A new species of *Cenopalpus* Pritchard & Baker (Acari: Tenuipalpidae) from Japan, with ontogeny of chaetotaxy and a key to the world species

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ABSTRACT

A new species of flat mite, *Cenopalpus umbellatus* sp. nov. (Acari: Trombidiformes: Tenuipalpidae) is described and illustrated based on females, males, deutonymphs, protonymphs and larvae. The morphological ontogeny in idiosomal and leg chaetotaxy is briefly described for all stages. Mite specimens were collected from the leaves of *Rhaphiolepis indica* var. *umbellata* Makino (Rosaceae), an evergreen shrub native to Japan. An identification key to the world species of *Cenopalpus* is also provided.

INTRODUCTION

Mites of the family Tenuipalpidae *Berlese, 1913* (Acari: Trombidiformes) are harmful pests to a wide range of plants (*Jeppson, Keifer & Baker, 1975*; *Mesa et al., 2009*). The genus *Cenopalpus Pritchard & Baker, 1958*, currently contains 70 species (including the present new species), mostly described from Palearctic and Afrotropical ecozones (Table 1). *Mesa et al. (2009)* listed the genus *Cenopalpus* with 60 species, assigning the two species, *salignae* (*Meyer, 1979*) and *thelycraniae* (*Livschitz & Mitrofanov, 1967*), under *Brevipalpus*. Later, *Saccaggi et al. (2017)* cited *B. salignae* in the genus *Cenopalpus*, however, the Russian species (*B. thelycraniae*) was already transferred to *Cenopalpus* by *Mitrofanov & Strunkova (1979)*. Also, *C. iqbali Iqbal, Akbar & Ali, 2007*, was not included in *Mesa et al. (2009)*.

In Japan, comparing to spider mites (Tetranychidae), few studies have been done on the taxonomy of tenuipalpid mites. It is expected that several localities are most likely to hold undiscovered species. *Ehara & Gotoh (2009)* listed 14 species of flat mites from Japan, belonging to the genera *Aegyptobia* Sayed, *Brevipalpus* Donnadieu, *Cenopalpus*, *Dolichotetranychus* Sayed, *Pentamerismus* McGregor and *Tenuipalpus* Donnadieu, with only one species of *Cenopalpus* (*C. lineola*; Table 2). Therefore, the present work aimed to

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Table 1 List of *Cenopalpus* mites of the world (70 species)*.

	Species	Country
1	*abaii Khosrowshahi & Arbabi, 1997*	Iran
2	*adventicius Ueckermann & Ripka, 2015*	Hungary
3	*aratus Chaudhri, 1971*	Pakistan
4	*arbuti Hatzinikolis & Emmanouel, 1987*	Greece
5	*bagdasariani (Livschitz & Mitrofanov, 1970)*	Tajikistan
6	*bakeri Düzgünes, 1967*	Turkey
7	*brachypalpus Hatzinikolis, Panou & Papadoulis, 1999b*	Greece
8	*capacis Chaudhri, 1971*	Pakistan
9	*capensis (Meyer, 1979)*	South Africa
10	*carpini (Livschitz & Mitrofanov, 1967)*	Ukraine
11	*chitraliensis Akbar & Chaudhri, 1985*	Pakistan
12	*crataegi Dosse, 1971*	Iran
13	*creticus Hatzinilkolis, Papadoulis & Panou, 1999a*	Greece
14	*cumanicus Ueckermann & Ripka, 2015*	Hungary
15	*dignus Akbar & Chaudhri, 1985*	Pakistan
16	*eriobotryi Hatzinikolis, 1969*	Greece
17	*evini Khosrowshahi, 1991*	Iran
18	*favosus Chaudhri, 1971*	Pakistan
19	*halperini Castagnoli, 1987*	Israel
20	*haqii Akbar & Chaudhri, 1985*	Pakistan
21	*hederae Papaioannou-Souliotis, 1986*	Greece
22	*homalos Akbar & Chaudhri, 1985*	Pakistan
23	*iqbali Iqbal, Akbar & Ali, 2007*	Pakistan
24	*irani Dosse, 1971*	Iran
25	*japonicus Hasan, Akbar & Khalid, 2001*	Pakistan
26	*khosrowshahii Khanjani et al., 2012*	Iran
27	*kritos Hasan et al., 2004*	Pakistan
28	*lanceolatisetae (Attiah, 1956)*	Egypt
29	*limbatus Akbar & Chaudhri, 1985*	Pakistan
30	*lineola (Canestrini & Fanzago, 1876)*	Italy
31	*longirostris (Livschitz & Mitrofanov, 1967)*	Ukraine
32	*mespili (Livschitz & Mitrofanov, 1967)*	Ukraine
33	*meyerae Khosrowshahi, 1991*	Iran
34	*mughalii Akbar & Aheer, 1990*	Pakistan
35	*musai Dosse, 1975*	Lebanon
36	*natalensis (Lawrence, 1943)*	South Africa
37	*naupakticus Hatzinikolis, Panou & Papadoulis, 1999b*	Greece
38	*officinalis Papaioannou-Souliotis, 1986*	Greece
39	*oleunus (Meyer, 1979)*	South Africa
40	*orakiensis Akbar & Chaudhri, 1985*	Pakistan
41	*pegazzanoae Castagnoli, 1987*	Italy
42	*pennatisetis (Wainstein, 1958)*	Kazakhistan

	Species	Country
	Table 1 (continued).	
43	*picitilis Chaudhri, 1971*	Pakistan
44	*piger Wainstein, 1960*	Kazakhistan
45	*pistaciae Hatzinilkolis, Papadoulis & Panou, 1999a*	Greece
46	*platani (Livschitz & Mitrofanov, 1967)*	Georgia
47	*populi (Livschitz & Mitrofanov, 1967)*	Georgia
48	*pritchardi Düzgünes, 1967*	Turkey
49	*prunusi Khanjani et al., 2012*	Iran
50	*pseudospinosus (Livschitz & Mitrofanov, 1967)*	Ukranie
51	*pterinus Pritchard & Baker, 1958*	Spain
52	*pulcher (Canestrini & Fanzago, 1876)*	Italy
53	*quadricornis (Livschitz & Mitrofanov, 1967)*	Armenia
54	*quercusi Khanjani et al., 2012*	Iran
55	*ramus Manson, 1963*	Pakistan
56	*ruber Wainstein, 1960*	Tajikistan
57	*rubusi Khanjani et al., 2012*	Iran
58	*salignae (Meyer, 1979)*	South Africa
59	*saryabiensis Akbar & Chaudhri, 1985*	Pakistan
60	*scoopsetus Hatzinikolis & Papadoulis, 1999*	Greece
61	*spinosus (Donnadieu, 1875)*	France
62	*sunniensis Hasan et al., 2004*	Pakistan
63	*tamarixi (Nassar & Kandeel)—Zaher (1984)*	Egypt
64	*taygeticus Hatzinikolis, Panou & Papadoulis, 1999b*	Greece
65	*thelycraniae (Livschitz & Mitrofanov, 1967)*	Ukraine
66	*umbellatus* sp. nov. Negm, Ueckermann & Gotoh	Japan
67	*viniferus Hatzinikolis, Papadoulis & Kapaxidi, 2001*	Greece
68	*virgulatus Akbar & Chaudhri, 1985*	Pakistan
69	*wainsteini (Livschitz & Mitrofanov, 1967)*	Ukraine
70	*xini Ma & Li, 1984*	China

Note:
* Synonymy. (1) *Cenopalpus fewstrii Zaher & Yousef, 1969* (= *C. wainsteini* (*Livschitz & Mitrofanov, 1967*))—*Hatzinikolis & Emmanouel (1987)*. (2) *Cenopalpus kalandadzei* (*Reck, 1951*) (= *C. lineola* (*Canestrini & Fanzago, 1876*))—*Hatzinikolis & Emmanouel (1987)*. (3) *Brevipalpus asyntactus Baker & Pritchard, 1952* (= *C. lineola*)—*Mesa et al. (2009)*.

increase our knowledge about the tenuipalpid mite fauna in Japan through describing a new species of *Cenopalpus*. Since immature stages of mites can provide valuable information for better mite systematics, we have described all stages of the new species, with remarks on their ontogenetic changes. Also, an identification key to the world species of *Cenopalpus* is provided.

MATERIALS AND METHODS

Mite collection, examination and slide preparations were conducted as previously described in *Negm & Gotoh (2019)*. Measurements (in micrometres) were done using the imaging software Sensiv Measure® ver. 2.6.0 and were presented for the holotype specimen

Table 2 List of tenuipalpid mites known from Japan.

