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Establishment of a new mite family, Bulacaridae (Acari: Astigmata)

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Original research

ABSTRACT

Morphological and molecular data led to the proposal of a new family named Bulacaridae for *Bulacarus curvisetus* **gen. nov.** and **sp. nov.**, found on taro corms (*Colocasia esculenta*, Araceae) imported from Fiji at New Zealand border. The morphological evidence of *Bulacarus curvisetus* **gen. nov.** and **sp. nov.** were collected and described. The phylogenetic relationship of the new species was investigated by utilizing data derived from the near full-length small subunit (SSU) of rRNA genes. Furthermore, this paper discussed the characteristics and taxonomic placement of this family in the superfamily Acaroidea.

Keywords Sarcoptiformes; Acaroidea; taxonomy; Fiji; interception; taro; *Colocasia esculenta*; new genus; new species


Zoobank <http://zoobank.org/F4AB2357-9456-494C-BC38-FD7A2BE4EC37>

Introduction

An unusual astigmatid mite was detected on the corms of *Colocasia esculenta* (taro, Araceae) from Fiji that were intercepted at the New Zealand border. This mite species has only been observed on two occasions. The mite species possesses a range of unique characteristics and cannot be classified into any of the existing families of the hyporder Astigmata (Acari). Although it displays features consistent with the superfamily Acaroidea as defined by OConnor (2009), it differs from all known members of this superfamily.

The superfamily Acaroidea is a relatively large group within Astigmata (Schatz *et al.* 2011), encompassing approximately 576 species distributed among 104 genera (representing 9.4% of all Astigmata species and 9.2% of genera) across six families (OConnor 2009; Schatz *et al.* 2011). Among these families, Acaridae Latreille is the most diverse, containing 94% of all Acaroidea species, with many of its members associated with the nests of vertebrates and invertebrates, as well as stored products. Other families are relatively small, such as Scatoglyphidae Zachvatkin and Volgin and Glycacaridae Griffiths, which are monogeneric and associated with bird nests and stored products (Berlese 1913; Wang 1964; Griffiths 1977). Lardoglyphidae Oudemans has eight species in two genera that are typically found on stored products, bird nests, and vertebrate carrion. Gaudiellidae Atyeo, Baker and Delfinado has seven species in five genera that are associated with hymenopteran nests (OConnor 1992), while Suidasiidae Hughes has 18 species in five genera commonly found in the nests of both vertebrates and invertebrates, as well as stored products (OConnor 2009). The aim of this paper is to present evidence from morphological and molecular data for the establishment of a new family, and to describe a new genus and species.

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Material and methods

Morphological identification

The host materials intercepted at the border of New Zealand were transported to the Plant Health and Environment Laboratory in Auckland for identification. Mites were extracted from the samples and mounted in Hoyer's medium on microscope slides using a dissecting microscope. The mounted specimens were then examined, measured, and illustrated under a compound microscope (Nikon Eclipse 80i) with differential interference contrast (DIC). Illustrations were produced using a drawing tube (Nikon Y-IDT) attached to the microscope. Images were captured using a camera attached to a microscope (Zeiss Axio Image 1) and edited with Helicon Focus and Photoshop 2021 software (Fan *et al.* 2016).

To obtain measurements, a stage-calibrated ocular micrometer was used. The length of the dorsum was measured from the anterior margin in front of setae *vi* to the posterior margin of the idiosoma behind setae *h2*, while the width was measured at the greatest transverse distance posterior to *c1*. The length of the legs was measured from the base of the trochanter to the tip of the pretarsal claw, and the width of the conical setae was measured at their bases. All measurements are presented in micrometers (μm) for the holotype and accompanied by a range of measurements from all listed specimens in parentheses. The chaetotaxy followed that of Fan and Zhang (2007), which was derived from Griffiths *et al.* (1990) and Grandjean (1939), as well as Norton (1998).

Molecular identification

A single mite that was used for DNA extraction was initially mounted temporarily, examined, and then verified to be of the same species as those used for morphological analysis from the sample. Once the confirmation was made, the specimen was photo documented.

DNA extraction, Polymerase Chain Reaction (PCR) and DNA sequencing

To extract total genomic DNA from a single mite, we utilized a modified DNA extraction protocol introduced by Zheng *et al.* (2003). Specifically, we used worm lysis buffer that contained proteinase K, following the method described by Williams *et al.* (1992). The mite on the temporary slide was dismantled in an Eppendorf tube which contained 20 μL worm lysis buffer. The tube was stored at $-80\text{ }^{\circ}\text{C}$ for at least 30 mins before DNA extraction taking place. DNA extractions were stored at $-4\text{ }^{\circ}\text{C}$ until used as template for PCR amplification. Primers used for rDNA small subunit (SSU) were from Holterman *et al.* (2006): first SSU fragment forward primer 1096F, 5'-GGTAATTCTGGAGCTAATAC-3' and reverse primer 1912R, 5'-TTTACGGTCAGAACTAGGG-3'; and the second fragment forward primer 1813F, 5'-CTGCGTGAGAGGTGAAAT-3', and reverse 2646R, 5'-GCTACCTTGTTACGACTTTT-3', respectively. The 20 μL PCR reactions contained 10 μL Go Tag® Green Master Mix (Promega Corporation, Madison, WI, USA), 1 μL (0.05 μM) each of forward and reverse primer, and 2 μL of DNA template. The thermal cycling program was as follows: denaturation at $95\text{ }^{\circ}\text{C}$ for 3 min, followed by 30 cycles of denaturation at $94\text{ }^{\circ}\text{C}$ for 60 s, annealing at $55\text{ }^{\circ}\text{C}$ for 45 s, and extension at $72\text{ }^{\circ}\text{C}$ for 45 seconds. A final extension was performed at $72\text{ }^{\circ}\text{C}$ for 10 min. PCR products were purified by Wizard® SV Gel and PCR Clean-Up System (Promega Corporation, Madison, WI, USA). Purified PCR products were sequenced using Big Dye TM Terminator Cycle Sequencing Ready Reaction Mix v3.1 kit (Applied Biosystems, USA). Cycle sequencing products were cleaned by 96 well plate ethanol precipitation and analysed on an ABI 3100 Avant genetic analyzer (Applied Biosystems, USA). The quality of each sequence was confirmed by inspection of sequence trace files. The sequences were deposited into the GenBank database, and the accession numbers is MH745152.

DNA sequence alignment

Fifty-nine published sequences from GenBank were included in our phylogenetic analysis, respectively. Mite species and GenBank accession numbers are listed for each taxon in the phylogenetic trees, if known. The DNA sequences were aligned in Clustal X (Larkin *et al.* 2007) using the multiple alignment method with default parameter values. The resulting alignment was examined for any misaligned bases, which were subsequently corrected.

Phylogenetic inference

To select the optimal AIC model, we used ModelTest (Posada and Crandall 1998) and PAUP*4.0b10 (Swofford 1998). A Bayesian tree was obtained using MrBayes 3.1.2 (Ronquist and Huelsenbeck 2003). We ran 4 MCMC chains for 1,000,000 generations under the best-fit model (GTR+I+ Γ). Prior distributions were as follows: revmatpr = dirichlet (1,2,1,1,2,1), shapepr = exponential (5), brelenspr = unconstrained: exponential (10). The analysis started from a random topology and utilized a temperature of 0.2, a burn-in of 10%, and a thinning interval of 1,000. Multiple runs were performed to ensure convergence. The trees were rooted using two species of the family Histiostomatidae, *Histiostoma feroniaum* (GQ864328) and *Aphodanoetus teinophallus* (EU152478) from the hyporder Astigmata. The sequence was deposited in the GenBank database under accession number MH745152.

