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Two new species of *Arcuphantes* (Araneae: Linyphiidae: Micronetinae) from Owase, Kii Peninsula, Japan

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Abstract — Two new linyphiid species, *Arcuphantes shiozakii* sp. nov. and *A. yakiyama* sp. nov., from Owase, eastern Kii Peninsula, Japan, are described based on both sexes. Given the fact that the two new species share almost identical mitochondrial cytochrome *c* oxidase subunit I sequences, they may represent closely related sister species, but nonetheless, they are clearly distinguishable from each other by the genital characters. Additionally, the new species are closely related to *A. osugiensis* (Oi 1960) and *A. yamakawai* (Oi 1960), but they are also distinguished by the morphology of genitalia.

Key words — Arachnida, *Arcuphantes shiozakii* sp. nov., *Arcuphantes yakiyama* sp. nov., COI, taxonomy

Introduction

The linyphiid spider genus *Arcuphantes* Chamberlin & Ivie 1943 currently consists of 58 species that inhabit the west Nearctic and East Asia (World Spider Catalog 2023). The *Fusciphantes longiscapus* Oi 1960 and nine other close congeners were once classified as members of *Arcuphantes* (Saito 1992; Ihara 1995; Nakano et al. 2017); the genus *Fusciphantes* Oi 1960 has been deemed a distinct genus and treated as an accepted taxon (Ono et al. 2009; World Spider Catalog 2023). The Japanese *Arcuphantes* spiders are thus currently classified into 26 species (World Spider Catalog 2023). Nonetheless, Ihara (2007) stated that more than 50 unidentified species have been recognized in the Japanese Archipelago, and thus the true species richness of the Japanese *Arcuphantes* still remains unclear.

Unidentified *Arcuphantes* samples were collected from the southern slope of Mt. Tengurasan, Owase (Mie Prefecture), which is located on the central east coast of Kii Peninsula, Honshu, Japan (Fig. 1). Based on this preliminary finding, an additional field survey was carried out in the same area and other unidentified *Arcuphantes* samples, possibly belonging to a different species, were collected from Mt. Yakiyama, also in Owase. These two unidentified species are herein described as new species. DNA sequences are also provided to help differentiate the two new species.

Materials and methods

Sampling and morphological examination

Spiders were collected from several localities in Owase area (Mie Prefecture), Kii Peninsula, Honshu, Japan (Fig. 1) in 2003, 2012, 2020, and 2021. When possible, geographical coordinates for the sites were obtained using a Garmin eTrex® GPS unit. Specimens were mostly preserved in 70% ethanol. However, legs of some specimens were removed and preserved in 99% ethanol for DNA extraction.

Morphological examination was conducted and drawings of the specimens were performed using stereoscopic microscopes (M125 and M125C, Leica Microsystems, Wetzlar, Germany) with a drawing tube. Photos of the specimens was taken with the aid of a digital microscope (VHX-5000; KEYENCE, Osaka, Japan) or a Leica MC170 HD digital camera mounted on the Leica M125C and prepared using Leica Application Suite v. 4.12. Measurements were taken to the nearest 0.01 mm using the Leica Application Suite. Specimens examined in this study have been deposited in the Zoological Collection of Kyoto University (KUZ).

The chaetotaxy follows that described by Tanasevitch (2010). The morphological terminology of copulatory organs follows Nakano et al. (2017) and other previous studies (Saaristo & Tanasevitch 1996; Saaristo et al. 2006; Ma et al. 2016; Jin et al. 2018). The following abbreviations are used for morphological characters of copulatory organs in the figures: AP, apophysis of paracymbium; ATA, anterior part of terminal apophysis; BP, basal part of epigyne; CY, cymbium; ED, embolic division; EP, embolus proper; FG, Fickert's gland; LE, lamellar extension; MM, median membrane; PC, paracymbium; PL, pseudolamella; PMP, posterior median plate of epigyne; PTA, posterior part of terminal apophysis; R, radix; SC, scape of epigyne.

