

**“Estudos taxonômicos e filogenéticos
de *Tenuipalpus* Donnadieu
(sensu stricto e sensu lato) e
Colopalpus Pritchard & Baker
(Acari, Tenuipalpidae)”**

Elizeu Barbosa de Castro

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Elizeu Barbosa de Castro

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Tese apresentada como parte dos requisitos para obtenção do título de Doutor em Biologia Animal, junto ao Programa de Pós-Graduação em Biologia Animal, do Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista “Júlio de Mesquita Filho”, Campus de São José do Rio Preto.

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Rio Preto.

Comissão Examinadora

Prof. Reinaldo José Fazzio Feres
UNESP – São José do Rio Preto, Brasil
Orientador

Prof. Dr. Gilberto José de Moraes
ESALQ – Piracicaba, Brasil

Prof. Dr. Ronald Ochoa
USDA – Beltsville, Estados Unidos

Profa. Dra. Nora Cristina Mesa Cobo
Universidade Nacional de Colombia – Palmira, Colômbia

Prof. Dr. Fernando Barbosa Noll
UNESP – São José do Rio Preto, Brasil

São José do Rio Preto

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“So many mites, so little time!”

Barry M. OConnor

RESUMO

A família Tenuipalpidae (Acari: Prostigmata) possui mais de 1.100 espécies incluídas em 40 gêneros. *Tenuipalpus* Donnadieu é o maior gênero desta família com mais de 300 espécies descritas. *Colopalpus* Pritchard & Baker é um pequeno gênero de Tenuipalpidae com cinco espécies conhecidas, e que até recentemente era considerado um sinônimo júnior de *Tenuipalpus*. Nesse estudo são apresentadas contribuições sobre o conhecimento da taxonomia e a sistemática desses dois gêneros. Os quatro primeiros capítulos apresentam a descrição de seis novas espécies de *Tenuipalpus*. O quarto capítulo também inclui a re-descrição de *T. heveae* Baker. O quinto capítulo apresenta a revalidação do gênero *Colopalpus*, com a re-descrição da espécie tipo, *C. matthyssei* Pritchard & Baker, e transferência de quatro espécies de *Tenuipalpus* para *Colopalpus*. O sexto capítulo apresenta a definição e *Tenuipalpus* sensu stricto, com a re-descrição da espécie tipo, *T. caudatus* (Dugès) (= *T. palmatus* Donnadieu), e a descrição de uma nova espécie. O último capítulo apresenta uma análise filogenética incluindo espécies dos gêneros *Tenuipalpus* (grupos sensu stricto e sensu lato) e *Colopalpus*. Os resultados aqui apresentados contribuem para o conhecimento desses dois gêneros, e também de toda a família Tenuipalpidae.

Palavras-chave: Prostigmata. Taxonomia. Sistemática. Desenvolvimento da quetotaxia. Low-temperature scanning electron microscopy.

ABSTRACT

The family Tenuipalpidae (Acari: Prostigmata) is comprised of more than 1,100 species belonging to 40 genera. Tenuipalpus Donnadieu is the largest genus of Tenuipalpidae, with over than 300 described species. Colopalpus Pritchard and Baker is a small genus of Tenuipalpidae, with five species known, and until recently it was considered a junior synonymy of Tenuipalpus. There are advances presented here about the knowledge of the taxonomy and systematic of these two genera. The first four chapters present the description of six new species of Tenuipalpus. The chapter four also presents the redescription of T. heveae Baker. The chapter five presents the reinstatement of the genus Colopalpus, with the redescription of the type species, C. matthyssei Pritchard and Baker, and the transference of four species from Tenuipalpus to Colopalpus. The chapter six presents the definition of Tenuipalpus sensu stricto, with the redescription of the type species, T. caudatus (Dugès) (=T. palmatus Donnadieu), and the description of a new species. The last chapter presents a phylogenetic analysis including species of the genera Tenuipalpus (sensu stricto and sensu lato groups) and Colopalpus. The results presented here increase the knowledge about these two genera and all family Tenuipalpidae.

Keywords: Prostigmata. Taxonomy. Systematic. Development of chaetotaxy. Low-temperature scanning electron microscopy.

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INTRODUCTION

The flat mites (Acari: Tenuipalpidae) are included in the superfamily Tetranychoidae, and within this superfamily are characterized mainly by suppression of the palptibial thumb-claw complex (Walter *et al.* 2009). It includes over 1,100 species belonging to 40 genera (Mesa *et al.* 2009; Beard *et al.* 2014; Castro *et al.* 2015a – chapter 5). All species of this family are phytophagous, some of which, as *Brevipalpus phoenicis* (Geijskes) and *Raoiella indica* Hirst, are considered pests of different crops worldwide (Moraes and Flechtmann 2008; Gondim Jr *et al.* 2012). In Brazil, *Tenuipalpus heveae* Baker is considered a pest mite in plantations of rubber trees in different regions of the country (Hernandes and Feres 2006; Daud and Feres 2007).

Tenuipalpus Donnadieu is the largest genus of Tenuipalpidae, with over than 300 species described (Mesa *et al.* 2009; Ueckermann and Ripka 2015; Castro *et al.* 2015b – chapter 2). For a long time this genus was characterized only by the presence of a prodorsum wider than opisthosoma. Because of that, species morphologically dissimilar were included in *Tenuipalpus*. Mitrofanov (1973) proposed the division of *Tenuipalpus* into seven genera based mainly in the shape and presence of the dorsal setae. Meyer (1979) did not consider the characteristics used by Mitrofanov important enough to separate genera, and she proposed a division of *Tenuipalpus* in groups and subgroups of species based in characteristics similar of those used by Mitrofanov (1973). Despite some later modifications, this proposal was followed by Baker and Tuttle (1987) and Meyer (1993).

Recently, Castro *et al.* (2016a – chapter 6) proposed the division of *Tenuipalpus* into two groups: *Tenuipalpus* sensu stricto and sensu lato. These authors indicated the presence of a pair of lateral body projections associated with setae c3 as a synapomorphy for the group sensu stricto. This division can be considered as a first step to improve the systematic of *Tenuipalpus* and to allow the comparison of possible new species with those morphologically similar. The sensu stricto group includes the type

species of the genus, *T. caudatus* (Dugès) (= *T. palmatus* Donnadieu), and other 39 species (Castro *et al.* 2016a; 2016b – chapter 3).

Pritchard and Baker (1958) erected the genus *Colopalpus* to accommodate the new species *C. matthyssei*, described from The Philippines. These authors mentioned that *Colopalpus* shares characteristics with the genera *Tenuipalpus* and *Brevipalpus*. Meyer (1979), in her major revision of Tenuipalpidae, considered *Colopalpus* as a synonym junior of *Tenuipalpus*. Recently, Castro *et al.* (2015 – chapter 5) reinstated the genus *Colopalpus* based in the study and redescription of the type species. These authors used characteristics of females and males (e.g. shape of the body and position of leg setae), to distinguish *Colopalpus* from *Tenuipalpus* and *Brevipalpus*.

According to Seeman and Beard (2011), the establishment of ontogenetic patterns in the development of leg setae may be useful in the definition of more robust groups in Tenuipalpidae. Herein, the ontogenetic development of leg setae is presented and discussed for some species of *Tenuipalpus*, and when possible, are performed comparisons with related taxa (Castro *et al.* 2015b; Castro *et al.* 2016b). Furthermore, micrographs of morphological characters were taken using low-temperature scanning electron microscopy (LT-SEM), and are presented in different chapters of this study. These images contribute to a better understanding of the morphology, biology and ecology of these groups of flat mites.

In this study, are presented advances about the taxonomic and systematic knowledge of the genera *Tenuipalpus* and *Colopalpus*, and also about the family Tenuipalpidae. The first four chapters show the description of six new species of *Tenuipalpus* from Brazil, and also the redescription of *Tenuipalpus heveae* Baker. The chapter five presents the reinstatement of the genus *Colopalpus*, with the redescription of the type species of this genus. The chapter six presents the definition of *Tenuipalpus* sensu stricto, with the redescription of type species, and description of a new species from Costa Rica. Finally, the last chapter

presents a phylogenetic analysis including species of *Tenuipalpus* (sensu stricto and sensu lato groups) and *Colopalpus*.

References

- Baker, E.W., Tuttle, D.M. 1987. The false spider mites of Mexico (Tenuipalpidae: Acari). United States Department of Agriculture, Agricultural Research Service, Technical Bulletin, 1706:1–236.
- Beard, J.J., Seeman, O.D., Bauchan, G.R. 2014. Tenuipalpidae (Acari: Trombidiformes) from Casuarinaceae (Fagales). Zootaxa, 3778:1–157.
- Castro, E.B., Ochoa R., Feres, R.J.F., Beard, J.J., Bauchan G.R. 2015a. Reinstatement of the genus *Colopalpus* Pritchard and Baker (1958) and re-description of *Colopalpus matthyssei* Pritchard and Baker (1958), the type species of the genus (Acari, Tenuipalpidae). International Journal of Acarology, 41:310–328.
- Castro, E.B., Ramos, F.A.M., Feres, R.J.F., Ochoa, R. 2015b. A new species of *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Brazil, with ontogeny of chaetotaxy. Systematic and Applied Acarology, 20(3):339–356.
- Castro, E.B., Kane, E.C., Feres, R.J.F., Ochoa, R., Bauchan, G.R. 2016a. Definition of *Tenuipalpus* sensu stricto (Acari, Tenuipalpidae), with redescription of *Tenuipalpus caudatus* (Dugès) and description of a new species from Costa Rica. International Journal of Acarology, 42(2):106–126.
- Castro, E.B., Feres, R.J.F., Ochoa, R., Bauchan, G.R. 2016b. A new species of *Tenuipalpus* sensu stricto (Acari: Tenuipalpidae) from Brazil, with ontogeny and a key to the known species. Zootaxa, (in press).
- Daud, R.D., Feres, R.J.F. 2007. Dinâmica populacional de ácaros fitófagos (Acari, Eriophyidae, Tenuipalpidae) em seis clones de seringueira no

- sul do estado de Mato Grosso. *Revista Brasileira de Entomologia*, 51:377–381
- Gondim Jr., M.G.C., Castro, T.M.M.G., Marsaro Jr. A.L., Navia D., Melo J.W.S., Demite, P.R., Moraes, G.J.de. 2012. Can the red palm mite threaten the Amazon vegetation? *Systematics and Biodiversity*, 10(4):527–535.
- Hernandes, F.A., Feres, R.J.F. 2006. Diversidade e Sazonalidade de Ácaros (Acari) em Seringal (*Hevea brasiliensis*, Muell. Arg.) no Noroeste do Estado de São Paulo. *Neotropical Entomology*, 35(4):523–535.
- Mesa, N.C., Ochoa, R., Welbourn, W.C., Evans, G.A., Moraes, G.J.de. 2009. A catalog of the Tenuipalpidae (Acari) of the world with a key to genera. *Zootaxa*, 2098:1–185.
- Meyer, M.K.P. 1979. The Tenuipalpidae (Acari) of Africa with keys to the world fauna. *Entomology Memoir, Department of Agriculture Republic South Africa*, Pretoria, 50:1–133.
- Meyer, M.K.P. 1993. A revision of the genus *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) in the Afrotropical region. *Entomology Memoir of the Department of Agriculture Republic South Africa*, 88:1–84.
- Mitrofanov, V.I. 1973. Revision of the system of phytophagous mites of the subfamily Tenuipalpinae s. str. (Trombidiformes, Tenuipalpidae). *Zoologicheskii Zhurnal*, 52:1315–1320.
- Moraes, G.J., Flechtmann, C.H.W. 2008. *Manual de Acarologia. Acarologia Básica e Ácaros de Plantas Cultivadas no Brasil*. Editora Holos, Ribeirão Preto, p. 288.
- Pritchard, A.E., Baker, E.W. 1958. The false spider mites (Acarina: Tenuipalpidae). *University of California Publications in Entomology*, 14:175–274.
- Seeman, O.D., Beard, J.J. 2011. A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia. *Systematic and Applied Acarology*, 16:73–89.

- Ueckermann, E.A., Ripka, G. 2015. Three new species and a new record of tenuipalpid mites (Acari: Tenuipalpidae) from Hungary. *Journal of Natural History*, 50(15-16):989–1015.
- Walter, D.E., Lindquist, E.E., Smith, I.M., Cook, D.R., Krantz, G.W. 2009. Order Trombidiformes. In: Krantz, G.W., Walter, D.E. (Eds). *A Manual of Acarology*. 3 ed.; Lubbock: Texas Tech University Press. p. 233–420.

CHAPTER 1

NEW SPECIES OF *TENUIPALPUS* (ACARI: TENUIPALPIDAE) FROM SEMIDECIDUAL FOREST REMNANTS IN THE STATE OF SÃO PAULO, BRAZIL

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Authors: Elizeu B. de Castro and Reinaldo J.F. Feres

Abstract

Three new species of the genus *Tenuipalpus* (Acariformes: Tenuipalpidae), *T. tapiae* **sp. nov.**, *T. apichai* **sp. nov.**, and *T. nambii* **sp. nov.** collected in Semidecidual Forest native plants in the northwest of the state of São Paulo, Brazil are de-scribed and illustrated. A key of the Brazilian species of *Tenuipalpus* based on females is presented.

Keywords

flat mites, false spider mites, plant feeding mites, Euphorbiaceae, Malvaceae, Ulmaceae

Introduction

Tenuipalpus Donnadieu is the most numerous genus of the family Tenuipalpidae (Acariformes) with 306 species and 11 of them are described from Brazil (Mesa et al. 2009; Flechtmann & Noronha 2013).

During investigations of the mite fauna associated with native plants in Semidecidual Forest remnants in the northwest of the state of São Paulo, three new species of *Tenuipalpus* were recorded and are described herein: *T. tapiae* **sp. nov.**, *T. apichai* **sp. nov.**, and *T. nambii* **sp. nov.**

Material and Methods

Measurements for the holotype of each species are given in micrometers (μm), with the range of measurements for the paratypes shown in parentheses. The body length was measured from the apex of the rostrum to the posterior apex of the body, and the width was measured at the level of the sejugal furrow. Setal nomenclature follows that of Grandjean (1939), as applied by Kethley (1990). Photographs of differential interference contrast (DIC) microscopy are included in the illustrations. Type specimens are deposited in the collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRP, [http:// www.splink.cria.org.br](http://www.splink.cria.org.br)) and in the National Insect and

Mite Collection, National Museum of Natural History, Smithsonian Institution, located in the Systematic Entomology Laboratory, USDA, Beltsville, Maryland, USA (NMNH).

***Tenuipalpus tapiae* Castro and Feres sp. nov.**

(Figs. 1–11)

Description. FEMALE: (holotype, Figs. 1–8). Body length 270 (265–275 in 12 paratypes); width 170 (160–170). *Dorsum* (Figs. 1–2). Prodorsal setae *ve* 5 (5–6) reduced, setae *sci* 14 (10–13) and *sce* 9 (9–11) larger; prodorsal setae covered with small triangular scales (here named as squamous setae; Fig 1.) and similar to hysterosomal setae, except *h2* whiplike; *c1* 8 (8–10), *c3* 7 (6–7), *d1* 6 (6–7), *d3* 7 (6–7), *e1* 5 (4–6), *e3* 7 (6–7), *f2* 9 (8–9), *f3* 9 (8–10), *h1* 7 (7–8), *h2* 176 (145–175). *Venter* (Fig. 3). Ventral integument slightly striated; *IC3* setae relatively short; *IC4* setae long, extend beyond the bases of genital setae; genital setae short and similar to anal setae. *Gnathosoma* (Fig. 4). Palp 3-segmented, 2nd segment elongate with long filiform dorso-distal seta; 3rd segment short bearing long solenidion (7 long). *Legs* (Figs. 5–8). Setation (from coxa to tarsus): I 3–1–4–1–5–8(1), II 2–1–4–1–5–8(1), III 1–2–2–0–3–4, IV 1–1–1–0–3–4; *1a* setae of coxa very long; Femur I with 3 squamous setae (2 dorso-lateral and 1 ventral) and 1 pubescent ventral seta; Femur II with 3 dorsal-lateral squamous setae and 1 pubescent ventral seta.

Remark on female morphology. Underneath of the genitoventral shield there is a complex of integument folds. Similar structure was illustrated in *T. moraesii* Feres & Hernandez description, and mentioned in description of *T. bacuri* Flechtmann and Noronha 2013, as probable ovipositor.

MALE: Unknown.

Immatures. larvae, protonymphs and deutonymphs have the full complement of dorsal setae of the adult, squamous setae, viz. 3 prodorsal pairs (*ve*, *sci* and *sce*) and 10 hysterosomal pairs (*c1*, *c3*, *d1*, *d3*, *e1*, *e3*,

f2, *f3*, *h1* and *h2*). Central region of idiosoma covered by transverse rows of integument folds.

LARVA: (5 paratypes) (Fig. 9). Body length 140–150; width 100–115. *Dorsal setae*. *ve* 7–11, *sci* 13–15, *sce* 22–27, *c1* 13–17, *c3* 11–15, *d1* 13–16, *d3* 10–11, *e1* 4–6, *e3* 8–13, *f2* 9–13, *f3* 10–13, *h1* 8–11, *h2* 100. *Legs*. Setation (from coxa to tarsus): I 1–0–3–0–5–7(1), II 0–0–3–0–5–7(1), III 0–0–2–0–3–3.

PROTONYMPH: (3 paratypes) (Fig. 10). Body length 185–200; width 135–145. *Dorsal setae*. *ve* 3–7, *sci* 12–14, *sce* 30–33, *c1* 15–17, *c3* 14, *d1* 13–15, *d3* 7–10, *e1* 2–3, *e3* 9–12, *f2* 11–12, *f3* 10–12, *h1* 8–10, *h2* 58–78. *Legs*. Setation (from coxa to tarsus): I 2–0–4–1–5–8(1), II 3–0–4–1–5–8(1), III 1–1–2–0–3–4, IV 0–0–1–0–3–3.

DEUTONYMPH: (2 paratypes) (Fig. 11). Body length 250–255; width 170–175. *Dorsal setae*: *ve* 5–6, *sci* 13–14, *sce* 36–37, *c1* 14–16, *c3* 15–18, *d1* 13–14, *d3* 13–14, *e1* 2–3, *e3* 10–11, *f2* 14–16, *f3* 15–16, *h1* 12, *h2* 80–90. *Legs*. Setation (from coxa to tarsus): I 2–1–4–1–5–8(1), II 2–2–4–1–5–8, III 1–2–2–0–3–4, IV 1–0–1–0–3–3.

Type material. Holotype female (DZSJRP n. 8935) ex *Alchornea glandulosa* Poepp. and Endl (Euphorbiaceae), **BRAZIL**: São Paulo State, Paulo de Faria, Estação Ecológica de Paulo de Faria, 19°55'S; 49°31'W, June 2003, coll. R. Buosi. Paratypes with same data as holotype (DZSJRP n. 8936–8938 and 8940–8941): 1 female, June 2003; 4 females, 2 deutonymphs, and 1 protonymph, February 2004; 1 female, 1 protonymph, and 2 larvae, November 2003; 3 females and 1 larva, November 2003; 2 females, 1 protonymph, and 1 larva, June 2003; and (NMNH n. 2065657–8939): 1 female and 1 larva, April 2004.

Etymology. The specific name *tapiæ* refers to the indigenous name (Tupi-Guarani) Tapiá, used to designate trees of the genus *Alchornea*, most common host plants of this new species, *A. glandulosa*.

Differential diagnosis. This species is placed in the *caudatus* group, *annonae* subgroup; it is morphologically similar to *T. heteropyxis* Meyer,

1993, differing by the presence of 1 solenidion on the 3rd palpal segment and *sci* setae longer than *sce* setae (2 solenidion on the 3rd palpal segment and *sci* setae shorter than *sce* setae in *T. heteropyxis*). *T. tapiae* **sp. nov.** is also similar to *T. smithi* Meyer, 1979, but it differs further by number of solenidion on the the 3rd palpal segment and length of the *sci* and *sce* setae, and also by the presence of 2 pairs of *IC4* setae (1 pair of *IC4* setae in *T. smithi*).

***Tenuipalpus apichai* Castro and Feres sp. nov.**

(Figs. 12–19)

Description. FEMALE: (holotype, Figs. 12–19). Body length 260 (245–260 in 8 paratypes); width 150 (140–160). *Dorsum* (Figs. 12–13). Prodorsal setae *ve* 5 (3–6) and *sci* 7 (7–10) short; *sce* 13 (13–15), approximately twice the length of *sci*; hysterosomal setae similar to prodorsal; except *h2* whiplike; *c1* 8 (7–8), *c3* 6 (6–7), *d1* 7 (6–7), *d3* 5 (5–6), *e1* 7 (5–7), *e3* 6 (5–7), *f2* 11 (7–10), *f3* 11 (8–11), *h1* 9 (8–10), *h2* 120 (135–190). *Venter* (Fig. 14). Ventral integument slightly striate; *IC3* setae short; *IC4* setae long, extend beyond the bases of genital setae; pre-genital e genital setae of similar length and longer than anal setae. *Gnathosoma* (Fig. 15). Palp 3-segmented, 2nd segment elongate and with long filiform dorso-distal seta; 3rd segment short bearing a solenidion (5 long). Legs (Figs. 16–19). Setation (from coxa to tarsus): I 3-1-4-2-5-8(1), II 2-1-4-2-5-8(1), III 1-2-2-0-3-5, IV 1-1-1-0-3-5; *1a* setae the coxa I elongate and extend beyond the base of *IC3* setae (Fig. 14); Femur I with 2 dorso-lateral squamous setae and 2 pubescent ventral setae; Femur II with 3 dorso-lateral squamous setae and 1 pubescent ventral seta. **Remark on female morphology.** Underneath of the genitoventral shield there is a complex of integument folds (Fig. 3).

MALE: Unknown.

Type material. Holotype female (DZSJRP n. 8942) ex *Celtis iguanae* (Jacq.) Sarg. (Ulmaceae), **BRAZIL:** São Paulo State, São José do Rio Preto, 20°46'S; 49°15'W, April 2003, coll. P.R. Demite. Paratypes: same data as holotype (DZSJRP ns. 8943–8945) 6 females; and (NMNH n. 2065657-8946): 2 females.