Results

Order Sarcoptiformes

Suborder Oribatida

Hyporder Astigmata

Bulacaridae fam. nov.

Zoobank: [BE0A9218-A682-4E91-AC3F-D274A0B40031](https://zoobank.org/BE0A9218-A682-4E91-AC3F-D274A0B40031)

Type genus: *Bulacarus* gen. nov. (monotypy)

Diagnosis — Idiosomal cuticle smooth. Prodorsal shield divided into a pair of longitudinal parallel sclerites; most dorsal idiosomal setae narrowly lanceolate, barbed and curved; *ve* not developed, with alveoli only; supracoxal setae *scx* slender, scarcely barbed; Grandjean's organ undeveloped; sejugal furrow present, ventral sejugal apodeme prominent; epigynal apodeme elliptical; setae *4a* lanceolate and barbed. Chelicera bearing 2 setae (*cha* and *chb*). Palpal supracoxal seta *elcp* attenuate. Legs long and slender; each pretarsus consisting of a long and slightly hooked empodial claw with a pair of stout condylophores surrounded by a reduced ambulacrum.

Description — Idiosomal cuticle smooth, without micro projections or striation. Sejugal furrow present, ventral sejugal apodeme prominent. Prodorsal shield divided into a pair of longitudinal parallel sclerites. Most dorsal setae narrowly lanceolate, barbed and curved. Internal vertical setae (*vi*) situated between prodorsal sclerites; external vertical setae (*ve*) as alveoli. Supracoxal seta *scx* slender, scarcely barbed. Grandjean's organ undeveloped. Hysterosomal setation complete. Coxal plates I and II undeveloped. Oviporus inverted V-shaped. Terminus of the oviduct without discernible folds. Epigynal apodeme present, situated immediately anterior to genital opening, flat triangular shaped. Ventral setae *4a* lanceolate and barbed. Six pairs of setae (*ps1*, *ps2*, *ps3*, *ad1*, *ad2* and *ad3*) surrounding anus. Chelicera bearing 2 setae (*cha* and *chb*). Palpal supracoxal setae *elcp* attenuate with minute barbs. Leg tarsi with proral and unguinal setae spine-like, similar in form. Setation of legs (I–IV): femora 1, 1, 0, 0; genua 2 + 1 σ , 2 + 1 σ , 1 + 1 σ , 0; tibiae 2 + 1 ϕ , 2 + 1 ϕ , 1 + 1 ϕ , 1 + 1 ϕ ; tarsi 4 attenuate setae + 2 proximal/medial spines + 6 subterminal spines + 3 ω + 1 ϵ , 4 attenuate setae + 2 proximal/medial spines + 6 subterminal spines + 1 ω , 2 attenuate setae + 2 proximal/medial

spines + 6 subterminal spines, 2 attenuate setae + 2 proximal/medial spines + 6 subterminal spines.

Male and immature stages unknown.

Remarks — *Bulacaridae* **fam. nov.** is tentatively classified within the superfamily Acaroidea which currently includes six families, Acaridae, Gaudiellidae, Glycacaridae, Lardoglyphidae, Scatoglyphidae and Suidasiidae (Schatz *et al.* 2011). It shares several characteristics with these known families, such as having sejugal furrow, distinct sejugal apodemes, well developed pretarsal claws, stout and symmetrical pretarsal condylophores, and indistinct extension of bursa copulatrix. However, it can be distinguished from these families by having a combination of the following features, two distinct setae (*cha* and *chb*) on the chelicera, prodorsal shield being in the form of a pair of parallel sclerites; most dorsal setae being lanceolate, barbed and curved; Grandjean's organ undeveloped; genital opening bearing a small anterior epigynal apodeme; ventral setae *4a* lanceolate and barbed; anus distanced from the genital opening; pretarsal ambulacrum vestigial.

The new family can be distinguished from Acaridae by the combination of the following characters, including a prodorsal shield in the form of a pair of sclerites, majority of dorsal setae being lanceolate, barbed and strongly curved; Grandjean's organ undeveloped; genital opening bearing a small anterior epigynal apodeme; ventral setae *4a* lanceolate and barbed.

The new family can be distinguished from Gaudiellidae by having prodorsal shield in the form of a pair of sclerites, sejugal furrow clearly defined, Grandjean's organ undeveloped, genital opening bearing a small anterior epigynal apodeme.

The new family can be distinguished from Glycacaridae by the absence of microtrichia on the idiosomal cuticle, the rod-like supracoxal setae, the undeveloped Grandjean's organ, the presence of a small epigynal apodeme anterior to the genital opening, the presence of lanceolate and barbed ventral setae *4a*.

The new family can be differentiated from most Lardoglyphidae by the following characteristics: prodorsal shield in the form of a pair of sclerites; most dorsal setae being lanceolate, barbed and curved; Grandjean's organ undeveloped; genital opening bearing a small anterior epigynal apodeme; ventral setae *4a* lanceolate and barbed; empodial claws are not bifurcated in females.

The new family can be differentiated from Scatoglyphidae by the presence of a prodorsal shield in the form of a pair of sclerites, most dorsal setae being lanceolate and curved, Grandjean's organ undeveloped, genital opening bearing a small anterior epigynal apodeme, ventral setae *4a* being lanceolate and barbed, the copulatory opening not being encircled by a large sclerite, and leg segments lacking prominent ridges.

The new family can be differentiated from Suidasiidae by the following characteristics: smooth idiosomal cuticle, prodorsal shield in the form of a pair of sclerites, most dorsal setae being lanceolate and curved, Grandjean's organ undeveloped, genital opening bearing a small anterior epigynal apodeme, ventral setae *4a* lanceolate and barbed, tarsi with proral and unguinal setae of similar shape.

***Bulacarus* gen. nov.**

Zoobank: [6FFD575B-0792-4035-A67E-D671272998BB](https://zoobank.org/6FFD575B-0792-4035-A67E-D671272998BB)

Type species: *Bulacarus curvisetus* **sp. nov.**; monotypic.

Diagnosis and description — As for the family.

Etymology — The name of this genus is derived from the Fijian word “*bula*,” which means life, health, or greeting, combined with the genus name “*Acarus*”.

***Bulacarus curvisetus* sp. nov.**

Zoobank: [35E219F5-9110-4353-AB10-A58BE9B9597B](https://zoobank.org/35E219F5-9110-4353-AB10-A58BE9B9597B)

(Figures 1–9)

Material examined

Holotype female, ex taro (*Colocasia esculenta*) from Fiji (intercepted in Auckland, New Zealand), 16 Mar 2004 (Accession No. 09/2004/1665); 6 paratype females, ex taro (*Colocasia esculenta*), Fiji (intercepted in Auckland, New Zealand), 15 Dec 2009 (Accession No. 09/2009/5666).

Type deposition

Holotype female will be deposited in NZAC (New Zealand Arthropod Collection). Other slides are retained in the PANZ (Plant Health and Environment Laboratory, Auckland, New Zealand) insect reference collection.

Morphology results

Diagnosis — FEMALE. Prodorsal shield divided into a pair of longitudinal parallel sclerites; most dorsal idiosomal setae narrowly lanceolate, barbed and curved; *c1*, *d1* and *e1* overlapping bases of setae in next row; supracoxal setae *scx* slender, scarcely barbed; ratio *sci*: *sce* 0.6; coxal plates I and II undeveloped; epigynal (genital) sclerite situated just anterior to genital opening, flat triangular shaped; ventral setae *4a* lanceolate and barbed; 6 pairs of setae (*ps1*, *ps2*, *ps3*, *ad1*, *ad2* and *ad3*) surrounding anus; spermathecal duct mostly cylindrical, slightly expanded near copulatory opening; base of spermathecal sac nearly circular, about 3–4 times as wide as spermathecal duct; sclerites of oviducts Y-shaped. Palpal supracoxal seta *elcp* attenuate and smooth; chelicera bearing 2 setae (*cha* and *chb*). Chaetotaxy (I–IV): femora 1, 1, 0, 0; genua 2 + 1σ, 2 + 1σ, 1 + 1σ, 0; tibiae 2 + 1φ, 2 + 1φ, 1 + 1φ, 1 + 1φ; tarsi 4 attenuate setae + 2 proximal/medial spines + 6 subterminal spines + 3ω + 1ε, 4 attenuate setae + 2 proximal/medial spines + 6 subterminal spines + 1ω, 2 attenuate setae + 2 proximal/medial spines + 6 subterminal spines, 2 attenuate setae + 2 proximal/medial spines + 6 subterminal spines.