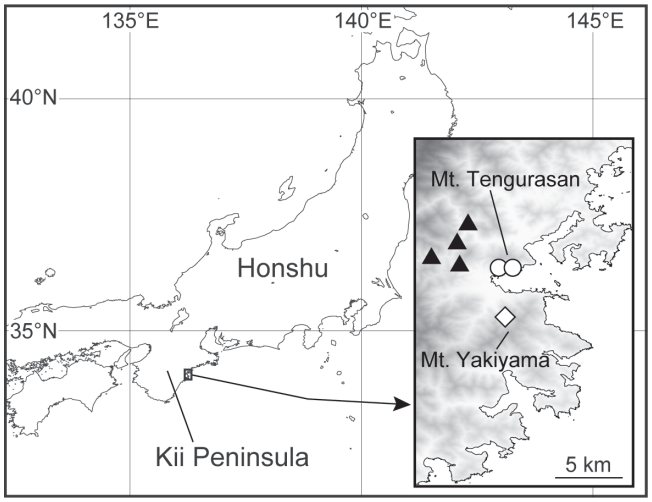

Fig. 1. Map showing the collection localities of the specimens. White circles, *Arcuphantes shiozakii* sp. nov.; white diamond, *Arcuphantes yakiyama* sp. nov.; black triangles, collection site where other *Arcuphantes* species were collected. Shoreline data were based on Wessel & Smith (1996) and National Land Information Division, MLIT of Japan (https://nlftp.mlit.go.jp/ksj/gml/datalist/KsjTmplt-C23.html#!).

PCR and DNA sequencing

Genomic DNA extraction was conducted as described by Matsuda et al. (2020). The primer set for the amplification of the mitochondrial cytochrome *c* oxidase subunit I (COI) marker and the conditions for the polymerase chain reactions and cycle sequencing reactions used in this study followed Sugawara et al. (2021). The DNA sequences obtained in this study were deposited with the International Nucleotide Sequence Databases (INSD) through the DNA Data Bank of Japan. Pairwise comparison of uncorrected *p*-distances for the obtained COI sequences (658 bp) was calculated manually.

Results and discussion

The male (KUZ Z5050; 658 bp, INSD accession number LC781733) and female (KUZ Z5051; 658 bp, LC781734) specimens from Mt. Yakiyama had identical COI sequences. The COI sequences of the specimens from Mt. Tengurasan were almost identical to those of the specimens from Mt. Yakiyama (only one or two substitutions were detected; uncorrected *p*-distances between them were 0.2%–0.3%). The 68th aligned position of the male (KUZ Z5048; 658 bp, LC781731) and female (KUZ Z5049; 658 bp, LC781732) COI sequences was "G" in the specimens from Mt. Tengurasan and "A" in the specimens from Mt. Yakiyama. This substitution detected between them was nonsynonymous (yielding valine in the northern unit and isoleucine in the southern unit). An additional substitution was detected between the COI sequences of the male and female from Mt. Tengurasan ("C" in the male at the 287th aligned position and "T" in the female; uncorrected *p*-distance was 0.2%), but this substitution was synonymous (triplets of both sequences translated as leucine).

Fig. 2. *Arcuphantes shiozakii* sp. nov., habitus of the female paratype (KUZ Z5054), dorsal view. Scale = 1 mm.

According to the clear morphological differences between the *Arcuphantes* specimens from Mt. Tengurasan and those from Mt. Yakiyama along with the nonsynonymous substitution of COI sequences, we conclude that each *Arcuphantes* population represents a distinct species. The distribution of the species from Mt. Tengurasan may be restricted to the region around the mountain because our field surveys showed that spiders that belong to this species were only found on the southern slope of Mt. Tengurasan (Fig. 1). The range of the other species remains unclear, but it may inhabit forest habitats surrounding Mt. Yakiyama. Because the COI sequences of the two species were so similar, they may have a close sister relationship that was produced by a recent speciation event.

