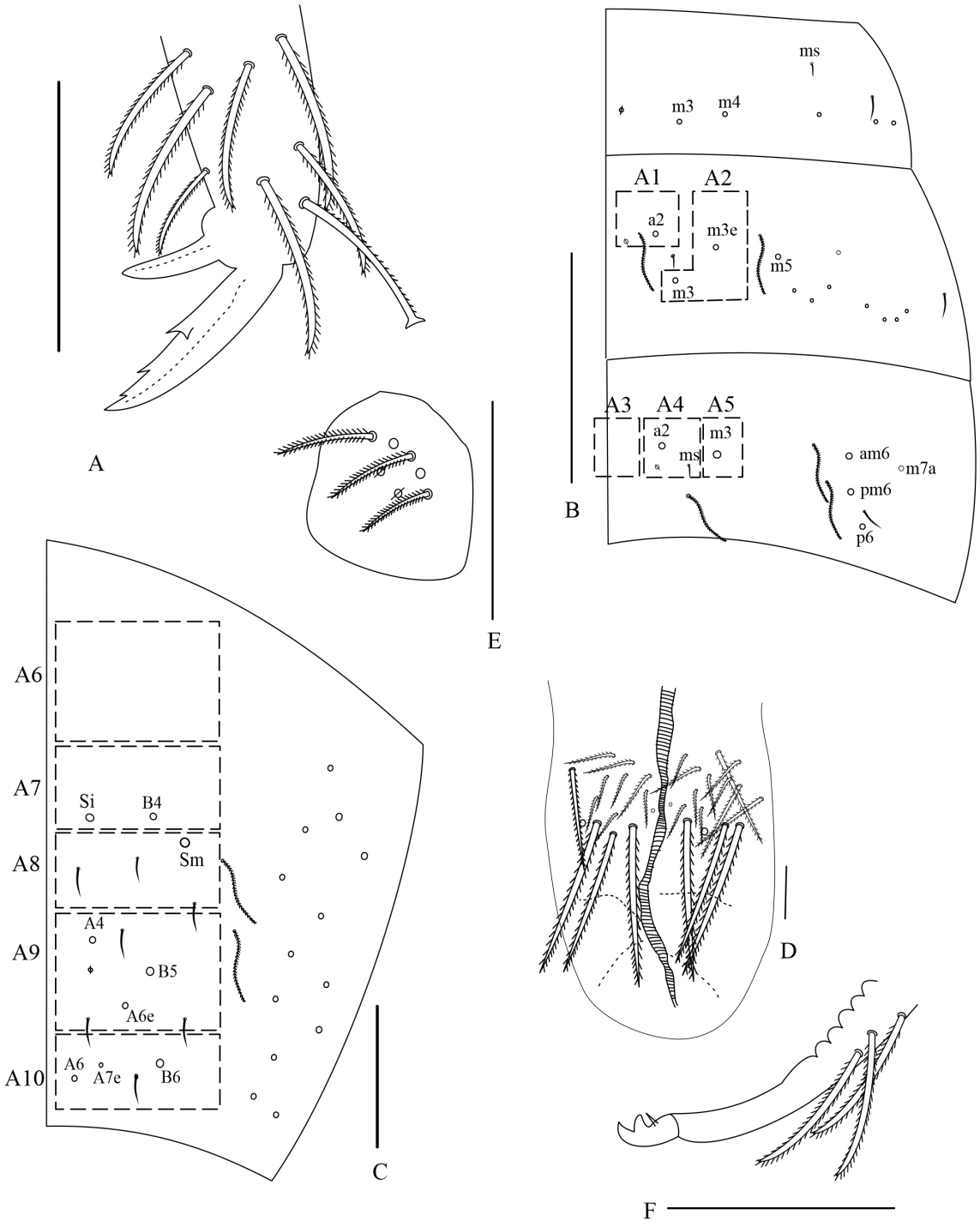

Fig. 6. *Willowsia arunachalensis* sp. nov., paratype, ♀ (reg. no. 3387/H14). **A**. Fore leg. **B**. Dorsal chaetotaxy Abd I–III. **C**. Abd IV dorsal chaetotaxy (right side). **D**. Anterior face of ventral tube. **E**. Manubrial plaque (left side). **F**. Distal part of dens with mucro. Scale bars: A, E–F = 50 μm; B = 200 μm; C = 100 μm; D = 20 μm.

Table 4. Comparison of *Willowsia arunachalensis* sp. nov., *W. cassagnaui* Zhang, 2015, *W. buski* (Lubbock, 1870) and *W. ieti* Yosii, 1971.