Description — FEMALE (n=7). Idiosoma oval, 316 (234–322) long and 188 (139–191) wide; idiosomal cuticle smooth, without striation.

Dorsum – (Figures 1, 3A and 7A). Prodorsum covered by a pair of longitudinal parallel sclerites, each about 14 wide at front and 18 wide at back, 55 (54–56) long, finely punctate, posterior margin slightly convex; ocelli absent; all prodorsal setae narrowly lanceolate, barbed and curved; internal vertical setae (*vi*) posteriomedial of front margins of sclerites, situated on membranous cuticle, slightly longer than prodorsal sclerites; external vertical setae (*ve*) not developed, with alveoli only, at midway between anterior and posterior rims of sclerites; internal scapular setae (*sci*) slightly shorter than *vi*, much shorter than external scapular setae (*sce*), *sci*: *sce*=0.6; distance *sci*–*sci* about as wide as *sci*–*sce*; supracoxal sclerite obscure, Grandjean's organ undeveloped; supracoxal seta (*scx*) slender, barbed at its terminal half. Setal lengths: *vi* 65 (53–69), *sci* 49 (49–51), *sce* 81 (81–86), *scx* 18 (18–25); distances: *vi*–*vi* 7 (6–7), *ve*–*ve* 46 (46–48), *vi*–*ve* 25 (23–27), *sci*–*sci* 19 (19–21), *sci*–*sce* 21 (19–22). Hysterosoma with 12 pairs of setae (*c1*, *c2*, *cp*, *c3*, *d1*, *d2*, *e1*, *e2*, *f2*, *h1*, *h2*, *h3*), all (except *h3*) narrowly lanceolate, barbed and curved, *h3* attenuate and smooth; *c3*, *f2* and *h3* on ventral side of hysterosoma in dorsoventrally mounted specimen; *c2* and *h3* much shorter than others; opisthonotal gland openings (*gla*) located closer to *d2* than to *e2*. Setal lengths: *c1* 86 (84–91) (Figure 1C), *c2* 37 (36–41), *cp* 93 (93–103), *c3* 32 (30–33), *d1* 87 (87–93), *d2* 89 (85–92), *e1* 93 (93–94), *e2* 111 (111–115), *f2* 44 (44–54), *h1* 87 (87–92), *h2* 140 (124–149), *h3* 20 (16–22); distances: *c1*–*c1* 31 (30–31), *c1*–*d1* 26 (23–29), *d1*–*d1* 82 (77–86), *d1*–*e1* 58 (54–62), *d2*–*gld* 36 (34–36), *e1*–*e1* 53 (46–53), *h1*–*h1* 65 (61–67), *h2*–*h2* 38 (36–39), *h3*–*h3* 39 (32–40).

Venter – (Figures 2, 3B–C, 4A and 7C–E). Coxal apodemes I joined at midline, forming a short prosternal apodeme directed posteromedially; coxal plate I narrow and triangular, directed posterolaterally; coxal apodemes II triangular, directed posterolaterally; sejugal apodeme mostly slender; epigynal apodeme situated just anterior to genital opening, flat triangular; apodemes III directed medially, apodemes IV directed anteromedially and joint

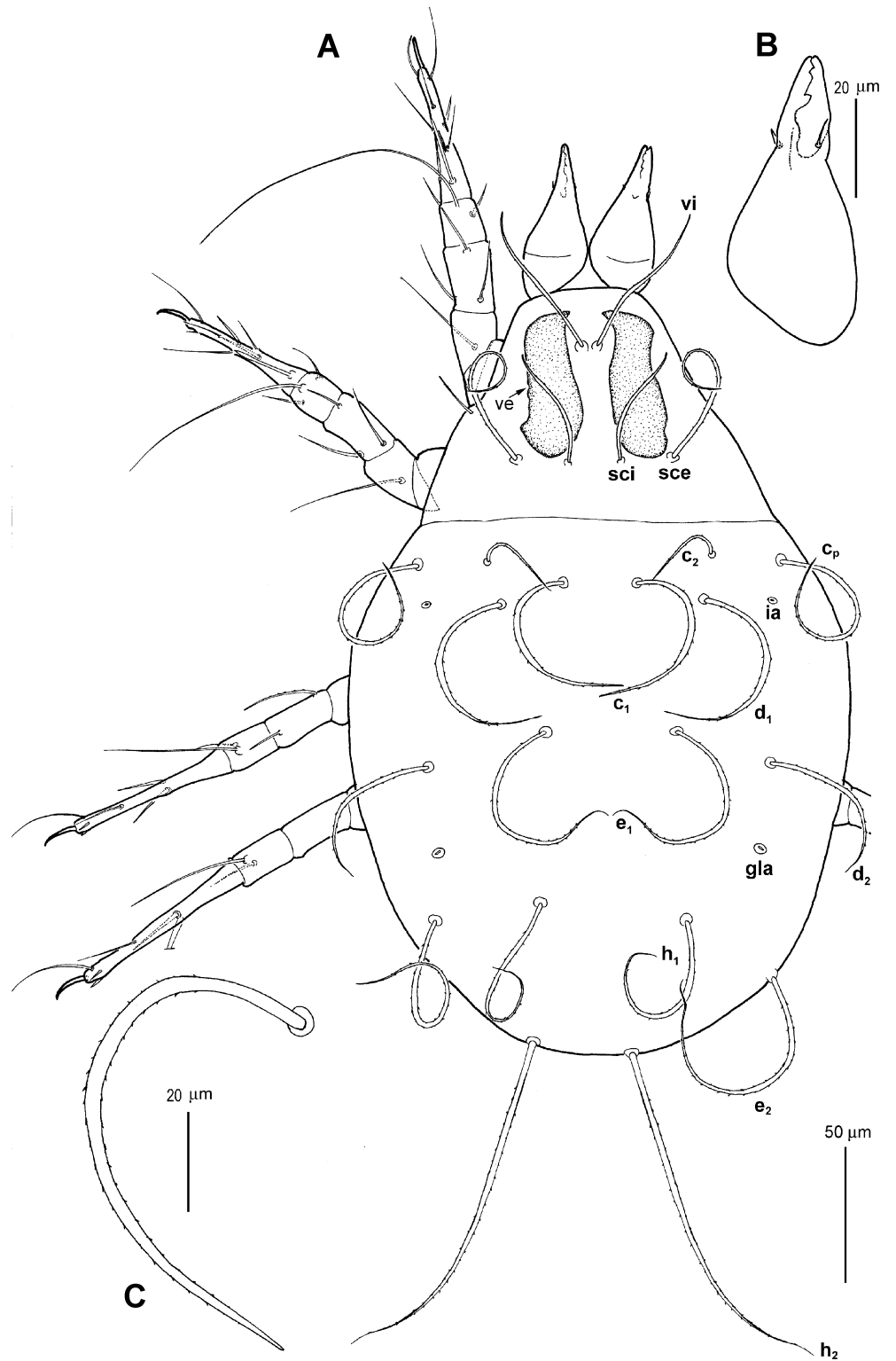


Figure 1 *Bulacarus curvisetus* sp. nov. (female). A – dorsal view of idiosoma; B – ventral view of chelicera; C – seta *c1*.

