

## A Review of the Harvestman Genus *Metadentobunus* (Opiliones: Sclerosomatidae: Gagrellinae) with A Description of A New Species From Taiwan

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**Ssu-Li Chen and Hsi-Te Shih (2018)** The harvestman genus *Metadentobunus* is endemic to Taiwan, and has two taxa, *M. formosae formosae* Roewer, 1915 and *M. formosae garampiensis* Suzuki, 1944. The two subspecies have been raised as two species, and this study redescribes the type species *M. formosae* based on the type specimen and a neotype of *M. garampiensis* Suzuki, 1944 is assigned. A new species, *Metadentobunus brevispinus* sp. nov., is also established from central Taiwan based on morphological and molecular evidence. This new species differs from other congeneric species by having one pair of shorter (than other congeners) spines at frontal margin of the ocularium. It can also be distinguished from *M. garampiensis* by the basal shape of the penile shaft (constricted vs. parallel), location of the seminal receptacle in ovipositor (5th-6th segment vs. 6th-7th segment) and number of ampullas in the terminal of the seminal receptacle (2 vs. 3). Molecular evidence from mitochondrial 16S rDNA and cytochrome oxidase subunit I (COI) further supports the identity of this new species. An identification key for this genus is included as well.

**Key words:** *Metadentobunus brevispinus*, *M. garampiensis*, Morphology, New species, Neotype, Redescription, 16S rDNA, COI.

### BACKGROUND

The genus *Metadentobunus* (Eupnoi: Sclerosomatidae: Gagrellinae) was erected by Roewer (1915) for *Metadentobunus formosae* Roewer, 1915 (type locality Rokko (= Lugang, Changhua), central Taiwan), as a monotypic genus. This genus is distinguished from other genera of the Gagrellinae from Taiwan by having one pair of frontal spines of the ocularium. Later, *Metadentobunus garampiensis* Suzuki, 1944 was published from southern Taiwan. After comparing the type specimen of *M. formosae*, Suzuki (1977) considered *M. garampiensis* Suzuki, 1944 as a

subspecies of *M. formosae* because the difference between the two taxa is minor. In conclusion, the pedipalpal patella of *M. garampiensis* has a pronounced apophysis at the inner tip (Suzuki 1944 1977), which is absent in *M. formosae* according to the original description by Roewer (1915); the frontal spines of ocularium in *M. garampiensis* is smooth at the tip, which is finely granulated at the tip in *M. formosae* (Suzuki 1977).

We examined the specimens of *Metadentobunus* collected extensively from southern and central Taiwan, and found that all have an apophysis at inner tip of each pedipalpal patella. The holotype of *M. formosae* was also

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examined, but the pedipalps of the holotype was unfortunately broken from patella to tarsus. We therefore followed the description of Roewer for *M. formosae* and considered specimens collected from central and southern Taiwan with a pronounced apophysis at the inner tip of the pedipalpal patella are different species. We treat subspecies as species for the taxa mentioned in this study (see Oláh et al. 2018).

Suzuki (1977) pointed out that one character described by Roewer (1915) was incorrect, i.e. there are some tubercles above the first cheliceral segment of *M. formosae*, but the original description from Roewer is smooth. After we examined the type of *M. formosae*, we also found that the sex of the holotype is actually female, not male like Roewer (1915) mentioned. As a result, it is necessary to redescribe *M. formosae* based on the holotype. In addition, because Suzuki (1977: 137) mentioned that the holotype of *M. garampiensis* was lost, a neotype collected from Sheding, near the type locality Eluanbi, Kenting National Park, was assigned. We also include the description and photos of *M. garampiensis* females.

After comparing the morphological characters of a series of *Metadentobunus* specimens collected from central and southern Taiwan, we confirmed that the species from central Taiwan, with different characters, is a new species and describe it in this study using further genetic evidence from the mitochondrial 16S rDNA and COI markers. A key for the genus *Metadentobunus* is also provided.

## MATERIALS AND METHODS

### Specimen collection

Specimens collected from central and southern Taiwan (Table 1; Fig. 7) were preserved in 70–95% ethanol, and examined and drawn under a stereomicroscope equipped with a drawing tube. Ovipositors were cleared in hot lactic acid prior to observation of seminal receptacles (Schwendinger and Martens 2002).

The morphological terminology follows Hillyard and Sankey (1990). All measurements are given in mm. Specimens have been deposited in the Zoological Collections of the Department of Life Science, National Chung Hsing University, Taichung, Taiwan (NCHUZOO) and National Museum of Natural Science, Taichung, Taiwan (NMNS). The type specimen of *Metadentobunus*

*formosae* (SMF 9801162-RI/1162-66) deposited in the Senckenberg Museum in Frankfurt am Main, Germany (SMF) was also examined.

### Molecular analyses

Genomic DNA was obtained from appendages (legs, pedipalps, and/or chelicera) using the Epicentre QuickExtract DNA extraction solution 1.0. Polymerase chain reaction (PCR) was used to amplify mitochondrial 16S rRNA and cytochrome oxidase subunits I (COI) genes. Primers of 16H10, 16L29 (Schubart 2009), 1471, 1472 (Crandall and Fitzpatrick 1996), 16Sar, 16Sbr (Palumbi et al. 1991) were used for 16S; and LCO1490, HCO2198 (Folmer et al. 1994), HCOoutout (Prendini et al. 2005) and HCOinner (Chen and Shih 2017) were used for COI. The PCR conditions for the above primers were 35 or 39 cycles of denaturation for 50 s at 94°C, annealing for 70 s at 47°C or 48°C, and extension for 60 s at 72°C, followed by extension for 10 min at 72°C. PCR products were sequenced with Applied Biosystems 3730xl DNA Analyzer, using BigDye Terminator Cycle Sequencing Kits. Sequences were aligned by MUSCLE (Edgar 2004) under default settings, with subsequent manual adjustments. Based on a preliminary phylogenetic analysis, the genera *Psathyropus* and *Gagrella* are closely related to *Metadentobunus* (unpublished data), so we selected *Psathyropus formosa* (Roewer, 1911), *Psathyropus* sp. 1 and *Gagrella* sp. 1 as outgroups (Table 1). Sequences of different haplotypes have been deposited in the DNA Data Bank of Japan (DDBJ) (accession numbers in Table 1).

Phylogenetic congruence between the two dataset partitions was tested under the maximum parsimony criterion using the incongruence length difference (ILD) test (Farris et al. 1994) implemented in the PAUP\* program (vers. 4.0b10, Swofford 2003) for a combined analysis of 16S and COI. The parameters included 1000 reiterations of a heuristic search with 100 randomly added sequence replications, TBR branch-swapping, using Steepest Descent and enabling the MULTREES option. The topologies of the two datasets were congruent ( $P = 0.12$ ) and as such, the sequences were combined.

For the combined dataset, the best-fitting models for sequence evolution of individual datasets were determined by jModelTest (vers. 2.1.4, Guindon and Gascuel 2003; Darriba et al. 2012), selected by the Bayesian information criterion (BIC). The best models obtained for 16S



and COI datasets were HKY + G and HKY + I + G, respectively. The Bayesian inference (BI) analysis was performed with MrBayes (vers. 3.2, Ronquist et al. 2012). The search was run with 4 chains for 10 million generations and four independent runs, with trees sampled every 1000 generations. The convergence of chains was determined by the average standard deviation of split frequency values below the recommended 0.01 (Ronquist et al. 2005) and the first 1000 trees were discarded as the burnin accordingly. The maximum likelihood (ML) analysis was conducted in RAxML (vers. 8.0.x, Stamatakis 2006) for the combined dataset. The model GTR + G (*i.e.* GTRGAMMA) was used for all subsets with 100 runs, and we found the best ML tree by comparing likelihood scores. The robustness of the ML tree was evaluated by 1000 bootstrap pseudoreplicates under the model GTRGAMMA. The pairwise estimates of Kimura two-parameter (K2P) model distance for interspecific and intraspecific genetic diversities

were calculated using MEGA (vers. 6, Tamura et al. 2013).

## RESULTS

### TAXONOMY

#### Family Sclerosomatidae Simon, 1879

#### Subfamily Gagrellinae Thorell, 1889

#### Genus *Metadentobunus* Roewer, 1915

*Metadentobunus* Roewer, 1915: 149; Roewer 1923: 949; Suzuki 1944: 253; Roewer 1955: 85; Suzuki 1977: 137; Crawford 1992: 30; Li and Song 1993: 241.

