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.

Subjects Agricultural Science, Entomology, Taxonomy, Zoology

Keywords Acarology, Systematics, Acari, Trombidiformes, Prostigmata, Phytophagous, Classification, Pest

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. iqbalii 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...
| Species         | Country                  |
|-----------------|--------------------------|
| abaii           | Iran                     |
| adventicius     | Hungary                  |
| aratus          | Pakistan                 |
| arbuti          | Greece                   |
| bagdasariani    | Tajikistan               |
| bakeri          | Turkey                   |
| brachypalpus    | Greece                   |
| capacis         | Pakistan                 |
| capensis        | South Africa             |
| carpini         | Ukraine                  |
| chitraliensis   | Pakistan                 |
| crataegi        | Iran                     |
| creticus        | Greece                   |
| cumanicus       | Hungary                  |
| dignus          | Pakistan                 |
| eriobotryi      | Greece                   |
| evini           | Iran                     |
| favosus         | Pakistan                 |
| halperini       | Israel                   |
| haqii           | Pakistan                 |
| hederae         | Greece                   |
| homalos         | Pakistan                 |
| iqballi         | Pakistan                 |
| irani           | Iran                     |
| japonicus       | Pakistan                 |
| khosrowshahii   | Iran                     |
| kritos          | Pakistan                 |
| lanceolatissae  | Egypt                    |
| limbatus        | Pakistan                 |
| lineola         | Italy                    |
| longirostris    | Ukraine                  |
| mespili         | Ukraine                  |
| meyerae         | Iran                     |
| mughalii        | Pakistan                 |
| musai           | Lebanon                  |
| natalensis      | South Africa             |
| naupakticus     | Greece                   |
| officinulis     | Greece                   |
| olecrunus       | South Africa             |
| orakiensis      | Pakistan                 |
| pegazzanoae     | Italy                    |
| pennatisetis    | Kazakhstan               |
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 1 (continued).

| Species   | Country     |
|-----------|-------------|
| 43 picitilis *Chaudhri, 1971* | Pakistan |
| 44 piger *Wainstein, 1960* | Kazakhstan |
| 45 pistaciae *Hatzinikolis, Papadoulis & Panou, 1999a* | Greece |
| 46 platani *(Livschitz & Mitrofanov, 1967)* | Georgia |
| 47 populi *(Livschitz & Mitrofanov, 1967)* | Georgia |
| 48 pritchardi *Düzgünès, 1967* | Turkey |
| 49 prunusi *Khanjani et al., 2012* | Iran |
| 50 pseudospinosus *(Livschitz & Mitrofanov, 1967)* | Ukrainie |
| 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 *(Domnæiu, 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).*
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; Hatzinikolis, Papadoulis & Panou, 1999a; Hatzinikolis, Panou & Papadoulis, 1999b (Greece); Khosrowsahi & Arbabi, 1997; Khanjani et al., 2012 (Iran); Çobanoğlu, Ueckermann & Sağlam, 2016; Çobanoğlu, Erdoğan & Kılıç, 2019 (Turkey)).

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The LSID for this publication is: urn:lsid:zoobank.org:pub:268B04C7-028B-4C03-8F6C-930035941B89, and the LSID for the new species, Cenopalpus umbellatus is urn:lsid:zoobank.org:act:957E754C-A7F0-4081-A814-48115D276F76. The online version of this

| Species | Reference |
|---------|-----------|
| Aegyptobia arenaria | Ehara (1982) |
| Brevipalpus californicus | Ehara (1962) |
| B. lewisi | Ehara (1956b) |
| B. obovatus | Ehara (1956a) |
| B. phoenicis | Ehara (1966) |
| B. russulus | Ehara (1968) |
| Cenopalpus lineola | Ehara (1966) |
| C. umbellatus | Present study |
| Dolichotetranychus floridanus | Baker & Pritchard (1956) |
| D. zosiae | Ehara (2004) |
| Pentamerismus oregonensis | Ehara (1962) |
| P. taxi | Ehara (1962) |
| Tenuipalpus boninensis | Ehara (1982) |
| T. pacificus | Ehara & Ohkubo (1992) |
| T. zhizhilashviliae | 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.

Table 2: List of tenuipalpid mites known from Japan.

- Aegyptobia arenaria *Ehara, 1982*
- Brevipalpus californicus *(Banks, 1904)*
- B. lewisi *McGregor, 1949*
- B. obovatus *Donnadieu, 1875*
- B. phoenicis *(Geijskes, 1939)*
- B. russulus *(Boisdalav, 1867)*
- Cenopalpus lineola *(Canestrini & Fanzago, 1876)*
- C. umbellatus sp. nov. Negm, Ueckermann & Gotoh
- Dolichotetranychus floridanus *(Banks, 1900)*
- D. zosiae *Ehara, 2004*
- Pentamerismus oregonensis *McGregor, 1949*
- P. taxi *(Haller, 1877)*
- Tenuipalpus boninensis *Ehara, 1982*
- T. pacificus *Baker, 1945*
- T. zhizhilashviliae *Reck, 1953*

**Table 2: List of tenuipalpid mites known from Japan.**
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;
opisthosomal pores absent; propodosomal setae $v_2$ and $sc1$ broadly lanceolate, serrate, setae $sc2$ narrowly lanceolate; setae $v_2$ shorter than distance between $v_2$–$v_2$; opisthosomal setae narrowly lanceolate. Lengths of dorsal setae: $v_2$ 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 $g1$
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
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.
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.