with post-apodemes of coxae III. Ventral setae *1a* inserted laterad of prosternal apodeme, *4b* laterad of genital opening, *g* at level of posterior margin of first pair of genital papillae; *4a*

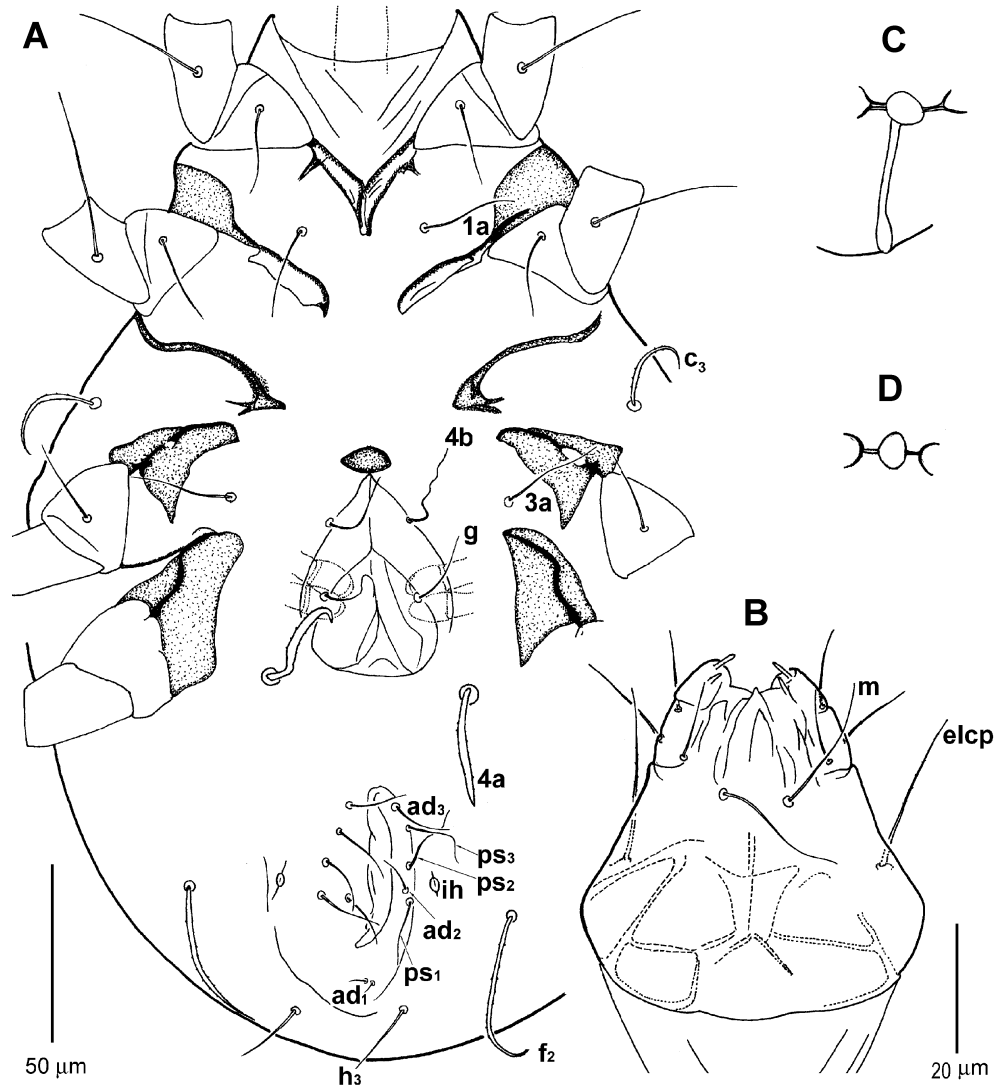


Figure 2 *Bulacarus curvisetus* sp. nov. (female). A – ventral view of idiosoma; B – ventral view of subcapitulum; C – spermathecal apparatus; D – base of spermathecal sac.

lanceolate and barbed, posterolateral to genital opening. Genital opening inverted V-shaped, situated centrally between coxae III–IV. Terminus of the oviduct without discernible folds. Anal opening nearly as long as genital opening, far posterior to genital opening, surrounded by 3 pairs of pseudanal and 3 pairs of adanal setae; pseudanal setae (*ps1*–*3*) subequal. Copulatory opening posterior to anus; spermathecal duct (Figure 2C) mostly cylindrical, slightly expanded near copulatory opening; base of spermathecal sac nearly circular, about 3–4 times as wide as spermathecal duct; sclerites of oviducts (Figure 2C–D) Y-shaped. Setal lengths: *1a* 26 (25–30), *4b* 27 (27–33), *3a* 33 (21–34), *g* 24 (24–31), *4a* 35 (33–38), *ps3* 24 (24–30), *ps2* 24 (24–30), *ps1* 23 (22–28), *ad3* 20 (20–25), *ad2* 9 (9–13), *ad1* 7 (6–10).

Gnathosoma – (Figures 1B, 2B and 7B). Chelicerae chelate, apical 2/3 tapered, each bearing 2 setae (*cha* and *chb*), *cha* conical, small (3), *chb* slender, about twice as long as *cha*, 5.5–6.5; movable digit 22 (22–23); subcapitulum bearing a pair of setae, *m* 21 (21–24); palpal supracoxal setae (*elcp*) attenuate and barbed, 28 (27–28); palptibia with a dorsal and a lateral setae, both attenuate, 14 (14–16) and 11 (11–12), respectively; palptarsus with an attenuate dorsal seta and a tiny terminal solenidion, 4 (3.5–4).

