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New record and redescription of *Mullederia sichuanensis* Wang from evergreen forests in Japan, with remarks on morphological variations among world species of *Mullederia* Wood (Acari: Stigmaeidae)

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Abstract

The *Mullederia* Wood, 1964 (Acari: Stigmaeidae) is a species-limited genus with a geographic distribution so far restricted to eastern Palaearctic, Indomalaya and Australasia regions. *Mullederia sichuanensis* Wang, 1986 is newly recorded from Japan based on specimens collected from two different evergreen broad-leaved forests at Bōsō Peninsula, Chiba Prefecture (Honshu). Adult females, males and deutonymphs are redescribed and illustrated. Interspecific morphological variations among world species of *Mullederia* are provided. Also, stigmaeid mite species recorded from Japan are listed.

Key words: Trombidiformes, Raphignathoidea, morphology, description, mites, taxonomy

Introduction


Although several works have been published about the taxonomy of stigmaeid mites in Japan (Ehara 1962, 1964, 1967, 1980, 1985; Ehara & Ueckermann 2006; Negm et al. 2015; Negm & Gotoh 2019), species richness is still limited (Table 1). Also, Shiba (2015) listed an unidentified species of *Mullederia* collected from evergreen oak trees (Fagaceae) in Shikoku. The present study aims to redescribe and illustrate females, males and deutonymphs of *M. sichuanensis* as a new record of Stigmaeidae from Japan.
TABLE 1. List of stigmaeid mites known from Japan.

<table>
<thead>
<tr>
<th>Taxa*</th>
<th>Host plant; Locality</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agistemus citrinus</td>
<td>ex Hibiscus tiliae L. (Malvaceae); Okinawa</td>
<td>Ehara (1967)</td>
</tr>
<tr>
<td>A. exsertus</td>
<td>ex orange (Rutaceae); Kyushu</td>
<td>González-Rodríguez (1963)</td>
</tr>
<tr>
<td>A. iburiensis</td>
<td>ex bamboo, Sasa apoienis Nakai. (Poaceae); Hokkaido</td>
<td>Ehara (1985)</td>
</tr>
<tr>
<td>A. lobatus</td>
<td>ex apple, Malus sp. (Rosaceae); Honshu</td>
<td>Ehara (1964)</td>
</tr>
<tr>
<td>A. summersi</td>
<td>ex bamboo, Sasa sp.; Hokkaido</td>
<td>Ehara (1964)</td>
</tr>
<tr>
<td>A. terminalis</td>
<td>ex citrus (Rutaceae); Honshu</td>
<td>Ehara (1962)</td>
</tr>
<tr>
<td>Eryngiopus sp.</td>
<td>no information available</td>
<td>Shiba (2015)</td>
</tr>
<tr>
<td>Eustigmaeus anauniensis (Canestrini, 1889)</td>
<td>not specified; Shikoku, Kyushu</td>
<td>Ehara (1980)</td>
</tr>
<tr>
<td>E. arcuatus</td>
<td>not specified; Hokkaido</td>
<td>Ehara (1980)</td>
</tr>
<tr>
<td>E. lirellus</td>
<td>not specified; Honshu, Shikoku, Kyushu</td>
<td>Ehara (1980)</td>
</tr>
<tr>
<td>E. segnis</td>
<td>not specified; Honshu, Shikoku, Kyushu</td>
<td>Ehara (1980)</td>
</tr>
<tr>
<td>Ledermuelleriopsis sp.</td>
<td>no information available</td>
<td>Shiba (2015)</td>
</tr>
<tr>
<td>Mullederia sp.</td>
<td>ex oak trees (Fagaceae); Shikoku</td>
<td>Shiba (2015)</td>
</tr>
<tr>
<td>Mullederia sichuanensis Wang, 1986</td>
<td>ex shrubs, Moea japonica Merr. (Primulaceae) and</td>
<td>Present study</td>
</tr>
<tr>
<td></td>
<td>Ilex sp. (Aquifoliaceae); Honshu</td>
<td></td>
</tr>
<tr>
<td>Stigmaeus calliniae Evans, 1954</td>
<td>not specified; Shikoku</td>
<td>Ehara (1980)</td>
</tr>
<tr>
<td>S. fissuricolus Halbert, 1920</td>
<td>not specified; Shikoku, Kyushu</td>
<td>Ehara (1980)</td>
</tr>
<tr>
<td>Storchia robusta</td>
<td>(Berlese, 1885)</td>
<td>not specified; Shikoku</td>
</tr>
<tr>
<td>Zetzellia camphorae Negm, Johann, Ferla &amp; Amano, 2015</td>
<td>ex camphor trees, Cinnamomum camphora (L.) J. Presl. (Lauraceae); Honshu</td>
<td>Negm et al. (2015)</td>
</tr>
</tbody>
</table>