*Type species: Metadentobunus formosae* Roewer, 1915, by monotypy.

*Diagnosis:* Abdominal scute with a median spine on second tergite. Pedipalpal tarsus longer than tibia; claw pectinate. Leg II femur with two

**Table 1.** Haplotypes of 16S rRNA and COI genes of *Metadentobunus garampiensis* Suzuki, 1944, *M. brevispinus* sp. nov. and outgroups from Taiwan. The numbers behind localities are the collecting localities in figure 7

Species	Locality	NCHUZOO Catalog no.	Sample size	Haplotype of 16S	DDBJ Access. no. of 16S	Haplotype of COI	DDBJ Access. no. of COI
<i>M. garampiensis</i>	Kenting National Park, Hengchun, Pingtung [9]	14581	1	Mfg-1	LC433979	Mfg-C1	LC433996
		14582	1	Mfg-2	LC433980	Mfg-C2	LC433997
		14583	1	Mfg-1	LC433979	Mfg-C3	LC433998
	Jihben Forest Road, Beinan, Taitung [10]	14593	1	Mfg-4	LC433981	Mfg-C4	LC433999
<i>M. brevispinus</i>	Tengjhih, Taoyuan, Kaohsiung [11]	14598	1	Mfg-5	LC433982	Mfg-C5	LC434000
	Sun Moon Lake, Yuchih, Nantou [7]	14585	1	Mdb-1	LC433983	Mdb -C1	LC434001
	Sitou, Lugu, Nantou [6]	14586	1	Mdb-2	LC433984	Mdb -C2	LC434002
		14587	1	Mdb-3	LC433985	Mdb -C3	LC434003
	Huisun Forest Area, Ren-ai, Nantou [8]	14588	1	Mdb-4	LC433986	Mdb -C4	LC434004
	Furong Waterfall, Guosing, Nantou [2]	14589	1	Mdb-5	LC433987	Mdb -C5	LC434005
	Aowanda National Forest Recreation Area, Ren-ai, Nantou [4]	14590	1	Mdb-6	LC433988	Mdb -C6	LC434006
	Dasyueshan Forest Recreation Area, Heping, Taichung [1]	14591	1	Mdb-7	LC433989	Mdb -C7	LC434007
	Tunyuan, Ren-ai, Nantou [3]	14594	1	Mdb-8	LC433990	Mdb -C8	LC434008
	Tongfu, Sinyi, Nantou [5]	14596	1	Mdb-9	LC433991	Mdb -C9	LC434009
outgroups							
<i>Gagrella</i> sp. 1	Dasyueshan Forest Recreation Area, Heping, Taichung	14493	1	Gag-1	LC433992	Gag-C1	LC434010
		14494	1	Gag-1	LC433992	Gag-C1	LC434010
<i>Psathyropus</i> sp. 1	Sitou, Lugu, Nantou	14495	1	Prf-1	LC433993	Prf-C1	LC434011
<i>Psathyropus formosa</i>	Lianhuachih, Yuchih, Nantou	14496	1	Prf-2	LC433994	Prf-C2	LC434012
		14497	1	Prf-3	LC433995	Prf-C3	LC434013

false articulations. Ocularium with 1 frontal spine on each side.

*Distribution*: Taiwan.

*Remarks*: *Metadentobunus* is an endemic genus to Taiwan. They are often found on the tree trunk, with camouflage coloration similar with the background.

### Key to the genus *Metadentobunus*

1. Pedipalp with inner apophysis on patella ..... 2  
 Pedipalp without inner apophysis on patella ..... *M. formosae*
2. Frontal margin of ocularium with long sharp-pointed spine ..... *M. garampiensis*  
 Frontal margin of ocularium with short spine ..... *M. brevispinus* sp. nov.

### *Metadentobunus formosae* Roewer, 1915

(Fig. 1)

*Metadentobunus formosae* Roewer, 1915: 149, fig. 81 (type locality: Lugang, Taiwan); Roewer 1923: 949, fig. 1084 (Lugang, Taiwan); Roewer 1955: 85 (Lugang, Taiwan); Suzuki 1970: 33 (list); Wang 1953: 509 (list); Li and Song 1993: 241 (list).

*Metadentobunus formosae formosae*-Suzuki 1977: 137 (Rokko, Taiwan).

*Type material*: Holotype: 1 ♀ (SMF 9801162-RI/1162-66), Rokko, Formosa (= Lugang, Changhua, Taiwan).

*Diagnosis*: Ocularium rectangle, length larger than width, constricted basally, with one pair of sharp and long spines at frontal margin (Fig. 1C-D). Frontal spines of ocularium with tubercles. Patella of pedipalp without inner apophysis at tip (Roewer 1915). Genital operculum protruding from frontal margin (Fig. 1H).

*Redescription*: Female holotype. Dorsal surface of body granulated. Abdomen with 1 short median spine on the second tergite. Supracheliceral lamellae tipped with 4-5 small tubercles (Fig. 1G). Ocularium rectangle (Fig. 1C-D), length larger than width, constricted basally, with one pair of frontal spines, sharp and long. Frontal spines of ocularium finely granulated. All free sternites and genital operculum smooth. Genital operculum protruding from frontal margin (Fig. 1H). Surface of all coxae with scattered coarse granules. Coxa I and IV with a row of humps anteriorly and posteriorly; Coxa II and III with a row of humps anteriorly.

Chelicera. Basal segment with 5-9 tubercles dorsally. Distal segment with setae dorsally, outer side smooth, inner side with setae (Fig. 1E-F).

Pedipalp. Femur with numerous denticles ventrally.

Legs. Trochanters mound-shaped (Fig. 1A-B), femora II with two false articulations, tarsus longer than tibia.

Ovipositor. Unexamined.

*Measurements*: Holotype female (SMF 9801162-RI/1162-66): Total length of body 6, femur length of leg I-IV 8:15.5:7:12. Length of leg I-IV 33:67:29:45.

*Coloration*: Not available.

*Distribution*: Lugang, Changhua, central Taiwan (Fig. 7).

*Remark*: *Metadentobunus formosae* is similar to *M. garampiensis*, except for the morphology of its pedipalpal patella. The inner tip of pedipalpal patella of *M. garampiensis* has an apophysis at the inner tip of pedipalpal patella, but *M. formosae* does not.

### *Metadentobunus garampiensis* Suzuki, 1944

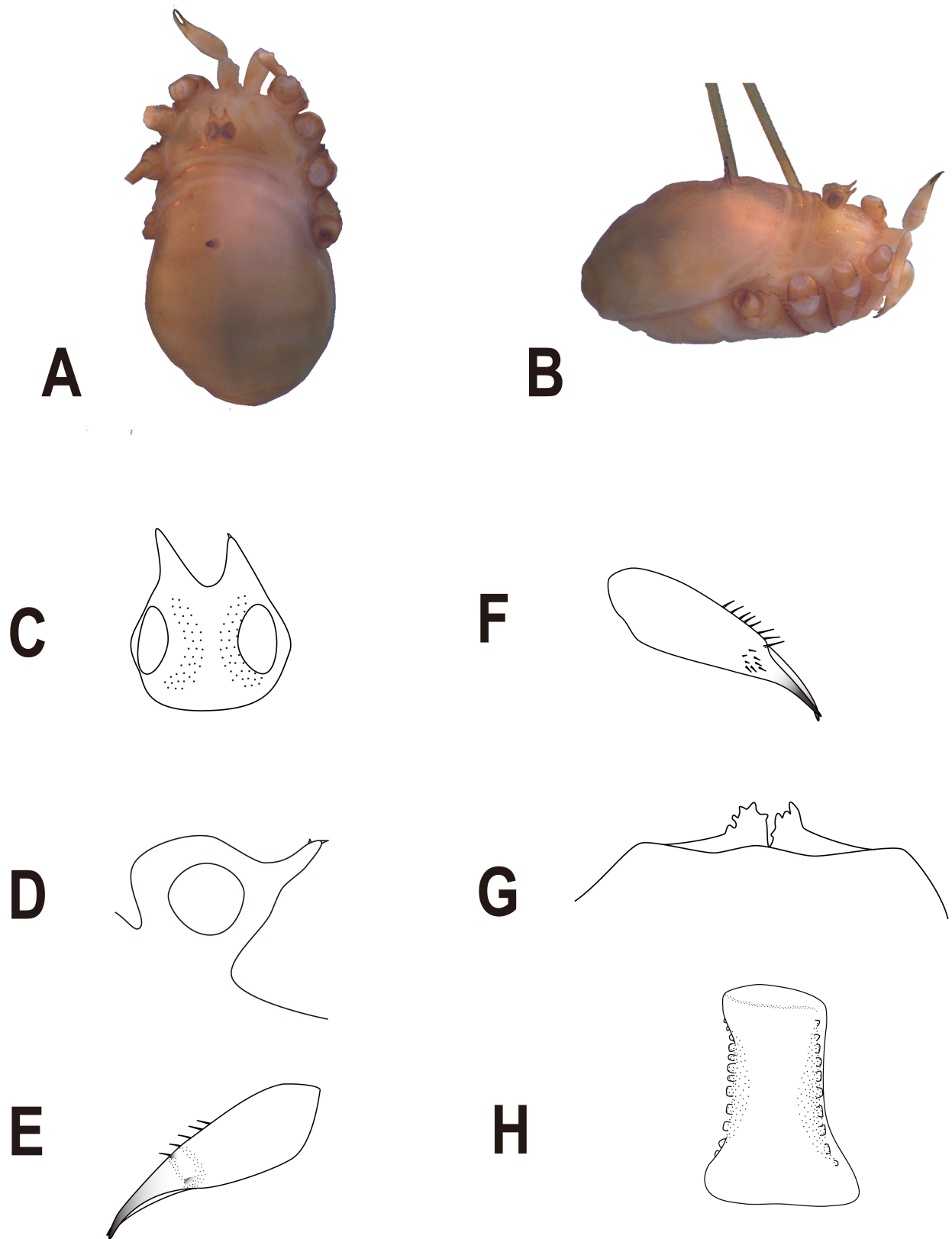
(Figs. 2-3)