Etymology. the specific name, *apichai*, indigenous name (Tupi-Guarani) of wrinkly, refers to the aspect of the dorsal integument.

Differential diagnosis. This species is placed in the *caudatus* group, *anoplus* subgroup, and is morphologically similar to *T. burserae* De Leon, 1957, and *T. melhaniae* Meyer, 1979, but differs from both by the length and shape of the dorsal squamous setae (dorsal setae are smooth in *T. burserae*, and setiform in *T. melhaniae*), by the pattern of dorsal ornamentation, which is highly wrinkled in *T. apichai* **sp. nov.** and more linear in *T. burserae*, and by the pattern on the genital plate, which is more linear in *T. apichai* **sp. nov.** and reticulated in *T. melhaniae*.

***Tenuipalpus nambii* Castro and Feres sp. nov.**

(Figs. 20–27)

Description. FEMALE: (holotype, Figs. 20–27). Body length 210 (215–230 in 6 paratypes); width 125 (120–130). *Dorsum* (Figs. 20–21). With 2 small projections on dorso-sub lateral region of the prosoma; hysterosomal pores C shaped; prodorsal setae *ve* 9 (9–11), *sci* 12 (12–13) and *sce* 16 (17–19) smooth and similar hysterosomal setae, except *h2* whiplike; *c1* 9 (10–12), *c3* 7 (6–10), *d1* 6 (6–8), *d3* 7 (6–8), *e1* 7 (6–7), *e3* 7 (6–9), *f2* 9 (9–13), *f3* 9 (10–13), *h1* 9 (9–14), *h2* 195 (135–150). *Venter* (Fig. 22). Ventral integument smooth; *IC3* setae short; *IC4* setae elongate and extend beyond the bases of genital setae; genital setae short and similar length to anal setae. *Gnathosoma* (Fig. 23). Palp 2-segmented; 1st palpal segment elongate and with 1 smooth dorso-distal seta; 2nd segment short and with long solenidion (10 long). *Legs* (Figs. 24–27). Setation (from coxa

to tarsus): I 3-1-4-3-5-8(1), II 2-1-4-3-5-8(1), III 1-2- 2-0-3-4, IV 1-1-1-0-3-4; 1a setae of the coxa I elongate; Femur I with 3 squamous setae (2 dorsal and 1 ventral) and 1 pubescent ventral setae; Femur II with 3 dorsal setae (2 squamous setae and 1 pubescent) and 1 pubescent ventral seta.

MALE: Unknown.

Type material. Holotype female (DZSJRP n. 8947) ex *Sterculia striata* St. Hil. and Naud. (Malvaceae), **BRAZIL:** São Paulo State, São João de Iracema, 20°28'S; 50°17'W, March 2008, coll. P.R. Demite. Paratypes: same data as holotype (DZSJRP n. 8948) 5 females, December 2007; and (NMNH n. 2065657-8949): 1 female.

Etymology. The specific name, *nambii*, is a compound of the indigenous words (Tupi-Guarani) nambi = ear + i = small, referring to the presence of 2 small ear-shaped projections on dorso-sub lateral region of prosoma.

Differential diagnosis. This species is placed in the *caudatus* group and *anoplus* subgroup; it is morphologically similar to *T. lawrencei* Baker & Pritchard, 1960, and *T. mopaneae* Meyer, 1979, but differs from both by having palp 2-segmented and 1 solenidion on 2nd segment (palp 3-segmented and 3rd segment with 2 solenidion of unequal length in *T. lawrencei* and *T. mopaneae*), and by smooth dorsal setae (*sce*, *c3*, *d3*, *h3*, *e3* and *f2* setae elliptic-lanceolate and squamous in *T. lawrencei* and *T. mopaneae*).

Discussion

Despite the large number of known species of *Tenuipalpus*, only 14 (including those described here) were described from Brazil. Moreover, the Brazilian species were collected mainly in the states of São Paulo and Rio de Janeiro (Mesa et al. 2006; Feres & Hernandez 2006). This is a very small number, considering the extent of the areas of natural vegetation still existing in the country. The specificity of *Tenuipalpus* to a single host plant, and the scarce knowledge about the mite fauna associated with natural

vegetation, indicate that many species are still not recorded (Arruda-Filho & Moraes 2002; Feres et al. 2007). Therefore, the samplings of mite fauna in various regions of the country should reveal the true diversity of this genus in Brazil.

Key to the Brazilian species of *Tenuipalpus* based on females

Variations occur in the setation of tibiae I and II in some specimens of *T. bacuri* Flechtmann and Noronha. These variations, 4 or 5 setae, were observed among different specimens as well as in the same specimen in relation to the left and right legs. The same applies to the setal count on trochanter III: 1 seta in a few specimens, 2 setae in most females (C.H.W. Flechtmann, personal communication).

- 1 With 7 pairs of dorso-lateral setae *caudatus* group 2
- With 6 pairs of dorso-lateral setae *proteae* group 12
- 2 With 2 pairs of *IC3* and 1 pairs of *IC4*
..... *bakeri* subgroup... *T. orchidofilo* Moraes and Freire
- With 1 pair of *IC3*.....3
- 3 With 2 pairs of *IC4* *annonae* subgroup... 4
- With 1 pair of *IC4*..... *anoplus* subgroup... 5
- 4 Setal formula of genua 3-3-1-0
..... *T. carlosflechtmanni* Feres and Hernandez
- Setal formula of genua 1-1-0-0 *T. tapiae* **sp. nov.** Castro and Feres
- 5 Palpus 2-segmented; with 2 small projections on dorso-sub lateral region of prossoma..... *T. nambii* **sp. nov.** Castro and Feres
- Palpus 3-segmented; without 2 small projections on dorso-sub lateral region of prossoma6
- 6 Genu I and II with 1 seta each *T. heveae* Baker
- Genu I and II with 2 or 3 setae each7

7 Genu I and II with 2 setae	8
- Genu I and II with 3 setae	10
8 Median area of propodosoma smooth	
..... <i>T. bacuri</i> Flechtmann and Noronha	
- Median area of propodosoma wrinkled	9
9 Dorsal ornamentation softly wrinkled; all prodorsal and hysterosomal setae reduced (except <i>h2</i>), not longer than 8	
..... <i>T. moraes</i> Feres and Hernandez	
- Dorsal ornamentation highly wrinkled; prodorsal setae <i>sce</i> not reduced, (13–15 long)	<i>T. apichai</i> sp. nov. Castro and Feres
10 Setae <i>sce</i> and <i>sci</i> subequal in length, (10–12 long) and (10 long), respectively	<i>T. oxalis</i> (Flechtmann)
- Setae <i>sci</i> and <i>sce</i> strongly differing in length	11
11 Setae <i>sci</i> longer than <i>sce</i> , (20–22 long) and (8–12 long), respectively	
..... <i>T. ariauae</i> Feres and Hernandez	
- Setae <i>sci</i> shorter than <i>sce</i> , (5–6 long) and (30–32 long), respectively	
..... <i>T. oliveirai</i> Flechtmann	
12 With 1 pair of <i>IC3</i> and 2 pairs of <i>IC4</i>	
..... <i>keiensis</i> subgroup... <i>T. isabelae</i> Mesa, Moraes and Ochoa	
- With 1 pair each of <i>IC3</i> and <i>IC4</i>	<i>rhysi</i> subgroup ...13
13 With lateral projection in anterior region of coxa III.....	
..... <i>T. flechtmanni</i> Mesa, Moraes and Ochoa	
- Without lateral projection in the anterior region of coxa III.....	
..... <i>T. latiseta</i> Aranda	

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We thank C.H.W. Flechtmann (ESALQ-USP, Brazil), for the critical review of the manuscript and suggestions. The new species described were collected with financial support of the “Fundação de Amparo à Pesquisa do Estado de São Paulo” (FAPESP) (Procs. n°s. 02/12086-4 and

06/55725-6). This work was supported by the “Coordenação de Aperfeiçoamento de Pessoal de Nível Superior” (CAPES) and “Conselho Nacional de Desenvolvimento Científico e Tecnológico” (CNPq) (Proc. n° 303049/2010-3), by fellowship and research grant to first and second authors, respectively.

References

- Arruda-Filho, G.P. de & Moraes, G.J. de. (2002) Grupos de ácaros (Arthropoda, Acari) encontrados em Arecaceae da Mata Atlântica do estado de São Paulo. *Biota Neotropica*, 2, 1–18. <http://dx.doi.org/10.1590/s1676-06032002000100007>
- Baker, E.W. & Pritchard, A.E. (1960) The tetranychoid mites of Africa. *Hilgardia*, 29 (11), 455–574.
- Feres, R.J.F. & Hernandez, F.A. (2006) Three new species of *Tenuipalpus* (Acari, Tenuipalpidae) from the State of São Paulo, Brazil. *Zootaxa*, 1125, 57–68.
- Feres, R.J.F., Buosi, R., Daud, R.D. & Demite, P.R. (2007) Padrões ecológicos da comunidade de ácaros em euforbiáceas de um fragmento de mata Estacional Semidecidual, no Estado de São Paulo. - *Biota Neotropica*, 7, 2. [Available from: <http://www.biotaneotropica.org.br/v7n2/pt/abstract?article+bn04907022007> (Accessed 20 Apr. 2013)]
- Flechtmann, C.H.W. & Noronha, A.C.S. (2013) A new species of the genus *Tenuipalpus* (Prostigmata: Tenuipalpidae) with remarks on a conceivable ovipositor in flat mites. *Zootaxa*, 3681 (4), 493–499. <http://dx.doi.org/10.11646/zootaxa.3681.4.10>
- Grandjean, F. (1939) Les segments post-larvaires de l’hysterossoma chez les Oribates (Acariens). *Bulletin de la Societe Zoologique de France*, 64, 273–284.

- Kethley, J. (1990) Acarina: Prostigmata (Actinedida). In: Dindal, D.L. (Ed.), Soil Biology Guide. John Wiley & Sons, New York, pp. 667–756.
- Mesa, N.C., Moraes, G.J. de & Ochoa, R. (2006) Two new species of *Tenuipalpus* (Acari: Tenuipalpidae) from southeastern Brazil. Zootaxa, 1138, 45–51.
- Mesa, N.C., Ochoa, R., Welbourn, W.C., Evans, G.A. & Moraes, G.J.de. (2009) A catalog of the Tenuipalpidae (Acari) of the World with a key to genera. Zootaxa, 2098, 1–185.
- Meyer, M.K.P.S. (1979) The Tenuipalpidae (Acari) of Africa with keys to the world fauna. Entomology Memoir of the Department of Agriculture Republic South Africa, 50, 1–135.
- Meyer, M.K.P.S. (1993) A revision of the genus *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) in the Afrotropical Region. Entomology Memoir of the Department of Agriculture Republic South Africa, 88, 1–84.

Figures

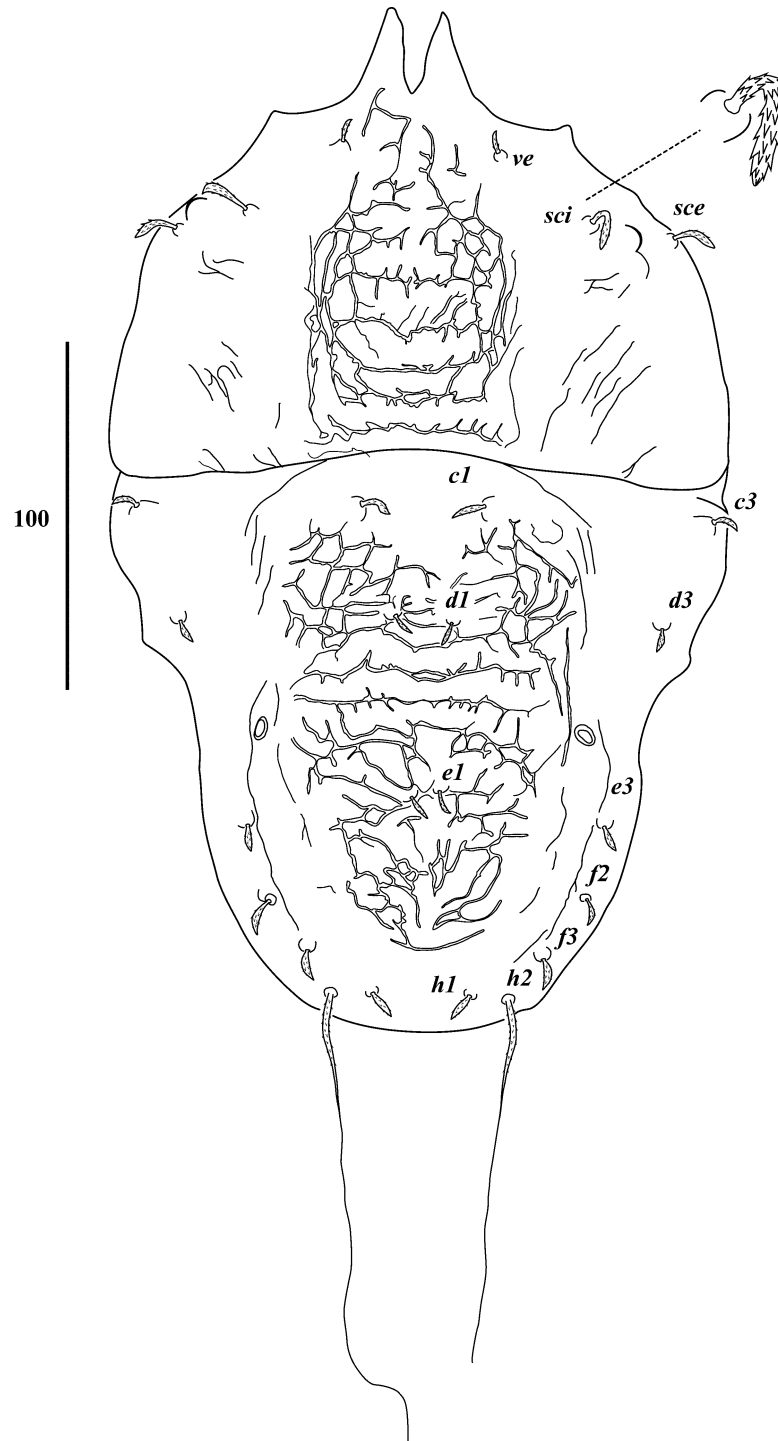


FIGURE 1. *Tenuipalpus tapiae* **sp. nov.**, female dorsum, with details of the squamous seta.

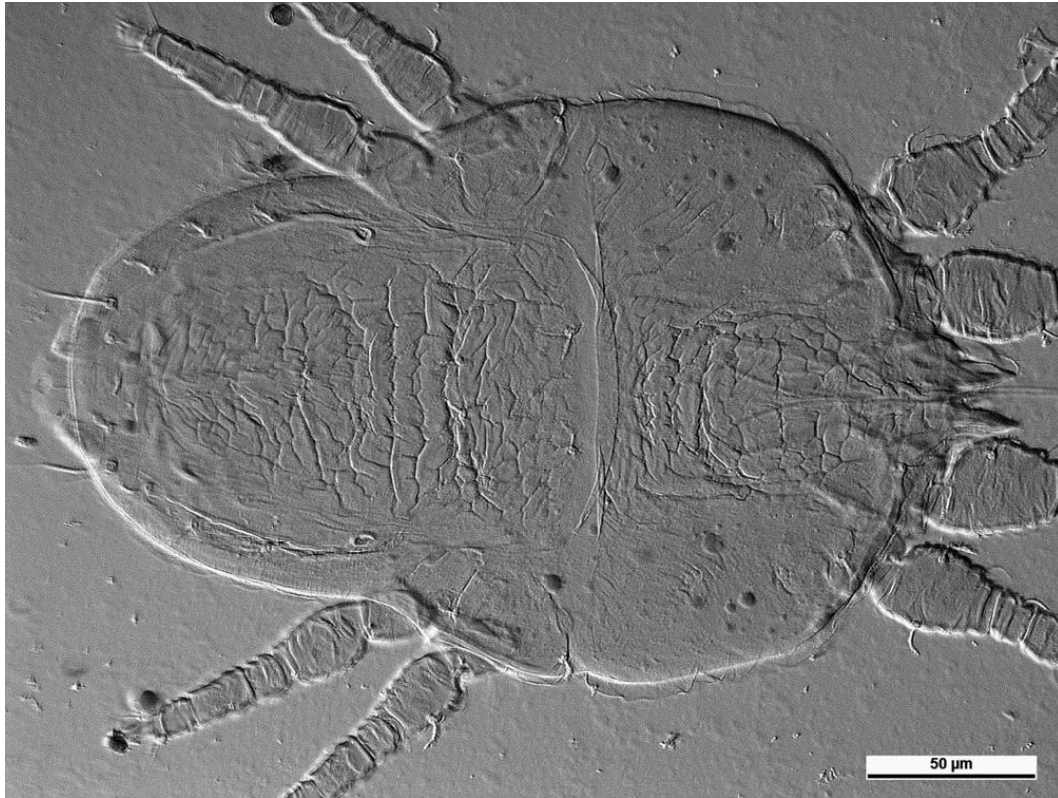
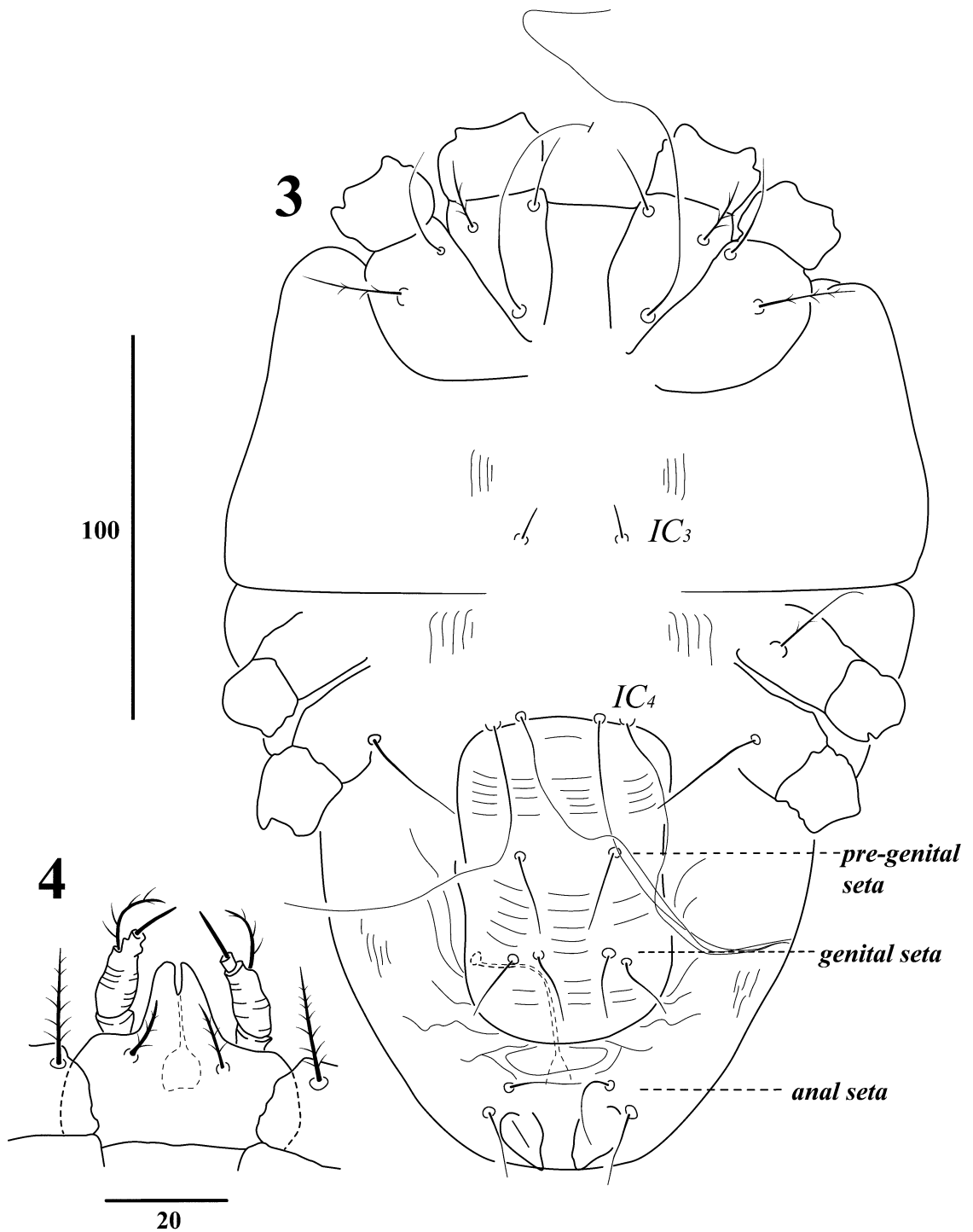
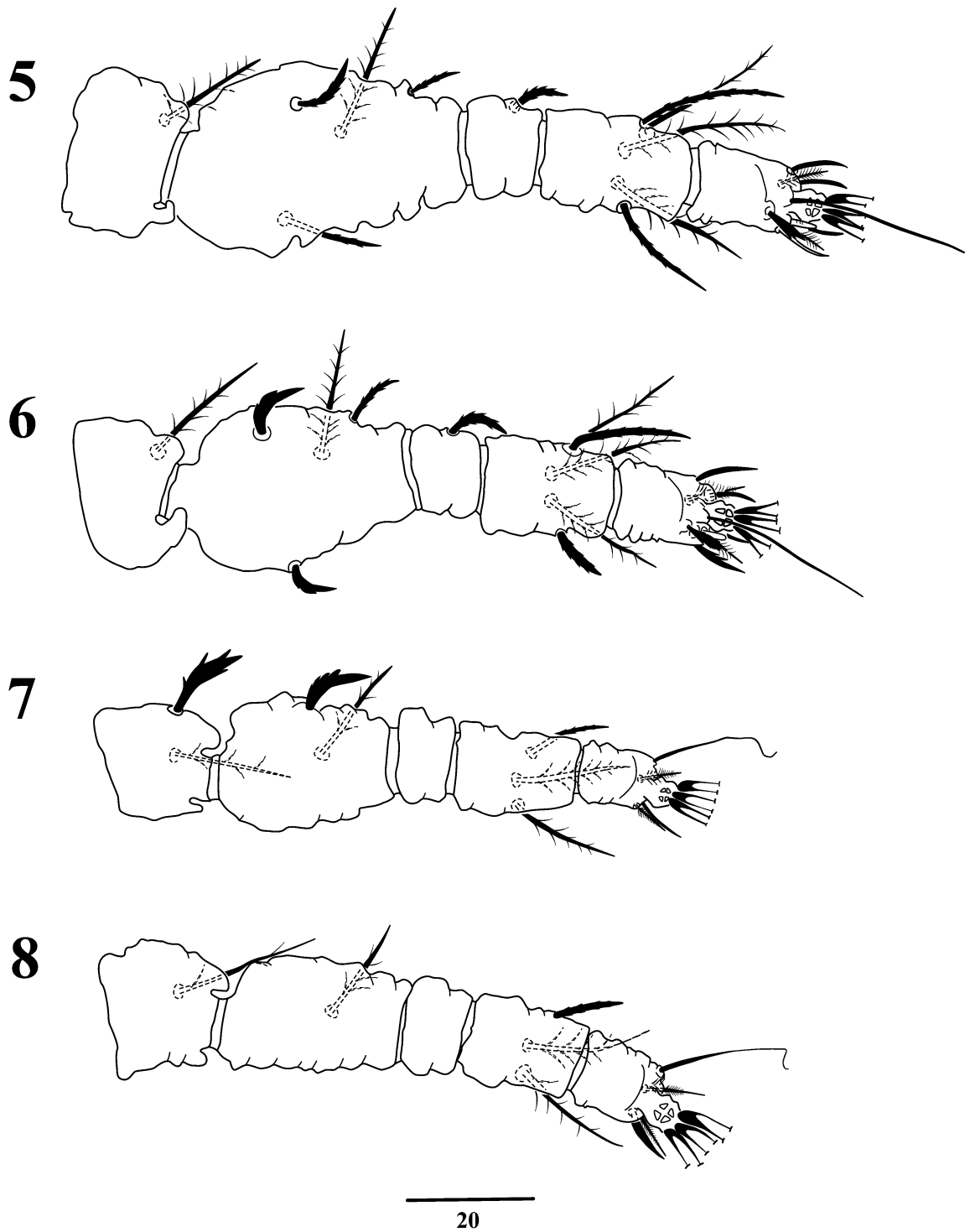


FIGURE 2. *Tenuipalpus tapiae* **sp. nov.**, female dorsum.