Species	Reference
Aegyptobia arenaria Ehara, 1982	*Ehara (1982)*
Brevipalpus californicus (Banks, 1904)	*Ehara (1962)*
B. lewisi McGregor, 1949	*Ehara (1956b)*
B. obovatus Donnadieu, 1875[a]	*Ehara (1956a)*
B. phoenicis (Geijskes, 1939)	*Ehara (1966)*
B. russulus (Boisduval, 1867)	*Ehara (1968)*
Cenopalpus lineola (Canestrini & Fanzago, 1876)	*Ehara (1966)*
C. umbellatus sp. nov. Negm, Ueckermann & Gotoh	Present study
Dolichotetranychus floridanus (Banks, 1900)	*Baker & Pritchard (1956)*
D. zoysiae Ehara, 2004	*Ehara (2004)*
Pentamerismus oregonensis McGregor, 1949	*Ehara (1962)*
P. taxi (Haller, 1877)	*Ehara (1962)*
Tenuipalpus boninensis Ehara, 1982	*Ehara (1982)*
T. pacificus Baker, 1945	*Ehara & Ohkubo (1992)*
T. zhizhilashviliae Reck, 1953[b]	*Ehara (1956b)*

Notes:
[a] *Brevipalpus obovatus (Donnadieu, 1875)* was firstly reported in Japan from its synonym *T. inornatus (Banks, 1912)* by *Ehara (1956a)*.
[b] *T. zhizhilashviliae (Reck, 1953)* was reported from its synonym *T. japonicus (Nishio, 1956)* by *Ehara, 1956b*.

then followed by the range for paratypes in parentheses. The terminology and abbreviations used in the description of the new species follows that of *Lindquist (1985)* and *Mesa et al. (2009)*. Leg chaetotaxy is adapted from *Lindquist (1985)* and *Seeman & Beard (2011)*. Several taxonomic keys to *Cenopalpus* species have been used in the present study, mostly regional (*Wainstein, 1960* (Kazakhstan); *Livschitz & Mitrofanov, 1967* (USSR); *Zaher & Yousef, 1969*, *Zaher, 1984* (Egypt); *Meyer, 1979* (World); *Akbar & Chaudhri, 1985* (Pakistan); *Hatzinikolis & Emmanouel, 1987*; *Hatzinilkolis, Papadoulis & Panou, 1999a*; *Hatzinikolis, Panou & Papadoulis, 1999b* (Greece); *Khosrowshahi & Arbabi, 1997*; *Khanjani et al., 2012* (Iran); *Çobanoğlu, Ueckermann & Sağlam, 2016*; *Çobanoğlu, Erdoğan & Kılıç, 2019* (Turkey)).

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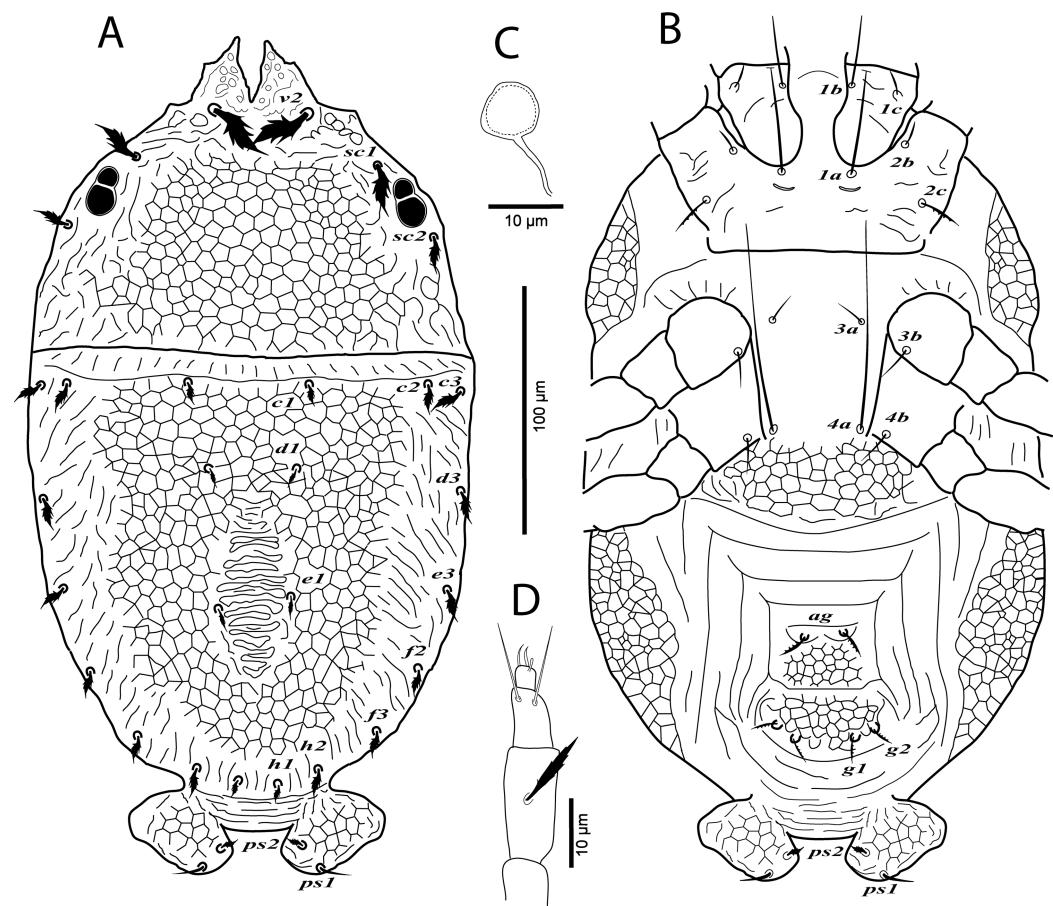
Figure 1 _Cenopalpus umbellatus_ sp. nov. Female, (A) dorsum, (B) venter, (C) spermatheca, (D) palp. (Image credit: Mohamed Waleed Negm).

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RESULTS

Family Tenuipalpidae _Berlese, 1913_
Cenopalpus Pritchard & Baker, 1958
Cenopalpus umbellatus sp. nov.
[Japanese name: Sharimbai-himehadani]
(Figs. 1–10)

DESCRIPTION

Female (_n_ = 10)

Dorsum (Fig. 1A). Idiosoma oval, length 300 (278–315), excluding gnathosoma; width 170 (157–174), at level of sejugal furrow. Rostral shield with 2 medial, 2 submedial and 2 lateral lobes; propodosoma regularly reticulated, with few irregular areolae sculpturing laterally; sejugal furrow thick and well defined; opisthosoma mostly reticulated, with few irregular transverse reticulations medially and small irregular areolae laterally;
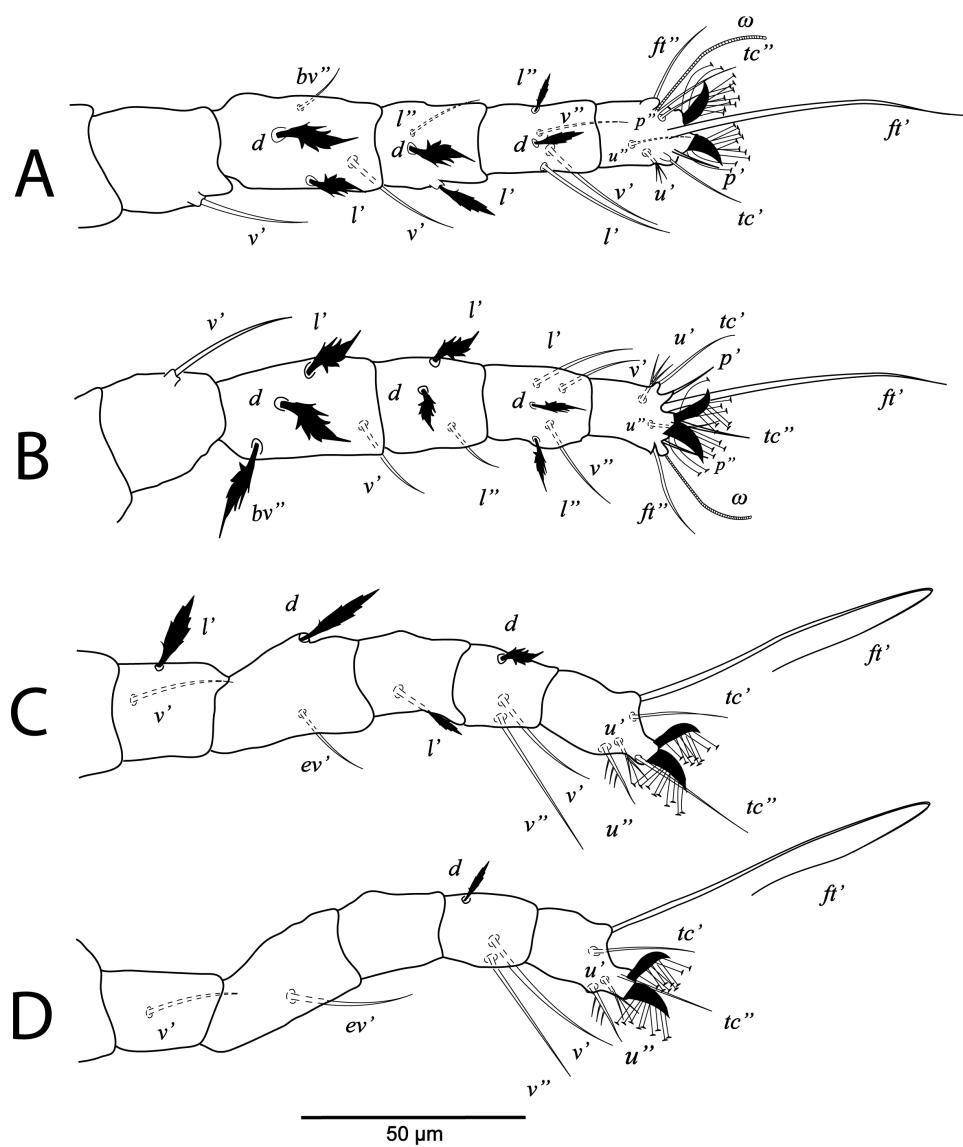
Figure 2 *Cenopalpus umbellatus* **sp. nov.** Female, (A) leg I (left), (B) leg II (right), (C) leg III (right), (D) leg IV (right). (Image credit: Mohamed Waleed Negm).

opisthosomal pores absent; propodosomal setae *v2* and *sc1* broadly lanceolate, serrate, setae *sc2* narrowly lanceolate; setae *v2* shorter than distance between *v2–v2*; opisthosomal setae narrowly lanceolate. Lengths of dorsal setae: *v2* 24 (22–26), *sc1* 16 (15–17), *sc2* 13 (12–14), *c1* 9 (9–11), *c2* 13 (14–15), *c3* 17 (16–19), *d1* 8 (7–8), *d3* 14 (13–14), *e1* 7 (6–7), *e3* 13 (12–14), *f2* 12 (10–11), *f3* 11 (11–12), *h1* 6 (6–7), *h2* 10 (9–10).