Taxonomy

Genus *Arcuphantes* Chamberlin & Ivie 1943

***Arcuphantes shiozakii* Ono, Ihara & Nakano, sp. nov.**
[Japanese name: Shiozaki-yamisaragumo]
(Figs. 2, 3)

Diagnosis. *Arcuphantes shiozakii* sp. nov. most closely resembles *A. yakiyama* sp. nov., but both sexes of *A. shiozakii* sp. nov. are clearly distinguished from those of the latter new species by their genital characters (features of *A. yakiyama* sp. nov. in parentheses). Males of *A. shiozakii* sp. nov. are distinguishable by the different shape of PC,

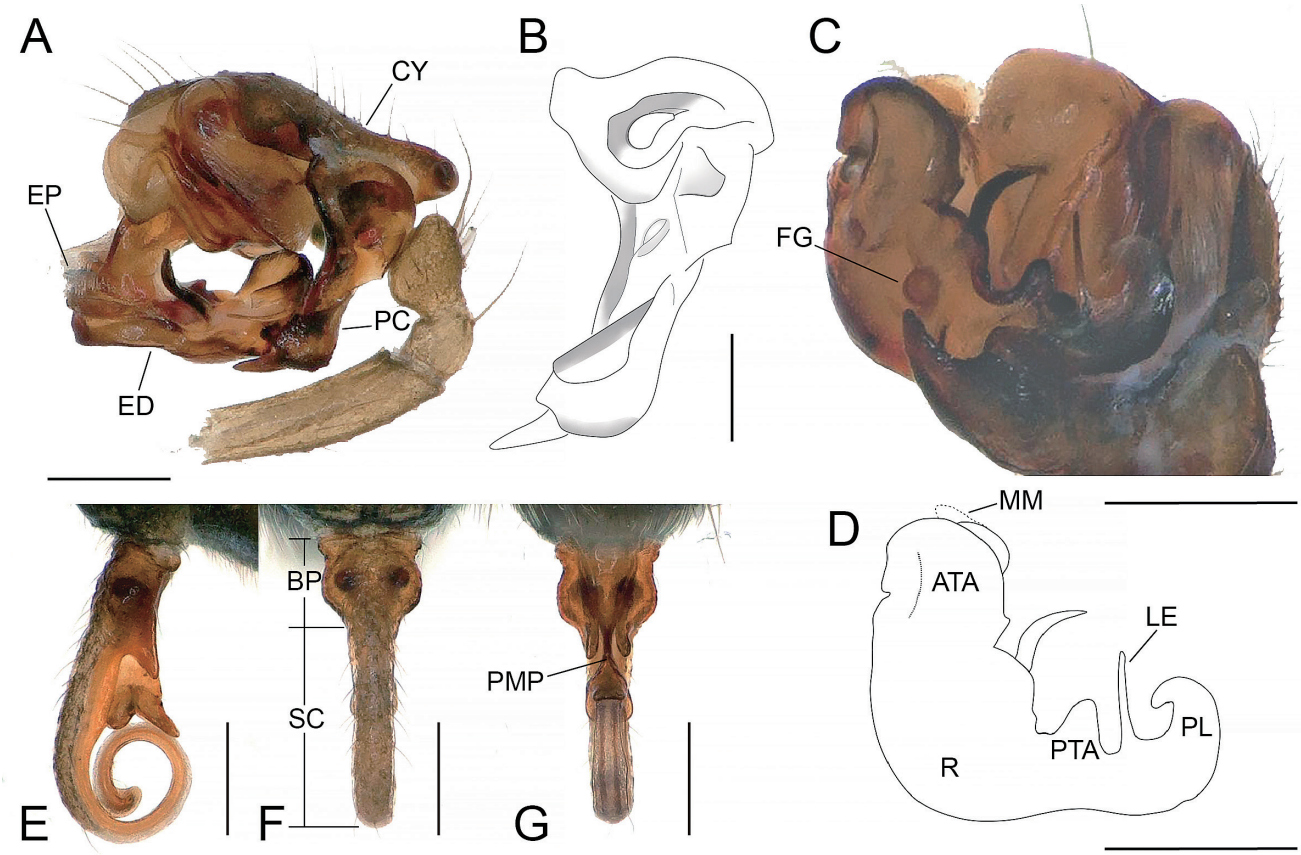

Fig. 3. *Arcuphantes shiozakii* sp. nov., male holotype (KUZ Z3907), left palp (B), male paratype (KUZ Z5059), left palp (A, C, D), and female paratype (KUZ Z3906), epigyne (E–G). A, retrolateral view; B, paracymbium, retrolateral view; C, ventral view; D, embolic division, ventral view; E, lateral view; F, ventral view; G, dorsal view. Scales = 200 μm (A, C–G); 100 μm (B).