*Metadentobunus garampiensis* Suzuki, 1944: 253-255, figs. 4-5 (type locality: Oluanpi, Kenting National Park, Taiwan); Suzuki 1970: 33 (list).

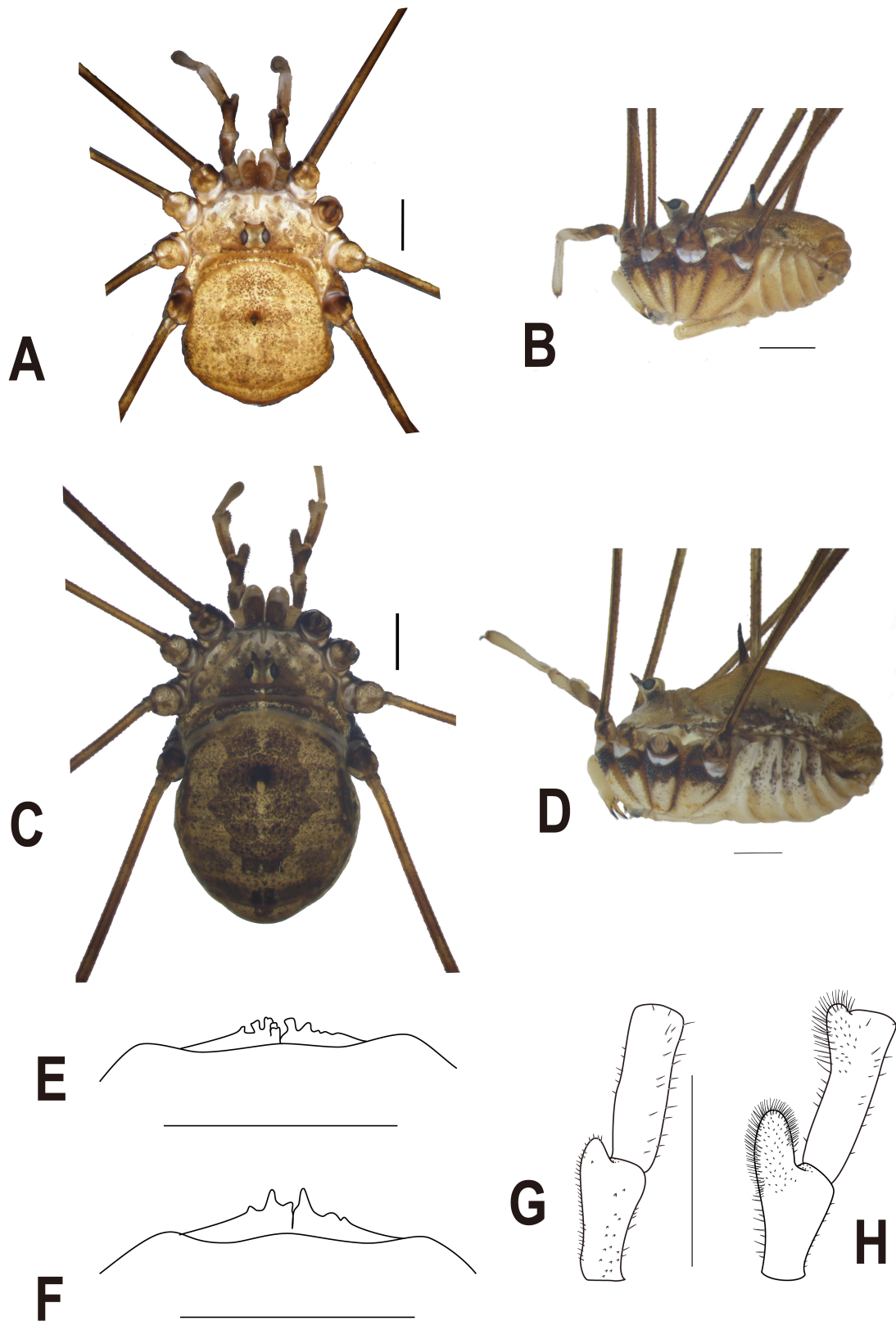
*Metadentobunus formosae garampiensis*-Suzuki, 1977: 137-139, fig. 7 (Kenting Botanical Garden, Kenting National Park, Taiwan); Li and Song 1993: 241 (list).

*Type material*: Neotype: 1 ♂ (NCHUZOL 14584), Sheding, Kenting National Park, Hengchun, Pingtung, Taiwan, 21°57'30.69"N, 120°48'42.41"E, elevation of 206 m, coll. S.-P. Wu, 16 July 2016.

*Other material examined from Taiwan*: 1 ♂ (NCHUZOL 14498) and 1 ♂ (NCHUZOL 14598), Tengjhih, Taoyuan, Kaohsiung, 23°03'54.74"N, 120°45'34.79"E, elevation of 1616 m, coll. S.-L. Chen, 9 May 2015; 1 ♂ (NCHUZOL 14499) and 1 ♀ (NCHUZOL 14597), Tengjhih, Taoyuan, Kaohsiung, 23°03'54.74"N, 120°45'34.79"E, elevation of 1616 m, coll. S.-L. Chen, 7 Sep. 2014; 2 ♀ (NCHUZOL 14500) and 1 ♀ (NCHUZOL 14583), Kenting National Park, Hengchun, Pingtung, 21°57'30.69"N, 120°48'42.41"E, elevation of 206 m, coll. S.-P. Wu, 26 July 2016; 1 ♀ (NCHUZOL 14501), Kenting National Park, Hengchun, Pingtung, 21°57'30.69"N, 120°48'42.41"E, elevation of 206 m, coll. S.-P. Wu, 24 July 2016; 1 ♀ 3 Juveniles (NCHUZOL 14502), Kenting National Park, Hengchun, Pingtung, 21°57'30.69"N, 120°48'42.41"E, elevation of 206 m, coll. S.-P. Wu, 23 Aug. 2016;



**Fig. 1.** *Metadentobunus formosae* Roewer, 1915 (holotype, SMF 9801162-RI/1162-66). A, B: dorsal and lateral views of female (body length: 6 mm); C, D: dorsal and lateral views of ocularium; E, F: outer and inner side of distal segment of left chelicera; G: dorsal view of supra-chelicera lamellae; H: ventral view of female genital operculum.



**Fig. 2.** *Metadentobunus garampiensis* Suzuki, 1944. Male (neotype, NCHUZOL 14584). A, B: dorsal and lateral view of neotype; E: supra-chelicera lamellae of male; G: dorsal view of male left pedipalp. Female (NCHUZOL 14583). C, D: dorsal and lateral view of body; F: supra-chelicera lamellae; H: dorsal view of left pedipalp. Scale bar = 1 mm.