Venter (Fig. 1B). Venter of propodosoma and area between setae *3a* and *4a* smooth; opisthosomal area behind ventral setae *4a* entirely reticulated; coxal seta *2c* serrate. ventral shield medially with a reticulation consisting of pentagonal cells; genital shields reticulated with pentagonal cells; genital setae *g1* posterior to *g2*. Lengths of ventral setae: *1a* 80 (75–82), *3a* 9 (8–10), *4a* 70 (65–70); aggenital setae *ag* 13 (12–14); genital setae *g1*
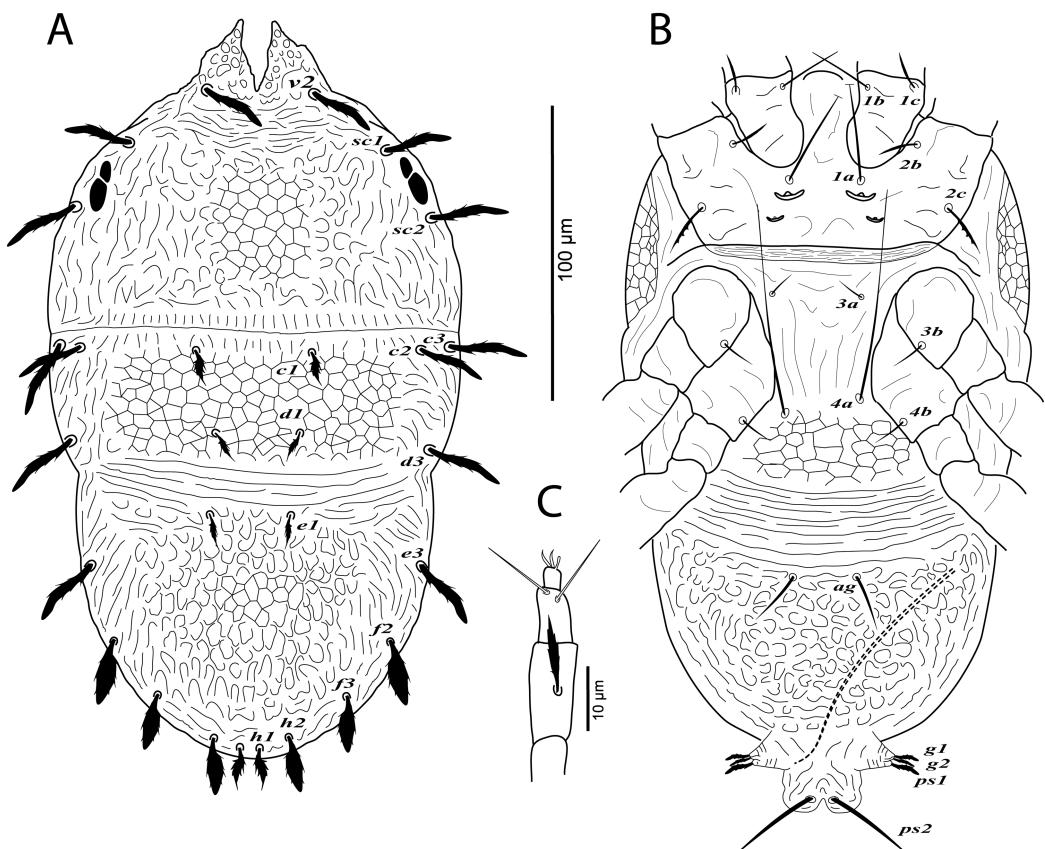
Figure 3 *Cenopalpus umbellatus* **sp. nov.** Male, (A) dorsum, (B) venter, (C) palp. (Image credit: Mohamed Waleed Negm).

10 (10–12), *g2* 9 (9–11); anal setae *ps1* 10 (9–10), *ps2* 8 (8–10). Distances between genital area setae: *ag–ag* 12–18, *g1–g1* 21–28, *g2–g2* 34–40. Spermatheca (*n* = 3) (Fig. 1C). Spermathecal tube narrow and vesicle semi-circular 8 (8–9) in diameter.

Gnathosoma. Rostrum not reaching distal end of femur I. Palp 4-segmented, palp tarsus with a solenidion and 2 eupathidia, palp tibia with 2 setae, palp femur/genu with 1 lanceolate-serrate dorsal seta (Fig. 1D).

Legs (Figs. 1B and 2A–2D). Chaetotaxy of legs as follows: coxae 2-2-1-1; trochanters 1-1-2-1; femora 4-4-2-1; genua 3-3-1-0; tibiae 5-5-3-3; tarsi 8+ω-8+ω-5-5. Setae *d* on femora I-III and genua I-II, setae *l'* on femora I-II and genua I-II broadly lanceolate-serrate. Setae *bv"* on femur II and *l'* on trochanter III also broadly lanceolate-serrate. Tarsus I and II with solenidia Iω 15–25, IIω 12–18.

Male (*n* = 10)
Dorsum (Fig. 3A). Idiosoma broadly oval, length 223–238; width 130–140. Rostral shield with 2 medial and 2 slightly shorter submedial lobes; propodosoma regularly reticulated medially, with irregular areolae sculpturing laterally; sejugal furrow distinct; metapodosoma and opisthosoma separated by transverse bands of striae, with irregular
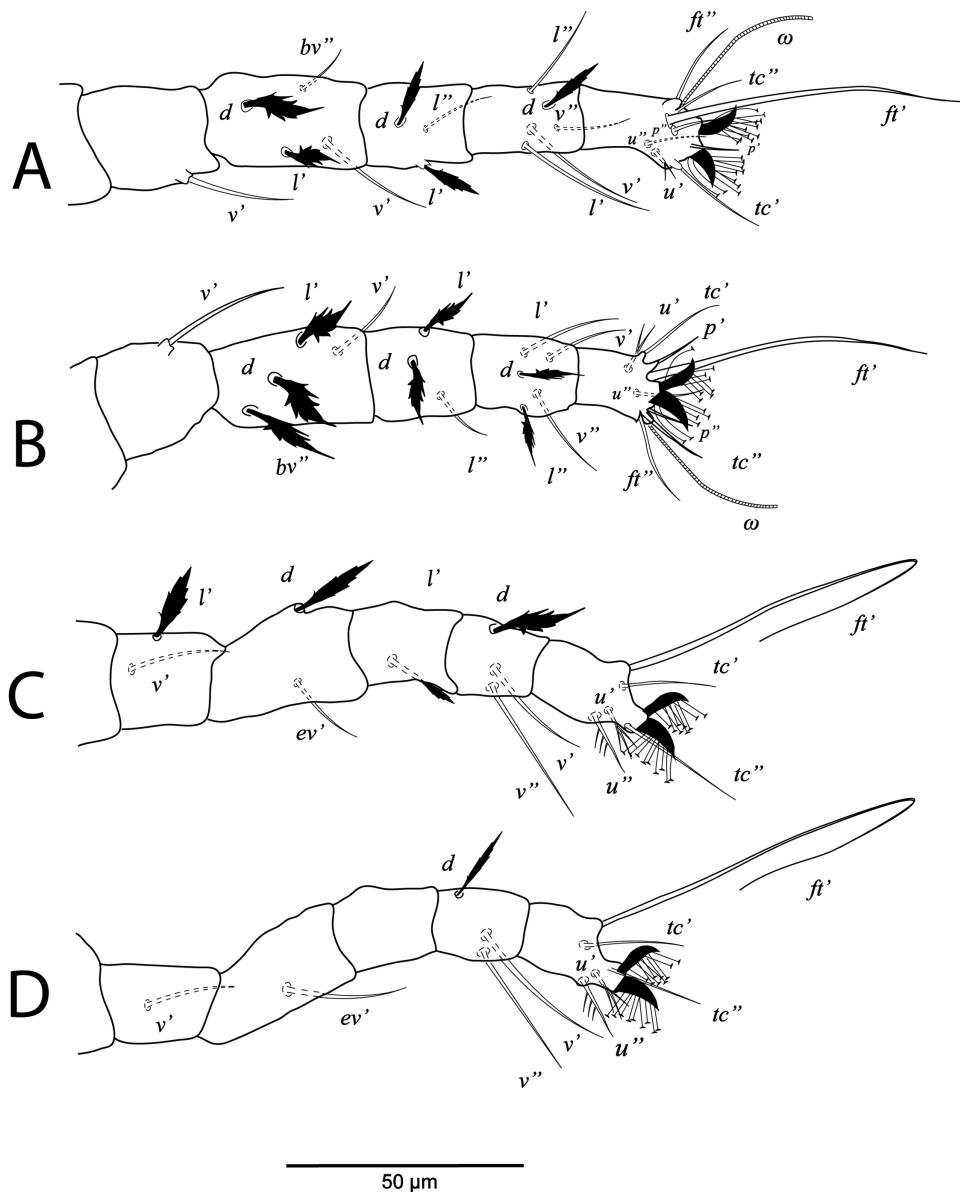
Figure 4 _Cenopalpus umbellatus_ sp. nov. Male, (A) leg I (left), (B) leg II (right), (C) leg III (right), (D) leg IV (right). (Image credit: Mohamed Waleed Negm).

reticulations and areolae sculpturing; opisthosomal pores indistinct; propodosomal and lateral setae of opisthosoma long and narrowly lanceolate, serrate; setae _v2_ shorter than distance between _v2–v2_. Lengths of dorsal setae: _v2_ 27–28, _sc1_ 24–26, _sc2_ 22–24, _c1_ 12–14, _c2_ 16–18, _c3_ 21–23, _d1_ 9–10, _d3_ 23–26, _e1_ 9–11, _e3_ 23–25, _f2_ 21–24, _f3_ 19–22, _h1_ 10–11, _h2_ 19–21.