lacking an AP in its middle part (Fig. 3B) (with a thin and crooked AP; Fig. 4B); by the triangular PTA of ED (Fig. 3C, D) (broad and double humped; Fig. 4C, D); and by the short hooked PL of ED (Fig. 3D) (prolonged; Fig. 4D). Females of *A. shiozakii* sp. nov. differ from those of *A. yakiyama* sp. nov. by the proximally narrowed BP when observed ventrally (Fig. 3F) (not narrowed; Fig. 4F), and by the sharply concaved distal part of PMP when observed laterally (Fig. 3E) (loosely concaved; Fig. 4E).

The epigynal scape of *A. shiozakii* sp. nov. females resemble those of *A. osugiensis* (Oi 1960) and *A. yamakawai* (Oi 1960), which are endemic to the Kii Peninsula. However, females of the new species differ from these species by the sharply concaved distal part of PMP when observed laterally (rounded in *A.osugiensis*, see fig. 279 in Oi 1960; straight in *A. yamakawai*, see fig. 281 in Oi 1960). Males of the new species are distinguishable from *A. osugiensis* by the PC lacking an AP in its middle part (with an AP in *A. osugiensis*, see fig. 278 in Oi 1960; males of *A. yamakawai* unknown).

Material examined. *Holotype*: KUZ Z3907, male, Mt. Tengurasan, Tenmaura, Owase, Mie Prefecture, Japan (34.08131°N, 136.21353°E), Tetsuya Shiozaki (TS), 20 October 2012. *Paratypes* (in total 7 specimens, 2 males and 5 females): KUZ Z3904, Z3905, 2 females, 27 July 2003, and KUZ Z3906, female, 20 October 2012, same locality as the holotype, by TS; KUZ Z5048, Z5059, 2 males, and KUZ Z5049, Z5054 (Fig. 2), 2 females, same locality as the holotype (34.08182°N, 136.21099°E), by Yoh Ihara (YI), 15 June 2021.

Additional materials: 12 specimens in total, KUZ Z5060, Z5061, 2 males, and KUZ Z5062–Z5071, 10 females, same locality as the holotype (34.08182°N, 136.21099°E), by YI, 15 June 2021.

Type locality. Mt. Tengurasan, Tenmaura, Owase, Mie Prefecture, Japan (34.08131°N, 136.21353°E).

Description. *Male* (KUZ Z3907, Z5059). Measurements (mm). CL 1.10, CW 0.92; AL 1.33; AW 0.79. Legs long and slender. Leg formula, I > IV > II > III; length of legs (femur + patella + tibia + metatarsus + tarsus): leg I 6.53 (1.76 + 0.27 + 1.78 + 1.78 + 0.94); leg II 5.56 (1.48 + 0.27 + 1.57 + 1.46 + 0.78); leg III 4.16 (1.21 + 0.27 + 1.57 + 1.46 + 0.78); leg IV 5.74 (1.65 + 0.25 + 1.59 + 1.49 + 0.76).

Eyes subequal in size except for smaller anterior median eyes; anterior eye row almost straight in frontal view; posterior eye row slightly recurved in dorsal view. Clypeus concave immediately below eyes, subequal length of median ocular area. Fang sinuous, promargin of fang furrow in chelicera with 2 teeth. Sternum convex, heart-shaped, sparsely with long bristles.