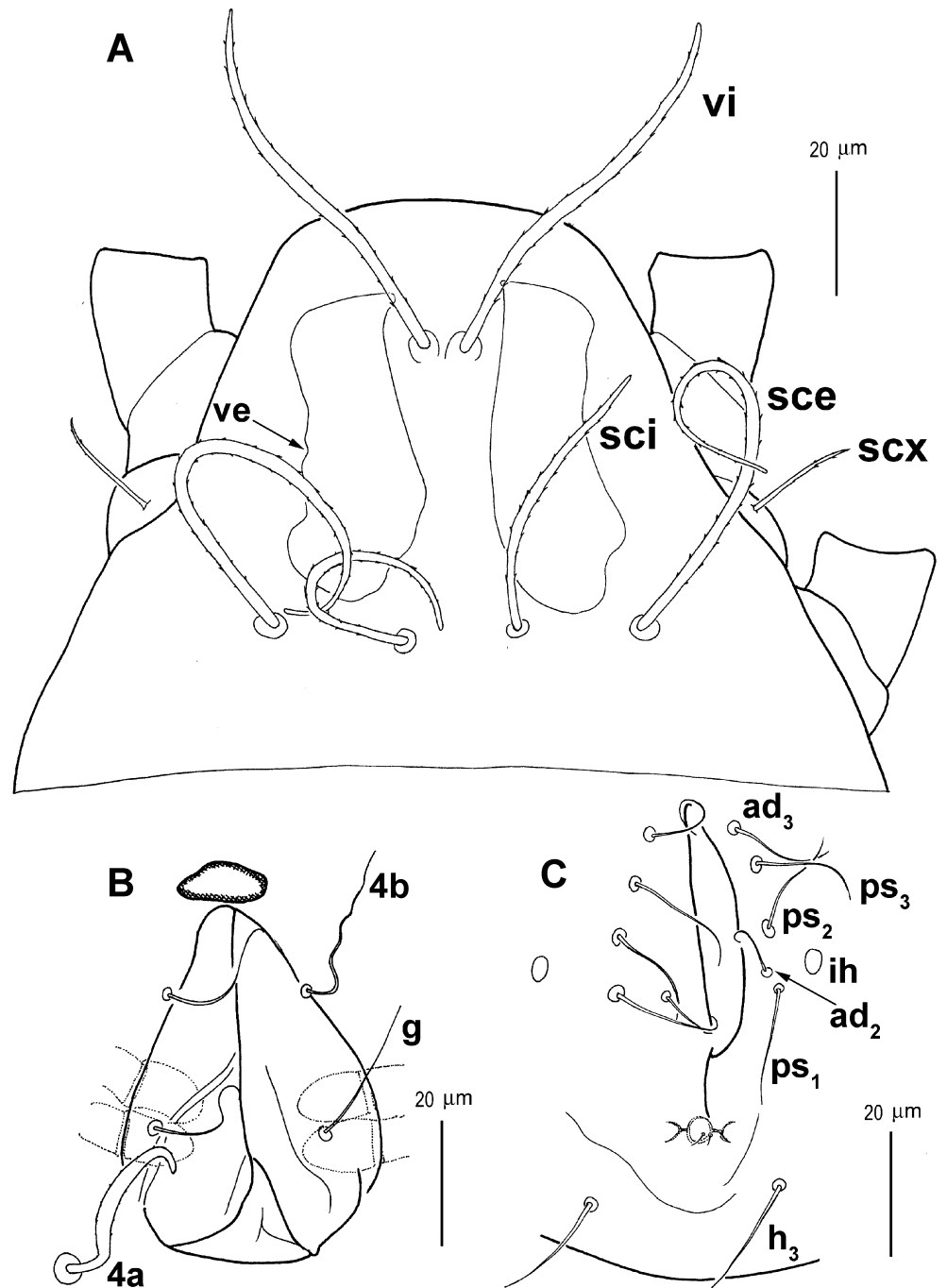


Figure 3 *Bulacarus curvisetus* sp. nov. (female). A – prodorsum; B – genital opening; C – anal area.

Legs – (Figures 4B–C, 5, 6 and 7F–G). Leg IV longer than others; lengths (I–IV): 147 (112–152), 141 (120–147), 152 (142–162), 181 (158–182).

Leg I (Figures 4B, 5A, 6A–A' and 7F). Trochanter smooth, bearing an attenuate seta, 24; femoral seta *vF* reaching to tip of genu, 48 (47–51); genu with one solenidion (σ), 19 (18–20), and 2 barbed setae, *cG* 29 (28–31), *mG* 25 (25–27); tibial solenidion ϕ extending far beyond tarsal tip, 116 (114–124), setae *gT* spiniform and smooth, 15 (14–16), *hT* barbed, 19 (19–21); tarsus (excluding pretarsus, same as below for other tarsi) about 3.7 (2.0–3.7)× as long as its

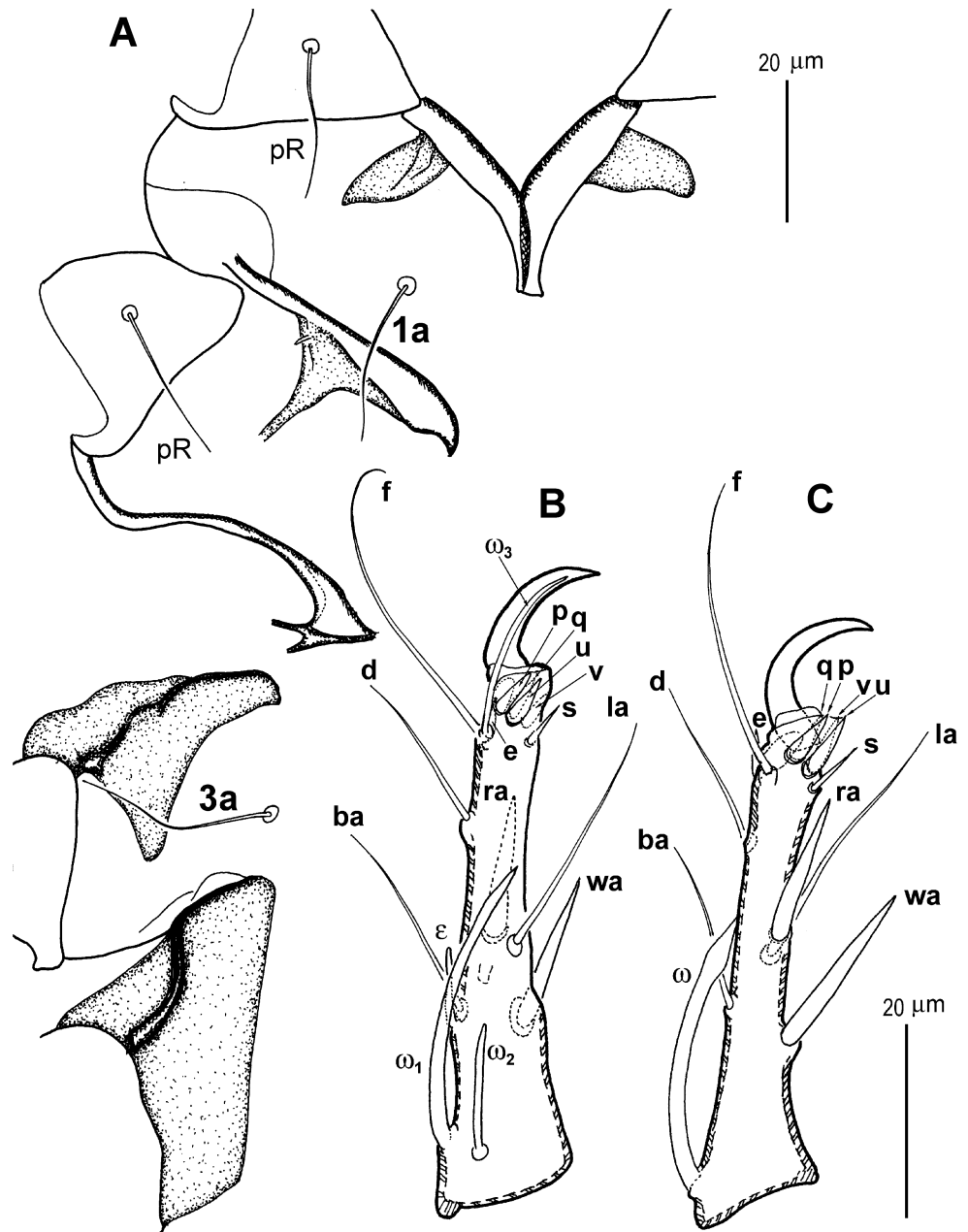


Figure 4 *Bulacarus curvisetus* sp. nov. (female). A – coxae I–IV; B – tarsus I; C – tarsus II.

basal width, solenidion $\omega 1$ nearly cylindrical, terminated in a sharply pointed tip, 33 (29–35); $\omega 2$ at about same level as $\omega 1$, 12 (12–14); famulus ε anterior to $\omega 1$ and close to base of seta ba , 8 (8–9); $\omega 3$ subterminal and close to base of seta f , 23 (20–27); setae wa spiniform, 20 (20–22), ra spiniform, 16 (15–17); ba , la , d and f attenuate, (23), (33), (21), (32), respectively; dorsal subterminal spine e 5 (4.5–5) long, 1.2 (1.1) wide; ventro-terminal spines: s attenuate, 9 (8–9) long and 0.7 (0.5–0.7) wide, u and v conical, 8 (7–8) long, 1.6 (1.6–1.8) wide, p and q conical, stouter than u and v , 7 (6–7) long, 2 (2–2.2) wide.