Venter (Fig. 3B). Venter of propodosoma and area between setae _3a_ and _4a_ slightly striated; opisthosomal area behind ventral setae _4a_ reticulated, followed by transverse striae posteriorly; coxal seta _2c_ serrate; ventral shield posterior to setae _ag_ areolate.
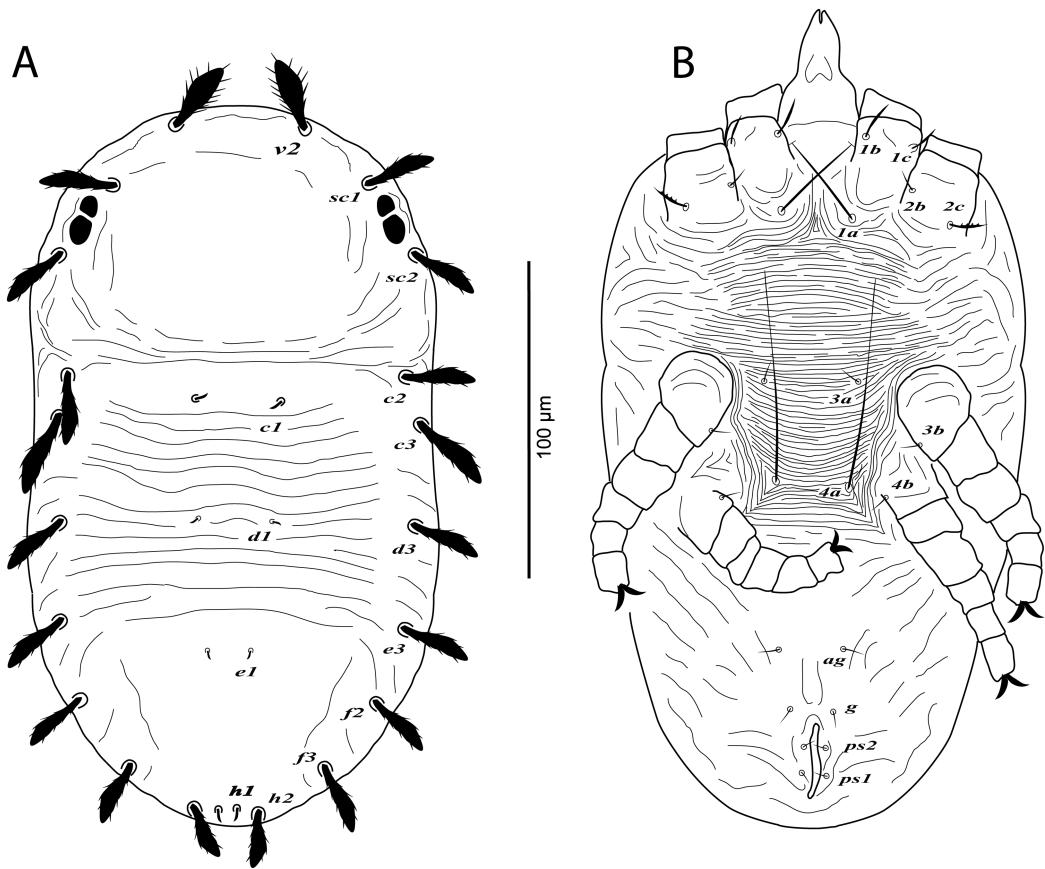
Figure 5 *Cenopalpus umbellatus* **sp. nov.** Deutonymph, (A) dorsum, (B) venter. (Image credit: Mohamed Waleed Negm).

Lengths of ventral setae: *1a* 58–68, *3a* 10–12, *4a* 55–63; *ag* 18–20; *g1* 8–9, *g2* 9–10; *ps1* 10–12, *ps2* 26–28.

Gnathosoma. Rostrum short not reaching distal end of trochanter I. Palp 4-segmented, palp tarsus with a solenidion and 2 eupathidia, palp tibia with 2 setae, palp femur/genu with 1 lanceolate-serrate dorsal seta (Fig. 3C).

Legs (Figs. 3B and 4A–4D). Chaetotaxy of legs as in female. Leg setae also similar to that of female. Tarsus I and II with solenidia Iω 25–30, IIω 20–23.

Deutonymph (*n* = 6)
Dorsum (Fig. 5A). Idiosoma oval, length 257–266; width 144–162. Rostral shield absent; propodosoma rounded anteriorly, smooth; opisthosoma with transverse striae in the area between setae *c1* and *e1*; opisthosomal pores absent. Dorsal body setae long and narrowly lanceolate except dorsocentral setae *c1*, *d1*, *e1*, *h1* minute; setae *v2* distinctly shorter than distance between *v2–v2*. Lengths of dorsal setae: *v2* 28–30, *sc1* 26–27, *sc2* 25–27, *c1* 4–6, *c2* 23–25, *c3* 25–27, *d1* 2–4, *d3* 23–25, *e1* 2–3, *e3* 22–24, *f2* 21–23, *f3* 20–22, *h1* 4–6, *h2* 16–18.

50 µm
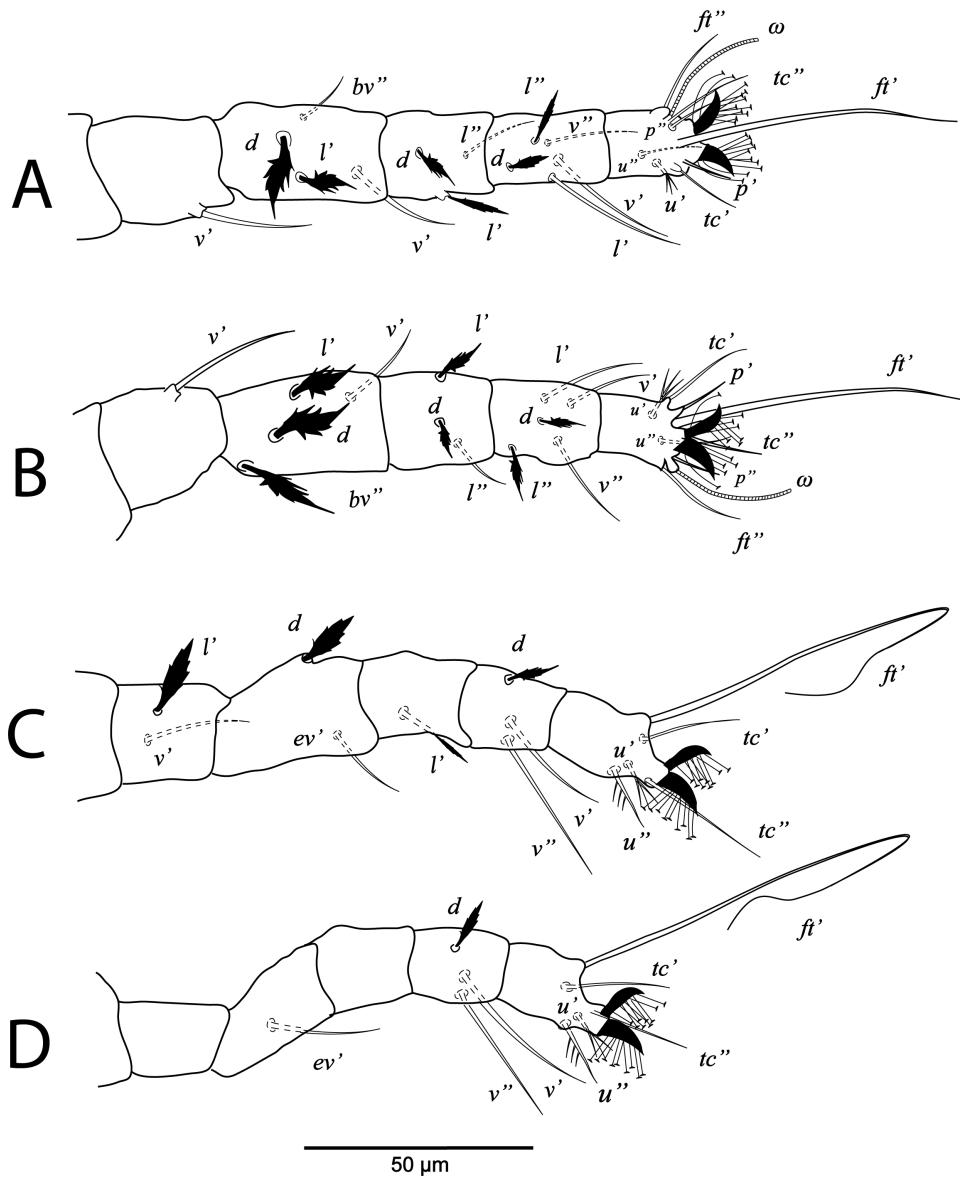
Figure 6 *Cenopalpus umbellatus* sp. nov. Deutonymph, (A) leg I (left), (B) leg II (right), (C) leg III (right), (D) leg IV (right). (Image credit: Mohamed Waleed Negm).