FIGURES 3–4. *Tenuipalpus tapiae* **sp. nov.**, female. 3. venter, 4. hypostome ventral.



FIGURES 5–8. *Tenuipalpus tapiae* **sp. nov.**, female legs I–IV, respectively.

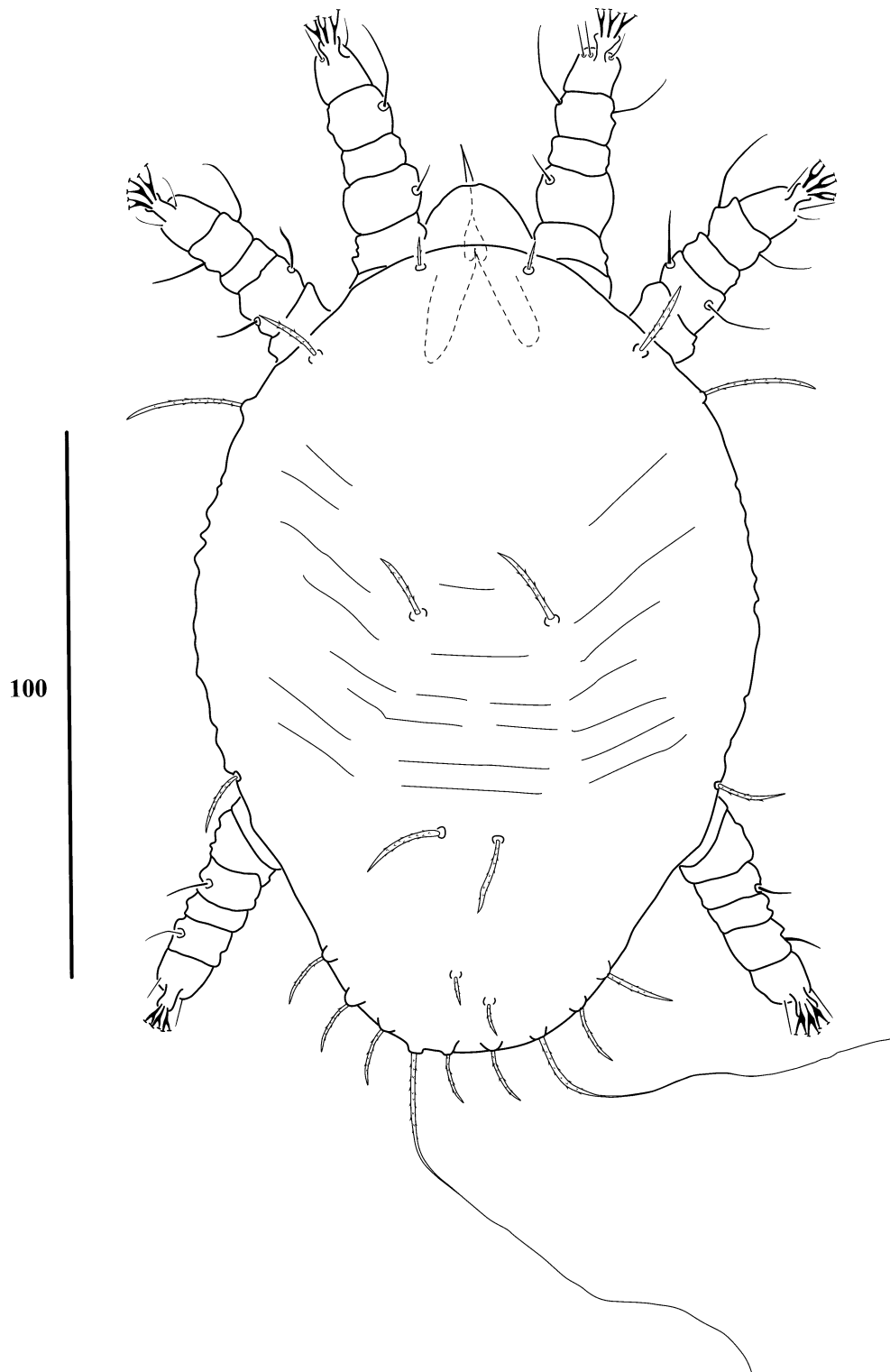


FIGURE 9. *Tenuipalpus tapiae* **sp. nov.**, larva dorsum.

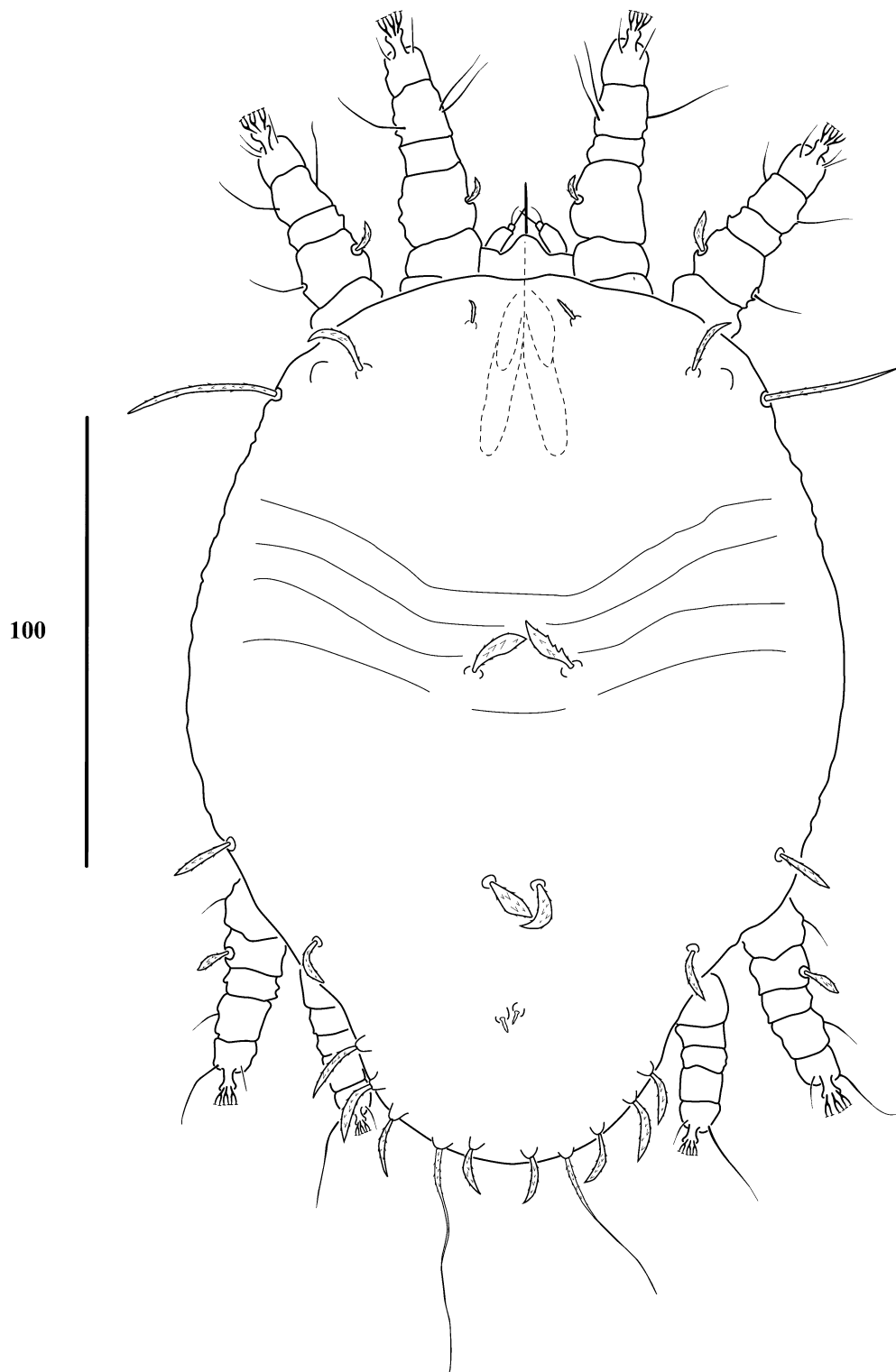


FIGURE 10. *Tenuipalpus tapiae* sp. nov., protonymph dorsum.

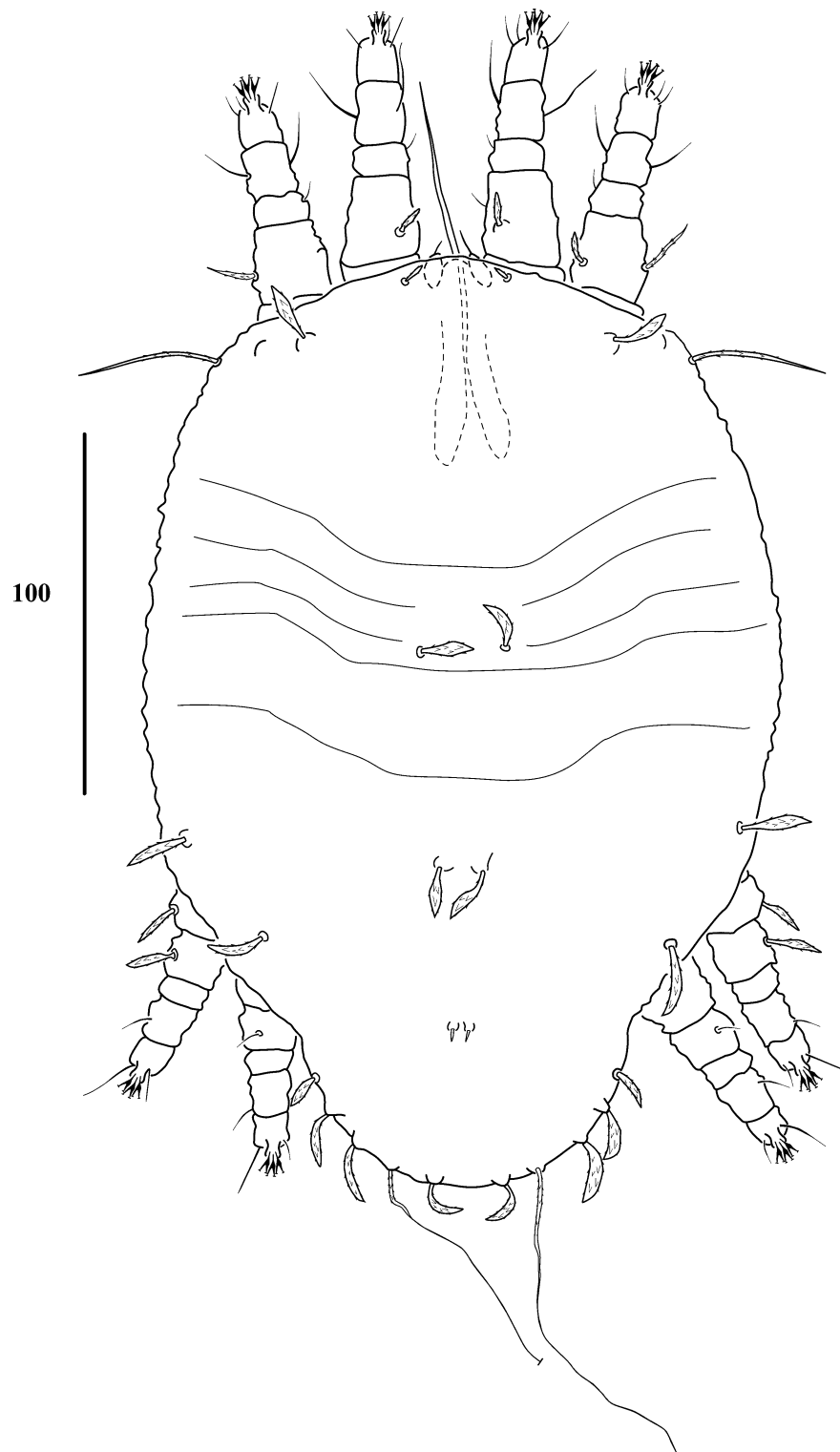


FIGURE 11. *Tenuipalpus tapiae* sp. nov., deutonymph dorsum.

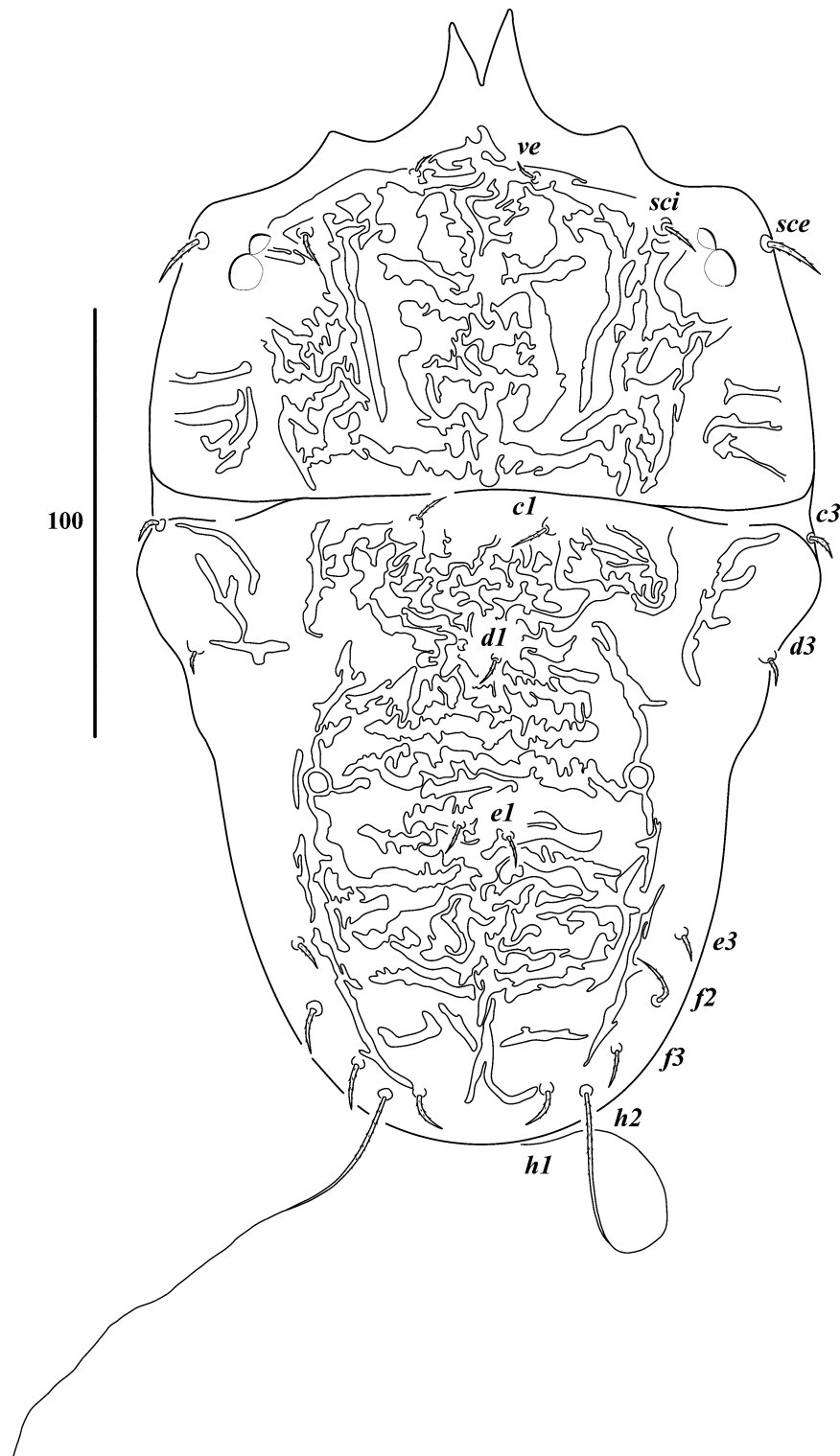


FIGURE 12. *Tenuipalpus apichai* sp. nov., female dorsum.

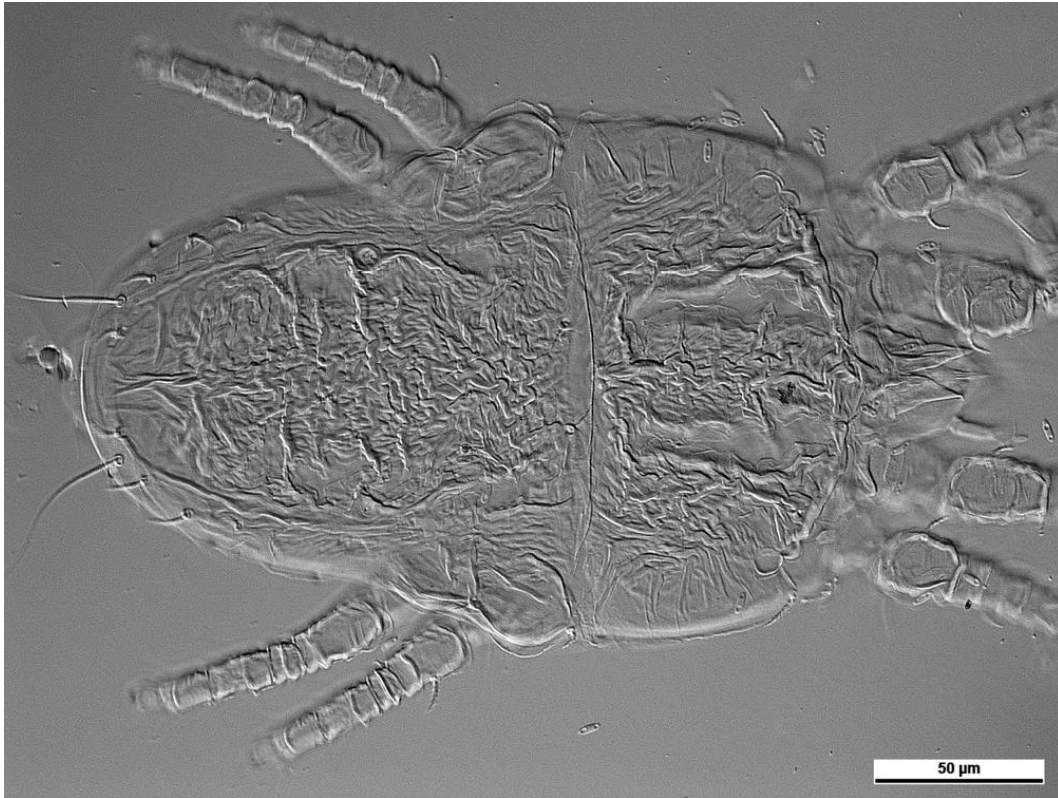


FIGURE 13. *Tenuipalpus apichai* **sp. nov.**, female dorsum.