1 ♂ (NCHUZOO 14581) and 1 ♀ (NCHUZOO 14582), Kenting National Park, Hengchun, Pingtung, 21°57'30.69"N, 120°48'42.41"E, elevation of 206 m, coll. H.-Y. Chang, 19 Aug. 2015; 1 ♀ (NCHUZOO 14593), Jhihben Forest Trail, Beinan, Taitung, coll. S.-P. Wu, 29 Apr. 2016.

**Etymology:** The name *garampiensis* was derived from the Japanese pronunciation of type locality (Oluanpi = Eluanbi = Ngoluanpi, in Kenting National Park).

**Diagnosis:** Male: ocularium with one pair of sharp and long spines at frontal margin (Fig. 3D-E). Patella of pedipalp with an inner apophysis at tip (Fig. 2G). Patella of pedipalp with numerous sharp-tipped tubercles dorsally. Shaft long, parallel at base (Fig. 3G). Female: seminal receptacle at 6th-7th segment of ovipositor, with three ampullas terminally (Fig. 3L). Genital operculum of female protruding from frontal margin (Fig. 3M).

**Description:** Male neotype. Dorsal surface of body granulated. Supra-cheliceral lamellae tipped with 4-5 small tubercles (Fig. 2E). Abdomen with 1 short median spine on the second tergite. Ocularium rectangle, length larger than width, constricted basally, with one pair of sharp and long spines at frontal margin (Fig. 3D-E). Frontal spines of ocularium smooth except sparse short hairs. All free sternites and genital operculum smooth. Surface of all coxae with scattered coarse granules. Coxa I and Coxa IV with a row of humps anteriorly and posteriorly; Coxa II and Coxa III with a row of humps anteriorly.

Chelicera (Fig. 3J-K). Basal segment with a ventral spur below, 14-15 tubercles dorsally and a row of tubercles at inner side. Distal segment with setae above, outer side smooth, inner side with setae.

Pedipalp (Fig. 3A-B). All segments with lots of setae, excepting trochanter. Trochanter with 4 tubercles ventrally and 1 spine-like tubercles dorsally. Femur with numerous tubercles ventrally,

inner side with a row of tubercles. Patella thickened distally, with an inner apophysis at tip, numerous sharp-tipped tubercles dorsally (Fig. 2G). Tibia covered with many simple setae especially in inner tip. Tarsus elongated, with a row of tubercles at inner side (Fig. 3A). Claw pectinate.

Legs. All legs slim and elongate. Trochanters mound-shaped (Fig. 2A-B), femora II with two false articulations, tarsus longer than tibia.

Penis (Fig. 3G-H). Shaft 2.6 long, 0.28 wide at base, 0.28 wide at middle; glans 0.23 long, 0.1 wide at base. Shaft long, parallel at base; alate part with sacs (Fig. 3G). Glans widest at base. Stylus acicular.

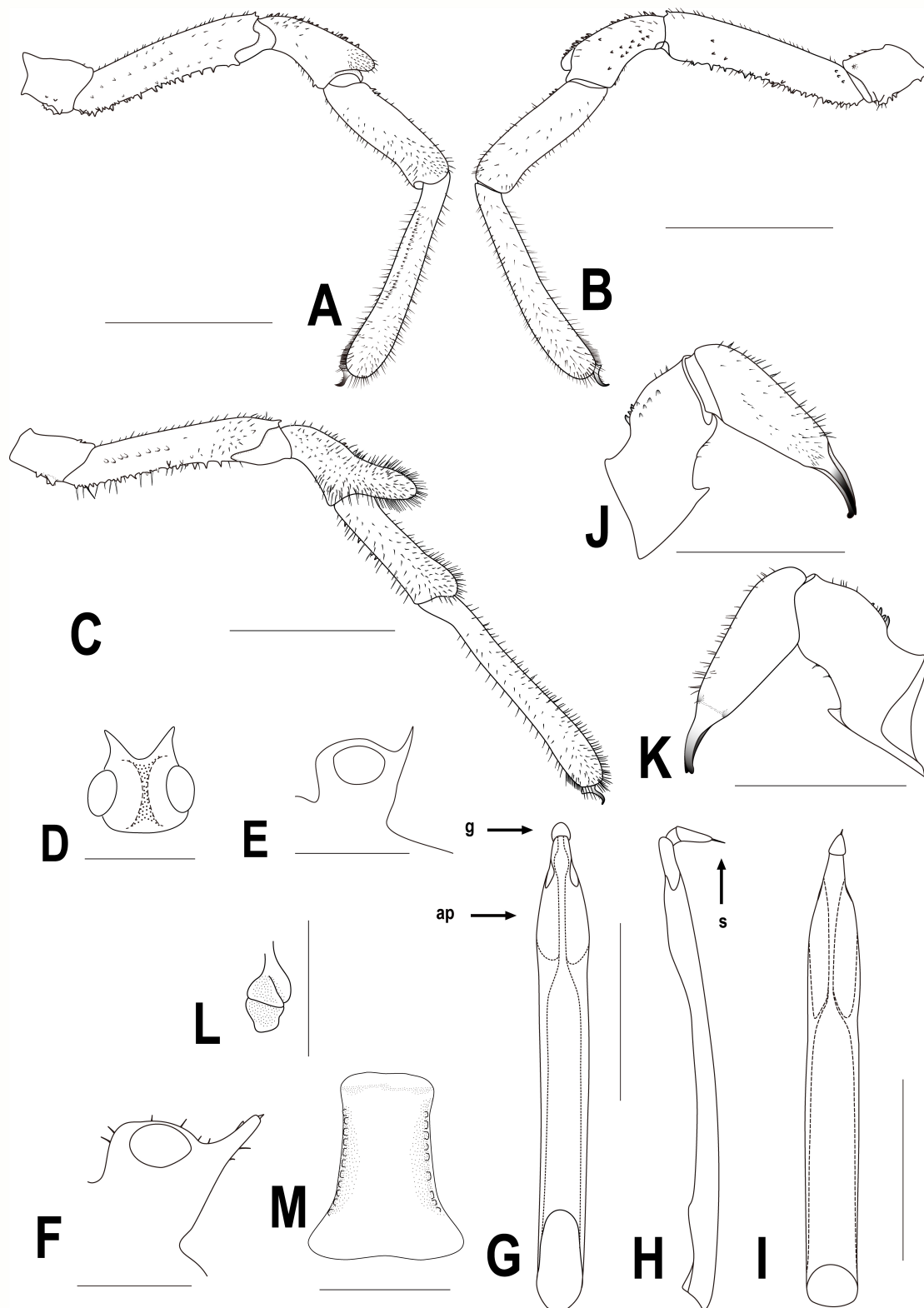
**Female** (NCHUZOO 14583): Dorsal surface of body similar to male, excepting abdomen of female longer than male (Fig. 2C-D). Frontal spines of ocularium with tubercles and sparse short hairs. Supra-cheliceral lamellae tipped with 3-4 small tubercles (Fig. 2F). Trochanter of pedipalps with 4 tubercles ventrally. Pedipalpal femur with a longitudinal row of tubercles at inner side, tibia normal with covering of many hairs entirely (Fig. 3C). Inner-tip apophysis of pedipalpal patella longer than male. Pedipalpal tibia of female with a small apophysis at inner tip (Fig. 2H). Genital operculum protruding from frontal margin (Fig. 3M). Seminal receptacle (NCHUZOO 14501, Fig. 3L; NCHUZOO 14593) located in 6th-7th segment of ovipositor, terminal with three ampullas.

**Measurements:** Neotype male (female of NCHUZOO 14583): Cephalothorax 1.12 (1.58) long, 2.72 (3.45) wide; abdomen 2.73 (3.87) long, 2.84 (3.68) wide. Total length of body 3.85 (5.45). Measurements of left pedipalp and legs are shown in table 2.

**Coloration:** Male. Dorsum golden yellow with granules (Fig. 2A-B). Carapace golden yellow with small light brown flecks along frontal and lateral edge. Ocularium golden yellow, with white eye rings. Coxa of all legs golden yellow, edge brown.