Venter (Fig. 5B). Venter of propodosoma and area between setae *1a* and *4a* with transverse striae; seta *2c* serrate; posterior opisthosomal area with irregular striae. Lengths of ventral setae: *1a* 42–48, *3a* 6–8, *4a* 38–45; *ag* 6–7; *g1* 4–5; *ps1* 3–4, *ps2* 3–4.

Gnathosoma. Palp 4-segmented, palp chaetotaxy as in female.

Legs (Figs. 5B and 6A–6D). Chaetotaxy of legs: coxae 2-2-1-1; trochanters 1-1-2-0; femora 4-4-2-1; genua 3-3-1-0; tibiae 5-5-3-3; tarsi 8+ω-8+ω-5-5. Leg setae similar to that of female.
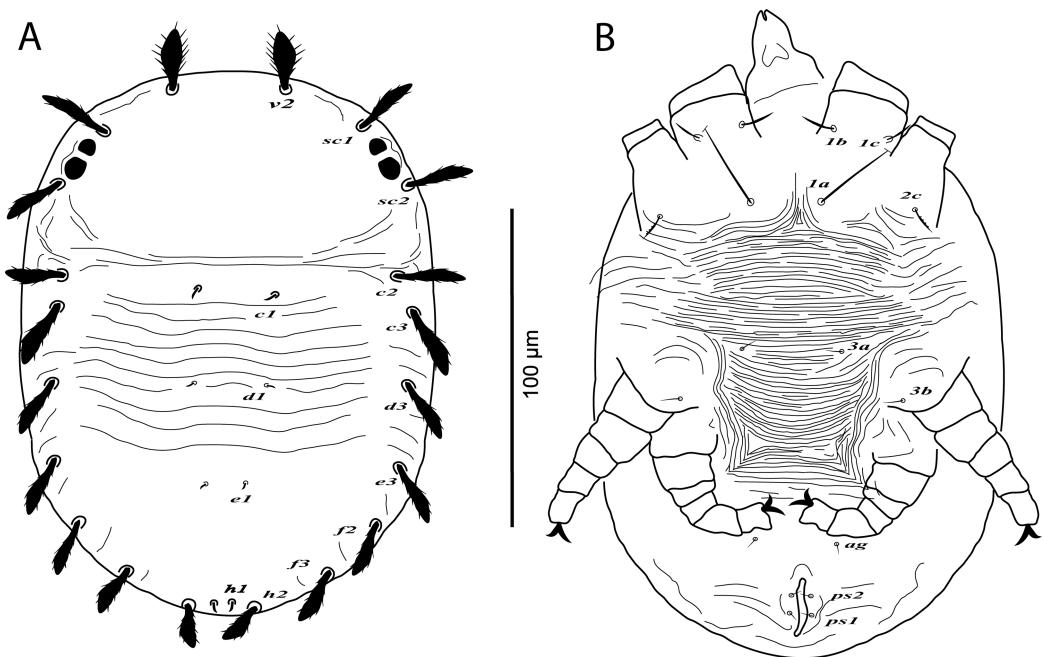
Figure 7 *Cenopalpus umbellatus* sp. nov. Protonymph, (A) dorsum, (B) venter. (Image credit: Mohamed Waleed Negm).

Protonymph (n = 2)

Dorsum (Fig. 7A). Idiosoma broadly oval, length 164–170; width 106–110. Rostral shield absent; propodosoma rounded anteriorly, smooth; opisthosoma with transverse striae in the area between setae *c1* and *e1*; opisthosomal pores absent. Dorsal body setae long and narrowly lanceolate except dorsocentral setae *c1*, *d1*, *e1*, *h1* minute; setae *v2* distinctly shorter than distance between *v2*–*v2*. Lengths of dorsal setae: *v2* 21–24, *sc1* 17–18, *sc2* 19–21, *c1* 4–5, *c2* 16–18, *c3* 19–20, *d1* 2–3, *d3* 17–19, *e1* 2–3, *e3* 14–15, *f2* 15–17, *f3* 15–16, *h1* 3–5, *h2* 12–13.

Venter (Fig. 7B). Venter of idiosoma with transverse striae; posterior opisthosomal area with irregular striae; seta *2c* smooth or slightly serrate, *2b* absent; ventral setae *4a*, *4b* and genital setae *g* absent. Lengths of ventral setae: *1a* 31–40, *3a* 4–5; *ag* 3–4; *ps1* 2–3, *ps2* 2–3.

Gnathosoma. Palp 4-segmented, palp chaetotaxy as in deutonymph.

Legs (Figs. 7B and 8A–8D). Chaetotaxy of legs: coxae 2-1-1-0; trochanters 0-0-1-0; femora 4-4-2-1; genua 1-1-1-0; tibiae 5-5-3-3; tarsi 8+ω-8+ω-5-3. Leg setae similar to that of female.

Larva (n = 4)

Dorsum (Fig. 9A). Idiosoma broadly oval, length 150–162; width 110–118. Rostral shield absent; idiosoma smooth, with few transverse striae posteriorly; opisthosomal pores absent. Dorsal body setae long and narrowly lanceolate except dorsocentral setae *c1*, *d1*, *e1*, *h1* minute; setae *v2* shorter than distance between *v2*–*v2*. Lengths of dorsal setae: *v2* 16–18,
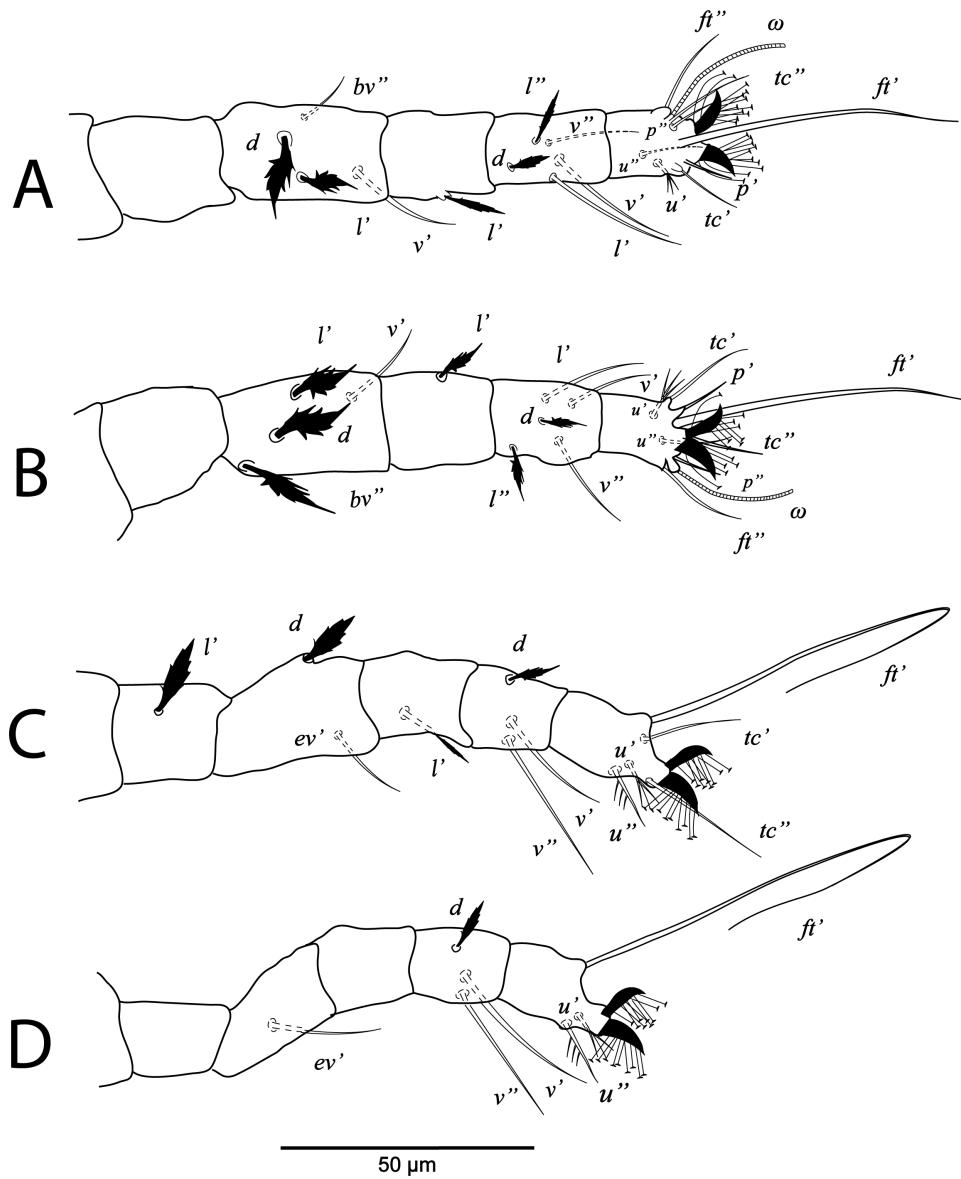
Figure 8 *Cenopalpus umbellatus* **sp. nov.** Protonymph, (A) leg I (left), (B) leg II (right), (C) leg III (right), (D) leg IV (right). (Image credit: Mohamed Waleed Negm).

sc1 14–16, *sc2* 15–17, *c1* 3–4, *c2* 12–14, *c3* 15–16, *d1* 2–3, *d3* 15–17, *e1* 2–3, *e3* 17–18, *f2* 16–17, *f3* 16–17, *h1* 3–5, *h2* 17–18.