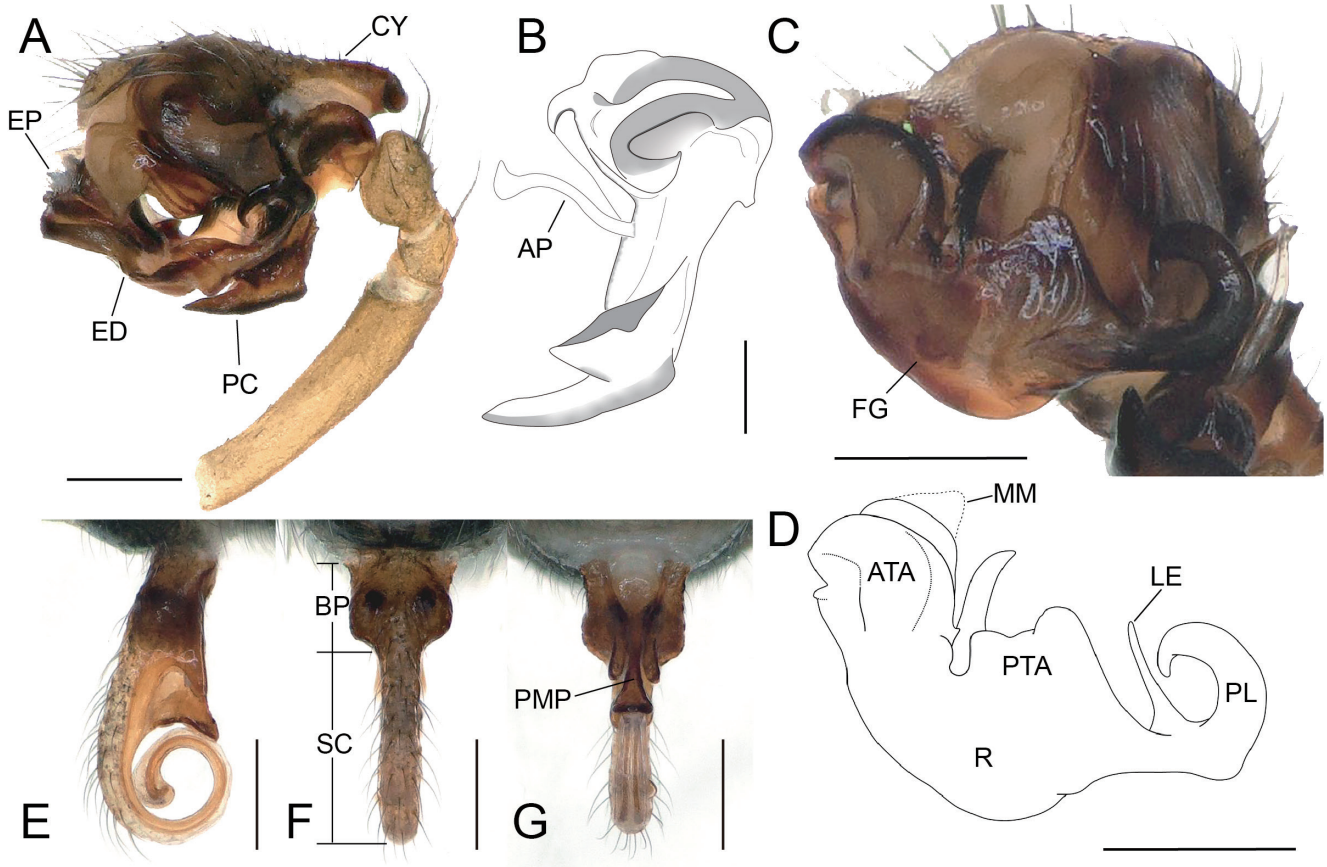

Fig. 4. *Arcuphantes yakiyama* sp. nov., male holotype (KUZ Z5072), right (A) and left (B–D) palps, and female paratype (KUZ Z5075), epigyne (E–G). A, retrolateral view (horizontally flipped); B, paracymbium, retrolateral view; C, ventral view; D, embolic division, ventral view; E, lateral view; F, ventral view; G, dorsal view. Scales = 200 μm (A, C–G); 100 μm (B).