**Table 2.** Pedipalp (left) and legs (left) measurements (in mm) of the neotype male (NCHUZOO 14584) of *Metadentobunus garampiensis* Suzuki, 1944. Measurements of female (NCHUZOO 14583) are shown in parentheses

	Trochanter	Femur	Patella	Tibia	Tarsus	Total
Pedipalp	0.33 (0.47)	1.41 (1.17)	0.52 (0.61)	0.77 (0.92)	1.35 (1.44)	4.38 (4.61)
Leg I	0.47 (0.44)	8.32 (6.55)	1.12 (1.15)	7.46 (5.92)	19.28 (16.34)	36.65 (30.4)
Leg II	0.49 (0.49)	17.97 (14.02)	1.66 (1.51)	18.71 (14.66)	49.44 (41.33)	88.27 (72.01)
Leg III	0.51 (0.51)	7.53 (6.24)	1.29 (1.05)	6.79 (5.53)	20.14 (17.24)	36.26 (30.57)
Leg IV	0.54 (0.57)	12.26 (10.73)	1.75 (1.31)	10.58 (8.47)	31.55 (25.79)	56.68 (46.87)



**Fig. 3.** *Metadentobunus garampiensis* Suzuki, 1944. Male (neotype, NCHUZOL 14584). A, B: inner and outer side of left pedipalp; D, E: dorsal and lateral views of ocularium; G, H: ventral and lateral views of penis; I: different morphology of penis from Tengjih, ventral view (NCHUZOL 14598); J: inner side of left chelicera; K: outer side of left chelicera. Female (NCHUZOL 14583). C: inner side of female left pedipalp; F: lateral view of ocularium; L: female seminal receptacle (NCHUZOL 14501); M: ventral view of female genital operculum (NCHUZOL 14583). s: stylus; g: glans; ap: alate part. Scale bars: A-C, G-K, M = 1 mm; D, E, F = 0.5 mm; L = 0.1 mm.

Genital operculum golden yellow, light yellow base, distal edge light yellow, edge brown. Sternites pale yellow, whiten posterior. Chelicerae pale yellow, basal segment with brown spots dorsally. Pedipalps pale yellow, with femora and patellae brown. All legs brown with golden yellow rings. Female similar with male, but darker (Fig. 2C-D).

**Variation:** One male specimen (NCHUZOO 14581) has frontal spines with finely granulated tip on ocularium. In addition, the specimen (NCHUZOO 14598) from Tengjhih have slightly different morphology of penis, *i.e.* alate part with longer sacs (Fig. 3I).

**Distribution:** Southern Taiwan (Fig. 7).

**Habitat:** The specimens were found on tree trunks, which appeared to be one of their habitats.

**Remarks:** After examining of a series of specimens, we found the character of frontal spines on ocularium with finely granulated tip is variable, which is different from Suzuki's description (1977).

***Metadentobunus brevispinus* sp. nov.**

(Figs. 4-5)

urn:lsid:zoobank.org:act:0CBDAE16-E48C-4753-A40A-0E09999E4DEF

**Type material:** Holotype: 1 ♂ (NCHUZOO 14599), Sitou, Lugu, Nantou, Taiwan, 23°40'27.92"N, 120°47'45.19"E, elevation of 1107 m, coll. S.-L. Chen, 1 Dec. 2013. Paratypes: 1 ♀ (NCHUZOO 14600), 1 ♂ (NCHUZOO 14586), 1 ♀ (NCHUZOO 14587), 1 ♂ (NMNS 7926-001) and 1 ♀ (NMNS 7926-002), same data as holotype; 1 ♂ (NCHUZOO 14585), Sun Moon Lake (= Rihyuetan), Yuchih, Nantou, Taiwan, 23°51'26"N, 120°56'42"E, elevation of 764 m, coll. H.-Y. Chang, 19 Jan. 2014; 1 ♂ (NCHUZOO 14595) and 1 ♂ (NCHUZOO 14596), Tongfu, Sinyi, Nantou, Taiwan, 23°31'23"N, 120°53'60"E, elevation of 2250 m, coll. S.-L. Chen, 15 July 2015.

**Other material examined from Taiwan:** 1 ♀ (NCHUZOO 14503), Sitou, Lugu, Nantou, 23°40'29.15"N, 120°47'48.55"E, elevation of 1107 m, coll. S.-L. Chen, 1 Dec. 2013; 4 ♂ 3 ♀ (NCHUZOO 14504), Tongfu, Sinyi, Nantou, 23°31'23"N, 120°53'60"E, elevation of 2250 m, coll. S.-L. Chen, 15 July 2015; 1 ♀ (NCHUZOO 14588), Huisun Forest Area, Ren-ai, Nantou, 24°05'26.55"N, 121°01'58.48"E, elevation of 688 m, coll. S.-L. Chen, 14 Nov. 2014; 1 ♀ (NCHUZOO 14589), Furong Waterfall, Guosing, Nantou, 24°05'31.14"N, 120°56'13.95"E, elevation of 636 m, coll. S.-L. Chen, 14 Sep. 2014; 1 ♂ (NCHUZOO

14590), Aowanda National Forest Recreation Area, Ren-ai, Nantou, 23°56'43.20"N, 121°10'58.01"E, elevation of 1243 m, coll. S.-L. Chen, 1 Oct. 2013; 1 ♂ (NCHUZOO 14505), Dasyueshan Forest Recreation Area, Heping, Taichung, 24°15'22.32"N, 121°00'24.82"E, elevation of 2240 m, coll. S.-L. Chen, 26 Nov. 2013; 1 ♀ (NCHUZOO 14591), Dasyueshan Forest Recreation Area, Heping, Taichung, 24°15'22.32"N, 121°00'24.82"E, elevation of 2240 m, coll. S.-L. Chen, 23 Aug. 2014; 1 ♂ (NCHUZOO 14592), Cingjing, Ren-ai, Nantou, 24°03'26.19"N, 121°09'47.48"E, elevation of 1891 m, coll. S.-L. Chen, 3 Aug. 2014; 1 ♀ (NCHUZOO 14594), Tunyuan, Ren-ai, Nantou, 24°03'1.16"N, 121°12'54.48"E, elevation of 1590 m, coll. S.-L. Chen, 16 June 2015.

**Etymology:** The name *brevispinus* is derived from the Latin *brevi* and *spinus*, which refers to the one pair frontal spines on ocularium of this species are shorter (Fig. 5D-E) than the other species of the genus *Metadentobunus* (Figs. 1C-D; 3D-E).

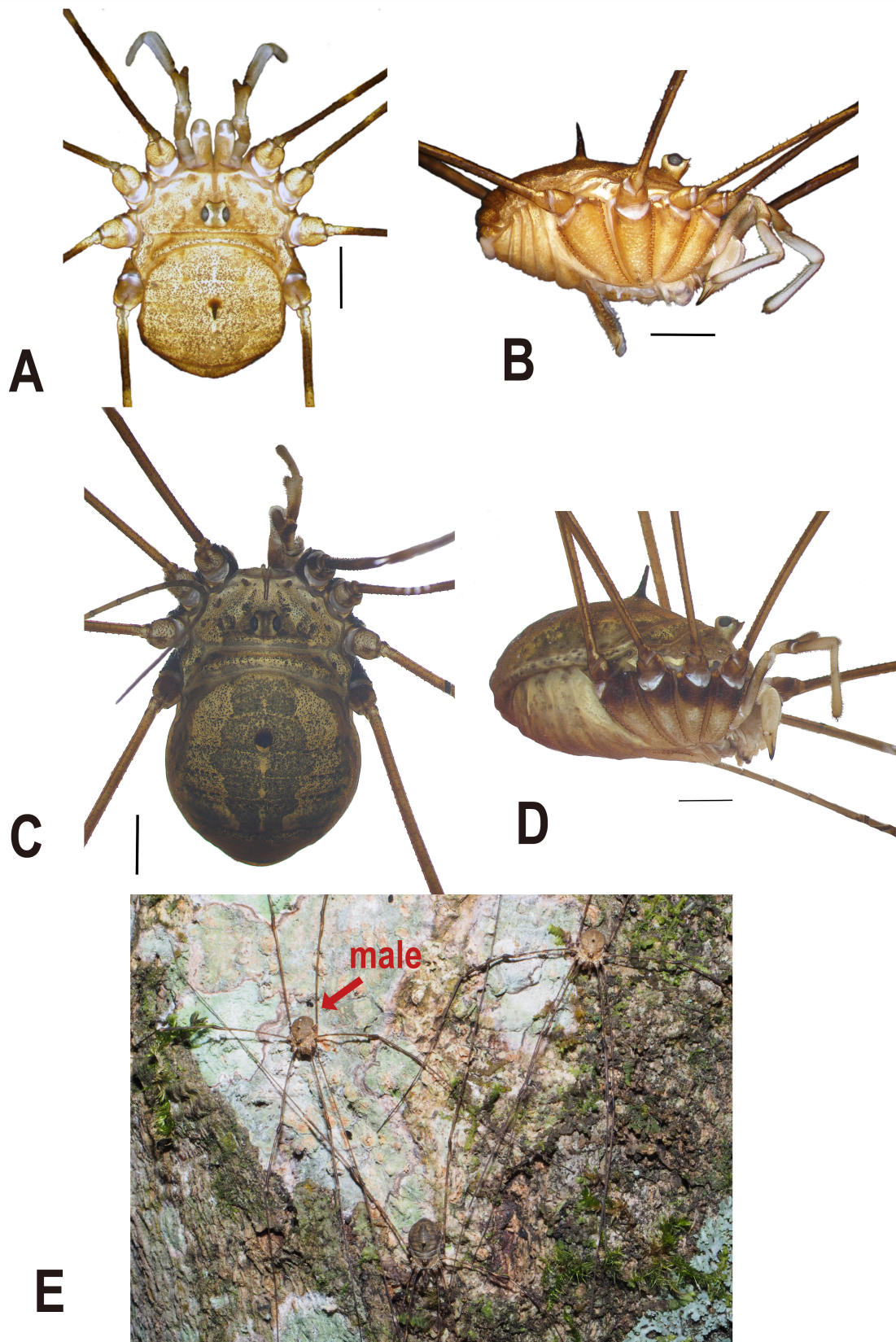
**Diagnosis:** Male: ocularium with one pair of short frontal spines (Fig. 5D-E). Patella of pedipalp with inner apophysis at tip (Fig. 5N-O). Shaft long, constricted at base (Fig. 5F). Female: seminal receptacle at 5th-6th segment of ovipositor, with two ampullas terminally (Fig. 5I). Genital operculum flat at frontal margin (Fig. 5P).