Venter (Fig. 9B). Venter of idiosoma completely striated; ventral setae *4a*, coxal setae *1c*, *2b*, *2c*, *3b*, aggenital setae *ag* and genital setae *g* absent. Lengths of ventral setae: *1a* 28–34, *3a* 6–7; *ps1* 3–4, *ps2* 2–3.

Gnathosoma. Palp 4-segmented, palp chaetotaxy as in female.

Legs (Figs. 9B and 10A–10C). Chaetotaxy of legs: coxae 1-0-0; trochanters 0-0-0; femora 3-3-2; genua 1-1-1; tibiae 5-5-3; tarsi $6+\omega$-$6+\omega$-3.
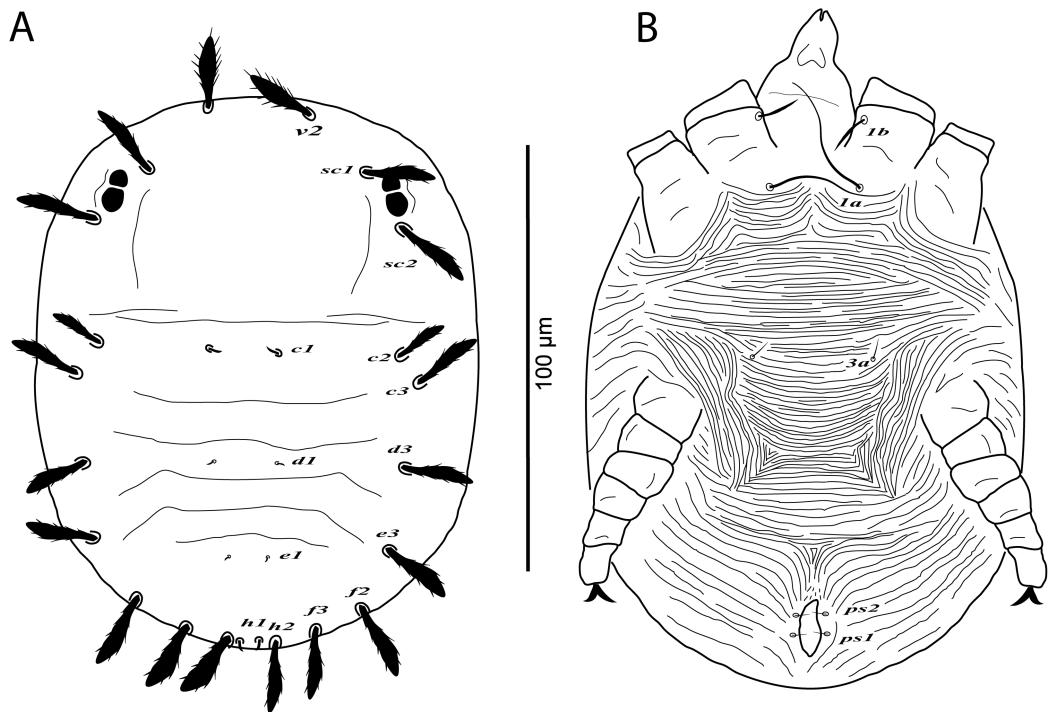
Figure 9 *Cenopalpus umbellatus* sp. nov. Larva, (A) dorsum, (B) venter. (Image credit: Mohamed Waleed Negm).

Type material

Female holotype, 24 female paratypes, 10 male paratypes, six deutonymphs, two protonymphs and four larvae; ex. leaves of *Rhaphiolepis indica* var. *umbellata* Makino (Rosaceae); Chiba, Japan (35°02′16″N, 139°50′15″E); 14 June 2018; leg. M.W. Negm. Type depository: female holotype, two female paratypes, three male paratypes, two deutonymphs, two protonymphs and two larvae will be deposited in the National Museum of Nature and Science (NMNS), Tsukuba, Ibaraki Prefecture, Japan. The remainder types are deposited in the Laboratory of Applied Entomology and Zoology, Ibaraki University (AEZIU) with the voucher specimen no. 895.

Etymology

The specific name *umbellatus* is named after the host plant species. The gender is masculine.

Differential diagnosis

Cenopalpus umbellatus sp. nov. closely resembles *C. lanceolatisetae* (*Attiah, 1956*) in various aspects including the chaetotaxy of legs; however, female differs in having rostrum not reaching distal end of femur I (vs. rostrum extending to middle of genu I in *C. lanceolatisetae*), reticulations behind ventral setae *4a* medially connected (vs. smooth or slightly striate medially in *C. lanceolatisetae*) and variation in lengths of some idiosomal setae (Table 3). Male of *C. umbellatus* sp. nov. also differs in having reticulations behind ventral setae *4a* (vs. reticulations absent in *C. lanceolatisetae*) and in having no

50 μm
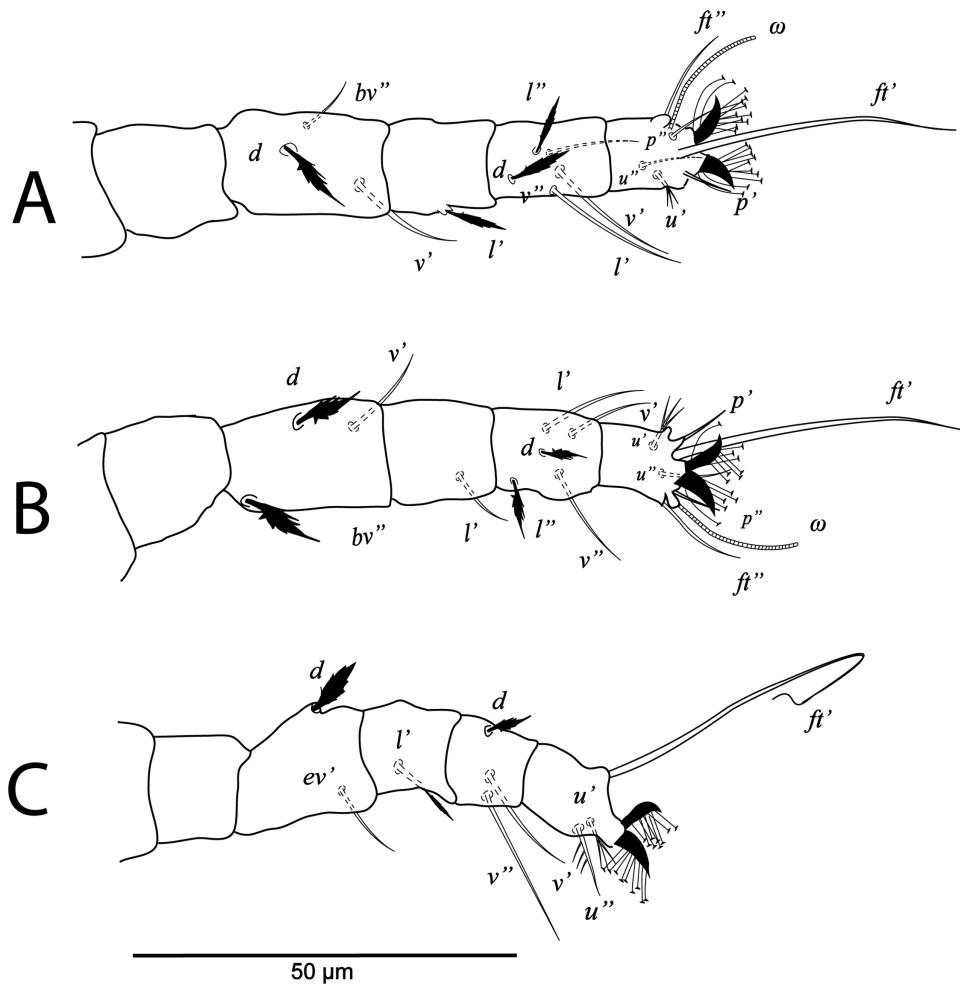
Figure 10 *Cenopalpus umbellatus* **sp. nov.** Larva, (A) leg I (left), (B) leg II (right), (C) leg III (right). (Image credit: Mohamed Waleed Negm).

opisthosomal pores (vs. one pair of opisthosomal pores present in *C. lanceolatisetae*). Also, the deutonymph of the new species has propodosoma smooth medially (vs. propodosoma reticulated medially in *C. lanceolatisetae*).