Leg macrosetae. Leg I: femur 0-1-0-0; tibia 2-1-1-0; metatarsus 1-0-0-0. Leg II: femur 0-0-0-0; tibia 2-0-1-0; metatarsus 1-0-0-0. Leg III: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 1-0-0-0. Leg IV: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 0-0-0-0, without trichobothrium.

Palp (Fig. 3A–D). Patella and tibia short, each with long stout bristle. Tibia unmodified. CY with a thumb-like proximal apophysis. PC large, proximally fan-shaped, without AP in middle, apical part bluntly pointed and divided into 2 parts. ED: ATA semicircular, with serrated margin; PTA triangular; PL hooked, short, with narrow LE basally; EP conical.

Female (KUZ Z3906). Measurements (mm). CL 0.89, CW 0.72; AL 1.31; AW 0.86. Length of legs (femur + patella + tibia + metatarsus + tarsus): leg I 5.73 (1.48 + 0.30 + 1.59 + 1.48 + 0.88); leg II 4.96 (1.36 + 0.31 + 1.29 + 1.24 + 0.76); leg III 3.58 (1.04 + 0.24 + 0.90 + 0.88 + 0.52); leg IV 4.81 (1.40 + 0.25 + 1.27 + 1.19 + 0.70).

Similar to male in general appearance, but differing from it in following characteristics: carapace rather oval; fang not modified, promargin of fang furrow with 3 teeth, retromargin with 5 small teeth.

Leg macrosetae. Leg I: femur 0-1-0-0; tibia 2-1-1-0; metatarsus 1-0-0-0. Leg II: femur 0-0-0-0; tibia 2-0-1-0; metatarsus 1-0-0-0. Leg III: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 1-0-0-0. Leg IV: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 0-0-0-0, without trichobothrium.

Epigyne (Fig. 3E–G). BP wide, quadrate in ventral view, proximal part slightly narrowed, with a pair of protrusions in lateral plate. SC long and slender, with constant thickness in distal direction, distal part spiral in lateral view. PMP long, almost 2/3× as long as epigyne; distal part sharply concaved in lateral view.

Coloration. Male and female (Fig. 2) with same coloration. Carapace bright yellowish-brown to brown with dark grayish-brown markings. Chelicerae bright yellowish-brown to brown. Sternum dark grayish-brown. Legs bright yellowish-brown, with faint dark grayish annulation. Abdomen dark grayish-brown, dorsally with pale white markings, ventrally with 2 pairs of white patches.

Distribution. *Arcuphantes shiozakii* sp. nov. is endemic to a very limited range in the southern slope of Mt. Tengurasan, Owase, Mie Prefecture, Kii Peninsula, central Honshu, Japan.

Arcuphantes yakiyama **Ihara & Nakano, sp. nov.**

[Japanese name: Yakiyama-yamisaragumo]

(Fig. 4)

Diagnosis. *Arcuphantes yakiyama* sp. nov. is similar to *A.*

shiozakii sp. nov.; see the Diagnosis of *A. shiozakii* sp. nov. for the details that differentiate these two species. Females of *A. yakiyama* sp. nov. also share SC features with females of *A. osugiensis* and *A. yamakawai*, but are distinguishable from the latter two species by the loosely concaved distal part of PMP when observed laterally (rounded in *A. osugiensis* and straight in *A. yamawakai*; see the Diagnosis of *A. shiozakii* sp. nov.). Males of *A. yakiyama* sp. nov. differ from *A. osugiensis* in having the double humped PTA of ED (triangular in *A. osugiensis*; see the Diagnosis of *A. shiozakii* sp. nov.).

Material examined. *Holotype*: KUZ Z5072, male, Mt. Yakiyama, Yanohama, Owase, Mie Prefecture, Japan (34.04387°N, 136.21267°E), YI, 15 June 2021. *Paratypes* (in total 7 specimens, 3 males and 4 females): KUZ Z5050, Z5073, Z5074, 3 males, and KUZ Z5051, Z5075–Z5077, 4 females, same locality as the holotype, by YI, 15 June 2021.