**Description:** Male holotype. Dorsal surface of body granulated. Supra-cheliceral lamellae tipped with 5 small tubercles (Fig. 5L). Abdomen with 1 short median spine on the second tergite. Ocularium rectangle (Fig. 5D), length slightly larger than width, constricted basally, with short spine at frontal margin (Fig. 5E). Frontal spines of ocularium smooth except sparse hairs. All free sternites and genital operculum smooth. Surface of all coxae with scattered coarse granules. Coxa I and IV with a row of humps anteriorly and posteriorly; Coxa II and III with a row of humps anteriorly.

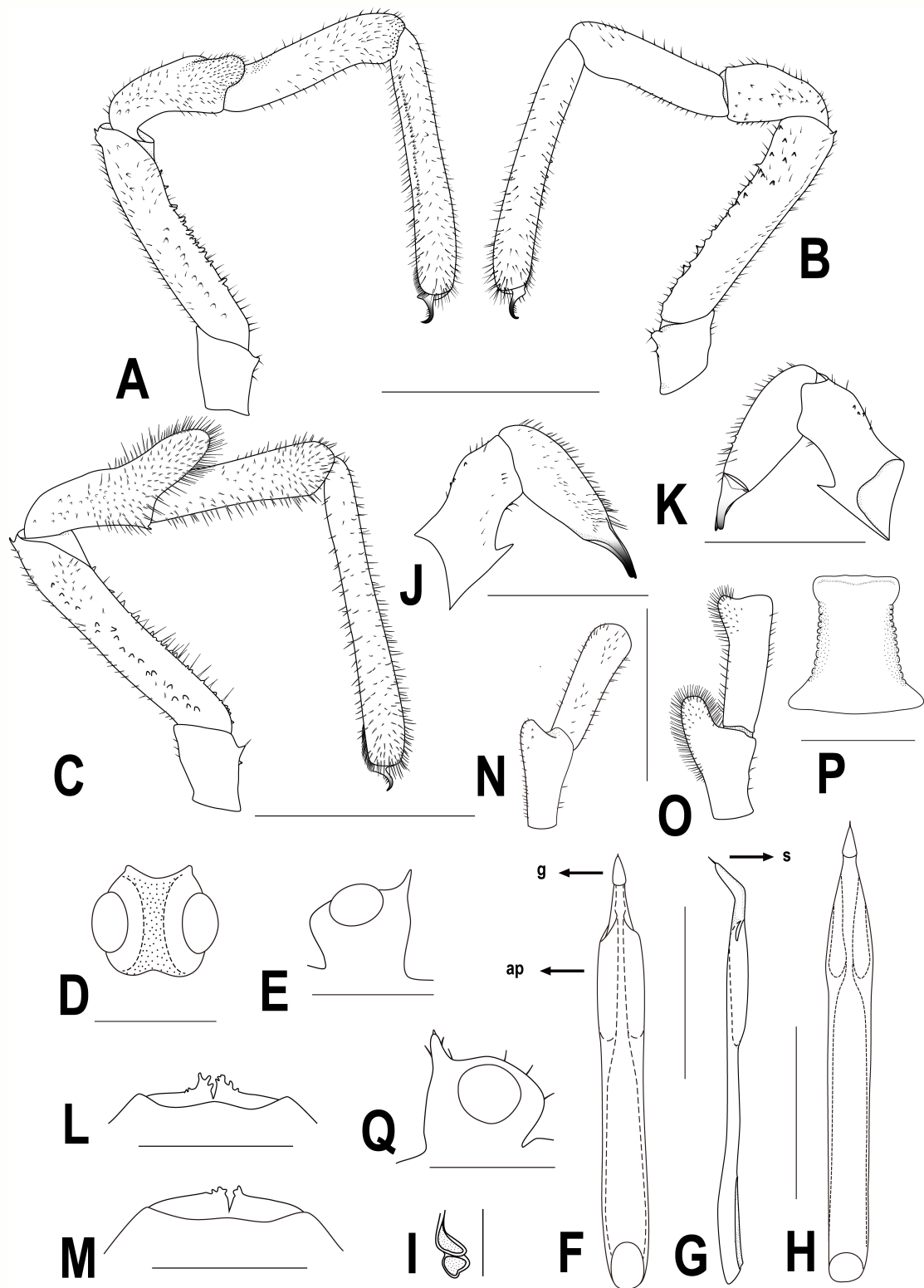
Chelicera (Fig. 5J-K). Basal segment with 7 tubercles and setae above, with a slender spur ventrally. Distal segment with setae above, outer side smooth, inner side with setae.

Pedipalp (Fig. 5A-B). All segments with lots of setae, excepting trochanter. Trochanter with 1 conspicuous tubercle. Femur with conspicuous tubercles ventrally, with 11 tubercles on outer side (Fig. 5B) and a row of tubercles on inner side (Fig. 5A). Patella thickened distally, with an inner apophysis at tip. Tibia covered with many simple setae especially in inner tip. Tarsus elongated, with a row of tubercles at inner side (Fig. 5A). Claw





**Fig. 4.** *Metadentobunus brevispinus* sp. nov. A, B: dorsal and lateral views of male (holotype, NCHUZ00L 14599); C, D: dorsal and lateral views of female (paratype, NCHUZ00L 14600); E: color in live, male and female. Scale bar = 1 mm.



**Fig. 5.** *Metadentobunus brevispinus* sp. nov. Male (holotype, NCHUZOL 14599). A, B: inner and outer side of left pedipalp; D, E: dorsal and lateral views of ocularium; F, G: ventral and lateral views of penis; J: inner side of left chelicera; K: outer side of left chelicera; L: supra-chelicera lamellae of male; H: different morphology of penis from Dasyueshan Forest Recreation Area, ventral view (NCHUZOL 14505). Female (paratype, NCHUZOL 14600). C: inner side of female left pedipalp; I: female seminal receptacle; M: supra-chelicera lamellae of female; N: dorsal view of left pedipalp; O: dorsal view of left pedipalp; P: ventral view of female genital operculum. s: stylus; g: glans; ap: alate part. Scale bars: A-C, J-K, F-H, L-P = 1 mm; D, E = 0.5 mm; I = 0.1 mm.

pectinate.

Legs. All legs slim and elongate. Trochanters mound-shaped (Fig. 4A-B), femora II with two false articulations, tarsus longer than tibia.

Penis (Fig. 5F-G). Shaft 2.28 long, 0.21 wide at base, 0.29 wide at middle; glans 0.2 long, 0.1 wide at base. Shaft long, constricted at base; alate part with sacs (Fig. 5F). Glans widest at base. Stylus acicular.