Ontogeny

The ontogenetic changes in the idiosomal and leg chaetotaxy of *Cenopalpus umbellatus* sp. nov. resemble the typical pattern for tenuipalpid mites (*Lindquist, 1985*). Regarding the setal additions on ventral idiosoma, the ventral (*1a*, *3a*) and anal (*ps2*, *ps1*) setae appeared since the larval stage. However, aggenital seta (*ag*) is added in the protonymph and the ventral seta (*4a*) is added in the deutonymph. Also, genital setae (*g1*) appeared in the deutonymph and *g2* in the adults. The coxal setae *1c*, *2c* and *3b* are added in the protonymph and the setae *2b* and *4b* are added in the deutonymph. Setae *v'* appeared on trochanters I, II and III in the deutonymph while appeared on trochanters IV in the adults. Seta *l'* on trochanter III is added in the protonymph. Also, seta *l'* is added to femora I and II in protonymph. Setae *l'* is present on genua I and II of the larva. Setae *d* and *l"* are

Table 3 Measurements of idiosomal setae for *Cenopalpus umbellatus* sp. nov. and its congener *C. lanceolatisetae* (*Attiah, 1956*).

Setae	*C. lanceolatisetae* (range for 10 females) (*Khanjani et al., 2012*)	*C. umbellatus* sp. nov. holotype (range for paratypes)
v2	18–26	24 (22–26)
sc1	17–23	16 (15–17)
sc2	18–24	13 (12–14)
c1	11–16	9 (9–11)
c2	13–19	13 (14–15)
c3	12–18	17 (16–19)
d1	7–11	8 (7–8)
d3	11–18	14 (13–14)
e1	7–12	7 (6–7)
e3	13–16	13 (12–14)
f2	13–16	12 (10–11)
f3	10–14	11 (11–12)
h1	5–9	6 (6–7)
h2	10–14	10 (9–10)
1a	75–103	80 (75–82)
3a	12–16	9 (8–10)
4a	80–119	70 (65–70)
ag	13–18	13 (12–14)
g1	9–12	10 (10–12)
g2	8–13	9 (9–11)
ps1	12–16	10 (9–10)
ps2	5–10	8 (8–10)

added to genua I and II in the deutonymph. The tectal setae (*tc'*, *tc''*) are added to tarsus I, II and III in the protonymphal stage.

Key to world species of *Cenopalpus* (based on females)

1. Opisthosoma with 6 pairs of dorsolateral setae 2
—Opisthosoma with 7 pairs of dorsolateral setae. 7
2. Palp-tibia and palp-tarsus with 2 setae each. 3
—Palp-tibia with 1 seta and palp-tarsus with 2 setae . . . . *creticus*
3. Rostrum extending beyond distal end of femur I. 4
—Rostrum extending to mid-level of femur I, not reaching to distal end 5
4. Dorsal setae rod-like. . . . . *pistaciae*
—Dorsal setae feather-like . . . . *pterinus*
5. Setal formula of tibiae 5-5-3-3 6
—Setal formula of tibiae 5-5-5-3 . . . . *arbuti*

6. Setal formula of trochanters 1-1-1-1; reticulations behind setae *4a* partly separated medially . . . . ***officinalis***

—Setal formula of trochanters 1-1-2-1; reticulations behind setae *4a* prominent and not separated medially . . . . ***adventicius***

7. Idiosoma mostly striate or partly striate and partly reticulate. 8

—Idiosoma mostly reticulate 12

8. Dorsum mostly striate but also with reticulations on prodorsum and between *c* and *d* series on hysterosoma; setae *3a* and *4a* very long. . . . . ***tamarixi***

—Dorsum striate with setae *4a* much longer than short *3a* 9

9. Rostral shield with 2 slightly notched medial lobes 10

—Rostral shield with 2 medial and 2 lateral lobes 11

10. Setae *4a* on venter much longer than distance between setae *3a* and *4a*, setae *1a* very long and whip-like extending considerably pass rostrum . . . . ***wainsteini***

—Setae *4a* approximately equal to, or little longer than, distance between setae *3a* and *4a*, setae *1a* not extending pass rostrum . . . . ***saryabiensis***

11. Rostrum reach almost to middle of genu I; hysterosoma with transverse striae from prodorsum to behind setae *d1* and longitudinal to posterior margin . . . . ***aratus***

—Rostrum reach almost to middle of femur I; striae on hysterosoma mainly transverse. . . . .*lineola*

12. Propodosomal setae broadly lanceolate to spatulate or scoop-like 13

—Propodosomal setae narrowly lanceolate to setiform or slender 37

13. Propodosomal setae broadly lanceolate to spatulate; opisthosomal pores absent (one pair present in *pennatisetis*) 14

—Propodosomal setae scoop-like; 2 pairs of opisthosomal pores present. . . . . ***scoopsetus***

14. Rostrum reaching behind distal end of femur I 15

—Rostrum not reaching beyond distal end of femur I. 30

15. Rostrum extending beyond distal end of genu I. 16

—Rostrum not extending beyond distal end of genu I. 18

16. Setae *sc1* shorter than distance between bases of setae *sc1* and *sc2*. 17

—Setae *sc1* longer than distance between bases of setae *sc1* and *sc2*. . . . . . . ***khosrowshahi***

17. Setae *sc1* less than half of distance between bases of setae *sc1* and *sc2* . . . . . . ***prunusi***

—Setae *sc1* more than half of distance between bases of setae *sc1* and *sc2* . . . ***longirostris***

18. Propodosoma with reticulations regular. 19

—Propodosoma with reticulations irregular. 26

19. Setae *sc1* shorter than distance between bases of setae *sc1* and *sc2*. 20

—Setae *sc1* longer than, or equal to, distance between bases of setae *sc1* and *sc2*. 23

20. Dorsal body setae subspatulate, narrowly or broadly lanceolate 21

—Dorsal body setae broadly spatulate . . . . ***eriobotryi***

21. Setae *v2* broadly lanceolate and much longer than half of distance between their bases; rostral shield with 2 medial, 2 submedial and 2 lateral lobes 22

—Setae *v2* narrowly lanceolate and equal to, or little longer than, half of distance between their bases; rostral shield with 2 medial lobes . . . . ***chitraliensis***

22. Metapodosomal venter posterior to setae *4a* smooth medially or slightly striate; rostrum extending to middle of genu I . . . . *lanceolatisetae*

—Metapodosomal reticulations on venter posterior to setae *4a* connected medially; rostrum not reaching pass distal end of femur I . . . . **umbellatus sp. nov.**

23. Dorsal setae subspatulate with long spines . . . . *viniferus*

—Dorsal setae subspatulate or narrowly lanceolate and serrate 24

24. Dorsal setae narrowly lanceolate and setae *c1* almost as long as distance between its members 25

—Dorsal setae subspatulate with setae *c1* clearly shorter than distance between its members . . . . *xini*

25. Setal formula of trochanters 1-1-2-1, femora 4-4-2-1 . . . . *pennatisetis*

—Setal formula of trochanters 1-1-1-1, femora 4-4-2-0 . . . . *virgulatus*

26. Setae *v2* shorter than distance between their bases 27

—Setae *v2* longer than, or equal to, distance between their bases. 28

27. Rostrum at level of distal end of genu I; rostral shield basically with only 2 medial lobes. . . . . *halperini*

—Rostrum not reaching distal end of genu I; rostral shield with 2 medial and 2 lateral lobes. . . . . *pegazzanoae*

28. Rostrum reaching to middle or to distal margin of genu I; propodosomal setae broadly lanceolate 29

—Rostrum reaching beyond distal end of femur I; propodosomal setae spatulate . . . . *evini*

29. Propodosoma with large polygonal reticulations medially . . . . *abaii*

—Propodosoma smooth or weakly reticulate medially. . . . . *bagdasariani*

30. Dorsal body setae spatulate or subspatulate 31

—Dorsal body setae lanceolate. . . . . *haqii*

31. Dorsal body setae spatulate 32

—Dorsal body setae subspatulate 34

32. Propodosoma with regular polygonal reticulations. . . . . **capensis**

—Propodosoma with irregular reticulations, especially mediodorsally and mediolaterally. 33

33. Metapodosomal venter with area posterior to setae *4a* completely reticulated, anterior to *4a* weakly reticulate . . . . *salignae*

—Metapodosomal venter with area posterior to setae *4a* smooth medially or slightly striate and smooth anterior to *4a* . . . . *oleunus*

34. Metapodosomal venter with area posterior to setae *4a* smooth medially 35

—Metapodosomal venter with area posterior to setae *4a* reticulated 36

35. Setae *v2* equal to, or little shorter than, distance between their bases . . . . **platani**

—Setae *v2* approximately half of distance between their bases. . . . . **ramus**

36. Setae *v2* approximately half of distance between their bases; idiosoma with dorsal reticulations regular; dorsal setae short and serrate . . . . **natalensis**

—Setae *v2* equal to distance between their bases; idiosoma with dorsal reticulations irregular; dorsal setae clearly longer and strongly serrate . . . . **pritchardi**

37. Setae *v2* approximately longer than, or equal to, distance between their bases 38

—Setae *v2* shorter than distance between their bases 51

38. Rostral shield with 2 medial lobes, lateral lobes excluded 39

—Rostral shield with 4 medial lobes, one pair can be reduced or obsolete, lateral lobes also excluded 42