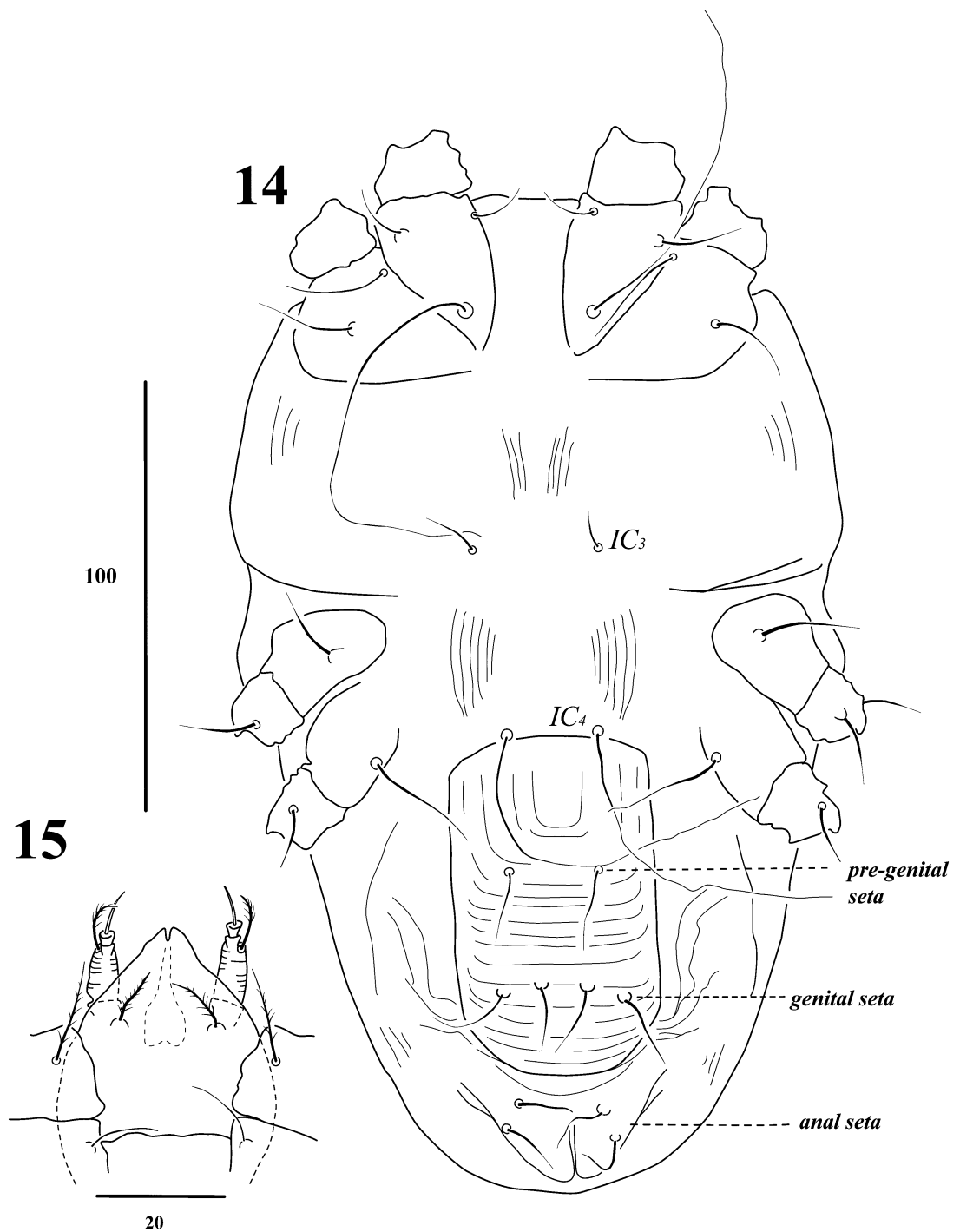
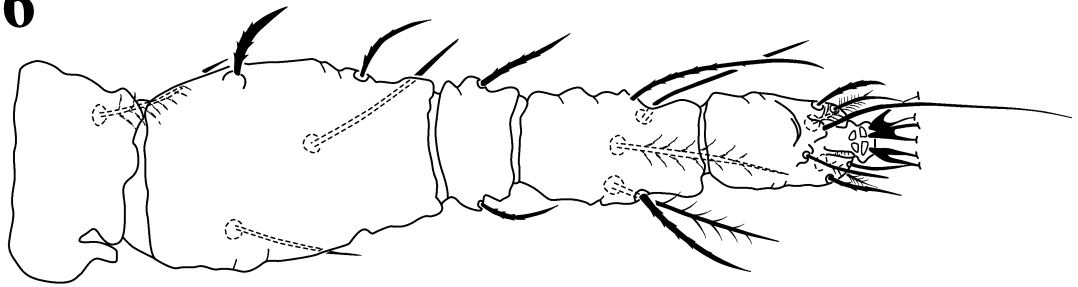
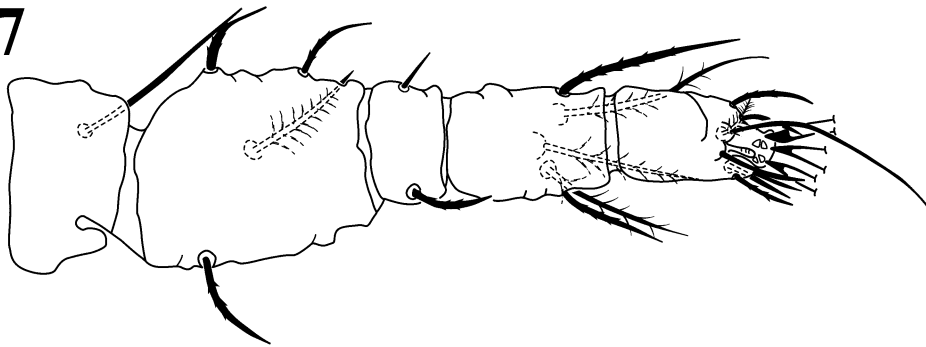


FIGURE 14–15. *Tenuipalpus apichai* **sp. nov.**, female. 14. venter, 15. hypostome ventral.

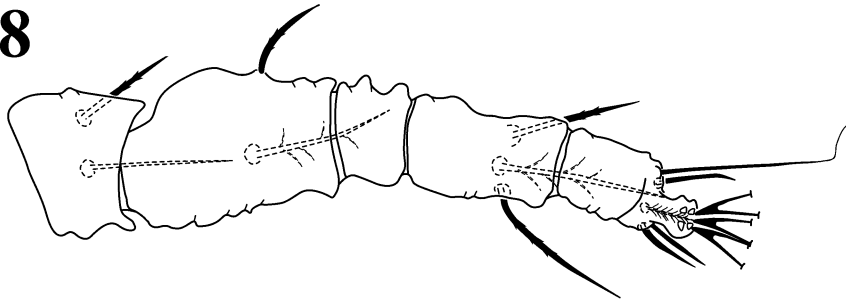
16



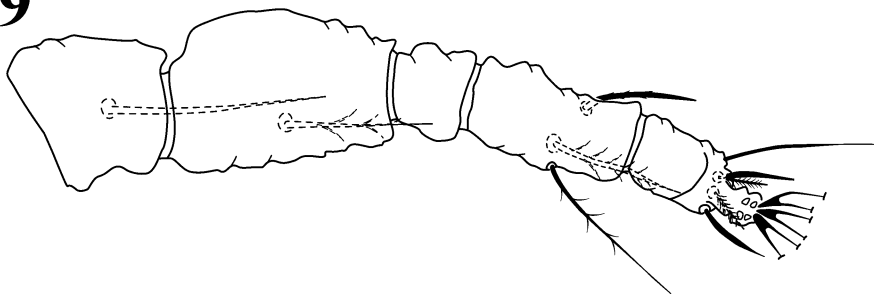
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19



20

FIGURES 16–19. *Tenuipalpus apichai* sp. nov., female legs I–IV, respectively.

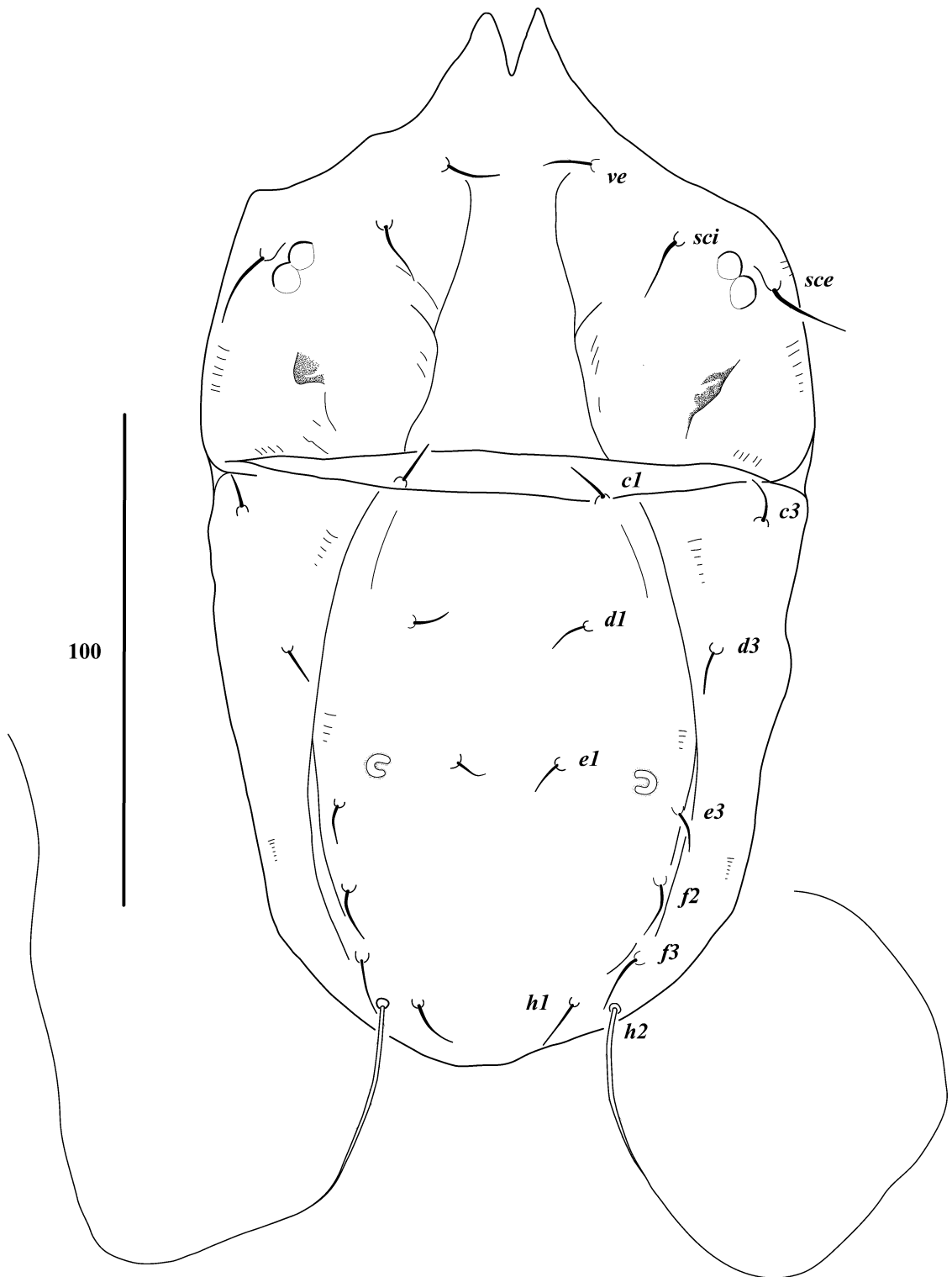


FIGURE 20. *Tenuipalpus nambii* sp. nov., female dorsum.

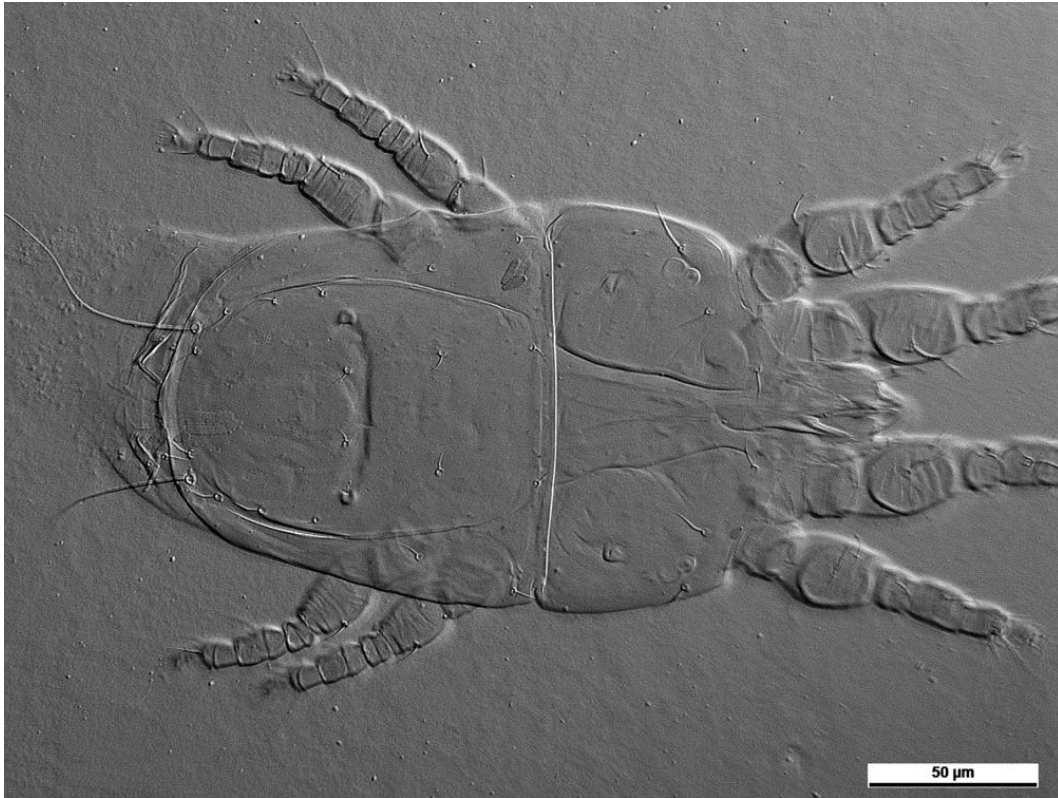


FIGURE 21. *Tenuipalpus nambii* **sp. nov.**, female dorsum.

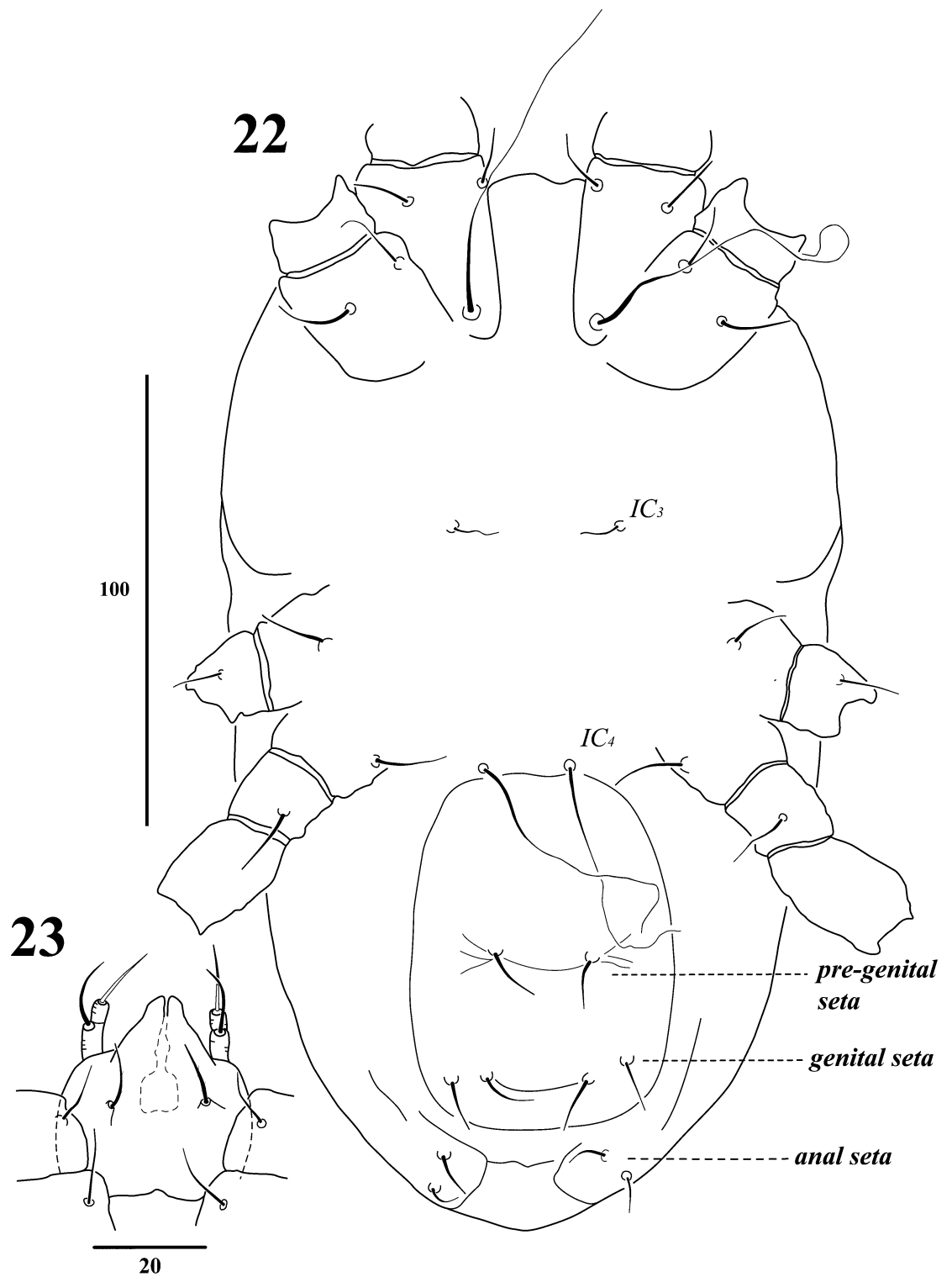
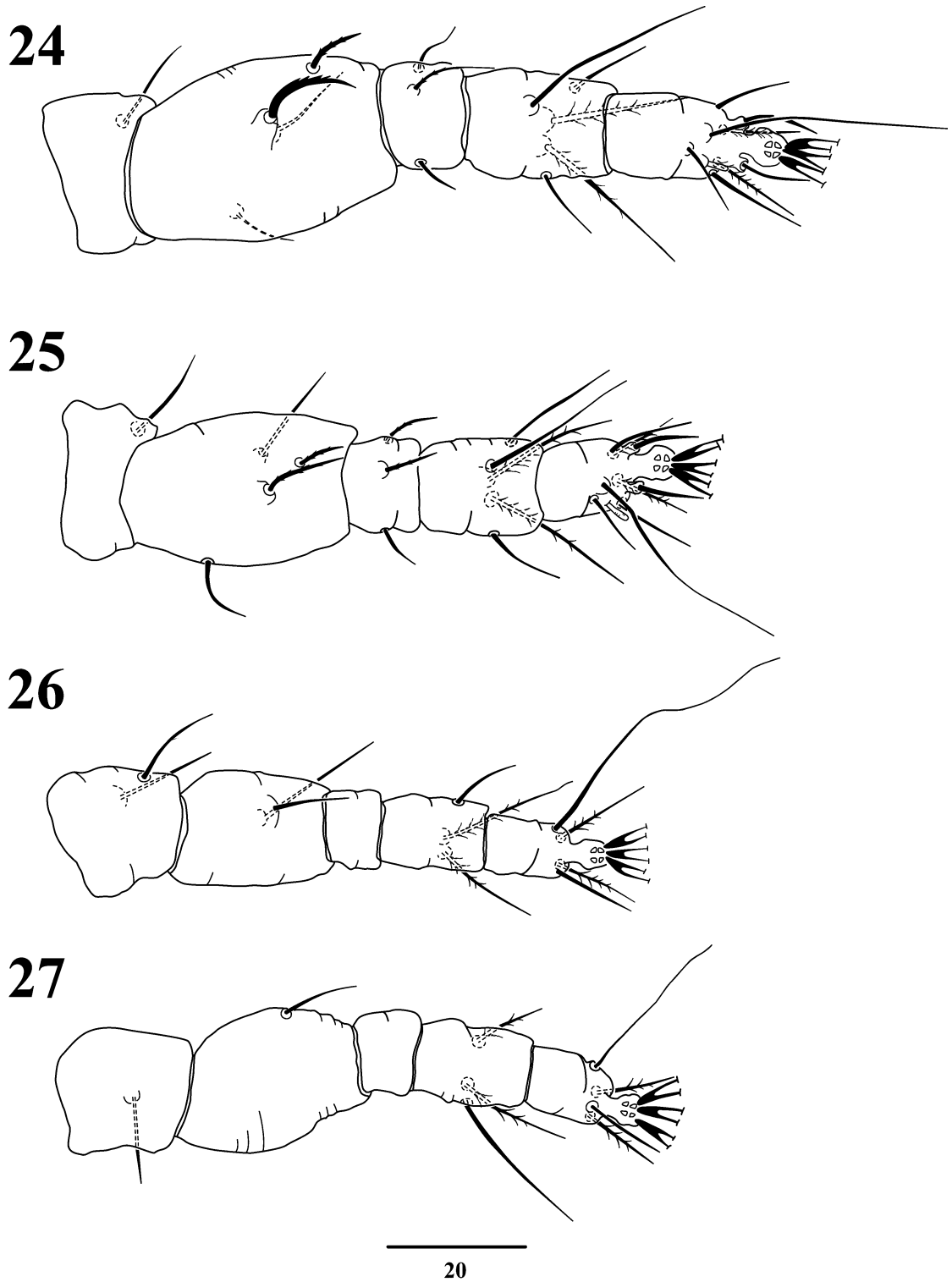


FIGURE 22–23. *Tenuipalpus nambii* **sp. nov.**, female. 22. venter, 23. hypostome ventral.



FIGURES 24–27. *Tenuipalpus nambii* sp. nov., female legs I–IV, respectively.

CHAPTER 2

A NEW SPECIES OF *TENUIPALPUS* DONNADIEU (ACARI: TENUIPALPIDAE) FROM BRAZIL, WITH ONTOGENY OF CHAETOTAXY

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**Authors: Elizeu B. de Castro, Felipe A.M. Ramos, Reinaldo J.F. Feres
and Ronald Ochoa**

Abstract

Tenuipalpus toropi **sp. nov.**, is described from females, males, deutonymphs, protonymphs and larvae collected on *Sapium glandulatum* (Vell.) Pax (Euphorbiaceae) from the northwest of the State of São Paulo, Brazil. We include details of the ontogenetic changes in idiosomal and leg chaetotaxy for all stages.

Keywords: flat mites, taxonomy, ontogeny, biodiversity, Euphorbiaceae

Introduction

Tenuipalpus Donnadieu is the largest genus of the family Tenuipalpidae (Acari: Prostigmata), containing 312 known species of which 14 are described from Brazil (Mesa et al. 2009; Flechtmann & Noronha 2013; Castro & Feres 2013). In this paper, we describe *Tenuipalpus toropi* **sp. nov.** from females, males, deutonymphs, protonymphs and larvae, collected on *Sapium glandulatum* (Vell.) Pax (Euphorbiaceae), from the remains of the semidecidual forest in the State of São Paulo, Brazil. The ontogenetic changes in idiosomal and leg chaetotaxy of all stages are presented for this new species.