* Species epithets might have different endings than in Japanese literature, to match the gender of the genus name. For example: Ehara (1980) reported the species Ledermuelleria lirrellia, and since this species was transferred from the genus Ledermuelleria to Eustigmaeus, the epithet 'lirrellia', which is feminine, was consecutively changed to 'lirellus' to fit the new masculine genus name 'Eustigmaeus' (see Fan et al., 2016).

1Ehara (1980) identified Eustigmaeus species under genus Ledermuelleria Oudemans, and reported E. anauniensis from its synonym Ledermuelleria pectinata (Ewing, 1917).

2 Storchia robusta was reported from its synonym Apostigmaeus navicella Grandjean by Ehara (1980).

Materials and methods

Mites were directly picked up from detached plant leaves under stereomicroscope (SZ40®, Olympus, Japan) and mounted on glass slides using Hoyer’s medium. Permanent slides were placed on a hot plate at 50°C to dry, then sealed with Thorne’s cement® (FHK, Fujihira Industry, Japan) applied around the edge of the coverslip using a slide ringer. Mites were examined for their different taxonomic features with the aid of phase contrast (BX43®, Olympus) and differential interference contrast (BX53®, Olympus) compound microscopes and drawn by a camera lucida (U-DA, Olympus) attached to the microscope. Final illustrations were done with Adobe Illustrator (Adobe Systems Incorporated, USA). Measurements were performed using the imaging software Sensiv Measure® ver. 2.6.0 and correspond to the mean followed by minimum and maximum values. Tubercles of dorsal stout setae and leg coxae were not included in measuring setae and legs.

In the present description, the idiosomal and leg setation follow Grandjean (1939, 1944). Voucher materials are deposited in the Laboratory of Applied Entomology and Zoology, Ibaraki University (AEZIU) under the serial voucher specimen numbers.

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Systematics
Family Stigmaeidae Oudemans, 1931
Genus Mullederia Wood, 1964
Type species: Mullederia arborea Wood, 1964: 1, by original designation.

Mullederia sichuanensis Wang, 1986
(Figures 1–6)

Redescription
Female (Figures 1 & 2) (n=10)
Idiosomal venter (Figure 1B): Three pairs of slender setae present between coxae, l1a 29 (27–32) at level of coxa I, 3a 20 (19–22) anterior to coxa III and 4a 18 (17–20) at level between coxae III and IV. Distances between their bases: 1a–1a 45 (43–47), 3a–3a 143 (141–146), 4a–4a 70 (68–73). Anogenital region with two pairs of aggenital setae ag1 11 (10–12), ag2 10 (9–11), agl–ag2 22 (20–24) laterad genital opening and three pairs of pseudanal setae ps3 7 (6–8), ps2 10 (9–11), ps1 8 (8–9). Suranal shield with two pairs of stout setae hl 40 (39–42), h2 34 (33–35). Distances between their bases: hl–hl 19 (18–21), h2–h2 46 (45–48).

Gnathosoma (Figures 1C & D): Chelicera 60 (57–63), movable digit 36 (34–39). Palp 79 (73–85), palp-coxa with a supracoxal seta (elop) dorsally. Number of setae on palpal segments: Tr 0, Fe 3 (d, l’, v’), Ge 2 (d, l’), Ti 2 (d, l’), Ts 8 (1) (fused eupathidia sul, eupathidion acm, ba, bp, lp, va, 1 solenidion ω). Subcapitulum 96 (90–103) wide, with two pairs of slender setae proximally, m 20 (18–22), n 22 (21–24) and two pairs of adoral setae distally, ro2 13 (12–14), ro1 16 (15–18). Distances between bases of subcapitular setae: n–n 39 (37–41), m–m 17 (15–19), ro1–ro1 7 (7–8), ro2–ro2 13 (11–16), n–m 20 (19–21), m–ro1 34 (32–37), ro1–ro2 9 (8–10).