39. Rostrum reaching up to distal end of femur I; metapodosomal venter with area posterior to setae *4a* smooth medially 40

—Rostrum reaching to middle of genu I; metapodosomal venter with area posterior to setae *4a* reticulated 41

40. Setal formula of tibiae 4-4-3-3 . . . . ***mughalii***

—Setal formula of tibiae 5-5-3-3 . . . . ***orakiensis***

41. Propodosoma with small, rounded crenulate elements . . . . ***spinosus***

—Propodosoma with large polygonal reticulations . . . . ***pulcher***

42. Dorsal body setae mostly lanceolate 43

—Dorsal body setae mostly setiform 47

43. Opisthosoma with pores 44

—Opisthosoma without pores 45

44. Rostrum not extending beyond distal end of femur I, rostral shield with 4 distinct lobes medially . . . . ***quadricornis***

—Rostrum extending beyond distal end of femur I, second pair of medial lobes obsolete . . . . ***irani***

45. Setae *c1* and *d1* long, almost as long as distances between their members . . . . ***quercusi***

—Setae *c1* and *d1* much shorter, half or less than half the distances between their members 46

46. Setal formula of genua 3-3-3-1, trochanters 1-1-2-1 . . . .***taygeticus***

—Setal formula of genua 3-3-1-0, trochanters 1-1-1-1 . . . . ***naupakticus***

47. Setae *sc1* approximately equal to, or longer than, distance between bases of setae *sc1* and *sc2* 48

—Setae *sc1* distinctly shorter than distance between bases of setae *sc1* and *sc2* . . . . ***meyerae***

48. Setae *sc1* approximately equal to distance between bases of setae *sc1* and *sc2* 49

—Setae *sc1* distinctly longer than distance between bases of setae *sc1* and *sc2* . . . . ***brachypalpus***

49. Setae *sc2* long, almost reaching to sejugal furrow . . . . ***musai***

—Setae *sc2* short, distinctly far from sejugal furrow 50

50.Venter between setae *3a* and *4a* striate . . . . ***rubusi***

—Venter between setae *3a* and *4a* smooth . . . . ***pseudospinosus***

51. Rostrum extending to middle of femur I or somewhat beyond middle 52

—Rostrum extending to distal end of femur I or beyond 56

52. Opisthosoma with dorsolateral setae *c3* about a fifth as long as distance to bases of setae *d3* 53

—Opisthosoma with dorsolateral setae *c3* about a third as long as distance to bases of setae *d3* 54

53. Setae *v2* shorter than half of distance between their bases; reticulations ventrally behind setae *4a* continuous . . . .**cumanicus**

—Setae *v2* longer than half of distance between their bases; reticulations behind setae *4a* smooth medially. . . . . **thelycraniae**

54. Metapodosomal venter at area posterior to setae *4a* with smaller polygonal to rounded crenulate elements medially 55

—Metapodosomal venter at area posterior to setae *4a* with medial reticulation elements polygonal and broader than long . . . . **carpini**

55. Setae *v2* shorter than half of distance between their bases . . . .**hederae**

—Setae *v2* longer than half of distance between their bases . . . . **mespili**

56. Rostrum reaching not beyond distal end of genu I; palp-tarsus with at least a solenidion and seta or eupathium 57

—Rostrum reaching to distal end of tibia I; palp-tarsus with 1 solenidion only . . **picitilis**

57. Rostrum reaching to mid-level or distal end of genu I 58

—Rostrum reaching not beyond distal end of femur I 63

58. Dorsal setae narrowly lanceolate. 59

—Dorsal setae setiform 60

59. Body almost round; rostrum reaching distal end of genu I; setal formula of tibiae 4-4-3-3 . . . . **sunniensis**

—Body oval; rostrum reaching to mid-level of genu I, not reaching distal end; setal formula of tibiae 5-5-3-3 . . . .**ruber**

60. All dorsal setae serrate 61

—All dorsal setae simple . . . .**dignus**

61. Rostrum reaching distal end of femur I 62

—Rostrum reaching distal end of genu I . . . . **favosus**

62. Setae *v2* more than 15 μm length; setal formula of tibiae 5-4-3-3, coxae 2-2-1-1 . . . .**kritos**

—Setae *v2* less than 10 μm; setal formula of tibiae 5-5-3-3, coxae 3-2-1-1 . . . . . **homalos**

63. Rostral shield with 2 medial lobes 64

—Rostral shield with more than 2 lobes. 65

64. Metapodosoma with large polygonal reticulation medioventrally; setae *4a* much longer than distance between bases of setae *3a* and *4a*; setal formula of coxae 2-2-1-1, trochanters 1-1-2-2 . . . . **piger**

—Metapodosoma with irregular reticulation medioventrally; setae *4a* shorter than distance between bases of setae *3a* and *4a*; setal formula of coxae 2-2-2-1, trochanters 1-1-1-0. . . . . **japonicus**

65. Reticulations almost absent or medially smooth behind ventral setae *4a* 66

—Area behind setae *4a* completely reticulated. 68

66. Area behind setae *4a* almost smooth with only a few reticulations behind coxae IV; dorsal setae narrowly lanceolate and serrate or short setiform, serrate 67

—Reticulations behind setae *4a* with a narrow smooth band medially; dorsal setae short, setiform and serrate or some smooth . . . . ***iqbali***

67. Dorsal setae narrowly lanceolate, serrate . . . . ***capacis***

—Dorsal setae short, setiform, serrate . . . . ***limbatus***

68. Rostral shield with 2 medial and 2 lateral lobes 69

—Rostral shield with 2 medial, 2 submedial and 2 lateral lobes . . . . ***crataegi***

69. Propodosomal setae narrowly lanceolate; some setae on opisthosoma also lanceolate . . . . ***populi***

—All dorsal setae setiform . . . . ***bakeri***

DISCUSSION

The present study provides morphological description of a new species of flat mites belonging to the genus *Cenopalpus*, with a key to the world species. This genus is mainly reported from the Mediterranean and East Asia regions. Only 14 tenuipalpid species were previously known from Japan, with only one *Cenopalpus* species. Though members of the Tenuipalpidae are currently not posing a serious threat to agriculture in the country, we must be prepared for the consequences of global trafficking of people and goods. Therefore, this study will for sure act as a very useful early intervention tool. Examination of all known species of *Cenopalpus* was toilsome especially with some species which are poorly described, and we had to rely on what was available.

CONCLUSIONS

Faunistic information about flat mites in Japan is scarce. The new mite species described with the world key to species increases the available information about the taxonomy of tenuipalpid mites in this country. We hope that this study will serve as the departure point for future research on *Cenopalpus* mites and encourage for more comprehensive surveys in Japan since a large number of undiscovered species is expected.

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Author Contributions
- Mohamed W. Negm conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- Edward A. Ueckermann performed the experiments, analyzed the data, authored or reviewed drafts of the paper, and approved the final draft.
- Tetsuo Gotoh analyzed the data, authored or reviewed drafts of the paper, and approved the final draft.

Data Availability
The measurements and type materials information are available in the Supplemental Files. The accession numbers as follows:

Laboratory of Applied Entomology and Zoology, Ibaraki University (AEZIU): 4th floor, Faculty of Agriculture, Ibaraki University, Ami, Ibaraki 300-0393, Japan.

Paratype female (yellow label) > 895-A1
Paratype female (yellow label) > 895-A2
Paratype female (yellow label) > 895-A3
Paratype female (yellow label) > 895-A4
Paratype female (yellow label) > 895-A5
Paratype female (yellow label) > 895-A6
Paratype female (yellow label) > 895-A7
Paratype female (yellow label) > 895-A8
Paratype female (yellow label) > 895-A9
Paratype female (yellow label) > 895-A10
Paratype female (yellow label) > 895-A11
Paratype female (yellow label) > 895-A12
Paratype female (yellow label) > 895-A13
Paratype female (yellow label) > 895-A14
Paratype female (yellow label) > 895-A15
Paratype female (yellow label) > 895-A16
Paratype female (yellow label) > 895-A17
Paratype female (yellow label) > 895-A18

Paratype female (yellow label) > 895-A19
Paratype female (yellow label) > 895-A20
Paratype female (yellow label) > 895-A21
Paratype female (yellow label) > 895-A22
Paratype male (white label) > 895-A23
Paratype male (white label) > 895-A24
Paratype male (white label) > 895-A25
Paratype male (white label) > 895-A26
Paratype male (white label) > 895-A27
Paratype male (white label) > 895-A28
Paratype male (white label) > 895-A29
Deutonymph (white label) > 895-A30
Deutonymph (white label) > 895-A31
Deutonymph (white label) > 895-A32
Deutonymph (white label) > 895-A33
Larva (white label) > 895-A34
Larva (white label) > 895-A35
National Museum of Nature and Science (NMNS): 4 Chome-1-1 Amakubo, Tsukuba, Ibaraki 305-0005, Japan.
Holotype female (red label) > 895-B1
Paratype female (yellow label) > 895-B2
Paratype female (yellow label) > 895-B3
Paratype male (white label) > 895-B4
Paratype male (white label) > 895-B5
Paratype male (white label) > 895-B6
Deutonymph (white label) > 895-B7
Deutonymph (white label) > 895-B8
Protonymph (white label) > 895-B9
Protonymph (white label) > 895-B10
Larva (white label) > 895-B11
Larva (white label) > 895-B12.

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