Material and Methods

Measurements for the holotype are given in micrometers (μm), with the range of measurements for the paratypes shown in parentheses. Photographs taken using differential interference contrast (DIC) microscopy are included. Photograph of an exsiccata of the host plant, *Sapium glandulatum*, is included. The terminology used follows that of Lindquist (1985) and Mesa et al. (2009). Leg chaetotaxy is adapted from Lindquist (1985), Zhang & Fan (2004), Xu & Fan (2010) and Seeman & Beard (2011). Tarsal setae are presented as the total number followed by the number of solenidia in parentheses. The specimens were collected on

native plants in semideciduous forest remnants from the northwest of the State of São Paulo, Brazil.

Type specimens are deposited in the collection of Acari, Departamento de Zoologia e Botânica, Universidade Estadual Paulista (UNESP), São José do Rio Preto, State of São Paulo, Brazil (DZSJRP, <http://www.splink.cria.org.br>) and in the National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located in the Systematic Entomology Laboratory (SEL), USDA, Beltsville, Maryland, USA (NMNH).

Family Tenuipalpidae Berlese, 1913

Genus *Tenuipalpus* Donnadieu, 1875

Type species *Tenuipalpus caudatus* (Dugès), 1834

Diagnosis. Prodorsum with 3 pairs of setae (*v2*, *sc1*, *sc2*); dorsal opisthosoma with 8–10 setae (*c3*, *d3*, *e3*, *f3*, *h1*, *h2* present; *c2*, *d2*, *e2* absent; *c1*, *d1*, *e1*, *f2* present or absent (*d1*, *e1* rarely absent)); setae *h2* elongate, flagellate; anterior margin of prodorsum extended medially in forked projection over the gnathosoma or broad flat plate emerging from trochanter II to trochanter II extending over the gnathosoma; two pairs of genital setae (*g1–g2*); two pairs pseudanal setae (*ps1–2*); ventral setae 3*a* and 4*a* often multiplied (1–3 pairs 3*a*, 1–6 pairs 4*a*); ventral cuticle often with weakly sclerotized plates; ventral and genital plates often developed, sometimes fused; anal plates not developed; palps 1–3 segmented; femora, genua, tibiae with *d* setae inserted in lateral position; true claws and empodia pad-like.

***Tenuipalpus toropi* sp. nov. Castro, Ramos & Feres (Figs 1–16)**

Diagnosis. FEMALE: Dorsum weakly striated; dorsal propodosoma with 3 pairs of squamous setae; dorsal opisthosoma with 10 pairs of setae

present; setae *c1*, *c3*, *d1*, *d3*, *e1* minute; setae *e3*, *f2*, *f3*, *h1* short; setae *h2* whip-like. Venter with 1 pair setae *3a* and *4a*; genito-ventral region with striate soft cuticle (plates not developed). Palps 3-segmented. MALE: Dorsal setae similar to those of female; opisthosoma distinctly narrower than propodosoma. Ventral integument with longitudinal striae in the propodosomal margin, and transverse swirling striae between setae *ag-g1*. IMMATURES: Dorsal setae similar to those of adults, except *c3*, *e3*, *f2*, *f3* palmate in protonymphs and deutonymphs; cuticle on propodosoma and legs of larvae with colliculate sculpturing.

Type material examined: Holotype female collected on *Sapium glandulatum* (Vell.) Pax (Euphorbiaceae) (Fig. 17), from Paulo de Faria, São Paulo, Brazil, 19°55'S; 49°31'W, April 2004, coll. R. Buosi (DZSJRP n. 9540). Paratypes: 5 females, 4 males, 1 pharate female, 3 larvae, 3 protonymphs and 4 deutonymphs, same data as holotype (DZSJRP n. 9541 to 9547); 2 females, same data as holotype (DZSJRP n. 9548, USNM).

Description

FEMALE (Figs 1–8, n=8).

Dorsum (Figs 1–2). Body measurements: distance between setae *v2-h1* 265 (260–285), *sc2-sc2* 150 (150–160); other measurements: *v2-v2* 39 (34–40), *sc1-sc1* 95 (92–95), *c1-c1* 43 (38–45), *c3-c3* 184 (180–185), *d1-d1* 15 (15–21), *d3-d3* 165 (145–165), *e1-e1* 11 (11–16), *e3-e3* 114 (92–115), *f2-f2* 97 (86–97), *f3-f3* 78 (69–78), *h2-h2* 58 (49–64), *h1-h1* 31 (21–31). Rostral shield with sharply tapered forked projection medially, reaching middle of femur of leg 1, with two small lobes anterolaterad setae *v2*. Dorsal cuticle ornamented with weak irregular reticulations of large incomplete cells, and transverse folds. Dorsal setae mostly minute to short and barbed; setae *sc2* longer and *h2* whip-like. Setal lengths: *v2* 4 (3–5), *sc1* 6 (4–6), *sc2* 26 (26–38), *c1* 6 (4–6), *c3* 8 (7–

10), *d1* 5 (4–5), *d3* 4 (4–6), *e1* 5 (4–6), *e3* 10 (7–10), *f2* 13 (11–14), *f3* 12 (12–13), *h1* 12 (10–12), *h2* 210 (180–210).

Venter (Fig. 3). Integument smooth on central region, propodosomal margin longitudinally striate and finely colliculate laterally; small area of transverse striae surrounding 3a setae. Ventral plate not developed, transversely striate soft cuticle; few striae in the opisthosomal borders. Setae 1c and 2c barbed, others smooth; 4a setae elongate and flagelliform. Setal lengths: 1a 140 (125–140), 1b 10 (10–12), 1c 17 (10–17), 2b 12 (9–15), 2c 26 (20–27), 3a 10 (10–11), 3b 25 (22–30), 4a 115 (75–125), 4b 30 (25–32), ag 26 (24–30), g1 24 (22–25), g2 22 (20–24), ps1 17 (17–18), ps2 21 (18–25).

Gnathosoma (Fig. 4). Palps 3-segmented, second segment elongate bearing 1 long, barbed seta *d* 10 (10–13); third segment short with 1 eupathidium *ul'* 7 (7–8). Ventral setae *m* 11 (10–13); distance between setae *m–m* 15 (12–15).

Legs (Figs. 5–8) Chaetotaxy (from coxae to tarsi): I 2-1-4-3-5-8(1), II 2-1-4-3-5-8(1), III 1-2-2-1-3-4, IV 1-1-1-0-3-4. Tarsi I and II each with 1 solenidion ω [tarsi I 5 (4–5) and tarsi II 4 (4–5)] and 2 eupathidia *p'* and *p* (6–9, 6–8; 6–9, 6–8 respectively). Details of the pattern of ontogenetic additions of leg chaetotaxy are presented in Table 1.

MALE (Figs. 9–12, n=4).

Dorsum (Figs. 9–10) Body measurements: distance between setae *v2–h1* 215–220, *sc2–sc2* 120–130; other measurements: *v2–v2* 28–30, *sc1–sc1* 69–75, *c1–c1* 30–34, *c3–c3* 130–140, *d1–d1* 21–31, *d3–d3* 100–110, *e1–e1* 6–9, *e3–e3* 60–65, *f2–f2* 57–62, *f3–f3* 50–58, *h2–h2* 28–43, *h1–h1* 18–21. Rostral shield similar to that of female. Dorsal cuticle weakly ornamented; opisthosoma distinctly narrower than propodosoma; dorsal setae similar to that of female. Setal lengths: *v2* 3–4, *sc1* 4–5, *sc2* 21–27, *c1* 3–5, *c3* 6–8, *d1* 4–5, *d3* 5, *e1* 5–6, *e3* 6–8, *f2* 10–12, *f3* 10–12, *h1* 7–11, *h2* 150–190.

Gnathosoma: Palps similar to those of female. Tibial seta *d* 9–10, tarsal eupathidium *ul'* 5–7. Ventral seta *m* 8–10; distance between setae *m–m* 11–12.

Venter (Fig. 11): Propodosomal margin heavily striated; region of transverse striae surrounding setae 3a more extensive than that present in female. Setal lengths: *1a* 90–115, *1b* 7–17, *1c* 12–15, *2b* 10–11, *2c* 16–21, *3a* 9–10, *3b* 17–25, *4a* 80–100, *4b* 20–25, *ag* 15–17, *g1* 11–14, *g2* 10–15, *ps1* 7–12, *ps2* 10–13. Setae *ps1* modified and inserted distally on the anal valves, in a slightly ventral position.

Legs: Same setal distribution as female; tarsi I and II each with 1 solenidion ω'' 7–8 (for both tarsi I and tarsi II) and 2 eupathidia *p'* and *p''* (6, 6; 6–7, 6–8 respectively).

Aedeagus (Fig. 12): As figured; 85–100 long.

LARVA (n=3).

Dorsum (Figs. 13–14) Body measurements: distance between setae *v2–h1* 155–160, *sc2–sc2* 97–98; other measurements: *v2–v2* 19–22, *sc1–sc1* 60–61, *c1–c1* 21–25, *c3–c3* 103–109, *d1–d1* 11, *d3–d3* 66–69, *e1–e1* 4–6, *e3–e3* 60–62, *f2–f2* 51–52, *f3–f3* 37–39, *h2–h2* 22–24, *h1–h1* 8–9. Longitudinal integument folds present in the center of the body. Propodosomal region with colliculate cuticle anteromedially; longitudinal to oblique folds sublaterally between setae *sc2–c1*.

Opisthosomal cuticle with weak widely spaced incomplete folds between setae *c1–d1*; with weak irregular striae and folds posteriorly. Setal lengths: *v2* 1–2, *sc1* 2, *sc2* 21–25, *c1* 2–3, *c3* 9–10, *d1* 2–3, *d3* 1–3, *e1* 3–4, *e3* 7–10, *f2* 10–14, *f3* 10–11, *h1* 7–9, *h2* 55–75.

Gnathosoma: Palps similar to that of adults. Tibial seta *d* 4–7, tarsal eupathidium *ul'* 4. Ventral setae *m* absent.

Venter: Integument with transverse striae, weak between setae *1a–3a*; cuticle with irregular pattern posterad *3a* setae. Setal lengths: *1a* 40–

50, *1b* 5–7, *3a* 4–5, *ps1* 4–5, *ps2* 4–5. As is normal for tenuipalpids, setae *1c*, *2b*, *2c*, *3b*, *4a*, *4b*, *ag*, *g1* and *g2* absent.

Legs: Chaetotaxy (from coxae to tarsi): I 1-0-3-1-5-6(1), II 0-0-3-1-5-6(1), III 0-0-2-0-3-3. Tarsi I and II each with 1 solenidion ω'' 2–3 (for both tarsi I and tarsi II) and 2 eupathidia *p'* and *p''* (4–5, 4–5; 5, 4–5 respectively). All legs covered with colliculate sculpturing.

PROTONYMPH (n=3).

Dorsum (Fig. 15) Body size measurements: distance between setae *v2–h1* 190–205, *sc2–sc2* 105–115; other measurements: *v2–v2* 20–22, *sc1–sc1* 65, *c1–c1* 23–29, *c3–c3* 125–141, *d1–d1* 11–19, *d3–d3* 86–99, *e1–e1* 4–12, *e3–e3* 69–76, *f2–f2* 63–68, *f3–f3* 49–52, *h2–h2* 30–31, *h1–h1* 11–12. Prodorsum smooth. Dorsal opisthosomal cuticle with widely spaced transverse folds between setae *c1–d1*; cuticle smooth posteriorly. Setal lengths: *v2* 1–2, *sc1* 1–2, *sc2* 32–36, *c1* 2, *c3* 11–14, *d1* 2, *d3* 1–3, *e1* 2, *e3* 11–15, *f2* 14–18, *f3* 15–16, *h1* 10–12, *h2* 60–80.

Gnathosoma: Palps similar to those of adults. Tibial seta *d* 6, tarsal eupathidium *ul'* 5. Ventral seta *m* 4–5; distance between setae *m–m* 9–10.

Venter: Integument covered with transversal striae, weak between setae *1a* and *3a*; cuticle with irregular pattern posterad *3a* setae. Setal lengths: *1a* 70, *1b* 4–6, *1c* 5–7, *2c* 9–10, *3a* 5–6, *3b* 7–9, *ag* 5–6, *ps1* 4–5, *ps2* 4–5. Setae *2b*, *4a*, *4b*, *g1* and *g2* absent.

Legs: Chaetotaxy (from coxae to tarsi): I 2-0-3-1-5-6(1), II 1-0-3-1-5-6(1), III 1-1-2-0-3-3, IV 0-0-1-0-3-3. Tarsi I and II each with 1 solenidion ω'' 3–4 (for both tarsi I and tarsi II) and 2 eupathidia *p'* and *p''* (4–5, 5; 5, 5 respectively).

DEUTONYMPH (n=4).

Dorsum (Fig. 16) Body size measurements: distance between setae *v2–h1* 200–285, *sc2–sc2* 115–135; other measurements: *v2–v2* 23–26, *sc1–sc1* 68–79, *c1–c1* 27–33, *c3–c3* 145–185, *d1–d1* 13–17, *d3–d3* 100–

130, *e1*–*e1* 6–9, *e3*–*e3* 74–94, *f2*–*f2* 70–83, *f3*–*f3* 40–64, *h2*–*h2* 36–39, *h1*–*h1* 14–16. Prodorsum cuticle smooth. Dorsal opisthosoma with widely spaced transverse folds between setae *c1*–*d1*; cuticle smooth posteriorly. Setal lengths: *v2* 1–2, *sc1* 2–3, *sc2* 32–39, *c1* 2–3, *c3* 13–17, *d1* 2, *d3* 2–3, *e1* 2–3, *e3* 11–20, *f2* 11–18, *f3* 14–17, *h1* 9–14, *h2* 85–105.

Gnathosoma: Palps similar to those of adults. Tibial seta *d* 7–8, tarsal eupathidium *ul'* 6. Ventral seta *m* 7–8; distance between setae *m*–*m* 9–10.

Venter: Integument covered with transverse striae, weak between setae *1a* and *3a*. Striae forming triangle pattern between *ag* setae. Setal lengths: *1a* 60–85, *1b* 6–11, *1c* 7–10, *2b* 6–12, *2c* 10–12, *3a* 5–9, *3b* 6–11, *4a* 40–70, *4b* 8–10, *ag* 7–9, *g1* 5–8, *ps1* 6–7, *ps2* 6–10. Setae *g2* absent.

Legs: Chaetotaxy (from coxae to tarsi): I 2-1-4-3-5-8(1), II 2-1-4-3-5-8(1), III 1-2-2-1-3-4, IV 1-0-1-0-3-3. Tarsi I and II each with 1 solenidion ω 3–4 (for both tarsi I and tarsi II) and 2 eupathidia *p'* and *p''* (5–6, 5–6; 5, 5 respectively). Details of the development of leg chaetotaxy in Table 1.

Etymology. The specific name *toropi* refers to the indigenous name (Tupi-Guarani language) Toropi, used to designate the host plant, *Sapium glandulosum* (L.) (Euphorbiaceae).

Remarks. Four Brazilian species of *Tenuipalpus* were collected from Euphorbiaceae plants (*T. heveae* Baker (1945), *T. moraes* Feres & Hernandez (2006), *T. isabelae* Mesa, Moraes & Ochoa (2006) and *T. tapiae* Castro & Feres (2013)), but none of them were collected on the same host species as *T. toropi* **sp. nov.** Furthermore, *T. toropi* is differentiated from these four species by the dorsal ornamentation pattern, the length of the dorsal setae and the presence of *3a* and *4a* setae.

This new species resembles *Tenuipalpus simarubae* De Leon (1965) collected from *Bursera simaruba* (L.) Sarg., a Burseraceae, in Puerto Rico, Caribbean Region, differing in the pattern of dorsal ornamentation, which is more striated on *T. toropi* **sp. nov.** and practically smooth on *T. simarubae*; *sc2* setae are approximately two times longer on

T. toropi than on *T. simarubae*; and the presence of colliculate cuticle on the ventral propodosomal margin, absent in *T. simarubae*. *Tenuipalpus toropi* **sp. nov.** bears one seta on genua III, whereas that of *T. simarubae* is bare. Also, larvae of both species have colliculate sculpturing on the propodosoma and legs. This pattern disappears in the protonymph and subsequent stages.

Ontogeny. Coxal seta *1b* is a larval seta. Coxal setae *1c*, *2c* and *3b* are added in the protonymph and setae *2b* and *4b* are added in the deutonymph. Setae *v'* on trochanters I, II and III appears in the deutonymph; *l'* on trochanters III appears in the protonymph; the addition of *v'* to trochanters IV is delayed until the adult. This pattern of expression of *v'* and *l'* is common in Tenuipalpidae, and is similar to that found in Tetranychidae (Lindquist 1985).

The presence of the setae *d*, *v'* and *bv'* on femora I and II of larvae is considered a synapomorphy in tetranychoid families (Lindquist 1985). Setae *l'* on femora I and II are added in the deutonymph. In most of the *Tenuipalpus* species, the number of femoral setae on the adult is 4-4-2-1 or 4-4-2-2 (Meyer 1979; Baker & Tuttle 1987).

Setae *l'* are present on genua I–II of the larva, and no additions occur in the protonymph. Setae *d* and *l''* are added to genua I and II in the deutonymph, so are setae *d* to genua III. The absence of setae on genua IV is common in tenuipalps, and may be considered a derived condition. The absence of setae on genua III was also reported for some tenuipalpid species (e.g. Beard *et al.* 2005; Xu & Zhang, 2013, 2014).

In *Tenuipalpus*, the common pattern of tibial setae is 5-5-3-3 in the adult, like that observed here, represents the larval complement. Although many additions are made to the tibiae in the Tetranychidae, no post-larval additions are made to the setal complement of the tibiae of many tenuipalps (Beard *et al.* 2014). Going further, there is a complete lack of additions in the deutonymph stage, and an almost complete lack of

additions in the adult stage for all tetranychoid families except the Tetranychidae (Beard *et al.* 2014).

Here, the pair of tectal setae, *tc'* and *tc''*, are added to tarsus I and II in the deutonymph. Setae *tc''* are added to tarsus III in the deutonymph and to tarsus IV in the adult; however, the addition of setae *tc'* is suppressed altogether on tarsus III and IV. In comparison, in the related taxon *Prolixus*, the tectal setae are added in a similar pattern but, in general, one stage earlier than that shown here for *T. toropi*. Setae *tc'* and *tc''* are added to tarsus I–II in the protonymph, while setae *tc''* are added to tarsus III–IV in the deutonymph, with setae *tc'* being suppressed. However, setae *tc'* are present in *P. forsteri*, and the tectal setae are added as a pair to legs III–IV in the deutonymph. The genus *Acaricis* has the same pattern of addition the tectal setae as *P. forsteri* (tectal pair added to tarsus I–III in protonymph, tectal pair added to tarsus IV in deutonymph). In contrast, the tectal pair is suppressed entirely in the genera *Gahniacarus* and *Cyperacarus* (Beard & Ochoa 2011). The suppression of one or both *tc* setae on tarsi III and IV, and even tarsi I–II, is a characteristic known to occur in tenuipalpids (Beard & Ochoa 2011; Beard *et al.* 2014; Xu *et al.* 2014). The suppression of these setae in some genera of Tetranychidae is considered a derived condition (Lindquist 1985).

Similar leg chaetotaxy in females and males has been observed in *Tenuipalpus* (e.g. *T. moraes* Feres & Hernandez, 2006 and *T. heveae* Baker, 1945). However, the males usually add one solenidion on tarsus I and II (e.g. *T. daneshvari* Khosrowshahi & Arbabi, 1997 (see Khanjani *et al.* 2013) and *T. eugeniae* De Leon, 1965), and sometimes on tarsi III (e.g. *T. caudatus* (Dugès), 1834). This characteristic occurs also in other genera of Tenuipalpidae, such as *Prolixus* and *Acaricis* (Beard *et al.* 2005; Beard & Gerson 2009), *Ultratenuipalpus*, and also in more distantly related taxa including *Dolichotetranychus*, *Raoiella* and *Obuloides* (R. Ochoa and J.J. Beard, pers. obs.). The pattern of additions to the leg chaetotaxy during

ontogeny is listed in Table 1. It is interesting to note that only two setae are added to the legs in the adult stage, *v'* to trochanter IV and *tc''* to tarsi IV.

In addition to the coxal setae discussed previously, the ventral chaetotaxy changes as follows: setae *1a*, *3a*, *ps1* and *ps2* are present in the larva (as in all tenuipalpids); *ag* is added in the protonymph, *4a* and *g1* appear in the deutonymph and *g2* is added in the adult. This pattern of ontogeny is similar that observed to Tetranychidae by Lindquist (1985). All setae of the gnathosoma are present in the larva, except setae *m* which are added in the protonymphs.

Discussion

The number of *Tenuipalpus* currently known species from Brazil is very small for a country of its size with such a large area of natural vegetation. Of the 15 Brazilian species (including the species described herein), 12 were described from São Paulo state alone (Mesa *et al.* 2009; Castro & Feres 2013; Flechtmann & Noronha 2013). Therefore, future sampling of the mite fauna in other regions and biomes of the country are predicted to produce many new taxa, and are necessary to better understand the distribution and diversity of this genus in Brazil.