Legs (Figure 2): Lengths of legs: leg I 209 (204–215), leg II 210 (202–218), leg III 196 (191–202), leg IV 194 (192–197). Coxa I with setae 1b 20 (19–22) and 1c minute, coxa II with seta 2c minute, coxa III with setae 3b and 3c minute, coxa IV with setae 4b and 4c minute. Measurements of solenidia: ϕp on Ti I 21 (20–21), ω on Ts I 24 (23–25); ϕp on Ti II 21 (20–21), ω on Ts II 23 (22–23); ϕp on Ti III 20 (20–21), ω on Ts III 24 (24–25). Chaetotaxy (I–IV): coxae 2-1-2-2; trochanters 1-1-1-1; femora 5-5-2-1 or 5-5-2-2, in some specimens; genua 2-0-0-0; tibiae 5+(1ϕp)-5+(1ϕp)-5; tarsi 12+(1ω)-9+(1ω)-7+(1ω)-7.

Male (Figures 3 & 4) (n=3)
Idiosomal dorsum (Figure 3A): As in female except posterior margin with median invagination, 251 (247–255) long, 223 (218–228) wide. Eye 16 (15–18) in diameter and pob 16 (14–19) in diameter. Dorsal setae shorter than in female. Lengths of prodorsal setae: vi 78 (75–81), ve 88 (86–90), sci 63 (61–65), sce 68 (66–71). Distances between their bases: vi–vi 44 (43–45), vi–ve 64 (62–

**FIGURE 1.** *Mullederia sichuanensis* Wang, 1986. Female. A—dorsum; B—venter; C—subcapitulum; D—palp.

*Idiosomal venter* (Figure 3B): Lengths of intercoxal setae: 1a 19 (17–22), 3a 15 (12–19) and 4a 16 (14–18). Distances between their bases: 1a–1a 24 (22–26), 3a–3a 97 (94–100), 4a–4a 39 (38–41). Aggenital setae: ag1 7 (7–8), ag2 10 (9–11), situated as in female. Pseudanal setae: ps3 6 (5–6), ps2 4 (4–5), ps1 3 (3–4). Suranal setae h1 14 (13–15), h2 16 (16–17). Distances between their bases: h1–h1 15 (14–17), h2–h2 39 (38–41).

FIGURE 2. Mullederia sichuanensis Wang, 1986. Female. A—leg I; B—leg II; C—leg III; D—leg IV.

Legs (Figure 4). Lengths of legs: leg I 175 (171–180), leg II 169 (167–172), leg III 165 (162–168), leg IV 167 (164–170). Measurements of solenidia: φp on Ti I 16 (16–17), ω1 on Ts I 17 (16–18), ω2 on Ts I 24 (24–25); φp on Ti II 15 (15–16), ω1 on Ts II 17 (17–18), ω2 on Ts II 25 (25–26); φp on Ti III 16 (15–17), ω1 on Ts III 18 (18–19), ω2 on Ts III 24 (23–25); ω1 on Ts IV 19 (19–20), ω2 on Ts IV 26 (25–27). Chaetotaxy (I–IV): coxae 2-1-2-2; trochanters 1-1-1-1; femora 5-5-2-2 or 5-5-2-2, in one specimen; genua 2-0-0-0; tibiae 5+(1φρ)-5+(1φρ)-5+(1φρ)-5; tarsi 12+(2ω)-9+(2ω)-7+(2ω)-7+(2ω).
**FIGURE 3.** *Mullederia sichuanensis* Wang, 1986. Male. A—dorsum; B—venter; C—subcapitulum; D—palp.

**Deutonymph** (Figures 5 & 6) (n=7)


**Gnathosoma** (Figures 5C & D): Chelicera 54 (52–56), movable digit 23 (20–26). Palp 50 (45–55). Subcapitulum 73 (70–76) wide, with subcapitular setae, *m* 18 (18–19), *n* 17 (17–18) and...
adoral setae, \(ro2\) 9 (8−10), \(ro1\) 10 (10−11). Distances between bases of subcapitular setae: \(n−n\) 30 (28−32), \(m−m\) 22 (22−23), \(ro1−ro1\) 6 (6−7), \(ro2−ro2\) 10 (9−11), \(n−m\) 17 (15−19), \(m−ro1\) 35 (33−37), \(ro1−ro2\) 7 (7−8).