Additional materials: in total 10 females, KUZ Z5078, Z5079, Z5081–Z5087, by YI, and KUZ Z5080, by Takafumi Nakano, same locality as the holotype, 15 June 2021.

Type locality. Mt. Yakiyama, Yanohama, Owase, Mie Prefecture, Japan (34.04387°N, 136.21267°E).

Description. *Male* (KUZ Z5072). Measurements (mm). CL 1.15, CW 0.95; AL 1.33; AW 0.83. Legs long and slender. Leg formula, I > IV > II > III; length of legs (femur + patella + tibia + metatarsus + tarsus): leg I 7.69 (1.99 + 0.46 + 2.15 + 2.01 + 1.08); leg II 6.57 (1.78 + 0.30 + 1.81 + 1.73 + 0.95); leg III 5.03 (1.36 + 0.30 + 1.23 + 1.28 + 0.86); leg IV 6.64 (1.94 + 030 + 1.84 + 1.71 + 0.85).

Eyes subequal in size except for smaller anterior median eyes; anterior eye row almost straight in frontal view; posterior eye row slightly recurved in dorsal view. Clypeus concave immediately below eyes, subequal length of median ocular area. Fang sinuous, promargin of fang furrow in chelicera with 2 teeth. Sternum convex, heart-shaped, sparsely with long bristles.

Leg macrosetae. Leg I: femur 0-1-0-0; tibia 2-1-1-0; metatarsus 1-0-0-0. Leg II: femur 0-0-0-0; tibia 2-0-1-0; metatarsus 1-0-0-0. Leg III: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 1-0-0-0. Leg IV: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 0-0-0-0, without trichobothrium.

Palp (Fig. 4A–D). Patella and tibia short, each with long stout bristle. Tibia unmodified. CY with a thumb-like proximal apophysis. PC large, proximally fan-shaped form, with thin and crooked AP in middle, apical part bluntly pointed and divided into 2 parts. ED: ATA semicircular, with serrated margin; PTA broad, double humped; PL hooked, prolonged, with narrow LE basally; EP conical.

Female (KUZ Z5075). Measurements (mm). CL 0.81, CW 0.75; AL 1.73; AW 1.08. Length of legs (femur + patella + tibia + metatarsus + tarsus): leg I 5.81 (1.55 + 0.31 + 1.56 + 1.60 + 0.79); leg II 5.44 (1.50 + 0.30 + 1.44 + 1.39 + 0.81); leg III 4.05 (1.16 + 0.29 + 1.01 + 1.03 + 0.56); leg IV 5.45 (1.61 + 0.30 + 1.41 + 1.40 + 0.73).

Similar to male in general appearance, but differing from it in following characteristics: carapace rather oval; fang not modified, promargin of fang furrow with 3 teeth, retromargin with 5 small teeth.

Leg macrosetae. Leg I: femur 0-1-0-0; tibia 2-1-1-1; metatarsus 1-0-0-0. Leg II: femur 0-0-0-0; tibia 2-0-1-0; metatarsus 1-0-0-0. Leg III: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 1-0-0-0. Leg IV: femur 0-0-0-0; tibia 2-0-0-0; metatarsus 0-0-0-0, without trichobothrium.

Epigyne (Fig. 4E–G). BP wide, quadrate in ventral view, with a pair of protrusions in lateral plate. SC long and slender, with constant thickness in distal direction, distal part spiral in lateral view. PMP long, almost 2/3× as long as epigyne; distal part loosely concaved in lateral view.

Coloration. Male and female with same coloration. Carapace bright yellowish-brown with dark grayish-brown markings. Chelicerae brownish-orange. Sternum dark grayish-brown. Legs bright yellowish-brown, with faint dark grayish annulation. Abdomen dark grayish-brown, dorsally with pale and white markings, ventrally with two pairs of white patches.

Distribution. *Arcuphantes yakiyama* sp. nov. is known only from the type locality, Mt. Yakiyama, Owase, Mie Prefecture, Kii Peninsula, central Honshu, Japan.

Acknowledgments

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