Characters	***W. cassagnaui*** Zhang, 2015	***W. ieti*** Yosii, 1971	***W. buski*** (Lubbock, 1870)	***W. arunachalensis*** sp. nov.
labral papillae	rounded	conical	conical	2–4 denticles
lateral process of labial palp	long	short	?	long
trochantral organ setae	about 14	<20	10	16–17
scales on				
Ant-I	absent	present present	absent	absent
furcula	present		absent	present
Hind unguiculas	lanceolate	truncate	lanceolate	lanceolate
manubrial plaque setae	?	6	?	5
anterior face of ventral tube (long ciliated setae)	5+5	4+4	5+5	4+4
chaetotaxy				
ch II	2 setae in p1	2 setae in p1	2 setae in p1	1 setae in p1
Abd. I	3+3	2+2	3+3	2+2
Abd. III (lateral setae)	3	3	3	4
Abd. IV (central)	7+7	7–8+7–8	5+5	8+8

Willowsia shiae Pan, Zhang, & Chen, 2006
Figs 7–9, Tables 1–2

Material examined

INDIA – **Arunachal Pradesh** • 1 ♀ (on slide), 48 specs in alcohol; West Kameng, Dirang; 27°23.383′ N, 92°11.464′ E, 5645 ft a.s.l., 25 Mar. 2023; G.P. Mandal leg.; reg no. 3382/H14; NZC • 1 ♀ (on slide), 5 specs in alcohol; West Kameng, Melonkgang bridge; 27°23.668′ N, 92°09.676′ E, 5950 ft a.s.l.; 25 Mar. 2023; G.P. Mandal leg.; reg no. 3383/H14; NZC • 1 ♀ (on slide), 14 specs in alcohol; West Kameng, Brokpublang; 27°13.588′ N, 92°24.413′ E; 5314 ft a.s.l., 26 Mar. 2023; P. Mandal leg.; reg no. 3384/H14; NZC • 1 ♀ (on slide), 20 specs in alcohol; West Kameng, near Kevin waterfall; 27°13.627′ N, 92°24.505′ E, 5335 ft a.s.l.; 26 Mar. 2023; K.K. Suman leg.; reg no. 3385/H14; NZC.

Diagnosis

Average adult body length 1.8–2.4 mm. General body colour pale straw yellow**,** blue pigment patches scattered all over body, Abd. III–V almost completely pigmented, rest of segments become darker at lateral edges, head with diffused pigment; antennae and legs evenly pigmented (Fig. 7A–B). Scales spinulate type (Fig. 8A), present on body, antennae, ventral side of manubrium. Legs without scales. Antennal segment ratio as I: II: III: IV = 1: 2: 1.3–1.9: 2–3.4. Ant. IV with bilobed apical bulb. Ant. III organ with two rod-like sense organ. Head with five antennal (An), four median (M_1–M_4), eight sutural (S_0–S_6, S_{4i}, S_{5i}) setae (Fig. 8B). Blunt and conical labral papilla without setae; labral setae formula as 4/4, 5, 4, prelabral setae ciliate, others smooth (Fig. 8C). Labial triangle with five finely ciliated and five smooth setae. Lateral process of labial palp not reaching the base (Fig. 8D). Dorsal chaetotaxy of Th. II as shown in the Fig. 8E with two medio-median (m2), four medio-lateral (m4, m4i, m4p, m5), 19 posterior mac and two sens. Th. III with 16 median, eight lateral mac and two sens (Fig. 8E). Unguis with one outer, paired inner and one unpaired teeth. Unguiculus lanceolate with a serreted edge. Tenent hair with a clavate tip and slightly larger than unguis in length. Trochanteral organ with 37–40 smooth spiny setae (Fig. 8F). Dorsal mac position as shown in Fig. 9. Abd. I with 4 mac (m2–m4, m4i) and