**FIGURE 4.** *Mullederia sichuanensis* Wang, 1986. Male. A—leg I; B—leg II; C—leg III; D—leg IV.

Legs (Figure 6): Lengths of legs: leg I 165 (160−170), leg II 170 (167−173), leg III 162 (160−164), leg IV 155 (151−159). Measurements of solenidia: \(\varphi p\) on Ti I 18 (17−19), \(\omega\) on Ts I 22 (21−22); \(\varphi p\) on Ti II 19 (19−20), \(\omega\) on Ts II 21 (20−22); \(\varphi p\) on Ti III 17 (16−18), \(\omega\) on Ts III 23 (23−24). Chaetotaxy (I–IV): coxae 2-1-2-2; trochanters 1-1-1-0; femora 5-5-2-1; genua 2-0-0-0; tibiae 5+(1\(\varphi p\))-5+(1\(\varphi p\))-5+(1\(\varphi p\))-5; tarsi 12+(1\(\omega\))-9+(1\(\omega\))-7+(1\(\omega\))-7.
Material examined

Ten females and 2 males, ex *Maesa japonica* Merr. (Primulaceae), Bōsō Peninsula, Chiba Prefecture, Japan, 35°10′14″N, 140°10′09″E, 320 m, 23 July 2018, M.W. Negm leg. (voucher specimen no. 890); 2 females, 1 male and 7 deutonymphs, *Ilex* sp. (Aquifoliaceae), Bōsō Peninsula, Chiba Prefecture, Japan, 35°09′21″N, 140°11′33″E, 80 m, 26 May 2018, M.W. Negm leg. (voucher specimen no. 891).
Mullederia sichuanensis \(Wang, 1986\) was originally described from China based on materials collected from different host plants, *Holboellia* sp. (Lardizabalaceae), *Rubus lambertianus* Ser. (Rosaceae) and *Viburnum brachybotryum* Hemsl. (Adoxaceae) (Wang 1986), which are deciduous broad-leaved plants. However, the Japanese specimens were found on another flowering host plants of the families Primulaceae and Aquifoliaceae, which are evergreen broad-leaved plants.

The Japanese specimens of *M. sichuanensis* can be separated from other species within the genus by the presence of the dorsal seta \(d1\) (= \(li\)—in original description) and the absence of seta \(f1\). Conversely, the New Zealand species (*arborea* Wood; *procurrens* Fan & Zhang; *scutellaris* Fan &
Zhang) lack seta d1 and bear seta f1. Table 2 lists the interspecific morphological variations among females of *Mullederia* species of the world.

**TABLE 2.** Morphological diagnostic variations among females of *Mullederia* species of the world.

<table>
<thead>
<tr>
<th>Species</th>
<th>Setae (d1)</th>
<th>Setae (f1)</th>
<th>Coxae (I–IV)</th>
<th>Trochanters (I–IV)</th>
<th>Femora (I–IV)</th>
<th>Genua (I–IV)</th>
<th>Tibiae (I–IV)</th>
<th>Tarsi (I–IV)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>arborea</em> Wood</td>
<td>absent</td>
<td>present</td>
<td>2+1aelcp-1-2*</td>
<td>1-1-1-0</td>
<td>5-5-2-1</td>
<td>2+1c-1-0-0</td>
<td>5+1pp,5+1pp-5+1pp</td>
<td>12+1ω-9+1ω-7+1ω-7</td>
<td>Fan &amp; Zhang (2005)</td>
</tr>
<tr>
<td><em>filipina</em> Rimando &amp; Corpuz-Raros</td>
<td>absent (j2)</td>
<td>present</td>
<td>1-0-0-0</td>
<td>1-1-1-1</td>
<td>5-5-2-1</td>
<td>2-0-0-0</td>
<td>5+1ω-5+1ω-5+1ω-5</td>
<td>11+1ω-8+1ω-7+1ω-7</td>
<td>Rimando &amp; Corpuz-Raros (1996)</td>
</tr>
<tr>
<td><em>parryorum</em> (Gupta)</td>
<td>absent</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Gupta (1991)</td>
</tr>
<tr>
<td><em>procurrens</em> Fan &amp; Zhang</td>
<td>absent</td>
<td>present</td>
<td>2+1aelcp-1-2-2</td>
<td>1-1-1-0</td>
<td>5-5-2-1</td>
<td>2+1c-1-0-0</td>
<td>5+1pp,5+1pp-5+1pp</td>
<td>12+1ω-9+1ω-7+1ω-7</td>
<td>Fan &amp; Zhang (2005)</td>
</tr>
<tr>
<td><em>sceutellaris</em> Fan &amp; Zhang</td>
<td>absent</td>
<td>present</td>
<td>2+1aelcp-1-2-2</td>
<td>1-1-1-0</td>
<td>5-5-2-1</td>
<td>2+1c-1-0-0</td>
<td>5+1pp,5+1pp-5+1pp</td>
<td>12+1ω-9+1ω-7+1ω-7</td>
<td>Fan &amp; Zhang (2005)</td>
</tr>
<tr>
<td><em>sichuanensis</em> Wang</td>
<td>present (ii)</td>
<td>absent</td>
<td>2-1-1-1 (2-1-2-2)</td>
<td>1-1-1-1</td>
<td>5-5-2-2=2-0-0-0</td>
<td>6-6-6-5</td>
<td>13-9-6-6 (12+1ω-9+1ω-7+1ω-7)</td>
<td>Wang (1986)</td>
<td></td>
</tr>
</tbody>
</table>