References

- Baker, E.W. (1945) Mites of the genus *Tenuipalpus* (Acarina: Trichadenidae). *Proceedings of the Entomological Society of Washington*, 47(2), 33–38.
- Baker, E.W. & Tuttle, D.M. (1987) The false spider mites of Mexico (Tenuipalpidae: Acari). *United States Department of Agriculture, Agricultural Research Service, Technical Bulletin*, 1706, 1–236.
- Beard, J.J., Seeman, O.D. & Bauman, G.R. (2014) Tenuipalpidae (Acari: Trombidiformes) from Casuarinaceae (Fagales). *Zootaxa*, 3778(1), 1–157. <http://dx.doi.org/10.11646/zootaxa.3778.1.1>

- Beard, J.J. & Ochoa, R. (2011) New flat mite genera (Acari: Trombidiformes: Tenuipalpidae) associated with Australian sedges (Cyperaceae). *Zootaxa*, 2941, 1–37.
- Beard, J.J. & Gerson, U. (2009) A new flat mite genus, *Acaricis* (Prostigmata: Tenuipalpidae), from Australian sedges (Cyperaceae). *Zootaxa*, 2073, 31–44.
- Beard, J.J., Fan, Q.H. & Walter, D.E. (2005) A new genus and two new species of Tenuipalpidae (Prostigmata: Tetranychoida) from an Australian sedge. *Acarologia*, 45, 161–181.
- Castro, E.B.de & Feres, R.J.F. (2013) New species of *Tenuipalpus* (Acari: Tenuipalpidae) from Semidecidual Forest remnants in the State of São Paulo, Brazil. *Zootaxa*, 3716(3), 475–493. <http://dx.doi.org/10.11646/zootaxa.3716.3.9>
- De Leon, D. (1965) Four new *Tenuipalpus* from Puerto Rico with notes on some previously described species (Acarina: Tenuipalpidae). *Proceedings of the Entomological Society of Washington*, 67(3), 193–196.
- De Leon, D. (1965) False spider mites of Jamaica and the Dominican Republic (Acarina: Tenuipalpidae). *Annals of the Entomological Society of America*, 58(4), 517–523.
- Dugès, A. (1834) Recherches pour servir a l'ordre des Acariens en general et la famille des Trombidies en particulier. *Annales des Sciences Naturelles Paris* (ser. 2), 1, 5–46.
- Feres, R.J.F. & Hernandez, F.A. (2006) Three new species of *Tenuipalpus* (Acari, Tenuipalpidae) from the State of São Paulo, Brazil. *Zootaxa*, 1125, 57–68.
- Flechtmann, C.H.W. & Noronha, A.C.S. (2013) A new species of the genus *Tenuipalpus* (Prostigmata: Tenuipalpidae) with remarks on a conceivable ovipositor in flat mites. *Zootaxa*, 3681(4), 493–499. <http://dx.doi.org/10.11646/zootaxa.3681.4.10>

- Khanjani, M., Alvandy, S., Khanjani, M. & Seeman, O.D. (2013) The flat mites of the genus *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Iran. *International Journal of Acarology*, 39(2), 97–129. <http://dx.doi.org/10.1080/01647954.2012.742137>
- Lindquist, E.E. (1985) External anatomy. In: Helle, W. & Sabelis, M.W. (Eds), *Spider mites: their biology, natural enemies and control*. Vol. 1a. Elsevier, Amsterdam. pp. 3–28.
- Mesa, N.C., Ochoa, R., Welbourn, W.C., Evans, G.A. & Moraes, G.J.de. (2009) A catalog of the Tenuipalpidae (Acari) of the World with a key to genera. *Zootaxa*, 2098, 1–185.
- Meyer, M.K.P.S. (1979) The Tenuipalpidae (Acari) of Africa with keys to the world fauna. *Entomology Memoir of the Department of Agriculture Republic South Africa*, 50, 1–135.
- Seeman, O.D. & Beard, J.J. (2011) A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia. *Systematic and Applied Acarology*, 16(1), 73–89. <http://dx.doi.org/10.11158/saa.16.1.10>
- Xu, Y. & Fan, Q.H. (2010) *Tenuipalpus orilloi* Rimando, a new record to the Chinese fauna (Acari: Tenuipalpidae). *Systematic and Applied Acarology*, 15(2), 135–138.
- Xu, Y., Fan, Q.H. & Huang, J. (2014) Description of a new species of *Terminalichus* (Acari: Trombidiformes: Tenuipalpidae) from China. *Zootaxa*, 3753(3), 233–250. <http://dx.doi.org/10.11646/zootaxa.3753.3.3>
- Xu, Y. & Zhang, Z.-Q. (2013) New Zealand Tenuipalpidae (Acari: Trombidiformes): A new species of *Acaricis* from Cyperaceae and its ontogenetic patterns in chaetotaxy. *Systematic & Applied Acarology*, 18(4), 357–388. <http://dx.doi.org/10.11158/saa.18.4.6>.
- Xu, Y. & Zhang, Z.-Q. (2014) *Prolixus* (Acari: Trombidiformes: Tenuipalpidae) newly recorded from New Zealand: A new species from Cyperaceae and its ontogenetic patterns in chaetotaxy. *Zootaxa*, 3900(1), 1–20. <http://dx.doi.org/10.11646/zootaxa.3900.1.1>

Zhang, Z.-Q. & Fan, Q.-H (2004) Redescription of *Dolichotetranychus ancistrus* Baker & Pritchard (Acari: Tenuipalpidae) from New Zealand. *Systematic & Applied Acarology*, 9, 111–131.

TABLE 1. Ontogeny development of leg setae in *Tenuipalpus toropi* **sp. nov.** Setae are indicated in the stage in which they first appear. Setae in parentheses represent pairs.

	Coxa	Troch.	Femur	Genu	Tibia	Tarsi
Leg I						
Larva	1b	-	d, v', bv''	l'	d, (v), (l)	(u), (p), (ft), ω''
Protonymph	1c	-	-	-	-	-
Deutonymph	-	v'	l'	d, l''	-	(tc)
Adult	-	-	-	-	-	-
Leg II						
Larva	-	-	d, v', bv''	l'	d, (v), (l)	(u), (p), (ft), ω''
Protonymph	2c	-	-	-	-	-
Deutonymph	2b	v'	l'	d, l''	-	(tc)
Adult	-	-	-	-	-	-
Leg III						
Larva	-	-	d, ev'	-	d, (v)	(u), ft'
Protonymph	3b	l'	-	-	-	-
Deutonymph	—	v'	-	d	-	tc''
Adult	-	-	-	-	-	-
Leg IV						
Protonymph	-	-	ev'	-	d, (v)	(u), ft'
Deutonymph	4b	-	-	-	-	-
Adult	-	v'	-	-	-	tc''

Figures

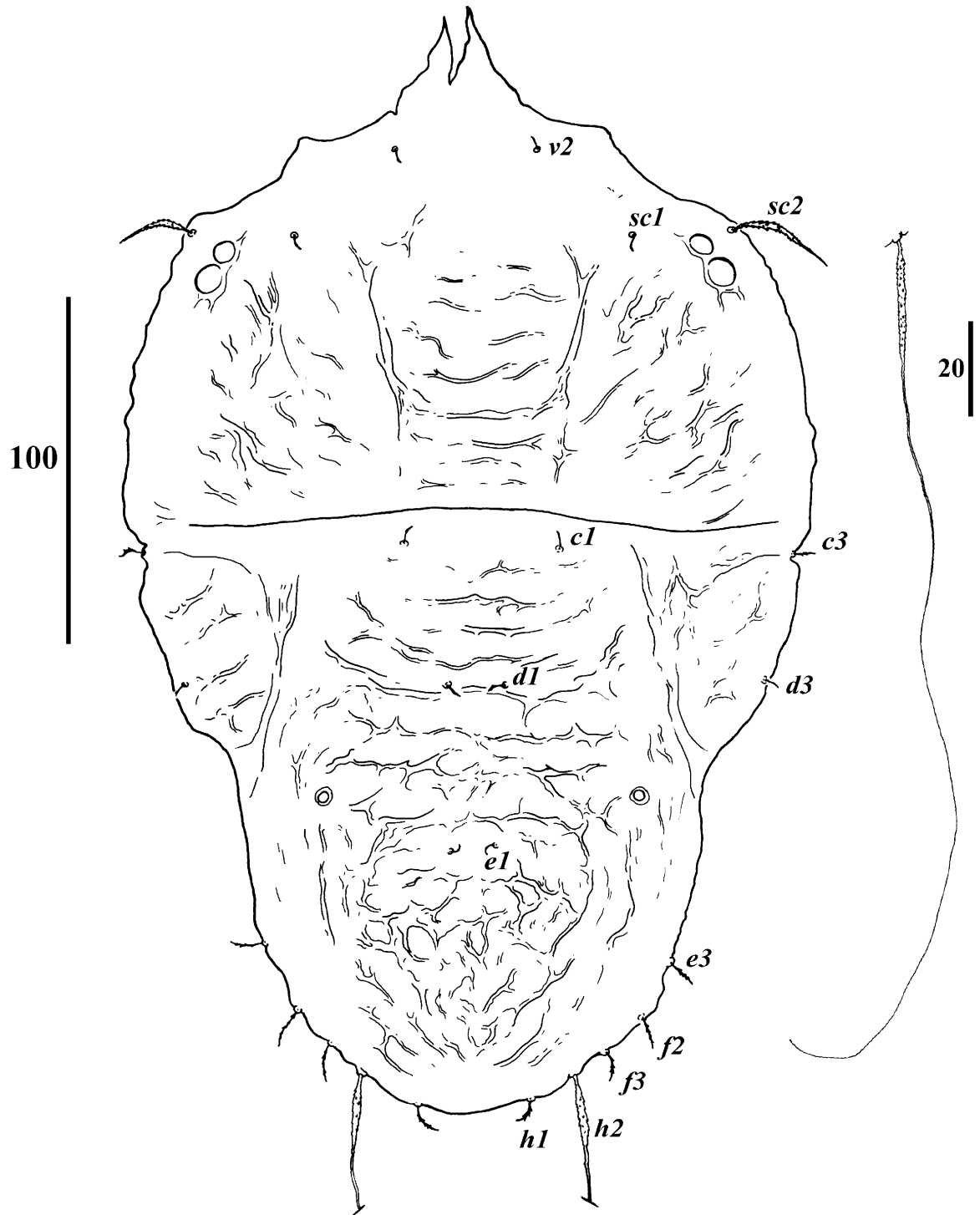


FIGURE 1. *Tenuipalpus toropi* sp. nov. (Female): dorsum, with detail of *h2* setae.

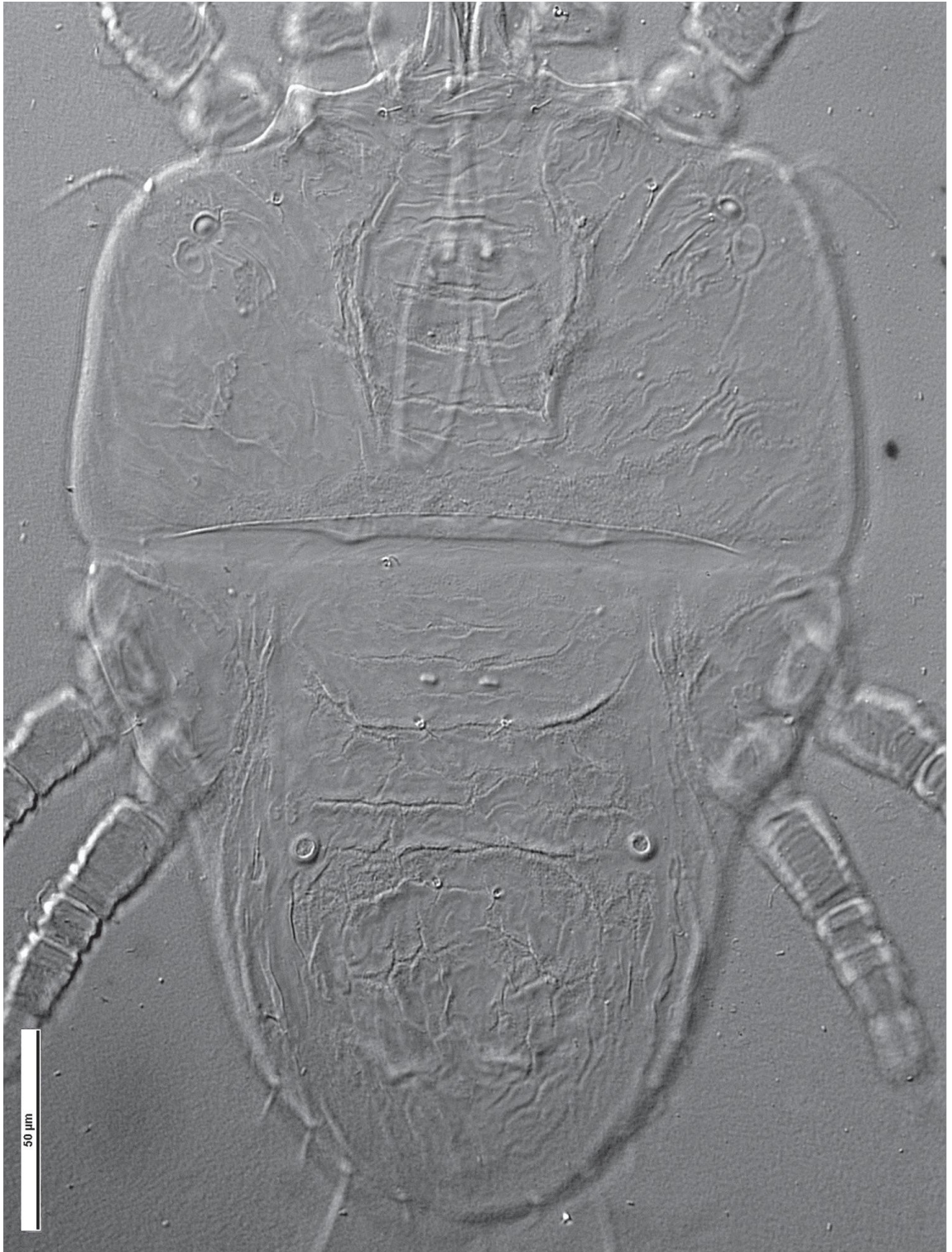
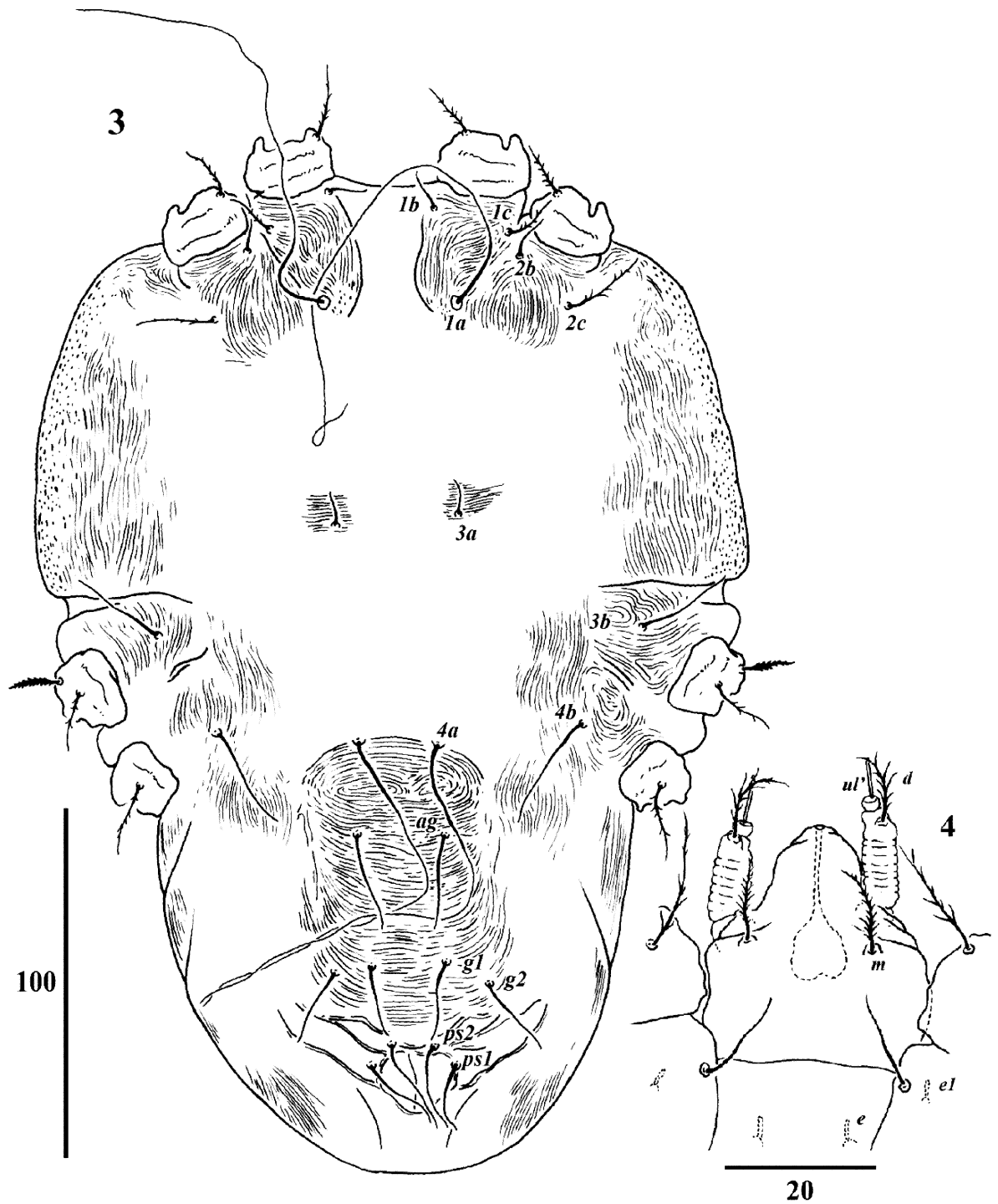
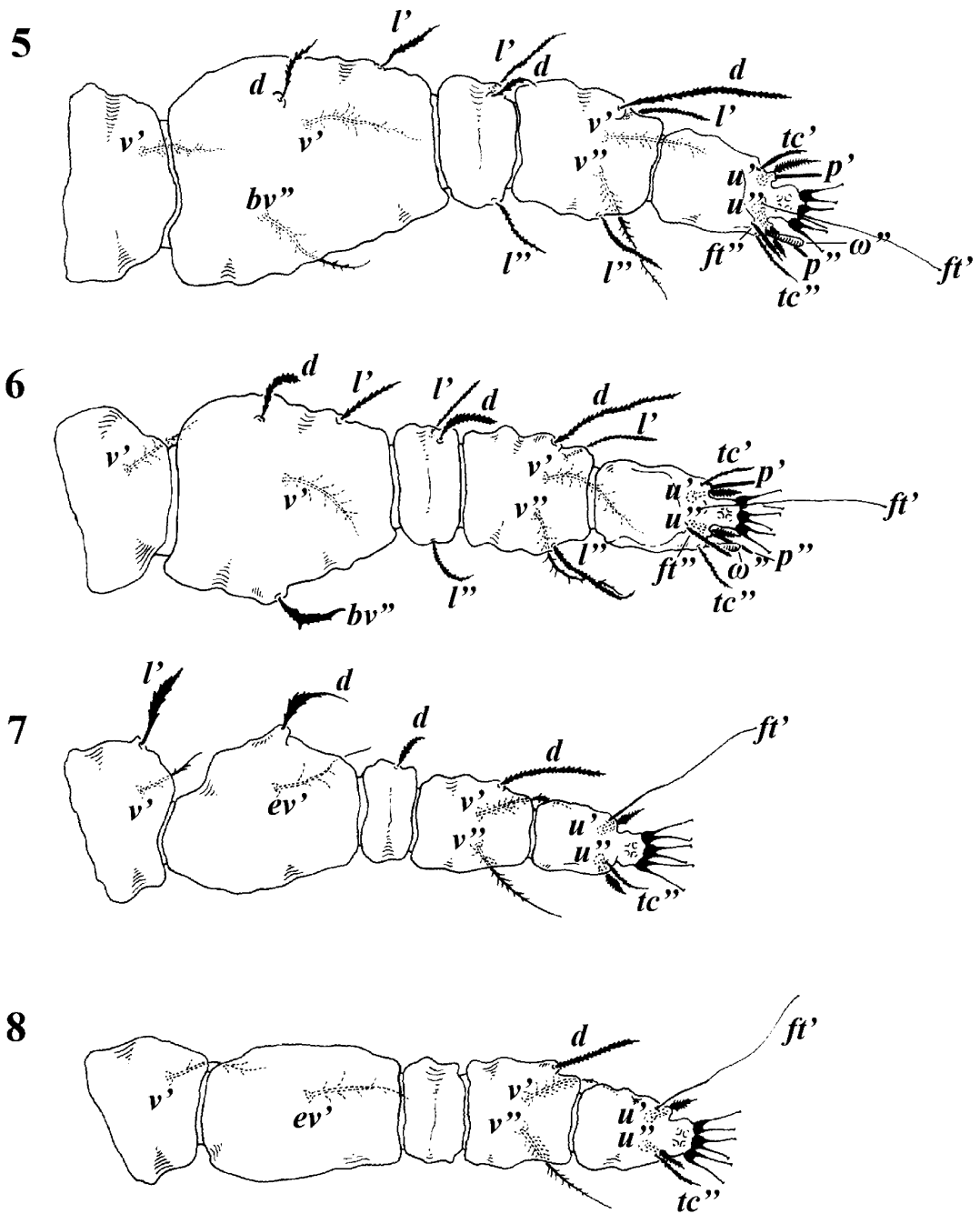


FIGURE 2. *Tenuipalpus toropi* sp. nov. (Female): dorsum.



FIGURES 3–4. *Tenuipalpus toropi* sp. nov. (Female): venter and infracapitulum.



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FIGURES 5–8. *Tenuipalpus toropi* sp. nov. (Female): legs I–IV, respectively.