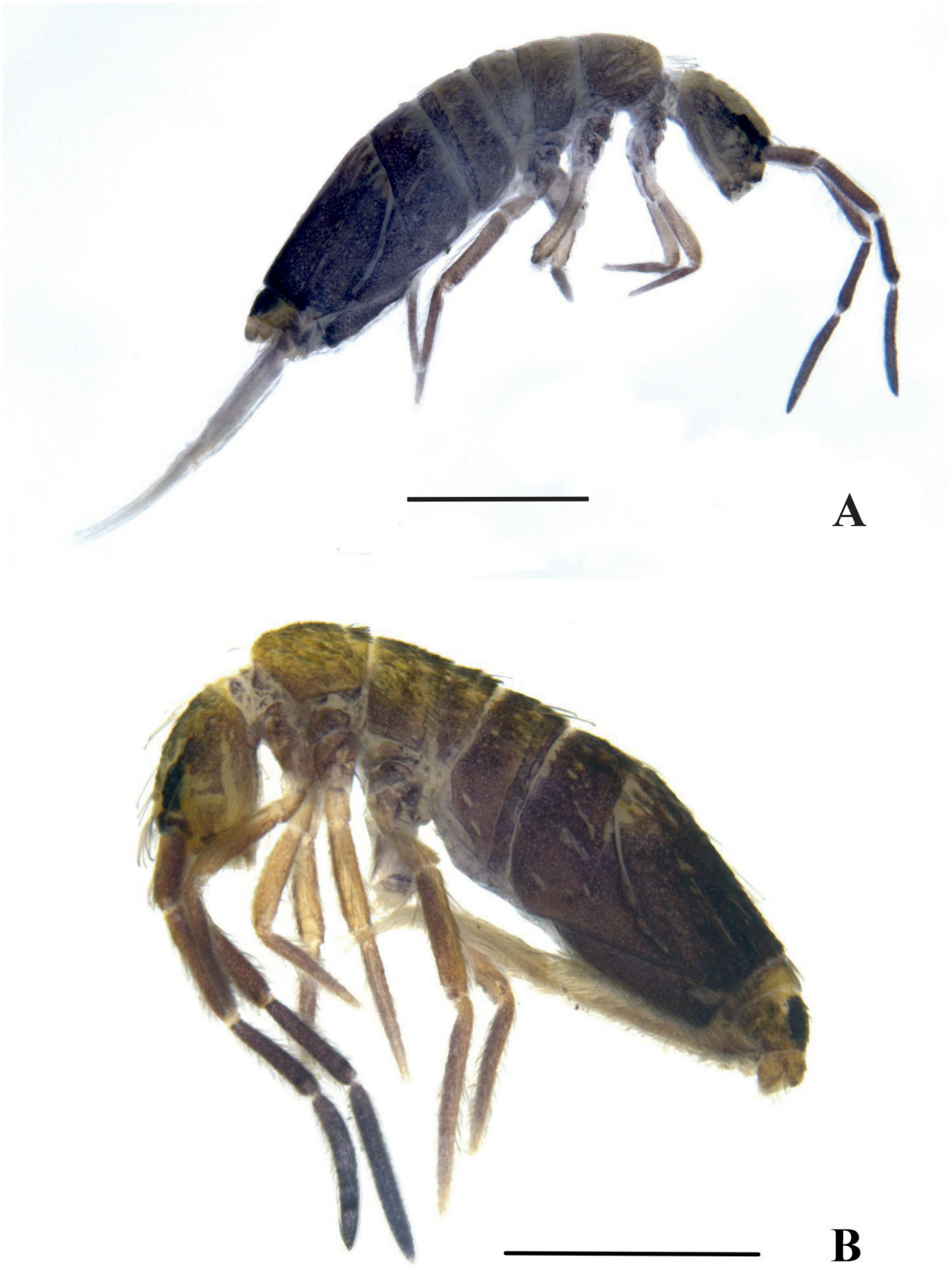

Fig. 7. *Willowsia shiae* Pan, Zhang & Chen, 2006, ♀ (reg. no. 3382/H14). Scale bars = 500 µm.

one sens, M3 arch of Abd. II with four setae (m3, m3ep, m3e, m3ea), inner area with one seta (a3), m5 present and two sens. Abd. III three central (a2–a3, m3) and five lateral setae (am6, pm6, p6, m7a, p7), three sens present. Abd. IV with nine dorso-central (A3–A4, A6, B3–B6, Sm, Si),12–16 lateral setae and 6 S-setae. Ventral tube with 5+5 anterior large and other small ciliated setae, 5+5 smooth and 12–14 ciliated setae on lateral flap, posterior side with 1+1 smooth setae. Tenaculum quadridented. Length