Leg II (Figures 4C, 5B, 6B–B' and 7G). Trochanter dorsally smooth, bearing an attenuate seta, 24; femoral seta vF extending beyond tip of genu, 46 (43–49); genu with a solenidion (σ) and 2 barbed setae (cG , mG), lengths: σ 19 (18–19), cG 29 (29–30), mG 25 (25–29); tibial

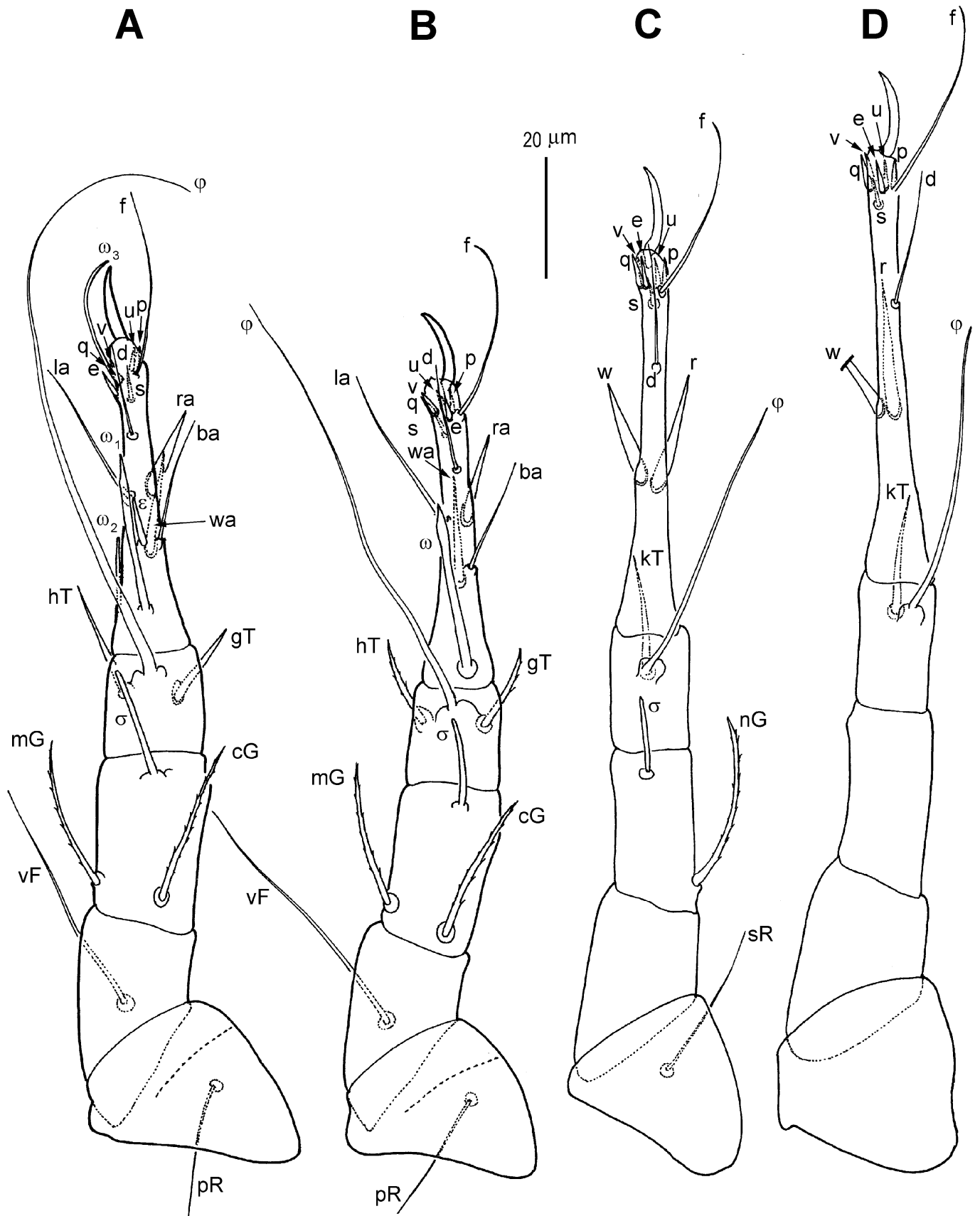


Figure 5 *Bulacarus curvisetus* sp. nov. (female). A – leg I; B – leg II; C – leg III; D – leg IV.

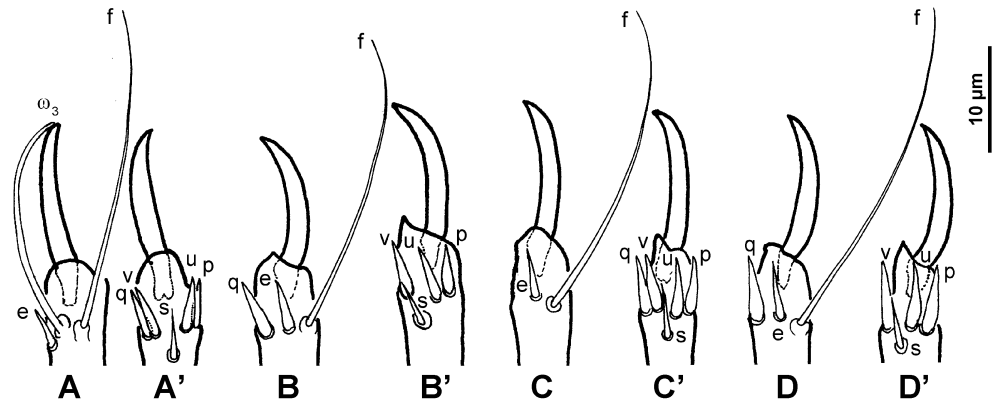


Figure 6 *Bulacarus curvisetus* sp. nov. (female). A – dorsal view of pretarsus I; A' – ventral view of pretarsus I; B – dorsal view of pretarsus II; B' – ventral view of pretarsus II; C – dorsal view of pretarsus III; C' – ventral view of pretarsus III; D – dorsal view of pretarsus IV; D' – ventral view of pretarsus IV.

solenidion ϕ extending beyond tarsal tip, ϕ 116 (78–116), setae gT and hT barbed, gT 15 (15–16), hT 19 (16–19); tarsus about 3.7 (2.8–3.7) \times as long as its basal width, solenidion ωI nearly cylindrical, terminated in a pointed tip, 31 (27–32); setae wa spiniform, 20, ra spiniform, 16; ba , la , d and f attenuate, (21), (20), (32), (32), respectively; dorsal subterminal spine e 5 (4.5–5) long, 1.2 (1.1) wide; ventro-terminal spines: s attenuate, 9 (8–10) long and 0.7 wide, u and v conical, 8 (7–8) long, 1.5 (1.5–1.6) wide, p and q conical, stouter than u and v , 7 (6–7) long, 2 wide.

Leg III (Figures 5C and 6C–C'). Trochanter dorsally smooth, bearing an attenuate seta, 24; femur nude; genu with a solenidion (σ) and a barbed seta (nG), σ 13 (13–15), nG 30 (27–34); tibial solenidion ϕ short, 51 (42–56), not extending to base of pretarsal claw, seta kT slender and barbed, 19 (18–21); tarsus about 6.6 (4.1) \times as long as its basal width; setae ra spiniform, 21 (17–21); wa spiniform 19 (18–20); d attenuate, 22 (18–23); f attenuate, 32 (27–34); dorsal subterminal spine e 5 (4.5–5) long, 1.1 wide; ventro-terminal spines: s attenuate, 9 (8–10) long and 0.7 wide, u and v conical, 8 (7–8) long, 1.5 wide, p and q conical, stouter than u and v , 7 (6–7) long, 2 wide.