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**Figure 5 Cenopalpus umbellatus sp. nov.** Deutonymph, (A) dorsum, (B) venter. (Image credit: Mohamed Waleed Negm). DOI: 10.7717/peerj.9081/fig-5
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.
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 \(8+8\)-\(8+8\)-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,
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+ω-6+ω-3.
**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...
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 d and l” are
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*

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**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)                                                   |
| c3    | 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)                                                 |
| la    | 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)                                                  |

Negm et al. (2020), *PeerJ*, DOI 10.7717/peerj.9081
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 .................................. adventicicus
7. Idiosoma mostly striate or partly striate and partly reticulate. ................. 8
   —Idiosoma mostly reticulate ........................................... adventicicus
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 ............................ aratus
9. Rostral shield with 2 slightly notched medial lobes ............................... 10
   —Rostral shield with 2 medial and 2 lateral lobes .................................. sarayabiensis
10. Setae 4a on venter much longer than distance between setae 3a and 4a, setae 1a very long and whip-like extending considerably past 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. ... 37
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

Negm et al. (2020), PeerJ, DOI 10.7717/peerj.9081
22. Metapodosomal venter posterior to setae 4a smooth medially or slightly striate; rostrum extending to middle of genu I ......................... \textit{lanceolatisetae} \\
—Metapodosomal reticulations on venter posterior to setae 4a connected medially; rostrum not reaching pass distal end of femur I ................ \textit{umbellatus} sp. nov. \\
23. Dorsal setae subspatulate with long spines ......................... \textit{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 ...................................................... \textit{xini} \\
25. Setal formula of trochanters 1-1-2-1, femora 4-4-2-1 ................ \textit{pennatisetis} \\
—Setal formula of trochanters 1-1-1-1, femora 4-4-2-0 ................ \textit{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. ...................................................... \textit{halperini} \\
—Rostrum not reaching distal end of genu I; rostral shield with 2 medial and 2 lateral lobes. ................................................ \textit{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 ............................................................ \textit{evini} \\
29. Propodosoma with large polygonal reticulations medially ........ \textit{abaii} \\
—Propodosoma smooth or weakly reticulate medially ................ \textit{bagdasariani} \\
30. Dorsal body setae spatulate or subspatulate ....................... 31 \\
—Dorsal body setae lanceolate ........................................ \textit{haqii} \\
31. Dorsal body setae spatulate ........................................... 32 \\
—Dorsal body setae subspatulate ...................................... 34 \\
32. Propodosoma with regular polygonal reticulations ................. \textit{capensis} \\
—Propodosoma with irregular reticulations, especially mediadorsally and mediolaterally .................................................. 33 \\
33. Metapodosomal venter with area posterior to setae 4a completely reticulated, anterior to 4a weakly reticulate ......................... \textit{salignae} \\
—Metapodosomal venter with area posterior to setae 4a smooth medially or slightly striate and smooth anterior to 4a ................ \textit{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 .... \textit{platani} \\
—Setae v2 approximately half of distance between their bases .......... \textit{ramus} \\
36. Setae v2 approximately half of distance between their bases; idiosoma with dorsal reticulations regular; dorsal setae short and serrate ........ \textit{natalensis} \\
—Setae v2 equal to distance between their bases; idiosoma with dorsal reticulations irregular; dorsal setae clearly longer and strongly serrate ................ \textit{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 ........................................................... meyerae
— Setae sc1 distinctly shorter than distance between bases of setae sc1 and sc2 ...... 48
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 ...... 49
— Setae sc1 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
|   | Description                                                                 | Key
|---|------------------------------------------------------------------------------|---
| 52. | Opisthosoma with dorsolateral setae \(c_3\) about a fifth as long as distance to bases of setae \(d_3\) | 53 |
|     | —Opisthosoma with dorsolateral setae \(c_3\) about a third as long as distance to bases of setae \(d_3\) | 53 |
| 53. | Setae \(v_2\) shorter than half of distance between their bases; reticulations ventrally behind setae \(4a\) continuous | \(cumanicus\) |
|     | —Setae \(v_2\) 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 \(v_2\) shorter than half of distance between their bases | \(hederae\) |
|     | —Setae \(v_2\) 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 \(v_2\) more than 15 \(\mu\)m length; setal formula of tibiae 5-4-3-3, coxae 2-2-1-1 | \(kritos\) |
|     | —Setae \(v_2\) less than 10 \(\mu\)m; 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.
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- Tetsuo Gotoh analyzed the data, authored or reviewed drafts of the paper, and approved the final draft.

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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
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