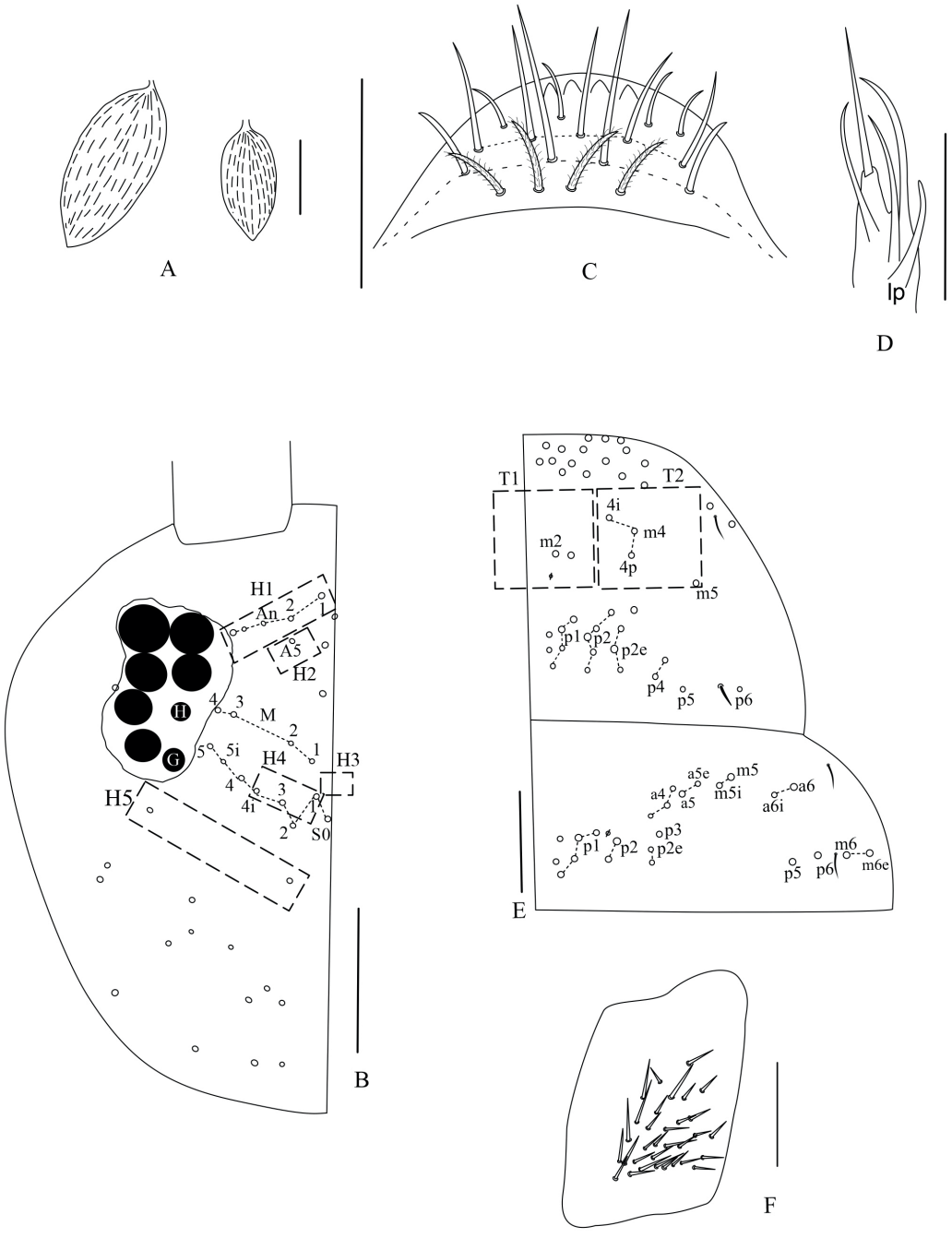

Fig. 8. *Willowsia shiae* Pan, Zhang & Chen, 2006, ♀ (reg. no. 3385/H14). **A**. Scales. **B**. Dorsal head chaetotaxy (left side). **C**. Labrum. **D**. Lateral processes of labial palp (right side). **E**. Dorsal chaetotaxy of Th II–III. **F**. Trochanteral organ. Scale bars: A = 20 μm; B, E = 100 μm; C, F = 50 μm; D = 25 μm.

ratio of manubrium: dens as 1:1.26; dens uncrenulated part: mucro as 1.4: 1. Mucro bidented with a basal spine.

Remarks

Most of the characters of the Indian specimens of *W. shiae* are similar as per the description of Pan *et al.* (2006); however, we have found that there are differences between them in dorsal head chaetotaxy; Th. II with two mac in Gr. I (T1 in Fig. 8E), three mac in Gr. II (T2 in Fig. 8E) and four mac in the p1 row of Th. II, p5 also present. Two sens present in each Th. segment. We have also named the mac of Th. II–III and Abd. I–IV following Zhang *et al.* (2019). Collected from the leaf litter of pine and other trees of tropical alpine forest.