* *Fan and Zhang (2005) depicted coxa IV with a single seta only.
* *This species is questionable due to inadequate original description.
* *The correct chaetotaxy after Fan and Ueckermann (2016), in parenthesis.

The examined mites conform to the original description of this species, considering the corrections published by Fan & Ueckermann (2016). However, most of the Japanese specimens have femur IV with one seta, while few individuals with two setae. We consider this alteration in setal counts as an intraspecific variation.

The current species is newly recorded from Japan based on specimens of females, males and deutonymphs. The chaetotaxy of legs between females, males and deutonymphs is relatively similar. However, males differ from females and deutonymphs in the presence of additional solenidia on tarsi I–IV, whereas deutonymphs differ from females and males in having trochanter IV nude.

**Discussion**

The present work redescribes a new record of stigmaeid mites in Japan, increasing their fauna to 9 genera and 19 species, including three unidentified species, to date. Also, deutonymphal stage of the genus *Mullederia* is described herein for the first time. Reporting such few numbers of stigmaeid species from Japan, in a rich family with about 600 species described globally, may indicate that this country is expected to contain more species awaiting discovery. The world distribution of *Mullederia* mites comprises only New Zealand, India, Philippines, China and Japan (Shiba 2015; present study), making this genus quite restricted to eastern Palaearctic, Indomalaya and Australasia biogeographic realms.

Rimando & Corpuz-Raros (1996) provided a key to *Mullederia* species and stated that *M. sichuanensis* has coxae I–IV with 2-1-1-1; however, the coxal chaetotaxy was recently corrected to 2-1-2-2 by Fan & Ueckermann (2016). They also re-examined paratype females and corrected the number of tenent hairs on the empodial shaft to 3 rather than 2 in contrast with Wang (1986) and Rimando & Corpuz-Raros (1996), and highlighted that tarsi I–IV with 12+1ω, 9+1ω, 7+1ω, 7 rather

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than 12+1ω, 8+1ω, 6, 6. Rimando & Corpuz-Raros (1996) mentioned about *M. sichuanensis* to be the only species that has 3 setae (2+1) on femur IV; however, the present specimens agree with the genus revised diagnosis (Fan & Ueckermann 2016) to have 1 seta (most specimens) or 2 setae (few specimens).

The species *M. filipina* was described from the Philippines due to the number of coxal setae on legs (I–IV) which were (1-0-0-0). This setal formula is questionable, especially because the coxal setae (1c, 2c, 3b, 3c, 4b, 4c) are minute and rather difficult to be observed. Also, the description of *M. parryorum* from India is brief and lacks specific information which makes the species difficult to be identified and distinguished from other species in the genus (Gupta 1991; Fan & Ueckermann 2016). Therefore, the genus *Mullederia* may be in need of updated revision.

Information about the biological traits of *Mullederia* mites is still unknown. Up to our knowledge, no studies have evaluated the predatory performance of *Mullederia* mites. This may be due to some difficulties in mite rearing. Despite preliminary trials have failed to rear these mites in laboratory, few individuals were seen attacking the eggs of *Tetranychus urticae* Koch (unpublished data). Such predation ability may encourage for more ecological studies to figure out the predator-prey interaction between the *Mullederia* mites and other pestiferous species. Further research should be directed to investigate their efficiency for a better use in biocontrol programs. Hopefully, this work would encourage for setting up new series of biological studies on *Mullederia* mites.

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