**Female paratypes** (NCHUZOOL 14600, NMNS 7926-002): Dorsal surface of body similar to male, excepting abdomen of female longer than male (Fig. 4C-D). Frontal spines of ocularium smooth except sparse hairs. Supra-cheliceral lamellae tipped with 2-4 small tubercles (Fig. 5M). Trochanter of pedipalps with 1 conspicuous tubercle ventrally. Pedipalpal femur with a row of black-tipped tubercles at inner side, tibia covered with simple setae entirely (Fig. 5C). Inner-tip apophysis of pedipalpal patella longer than male. Pedipalpal tibia of female with small apophysis at inner tip (Fig. 5O). Genital operculum flat at frontal margin (Fig. 5P). Seminal receptacle (Fig. 5I) located in 5th-6th segment of ovipositor, terminal with two ampullas.

**Measurements:** Holotype male (female paratype, NCHUZOOL 14600): Cephalothorax 1.15 (1.68) long, 2.62 (3.0) wide; abdomen 2.16 (3.78) long, 2.41 (3.39) wide. Total length of body 3.31 (5.46). Measurements of left pedipalp and legs are shown in table 3. Female: similar with male, but darker than male.

**Coloration:** Male. Dorsum golden yellow with granules, spine on second tergite black (Fig. 4A-B). Carapace golden yellow with small light brown flecks along frontal and lateral edge. Ocularium golden yellow, with white eye rings. Coxa of all legs golden yellow. Genital operculum golden yellow, light yellow base, distal edge light yellow. Sternites pale yellow, whiten posterior. Chelicerae pale yellow, basal segment with brown spots.

Pedipalps pale yellow, with femora and patellae brown. All legs brown with golden yellow rings. Female similar with male, but darker (Fig. 4C-D).

**Variation:** One female specimen (NCHUZOOL 14588) has frontal spines with finely granulated tip on ocularium. In addition, the female specimen (NCHUZOOL 14591) from the Dasyueshan Forest Recreation Area has slender and long penile shaft and the different morphology of penile alate part (Fig. 5H).

**Distribution:** Central Taiwan (Fig. 7).

**Habitat:** This species can be found on the tree trunks, sometimes on the artificial wooden guideboard.

**Remarks:** This new species can be separated from other congeneric species by having one pair of shorter (than other congeners) spines at frontal margin of the ocularium (Fig. 5D-E, Q). It can be also distinguished from *M. garampiensis* by the number of tubercles on the dorsal basal segment of the chelicera (7 vs. 14-15) (Fig. 5J-K vs. Fig. 3J-K), the basal shape of the penile shaft (constricted vs. parallel) (Fig. 5F vs. Fig. 3G), location of the seminal receptacle in ovipositor (5th-6th segment vs. 6th-7th segment) and number of ampullas in the terminal of seminal receptacle (2 vs. 3) (Fig. 5I vs. Fig. 3L).

## DNA analyses

A 451 base-pair (bp) segment of 16S and 624 bp segment of COI from 19 specimens of the genus *Metadentobunus* and outgroups were amplified and aligned (Table 1). No specimen of *M. formosae* was collected and therefore the species was not be included in the molecular analysis. The phylogenetic tree of the combined genes was constructed by BI (Fig. 6), and the bootstrap support values from ML analysis was also shown on the tree. It is clear that the genus *Metadentobunus* is monophyletic with high support

**Table 3.** Pedipalp (left) and legs (left) measurements (in mm) of the holotype male (NCHUZOOL 14599) of *Metadentobunus brevispinus* sp. nov. Measurements of female (NCHUZOOL 14600) are shown in parentheses

	Trochanter	Femur	Patella	Tibia	Tarsus	Total
Pedipalp	0.32 (0.37)	1.08 (1.18)	0.53 (0.56)	0.85 (0.8)	1.17 (1.41)	3.95 (4.32)
Leg I	0.4 (0.44)	7.7 (6.13)	0.93 (1.02)	6.34 (5.31)	17.52 (15.75)	32.89 (28.65)
Leg II	0.42 (0.44)	14.22 (13.09)	1.01 (1.05)	13.85 (13.26)	42.42 (39.74)	71.92 (67.58)
Leg III	0.41 (0.46)	5.81 (5.62)	0.92 (1.03)	5.31 (4.46)	17.29 (15.14)	29.74 (26.71)
Leg IV	0.42 (0.5)	9.5 (9.11)	1.28 (1.08)	8.28 (6.87)	27.45 (25.35)	46.93 (42.91)

by both BI and ML methods. There are two clades within *Metadentobunus* with high BI support, and they are referred to as *M. garampiensis* and *M. brevispinus* sp. nov., respectively.

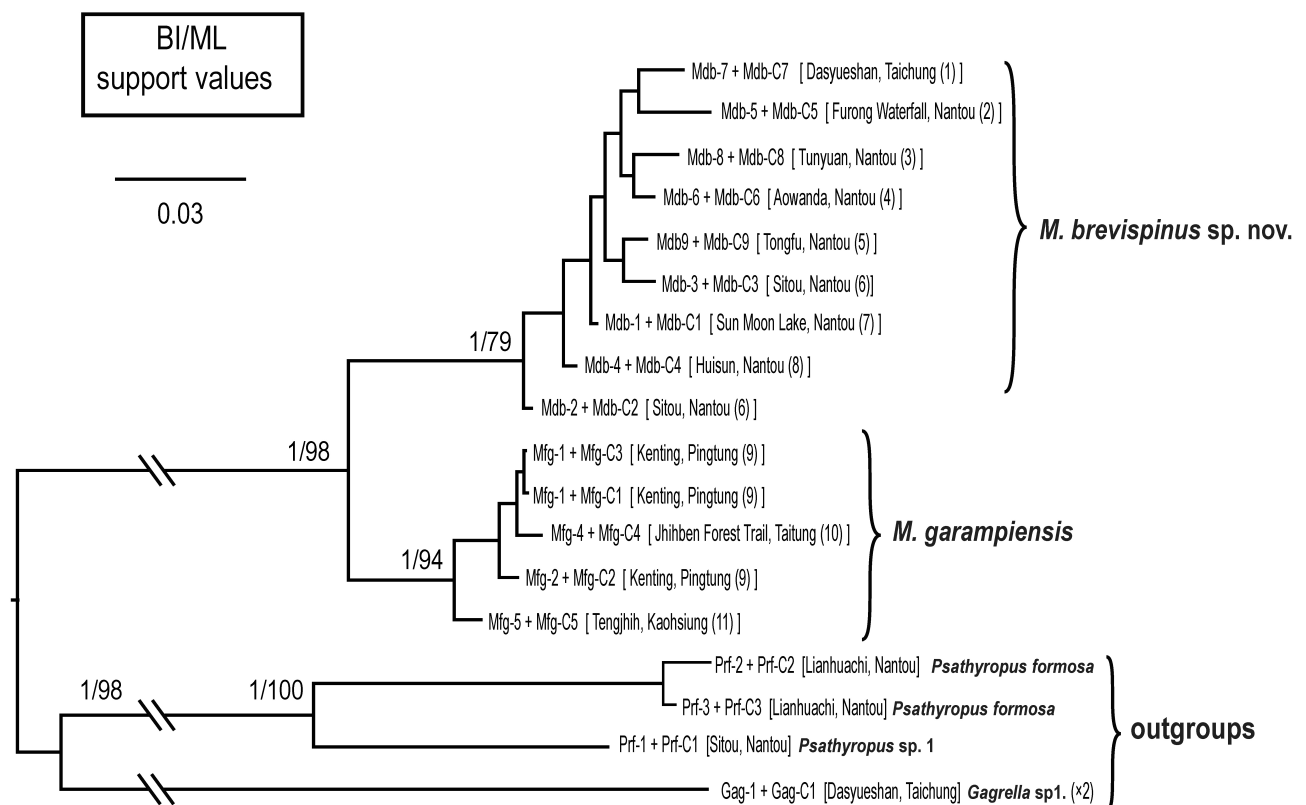
With regard to genetic divergence, the maximum intraspecific and the minimum interspecific COI distances of *Metadentobunus* are 2.63–5.03% and 6.79%, respectively (Table 4).