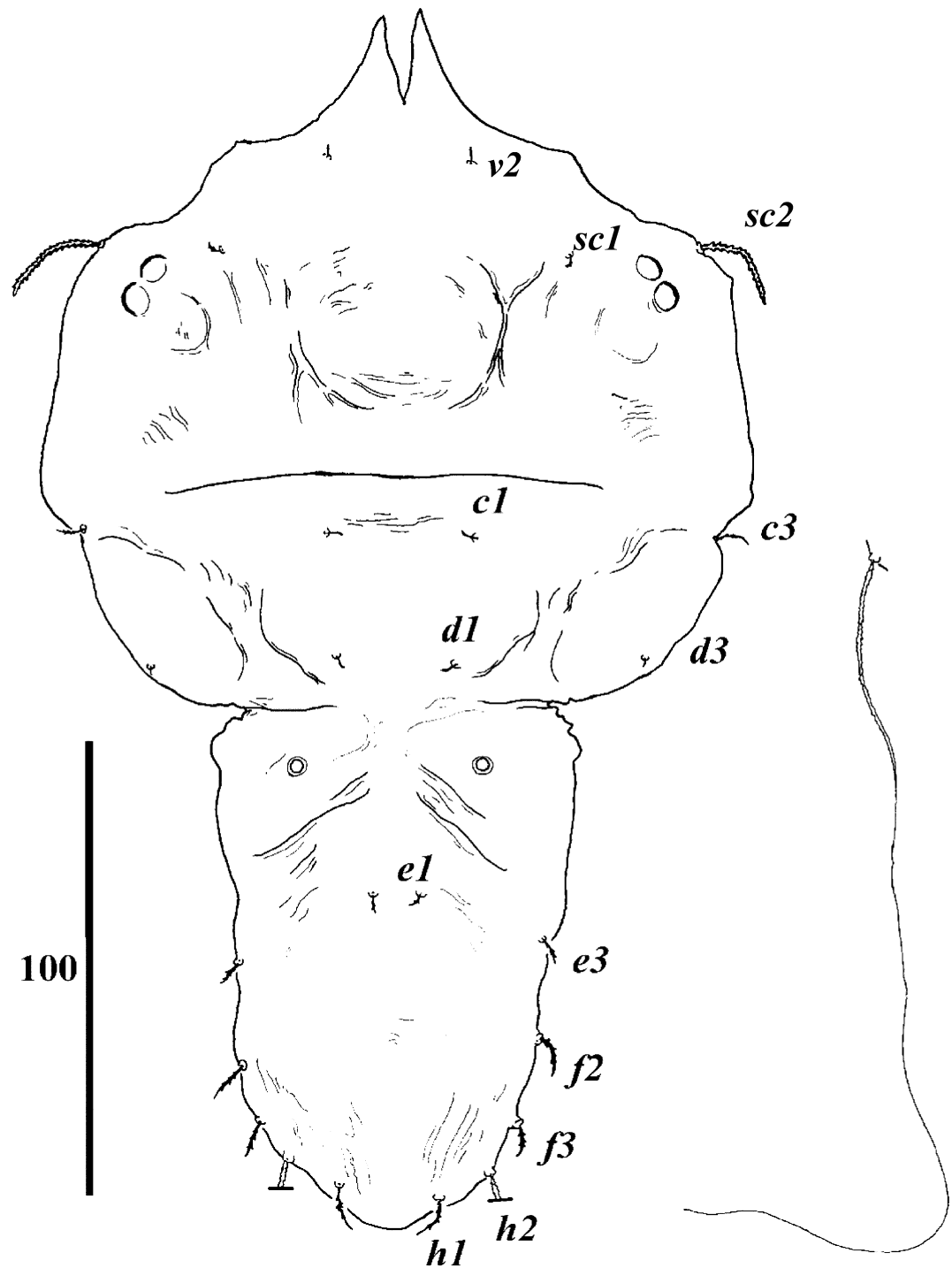


FIGURE 9. *Tenuipalpus toropi* sp. nov. (Male): dorsum, with detail of *h2* setae.

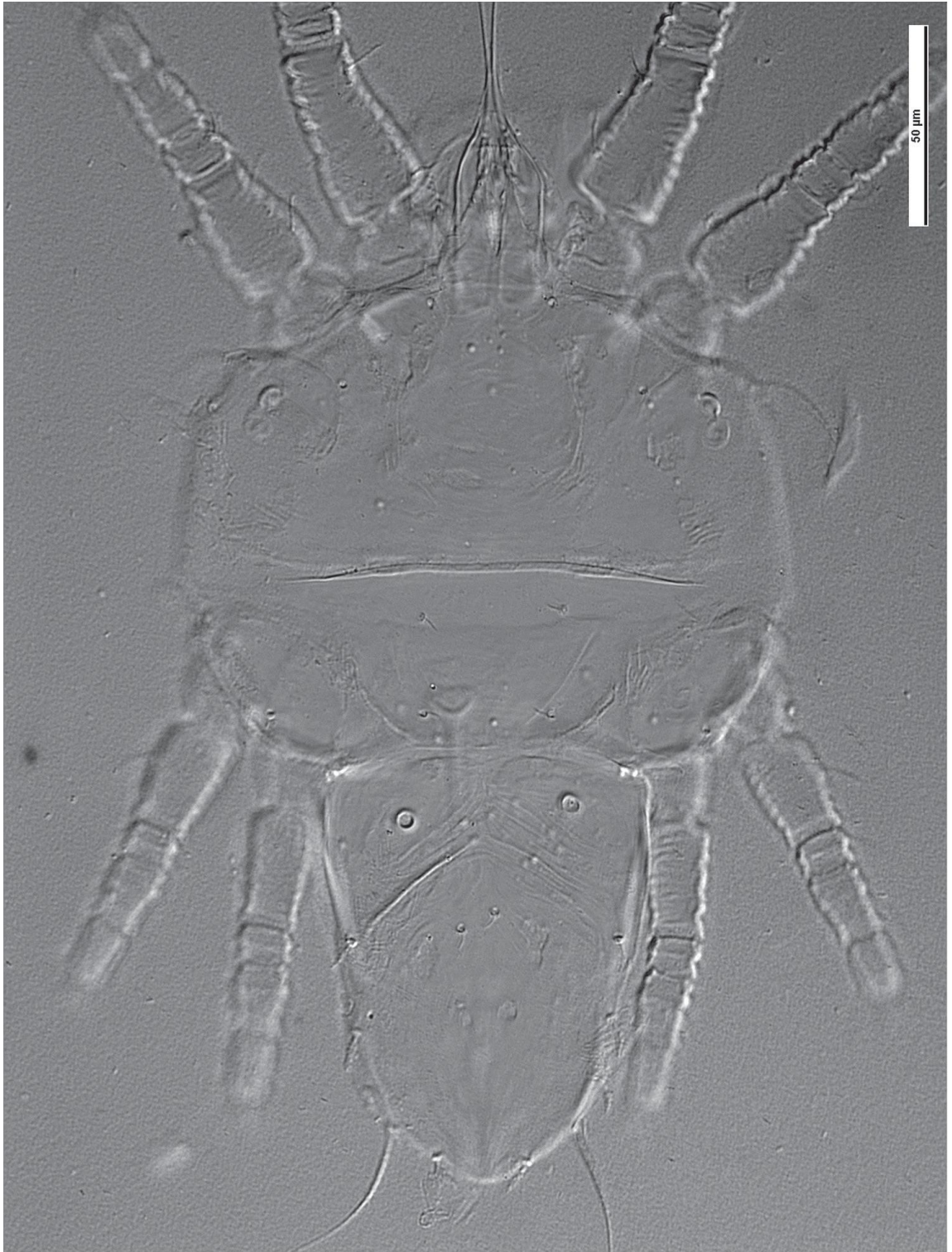
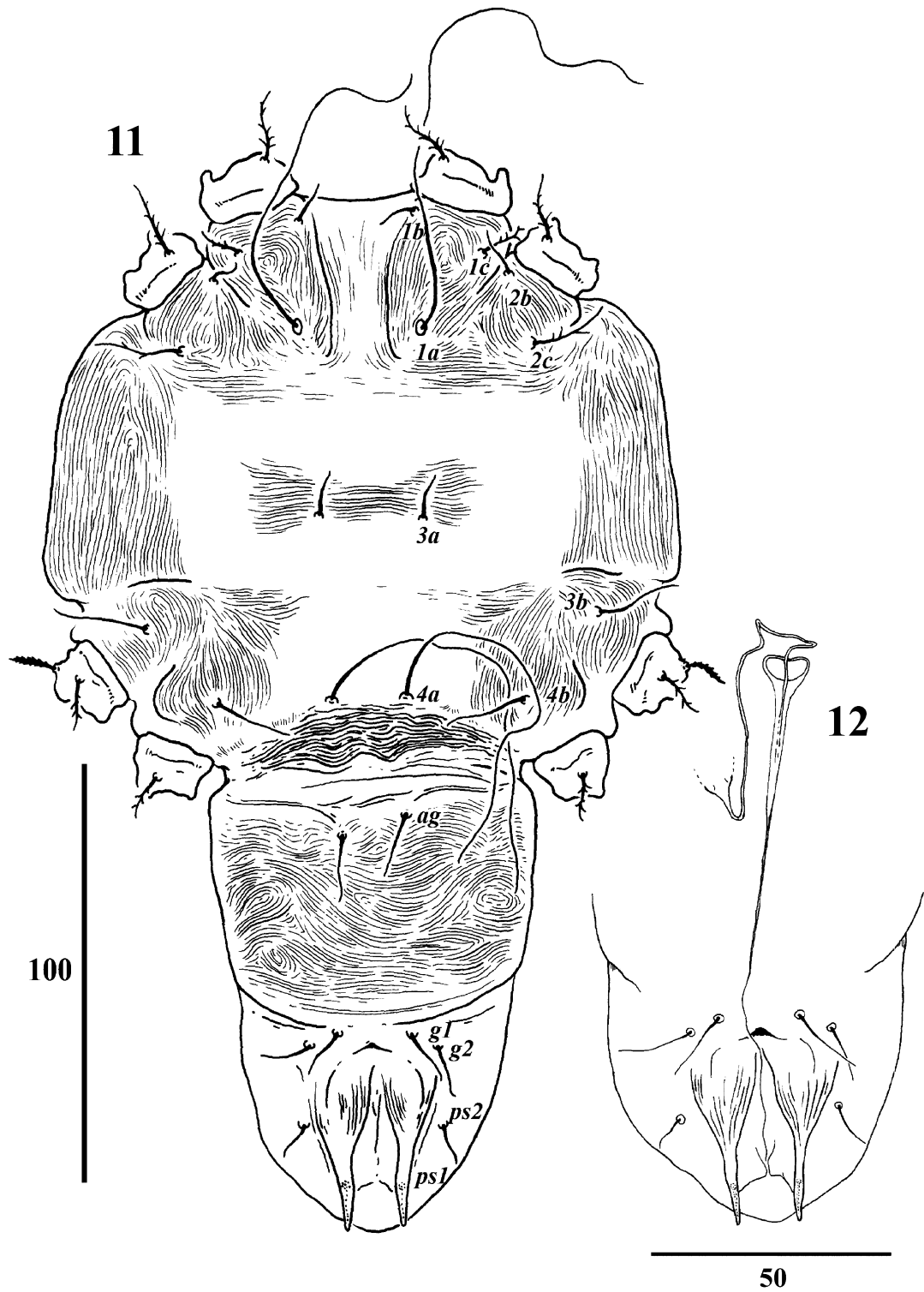


FIGURE 10. *Tenuipalpus toropi* sp. nov. (Male): dorsum.



FIGURES 11–12. *Tenuipalpus toropi* sp. nov. (Male): venter and aedeagus.

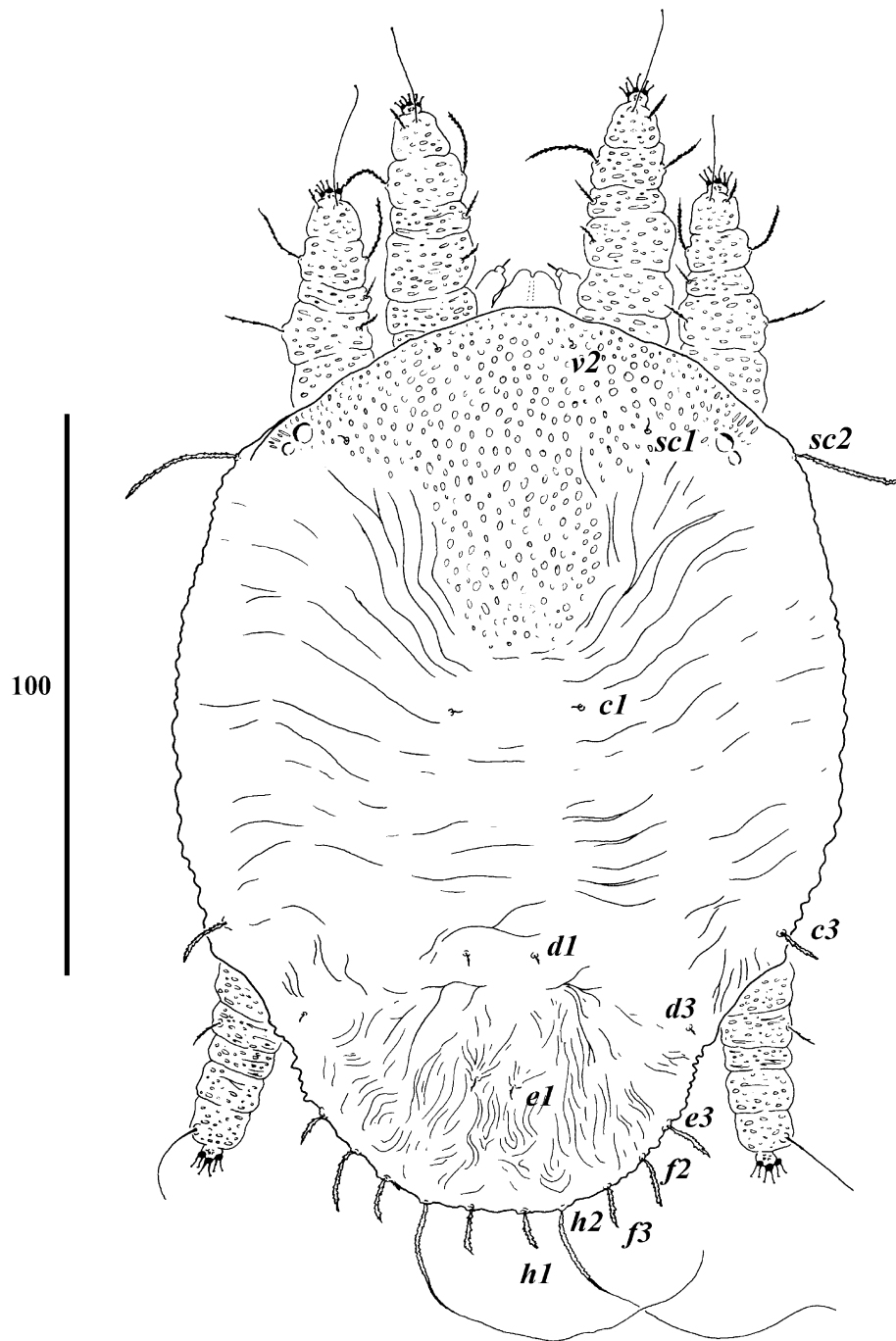


FIGURE 13. *Tenuipalpus toropi* sp. nov. (Larva): dorsum.



FIGURE 14. *Tenuipalpus toropi* sp. nov. (Larva): dorsum.

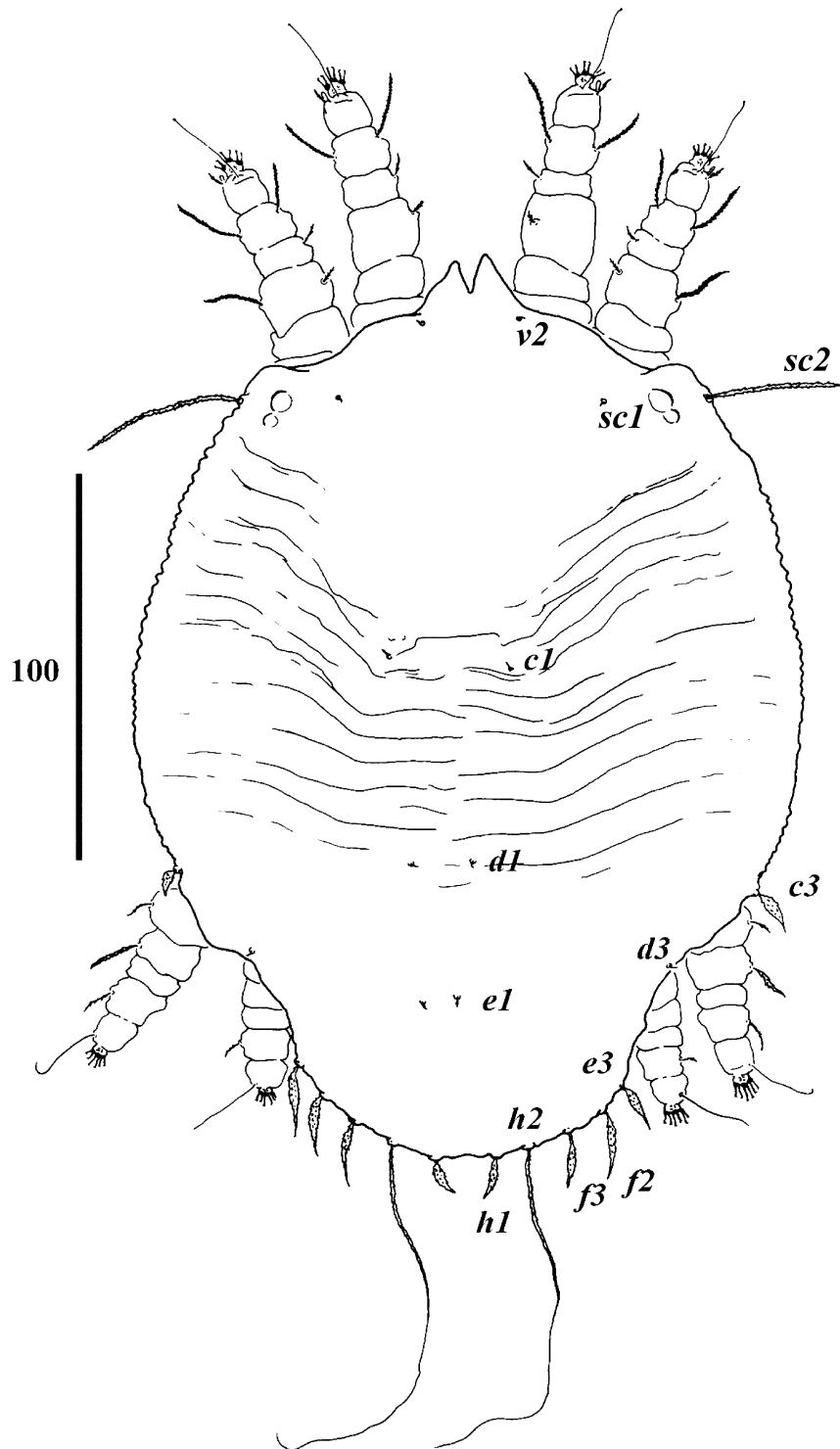


FIGURE 15. *Tenuipalpus toropi* sp. nov. (Protonymph): dorsum.

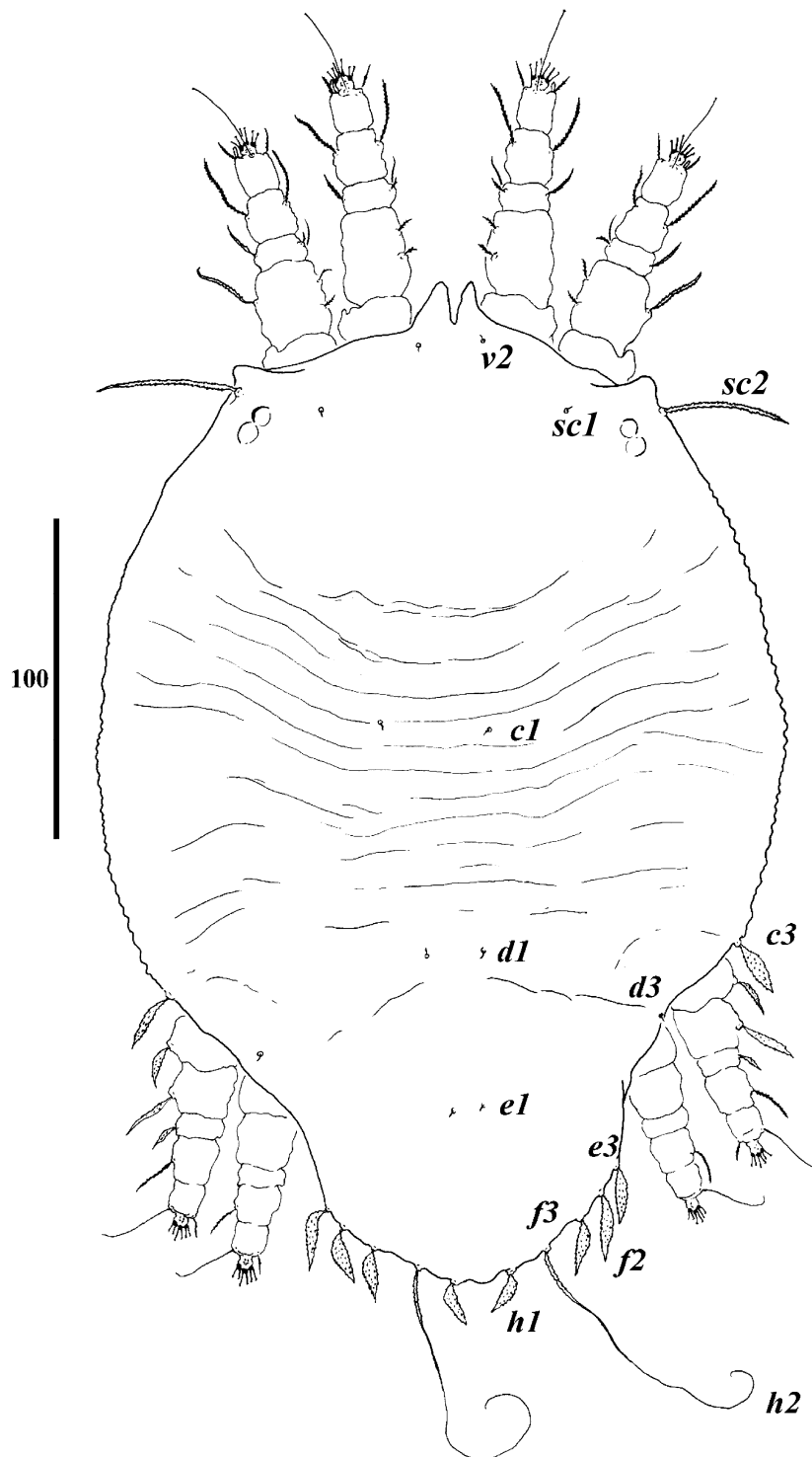


FIGURE 16. *Tenuipalpus toropi* sp. nov. (Deutonymph): dorsum.



FIGURE 17. Host plant, *Sapium glandulatum* (Vell.) Pax (Euphorbiaceae).