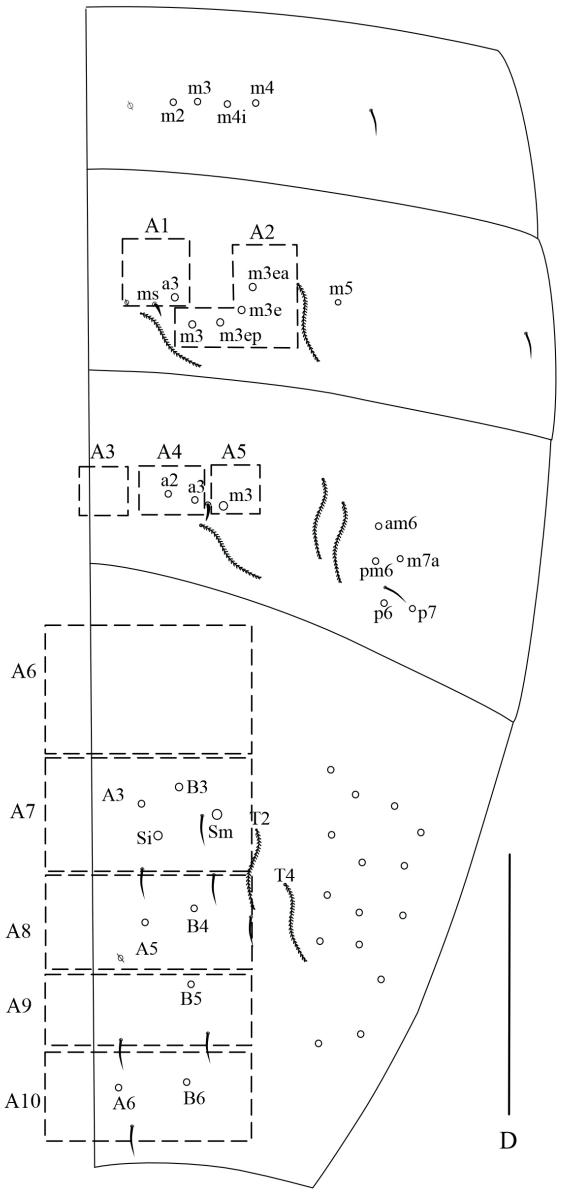

Fig. 9. *Willowsia shiae* Pan, Zhang & Chen, 2006, ♀ (reg. no. 3384/H14). Abd. I– Abd. IV chaetotaxy. Scale bar = 200 μm.

Key to the Indian species of Willowsia Shoebotham, 1917

1. Body scales with long basal rib 2
– Body scales spinulate type 3

2. Scales absent on ventral side of manubrium; Abd. I with 3+3 central mac.....
……..…… .....***W. nigromaculata*** (Lubbock, 1873)
– Scales present on ventral side of manubrium; Abd. I with 2+2 central mac .....
..... ***W. arunachalensis*** sp. nov.

3. Th. II & Abd. I non-pigmented; scales present on legs 4
– Th. II & Abd. I laterally pigmented; scales absent on legs .....***W. shiae*** Pan, Zhang & Chen, 2006

4. Abd. III & Abd. IV non pigmented; Abd. II with 3+3 central mac .....
..... ***W. kalatopensis*** Baquero & Jordana, 2015
– Abd. III & Abd. IV pigmented; Abd. II with 5+5 central mac ..... ***W. sikkimensis*** sp. nov.

Discussion

Body colour pattern, scale morphology and distribution are considered as main taxonomic characters for the species identification under genus *Willowsia* (Zhang *et al.* 2011). Generally, two types of scales (spinulate and striate) were considered as demarcating characters by Shi & Chen (2004). Later, one additional type (long basal rib) was introduced by Zhang *et al.* (2007b). In India, no species of *Willowsia* of the uninterrupted ribbed type has been recorded till now. Comparative tables of the identifying characters of the Indian and related species of *Willowsia* are given in the Tables 1–2.

Acknowledgements

We are thankful to Prof. Feng Zhang (Nanjing Agricultural University, China) and anonymous referees who provided their valuable suggestions for improvement of this manuscript. We are grateful to Dr Dhriti Banerjee, Director, Zoological Survey of India, for providing us all sorts of laboratory facilities and to all the members of Apterygota section for their constant support.

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Manuscript received: 9 July 2023
Manuscript accepted: 13 March 2024
Published on: 24 May 2024
Topic editor: Tony Robillard
Section editor: Javier Arbea
Desk editor: Eva-Maria Levermann