## DISCUSSION

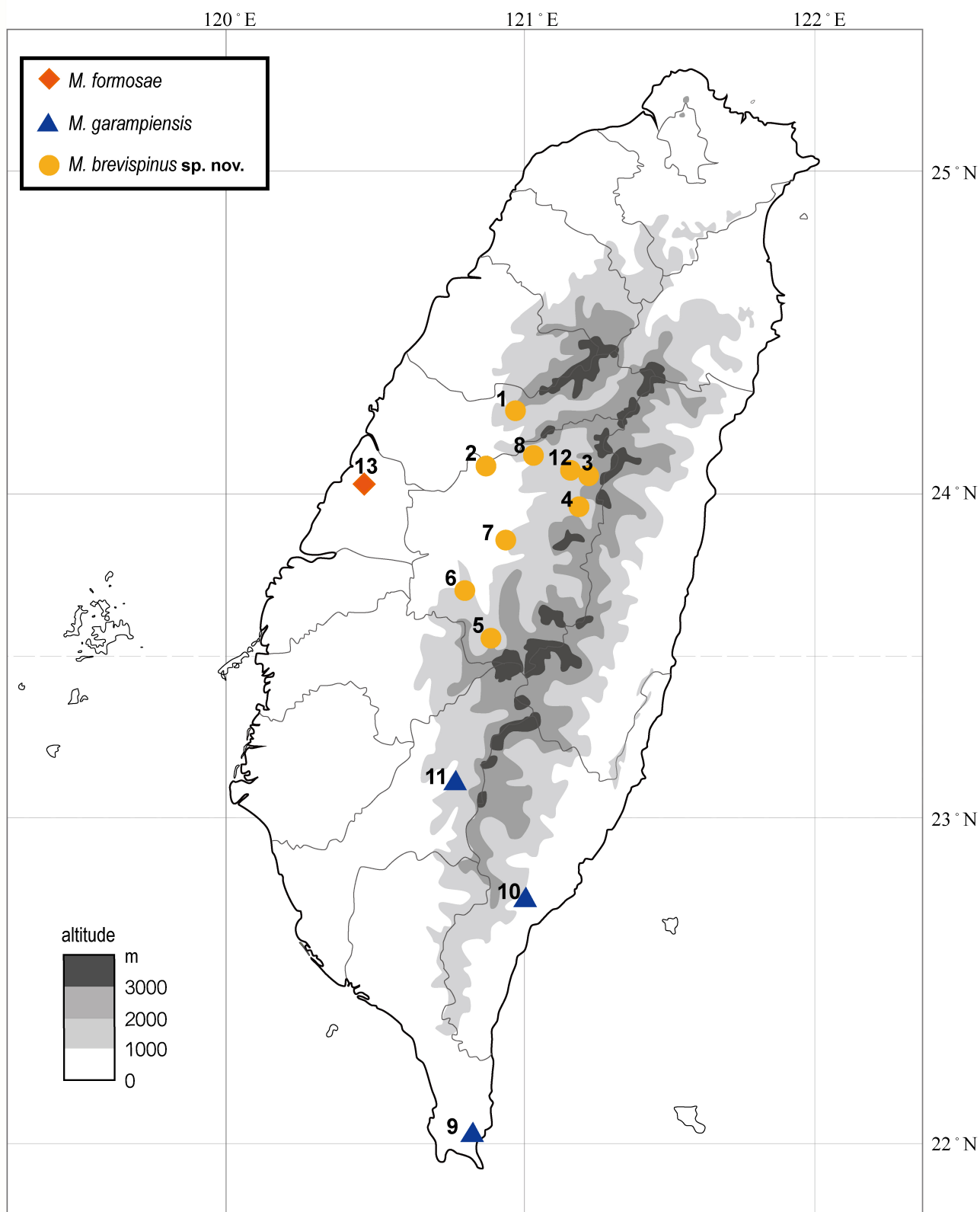
*Metadentobunus* was established by Roewer in 1915; however, Suzuki (1977) and our study found some incorrect descriptions in Roewer (1915), e.g. the morphology of chelicerae and the sex of type specimen. With regard to the type locality of *M. formosae*, we surveyed Lugang several times, but did not find any specimen of this species. One possibility is that its habitat in Lugang

**Table 4.** Matrix of percentage pairwise nucleotide divergences with K2P distance based on 16S rRNA and cytochrome *c* oxidase I (COI) genes of *M. garampiensis* Suzuki, 1944 and *M. brevispinus* sp. nov. In the right half, the lower left values are 16S and the upper right ones are COI. Values of range are shown in parentheses

Species	Intraspecific		Interspecific	
	16S	COI	<i>M. garampiensis</i>	<i>M. brevispinus</i>
<i>M. garampiensis</i>	0.64 (0–1.15)	1.49 (0.16–2.63)	-	11.08 (6.79–13.85)
<i>M. brevispinus</i>	1.23 (0–2.54)	2.44 (0.87–5.03)	4.72 (4–5.42)	-



**Fig. 6.** A Bayesian inference (BI) tree for the species of *Metadentobunus* from Taiwan and outgroups, based on the combined dataset of 16S and COI genes. Probability values at the nodes represent the support values for BI and maximum likelihood (ML). Numbers behind the collection sites correspond to the sites in figure 7.



**Fig. 7.** The collection sites for the species of *Metadentobunus* in Taiwan. Numbers beside the symbols correspond to the collection sites in table 1 and figure 6. In addition, the numbers 12 and 13 mean the sites for Cingjing, Nantou and Lugang (= Rokko), Changhua, respectively.

has been destroyed because this area is now a developed town. Another possibility is that the specimen might be collected from other unknown places in Taiwan or other regions, and was actually exported to Lugang, because Lugang was an international harbor in the 1910s.

Based on the series of specimens of *M. brevispinus* sp. nov., some variation can be observed in the penile alate part among specimens from different areas, although these morphological differences belong to intraspecific variation without further subdivision (Fig. 6). For example, specimens from the Dasyueshan Forest Recreation Area ("Mdb-7 + Mdb-C7" in Fig. 6) and Sitou ("Mdb-2 + Mdb-C2" in Fig. 6) belong to the same clade, but the penile alate part between specimens from the two areas is different (Fig. 5H vs. Fig. 5F). Similarly, specimens of *M. garampiensis* from Tengjhih ("Mfg-5 + Mfg-C5" in Fig. 6) and those from Kenting ("Mfg-1 + Mfg-C1" in Fig. 6) have different penile alate morphology (Fig. 3I vs. Fig. 3G). Apparently, there are intraspecific variations in the male penile alate part in both *M. brevispinus* and *M. garampiensis*. Despite this, *M. brevispinus* can also be distinguished from *M. garampiensis* by the basal shape of the penile shaft (constricted vs. parallel) (Fig. 5F, H vs. Fig. 3G, I), location of the seminal receptacle in ovipositor (5th-6th segment vs. 6th-7th segment) and number of ampullas in the terminal of the seminal receptacle (2 vs. 3) (Fig. 5I vs. Fig. 3L).

In terms of COI distance in *Metadentobunus* species, the minimum interspecific distances is 6.79% (Table 4), which is smaller than that on harvestmen from Germany (7.5%; Astrin et al. 2016) and the *Pseudogagrella* from Taiwan (9.08%; Chen and Shih 2017). Despite this, the maximum intraspecific distances are 2.63% and 5.03% for *M. garampiensis* and *M. brevispinus*, respectively, both of that are smaller than 6.79%. Due to the gap between intraspecific and interspecific COI distances exist, this makes the species delimitation of *M. brevispinus* clear. In addition, the phylogenetic tree (Fig. 6) has confirmed that both *M. garampiensis* and *M. brevispinus* are two clades, with high support. Therefore the mitochondrial 16S and COI (Table 4; Fig. 6) shows that *M. brevispinus* and *M. garampiensis* are distinct enough in genetic evidence. Some authors considered the mitochondrial markers to be limited in delimiting recently diverged species, and additional nuclear markers are suggested (Hickerson et al. 2006; Satler et al. 2013; Smith et al. 2018). Further studies using nuclear markers

to test if there is reproductive isolation between the two species and extensive surveys for their distributional ranges can clarify the species delimitation in depth.

In conclusion, according to the ocularium, pedipalp and penis characters, we describe a new species from central Taiwan, *M. brevispinus*, with molecular evidence from the mitochondrial 16S and COI. This increases the number of species in the genus *Metadentobunus* from Taiwan to three.

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**Authors' contributions:** SLC performed the morphological description and the molecular analysis, and drafted the manuscript. HTS performed the discussion and drafted the manuscript. Both authors read and approved the final manuscript.

**Competing interests:** SLC and HTS declare that they have no conflict of interest.

**Availability of data and materials:** Sequences generated in the study have been deposited in the DNA Data Bank of Japan (DDBJ) database (accession numbers in Table 1 in manuscript).

**Consent for publication:** Not applicable.

**Ethics approval consent to participate:** Not applicable.

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