Leg IV (Figures 5D and 6D–D'). Trochanter, femur and genu nude; tibial solenidion ϕ short, 50 (44–58), not extending to base of tarsal claw, seta kT slender and barbed, 19 (16–20); tarsus about 5.6 (5–5.8) \times as long as its basal width; setae ra spiniform, 24 (21–26); wa spiniform 23 (21–24); d attenuate, 24 (21–26); f attenuate, 33 (31–35); dorsal subterminal spine e 5 (4.5–5) long, 1.1 wide; ventro-terminal spines: s attenuate, 10 (8–10) long and 0.7 wide, u and v conical, 8 (7–8) long, 1.5 wide, p and q conical, stouter than u and v , 7 (6–7) long, 2 wide.

Egg – (n=1; Figure 8A). Broadly oval, 105 long, 79 wide; without ornamentation on surface.

Gut contents – (Figure 8B–C). After conducting further observations of the gut contents, we determined that the species possesses a component resembling starch in its gut. This finding suggests that it is a phytophagous species consuming the starchy components of taro.

Male and immature stages unknown.

Molecular results

This study was not intended to delve into the phylogenetics of the Acaroidea, and as such, we refrained from attempting to deduce relationships among families within this superfamily. After analysing a set of 59 mite sequences, it was established that the GTR+I+ Γ model offered the most suitable fit. Both Bayesian and maximum parsimony analyses produced similar

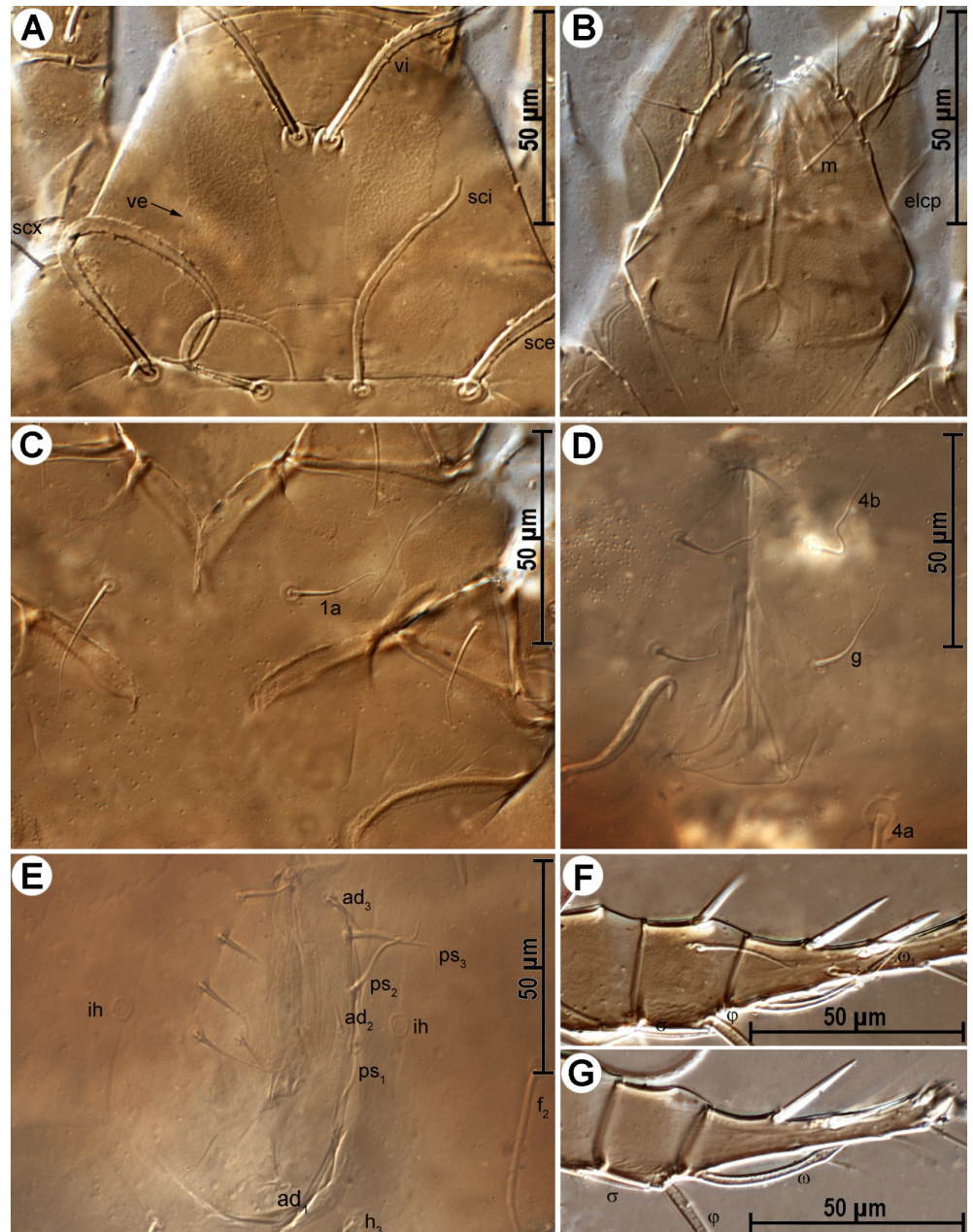


Figure 7 *Bulacarus curvisetus* sp. nov. A – prodorsum; B – subcapitulum; C – coxae I-II; D – genital opening; E – anal opening; F – genu, tibia and tarsus of leg I; G – genu, tibia and tarsus of leg II.

topologies, supported by robust nodal evidence. The consensus tree based on SSU (Figure 9) unveiled two noteworthy findings: 1) *Bulacarus curvisetus* sp. nov. appears to occupy a potentially basal position within Acaroidea, and clearly distinguishes itself from all other analysed sequences; 2) Acaridae are paraphyletic and spread in two distinct branches.

Etymology

The specific name is a combination of the Latin “*curvus*”, which means crooked, curved and bent, and “*seta*”, which means bristle, to describe the distinctive shape of the dorsal idiosomal setae.

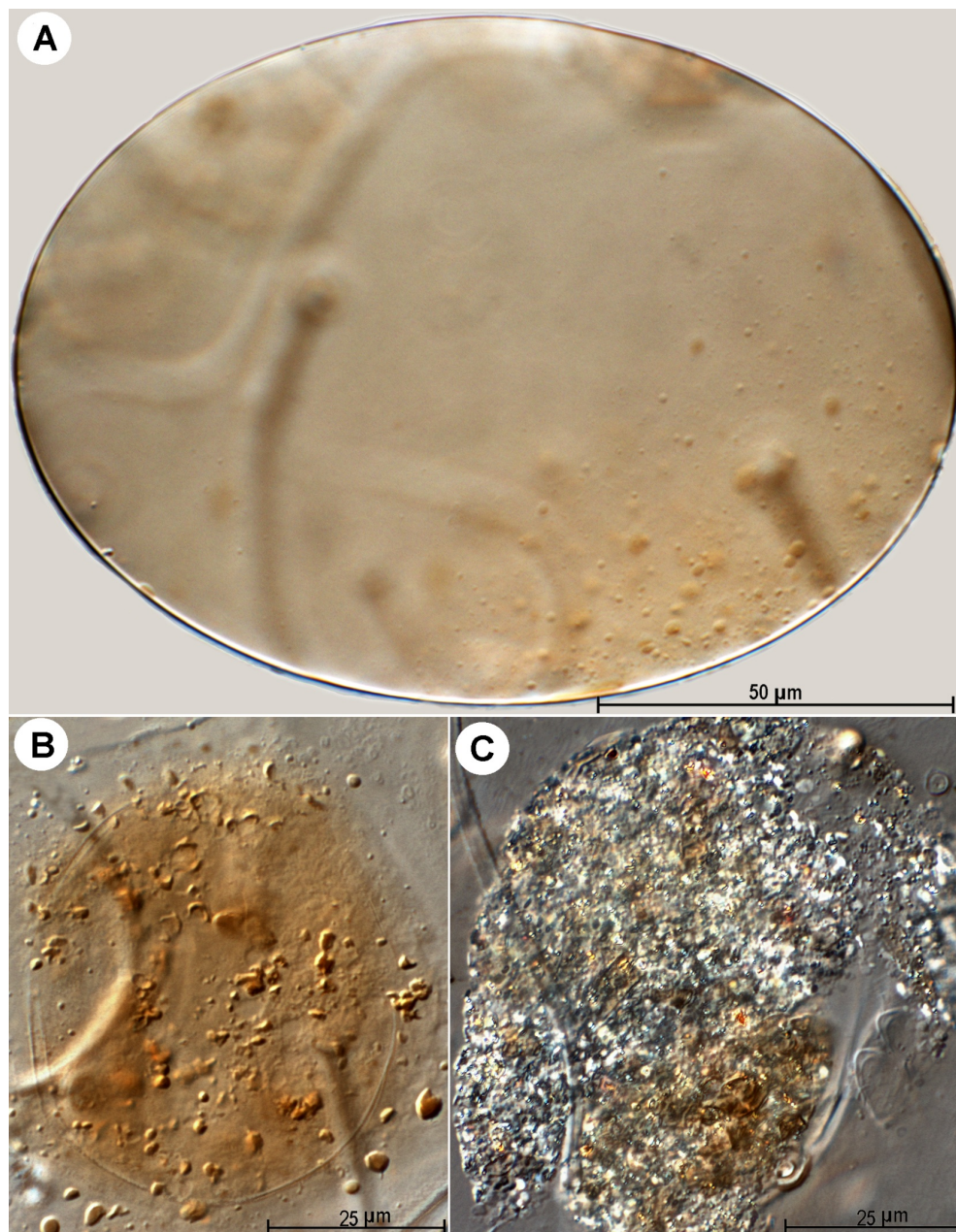


Figure 8 *Bulacarus curvisetus* sp. nov. A – egg; B and C – gut contents (food boli).

Discussion

Bulacarus curvisetus sp. nov. exhibits the characteristic chelate-dentate chelicerae but distinguishes itself from the majority of Astigmata by having two cheliceral setae (*cha* and *chb*) instead of the usual one (*cha*). This particular feature is shared with some Rosensteiniidae (OConnor and Reisen 1978), the majority of oribatid mites and some endeostigmatid mites (Norton and Behan-Pelletier 2009; Walter 2009). The existence of two cheliceral setae is considered an ancestral characteristic, suggesting that *B. curvisetus* sp. nov. likely represents an early stage in its evolutionary lineage.

The prodorsal shield of *B. curvisetus* sp. nov. is in the form of a pair of parallel sclerites, resembling those in Glycacaridae (Acaroidea), Aeroglyphidae and Euglycyphagidae

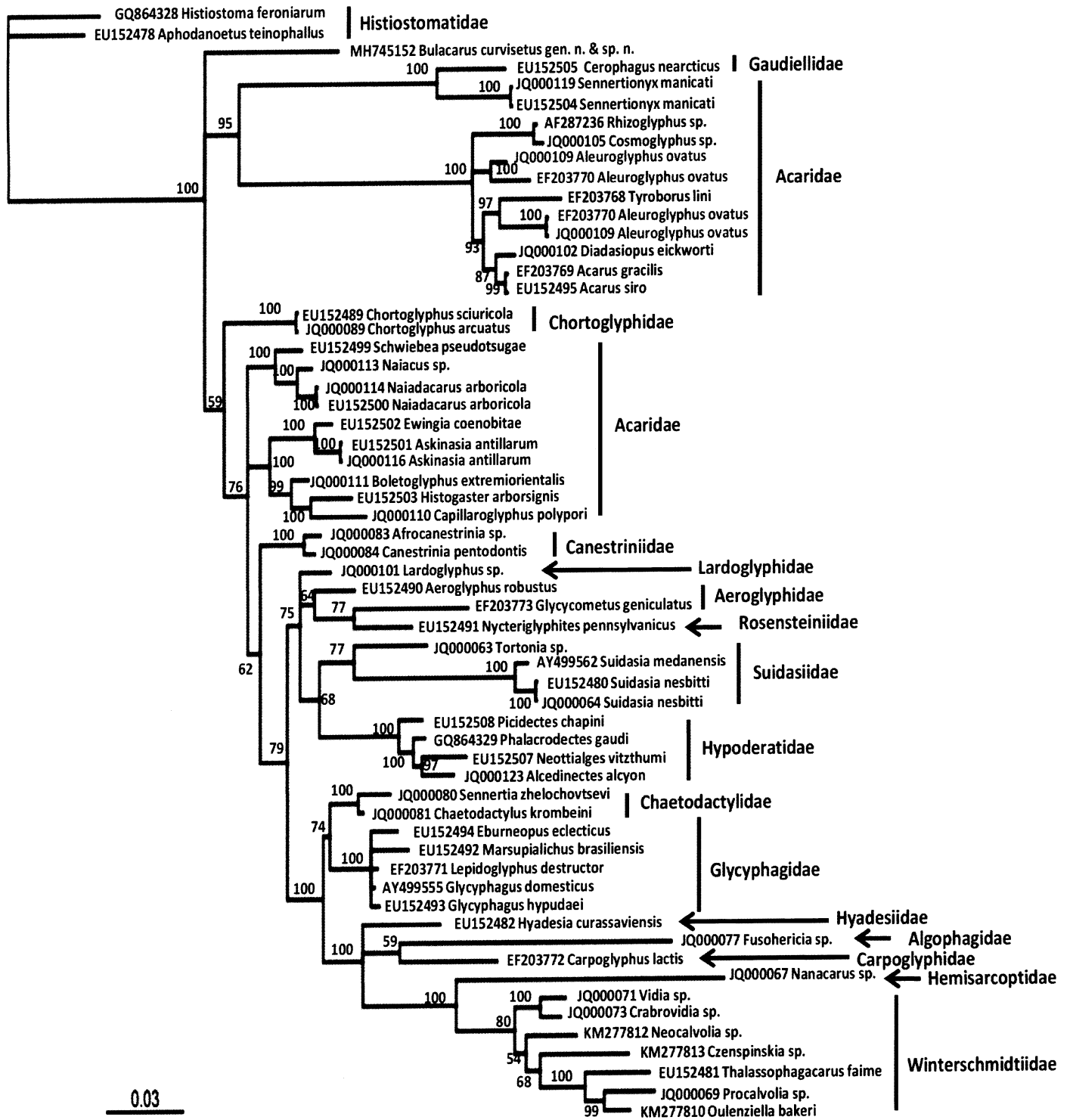


Figure 9 Bayesian tree estimated under the GTR+I+F model and inferred from SSU gene DNA sequences. Posterior probabilities exceeding 50% are given on appropriate clades. Mite species, GenBank numbers listed for each taxon.

(Glycyphagoidea), and Hypoderatidae (Hypoderatoidea) (OConnor 2009). This suggests that the development of this characteristic may have occurred independently on several occasions.

The taxonomic position of Bulacaridae **fam. nov.** remains somewhat uncertain, but it is plausible that it shares affinities with the superfamily Acaroidea based on the morphological

attributes discussed in the family remarks.

While it seems that *Bulacarus curvisetus* **sp. nov.** predominantly consumes taro corms, the limited encounters of this species, accounting for a mere 0.27% of intercepted taro fresh produce from 2004 to 2016, coupled with its low population, suggest that they are unlikely to pose a substantial pest threat.

Conflicts of interest

The authors declare no conflicts of interest.

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