CHAPTER 3

A NEW SPECIES OF *TENUIPALPUS* SENSU STRICTO (ACARI: TENUIPALPIDAE) FROM BRAZIL, WITH ONTOGENY AND A KEY TO THE KNOWN SPECIES

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**Authors: Elizeu B. Castro, Reinaldo J.F. Feres, Ronald Ochoa and
Gary R. Baughan**

Abstract

The Cerrado is the second largest Brazilian biome, and is considered to be a “hotspot” due the great concentration of endemic species and high rate of deforestation. Surveys of the mite fauna present in this biome have revealed a great number of new species. In this paper, we describe *Tenuipalpus spinosaurus* **sp. nov.** (Acari: Tenuipalpidae), a new species of *Tenuipalpus* sensu stricto, from adult females, deutonymphs, protonymphs, larvae and eggs, collected on *Terminalia argentea* (Combretaceae), from the Cerrado in Brazil. Females of this new species bear a prominent longitudinal crest on the opisthosoma. The ontogenetic changes in the idiosoma and leg chaetotaxy of all stages are presented. A key to the world species of *Tenuipalpus* sensu stricto is provided.

Key words: flat mites, *Tenuipalpus spinosaurus*, crest, body projections, taxonomic, systematic, biodiversity, Cerrado, LT-SEM.

Introduction

The Cerrado is the second largest Brazilian biome, surpassed only by the Amazon Rainforest (Klink & Machado 2005). It represents nearly 20% of the Brazilian territory, and is considered to be a “hotspot” due the great concentration of endemic species and high rate of deforestation (Myers *et al.* 2000). Surveys of the mite fauna present in this biome have revealed a great number of new species, including several tenuipalpid mites (Lofego & Moraes 2006; Demite *et al.* 2009; Rezende *et al.* 2014).

The definition of *Tenuipalpus* sensu stricto (Acari: Tenuipalpidae) was based on the re-description of *T. caudatus* (Dugès), 1834 (= *T. palmatus* Donnadieu, 1876), and on the study of 37 other known species of *Tenuipalpus* (Castro *et al.* 2016). These authors indicated the presence

of one pair of lateral body projections associated with setae c3 as a synapomorphy for this group.

In this paper, *Tenuipalpus spinosaurus* **sp. nov.**, a new species of *Tenuipalpus* sensu stricto is described from adult females, deutonymphs, protonymphs, larvae and eggs, collected on *Terminalia argentea* (Combretaceae), from the Cerrado in Brazil. We include details of the ontogenetic changes in idiosomal and leg chaetotaxy for all stages. A key to the world species of *Tenuipalpus* sensu stricto is provided.

Material and methods

Specimens were collected on *Terminalia argentea* (Combretaceae), from Itapagipe, Minas Gerais, Brazil, and maintained in 70% ethanol for subsequent use in low temperature scanning electron microscopy (LT-SEM) studies. Mites for LT-SEM were studied using the methodology previously described in Castro *et al.* (2015).

Measurements for the holotype are given in micrometers (μm), with the range of measurements for the paratypes shown in parentheses. The number of leg setae is written as the total number of setae followed by number of solenidia in parentheses. Leg chaetotaxy is adapted from Lindquist (1985), Xu & Fan (2010), and Seeman & Beard (2011). Photographs were obtained using a Leica DMR™ microscope with differential interference contrast (DIC) 40X Plan Fluotar objective. The key presented was based in the study of type specimens and descriptions available in the literature.

Type specimens are deposited in the Collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRP, [http:// www.splink.cria.org.br](http://www.splink.cria.org.br)) and in the National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located at the Systematic Entomology Laboratory (SEL), USDA, Beltsville, Maryland, USA (NMNH).

Family Tenuipalpidae Berlese, 1913

Genus *Tenuipalpus* Donnadieu, 1876

Type species: *Tenuipalpus palmatus* Donnadieu, 1876 (= *Tenuipalpus caudatus* (Dugès, 1834))

Diagnosis. Female: Body shape with prodorsum wider than opisthosoma or elongate-ovate; prodorsum with three pairs of setae (*v2*, *sc1*, *sc2*, except *v2* absent in *T. elegans* (Collyer)); dorsal opisthosoma with eight to ten pairs of setae (*c3*, *d3*, *e3*, *f3*, *h1*, *h2* present; *c2*, *d2*, *e2* absent; *c1*, *d1*, *e1*, *f2* present or absent (*d1*, *e1* rarely absent); setae *h2* elongate, flagellate. Palp one to three segmented. Venter with one to two pairs of setae *3a* (*3a2* present or absent) and one to four pair of setae *4a* (*4a2*, *4a3*, *4a4* present or absent); ventral and genital plates not developed, membranous genital flap present; commonly two pairs of pseudanal setae *ps1–2* present (setae *ps3* rarely present). Male: Opisthosoma distinctly narrower than that of female; legs and dorsal setae usually similar to those of female; pseudanal setae *ps1* modified as accessory genital stylet.

***Tenuipalpus* sensu stricto group**

Diagnosis. Adults female and male: Species of this group can be differentiated from other *Tenuipalpus* by presence of one pair of lateral body projections associated with setae *c3*. See Castro *et al.* (2016) for a detailed diagnosis.

***Tenuipalpus spinosaurus* sp. nov. Castro, Feres & Ochoa**

(Figs 1–18)

Diagnosis. Female: Prodorsal setae *v2* short to minute, *sc1* obovate to oblanceolate and *sc2* falcate, elongate; dorsal opisthosoma with 10 pairs

of setae (*f2* present); most of the dorsal opisthosomal setae obovate to oblanceolate, except setae *d3* and *e1* short to minute, and *h2* elongate and flagelliform; prodorsum with a pair of oblique converging ridges from *sc1* to near the sejugal furrow; opisthosoma bearing a prominent longitudinal crest between setae *e1*; dorsum with pair lateral projections anterior to setae *sc2* and pair lateral projections posterior to setae *c3*; palps one segmented; two pairs of setae *ps*; one pair of setae *3a* and *4a*. **Male:** unknown. **Immatures:** deutonymphs and protonymphs with lateral body projections anterior to setae *sc2* (lateral body projection associated with setae *c3* absent); dorsal setae similar to those of the female except narrower. Larvae with prodorsum and region of opisthosomal posterior to setae *d1–c3* with colliculate integument; setae *v2*, *sc1*, *c1*, *d1* and *e1* short to minute, with other dorsal setae similar to those of female except narrower.

Female (*n* = 16) (Figs 1–13). Body size measurements: distance between setae *v2–h1* 250 (240–255), *sc2–sc2* 155 (150–160); other measurements: *v2–v2* 30 (30–33), *sc1–sc1* 88 (80–88), *c1–c1* 48 (38–48), *c3–c3* 178 (165–180), *d1–d1* 28 (23–28), *d3–d3* 133 (125–133), *e1–e1* 30 (28–33), *e3–e3* 92 (87–95), *f2–f2* 80 (77–83), *f3–f3* 65 (62–68), *h1–h1* 35 (32–40), *h2–h2* 52 (50–55).

Dorsum (Figs 1–6). Anterior margin of prodorsal shield with four narrow conical projections mesally. Prodorsum with one pair of obtuse lateral projections anterior to setae *sc2*; and opisthosoma with one pair of rounded lateral projections associated with setae *c3*. Prodorsum with a pair of oblique converging ridges from *sc1* to near sejugal furrow. Opisthosoma bearing a prominent longitudinal, semi-circular crest between setae *e1*; when the mites are mounted on slides the crest is folded flat over the opisthosoma (Figs 1, 2, 3, 6); pair of large circular pores anterolaterad setae *e1*. Prodorsal setae *v2* short to minute; *sc1* obovate to oblanceolate and strongly concave like a scoop (Fig. 4B); *sc2*

falcate and elongate (Fig. 4A); opisthosomal setae similar to prodorsal setae *sc1* except longer, oblanceolate, and setae *d3* and *e1* short to minute and *h2* flagelliform and elongate. Setal measurements: *v2* 5 (3–6), *sc1* 28 (25–30), *sc2* 61 (60–67), *c1* 43 (40–47), *c3* 27 (25–30), *d1* 34 (33–40), *d3* 6 (4–6), *e1* 4 (3–5), *e3* 43 (43–51), *f2* 38 (38–45), *f3* 39 (38–42), *h1* 27 (24–30), *h2* 52 (60–105).

Venter (Figs 7, 8). Ventral integument with weak transverse striae centrally along midline and finely densely colliculate on lateral region of the prodorsum and opisthosoma; genital region entirely membranous and with transverse striae; anal flaps membranous with weak longitudinal striae. Most ventral setae filiform; coxal setae *1c*, *2c* and *3b* filiform and barbed (*1b* weakly barbed); coxal setae *4b* inserted posteromesad common position, closer to *4a*. Setal measurements: *1a* 95 (70–105), *1b* 10 (10–12), *1c* 16 (16–21), *2b* 17 (16–21), *2c* 22 (25–30), *3a* 11 (11–13), *3b* 30 (26–30), *4a* 75 (65–90), *4b* 24 (24–30), *ag* 20 (17–20), *g1* 30 (25–30), *g2* 23 (21–24), *ps1* 13 (12–14), *ps2* 16 (14–16).

Gnathosoma (Figs 9, 10, 11). Palps one segmented, elongate and bearing one long, barbed seta *d* 12 (11–14) and two eupathidia, *ul'* 3 (4–5), *ul''* 1–2 (1–2) (Fig. 9). Ventral setae *m* 11 (10–11), barbed (Figs 9, 10); distance between setae *m-m* 14 (13–16). Tips of cheliceral stylets with a few bluntly rounded lateral projections (Fig. 11).

Legs (Figs 12, 13). Setation (from coxae to tarsi): I 2–1–4–3–5–8(1), II 2–1–4–2–5–8(1), III 1–2–2–1–3–5, IV 1–1–1–0–3–5. Tarsi I–II each with one solenidion ω'' 6 (5–6) (for both tarsi I and tarsi II), two eupathidia $p\zeta'-p\zeta''$ (6–7, 6–7; 6, 6–7 respectively), and with seta *ft''* short, broadly lanceolate and positioned over the solenidion. Femur I with setae *d* oblanceolate, *l'* lanceolate, and with two barbed ventral setae. Femur II with *d* and *l'* lanceolate, *bv''* broadly lanceolate to falcate, and one barbed ventral seta. Femur III with seta *d* obovate. Femora and genua with setae *d*, and trochanter III with seta *l'*, inserted in lateral position on tubercles. Detail of the development of leg chaetotaxy in Table 1.

Color. Body and legs translucent green becoming dark green in central region of idiosoma. Leg and dorsal setae white, eyes red.

Eggs. Elongate with longitudinal ridges, and yellow in colour. Most of the eggs were found near the veins of the leaves.

Male: Unknown.

Deutonymph (n = 4) (Figs 14, 15): Body size measurements: distance between setae *v2-h1* 245–265, *sc2-sc2* 122–128; other measurements: *v2-v2* 25–30, *sc1-sc1* 65–68, *c1-c1* 25–28, *c3-c3* 152–160, *d1-d1* 17–20, *d3-d3* 105–110, *e1-e1* 22–25, *e3-e3* 67–73, *f2-f2* 60–73, *f3-f3* 47–50, *h1-h1* 15–18, *h2-h2* 30–33.

Dorsum. Anterior margin of prodorsum with pair short projections mesally, forming a notch. Lateral body projections anterior to setae *sc2* present. Prodorsum mostly smooth, with pair longitudinal ridges from anterior margin past eyes to posterior margin (Fig. 15). Region between setae *sc2-c3* with widely spaced transverse striations and region posterior to setae *d1-c3* smooth; pair circular pores laterad setae *e1*; central longitudinal ridge on posterior opisthosoma from setae *d1* to posterior margin (Fig. 15). Dorsal setae similar to that of female except smaller and thinner. Setal measurements: *v2* 2–3, *sc1* 20–25, *sc2* 46–56, *c1* 24–30, *c3* 20, *d1* 30–31, *d3* 2–3, *e1* 2, *e3* 27–28, *f2* 22–27, *f3* 19–22, *h1* 13–17, *h2* 38–55.

Gnathosoma. Palps similar to those of female. Setae *d* 12–14 long; eupathidia *ul'* 4, *ul''* 1–2. Ventral infracapitular setae *m* 6–7; distance between setae *m-m* 12–14.

Venter. Cuticle covered with fine and mostly transverse striae. Coxal, genital and pseudanal setae fine. Setal lengths: *1a* 55–65, *1b* 5–6, *1c* 6–8, *2b* 10–11, *2c* 10–12, *3a* 6–7, *3b* 11–12, *4a* 45–60, *4b* 7–10, *ag* 5–8, *g1* 5–6, *ps1* 5–7, *ps2* 5–6. Setae *g2* absent.

Legs. Setation (from coxae to tarsi): I 2–1–4–3–5–8(1), II 2–1–4–3–5–8(1), III 1–2–2–1–3–3, IV 1–0–1–0–3–3. Leg chaetotaxy similar to that of female, except trochanter IV nude, and *d* and *l* setae more lanceolate.

Tarsi I–II each with one solenidion ω'' (tarsi I 4–5 and tarsi II 4) and two eupathidia $p\zeta'-p\zeta''$ (5–6, 6; 5–6, 6 respectively). Detail of the development of leg chaetotaxy in Table 1.

Protonymph (n = 3) (Figs 16, 17): Body size measurements: distance between setae $v2-h1$ 185–210, $sc2-sc2$ 110–115; other measurements: $v2-v2$ 20–25, $sc1-sc1$ 55–60, $c1-c1$ 22–25, $c3-c3$ 127–133, $d1-d1$ 15–18, $d3-d3$ 87–93, $e1-e1$ 15–18, $e3-e3$ 62–65, $f2-f2$ 55–58, $f3-f3$ 45, $h1-h1$ 15, $h2-h2$ 27–30.

Dorsum. Anterior margin of prodorsum with pair short projections mesally, forming a short notch. Lateral body projections anterior to setae $sc2$ present. Prodorsum mostly smooth, with pair longitudinal ridges from anterior margin past eyes to posterior margin (Fig. 17). Prodorsal region smooth; region between setae $sc2-c3$ with widely spaced transverse striations and region posterior to setae $d1-c3$ smooth; pair circular pores laterad setae $e1$; short central longitudinal ridge on posterior opisthosoma from setae $d1$ to posterior margin (Fig. 17). Dorsal setae similar to that of female except shorter and thinner. Setal measurements: $v2$ 2–3, $sc1$ 10–12, $sc2$ 42–45, $c1$ 9–45, $c3$ 20–21, $d1$ 12–20, $d3$ 2–3, $e1$ 2–3, $e3$ 23–24, $f2$ 19–22, $f3$ 17–18, $h1$ 14–15, $h2$ 55–65.

Gnathosoma. Palps similar to those of female. Setae d 5–7; eupathidia ul' 3–4, ul'' 1–2. Ventral infracapitular setae m 6–7; distance between setae $m-m$ 11–12.

Venter. Cuticle covered with fine and mostly transverse striae. Coxal, genital and pseudanal setae fine. Setal measurements: $1a$ 60–75, $1b$ 5–6, $1c$ 6–7, $2c$ 11–12, $3a$ 7–8, $3b$ 10–11, ag 6–7, $ps1$ 5–7, $ps2$ 6–7. Setae $2b$, $4a$, $4b$, $g1$ and $g2$ absent.

Legs. Setation (from coxae to tarsi): I 2–0–3–1–5–6(1), II 1–0–3–1–5–6(1), III 1–0–2–0–3–3, IV 0–0–1–0–3–3. Tarsi I–II each with one solenidion ω'' 3–4 (for both tarsi I and tarsi II) and two eupathidia $p\zeta'-p\zeta''$ (5–6, 6; 5, 5 respectively). Detail of the development of leg chaetotaxy in Table 1.

Larva (n = 3) (Fig. 18): Body size measurements: distance between setae *v2-h1* 150–160, *sc2-sc2* 78–98; other measurements: *v2-v2* 15–18, *sc1-sc1* 50, *c1-c1* 25, *c3-c3* 97–105, *d1-d1* 12–15, *d3-d3* 67–72, *e1-e1* 7–10, *e3-e3* 57–63, *f2-f2* 47–55, *f3-f3* 35–40, *h1-h1* 10–13, *h2-h2* 22–25.

Dorsum. Anterior margin of prodorsum smoothly rounded, without notch. Prodorsal region with colliculate integument; region between setae *sc2-c3* with oblique and widely spaced transverse striations and region posterior to setae *d1-c3* with colliculate integument. Setae *v2*, *sc1*, *c1*, *d1*, *d3* and *e1* short to minute; other dorsal setae lanceolate except *sc2* falcate. Setal measurements: *v2* 2, *sc1* 3, *sc2* 22–26, *c1* 3–4, *c3* 15–18, *d1* 5–6, *d3* 2–3, *e1* 2, *e3* 15–17, *f2* 16–18, *f3* 13–15, *h1* 11–13, *h2* 35–45.

Gnathosoma. Palps similar to those of female. Seta *d* 5–6 long; eupathidia *ul'* 2, *ul''* 1. Ventral infracapitular setae *m* absent.

Venter. Cuticle covered with fine and mostly transverse striae. Coxal, genital and anal setae fine. Setal measurements: *1a* 35–43, *1b* 5–6, *3a* 5–6, *ps1* 5–7, *ps2* 5–6. Setae *1c*, *2b*, *2c*, *3b*, *4a*, *4b*, *ag*, *g1* and *g2* absent.

Legs. Setation (from coxae to tarsi): I 1–0–3–1–5–6(1), II 0–0–3–1–5–6(1), III 0–0–2–0–3–3. Tarsi I–II each with one solenidion ω'' 2–3 (for both tarsi I and II) and two eupathidia *pζ'-pζ''* (4–5, 5; 4, 5 respectively). Cuticle of all legs covered with colliculate sculpturing. Detail of the development of leg chaetotaxy in Table 1.

Type material. Holotype: female collected on *Terminalia argentea* (Combretaceae), Itapagipe, Minas Gerais, **Brazil**, (19°52'S, 49°39'W), 16 October 2008, coll. A. Mendonça (DZSJRP n. 10138). **Paratypes:** five females and three deutonymphs on same slide as holotype; two females, three protonymphs and three larvae, 19 August 2014, coll. E.B. Castro, same data as holotype (DZSJRP n. 10140 to 10144). Eight females and one deutonymph, same data as holotype (DZSJRP n. 10139, NMNH).

Other material examined. *Tenuipalpus boyani* De Leon (USNM n. 2610): **Paratypes:** one female, one deutonymph and one protonymph on

the slide, ex. *Pouteria* sp. (Sapotaceae), from Guyana (= British Guiana). *Tenuipalpus eugeniae* De Leon (USNM n. 2709): **Holotype**: female, ex. *Eugenia biflora* (Myrtaceae), from Jamaica. **Paratypes**: one female and one male on same slide as holotype.

Etymology. This specific name *spinosaurus* refers to presence of a prominent dorsal crest on opisthosoma which reminds us of that of the extraordinary crest of the dinosaur *Spinosaurus aegyptiacus* Stromer (Spinosauridae).

Differential diagnosis. This new species resembles *T. boyani* De Leon 1965a in sharing the presence of lateral body projections associated with setae *sc2* and *c3*, and a longitudinal crest on the opisthosoma (not illustrated in De Leon 1965a) and in having ventral seta *4b* inserted distinctly mesad of its more common position in the Tenuipalpidae. It differs by having a prodorsum with a pair of strongly developed longitudinal to converging ridges running from *sc1* to near the posterior margin of the shield (prodorsum with only weakly developed longitudinal ridges in *T. boyani*); setae *sc1* are larger in *T. spinosaurus* (25–30 long; 10 long in *T. boyani*); setae *sc1*, *c1* and *d1* are oblanceolate in the deutonymphs and protonymphs of the new species, while in the immatures of *T. boyani* these setae are minute.

Tenuipalpus spinosaurus also resembles *T. eugeniae* De Leon 1965b, but differs in the position of coxal setae *4b*, which are inserted much closer to setae *4a* in former, and in the more commonly observed position in the latter species.

Remarks. The new species was compared with the type specimens of *T. boyani* and *T. eugeniae*. In the many samples we analysed, only eggs, immatures and females were found, and no males were located. It suggests that this species may be parthenogenetic, or that males are produced only at certain times of the year or under certain conditions.

Ontogeny. *Tenuipalpus spinosaurus* **sp. nov.** has the pattern of additions to the coxae that is common to the family (Lindquist 1985). Coxal

setae *1c*, *2c* and *3b* are added in the protonymph and *2b* and *4b* are added in the deutonymph. Here, the coxal setae *4b* are inserted in an unusual position, off of coxal region IV and closer to setae *4a*. This characteristic is also found in *Tenuipalpus boyani* De Leon.

Seta *v'* is added to trochanters I, II and III in the deutonymph and is delayed until the adult stage on leg IV. Unusually, setae *l'* is added to trochanters III in the deutonymph (more commonly appears in the protonymph (Lindquist 1985)).

Setae *l'* are added to femora I and II in deutonymph, as occurs in other Tenuipalpidae (e.g. *Aegyptobia* (Seeman & Beard 2011)). Setae *l'* are present on genua I and II of the larvae, and setae *d* (common for the family) and *l''* (delayed addition, according to Lindquist (1985)) are added to genua I and II of the deutonymph, as occurs in other Tenuipalpidae (e.g. *Aegyptobia* (Seeman & Beard (2011))). As is common in the family, seta *d* is added to genu III in the deutonymph (Lindquist 1985); while genu IV remain nude.

As in most of *Tenuipalpus* species, the pattern of tibial setae is 5-5-3-3, and represents the larval complement. The patterns of addition of the tectal setae on the tarsi are variable amongst tenuipalpid taxa. *Tenuipalpus spinosaurus* sp. nov. displays a pattern commonly expressed within the family, but one in which the tectal pairs are delayed one stage from a standard pattern (Lindquist 1985). The pairs of tectal setae are added to tarsus I, II and III in the deutonymph (instead of protonymph), and to tarsus IV in the adult (instead of deutonymph).

Setae *d* on femora I and II are inserted in a lateral position on tubercles in *Tenuipalpus* sensu stricto. In species of *Tenuipalpus* sensu lato, setae *d* on femora I and II are commonly inserted in a dorsal position and not usually on tubercles. Similarly, seta *d* on genua and tibiae of *Tenuipalpus* sensu stricto and sensu lato are also usually inserted in a lateral position.

Discussion

The rapid replacement of the Cerrado by agricultural crops such as soybean, rice, corn, and cotton as well as pasture (Klink & Moreira 2002), increases the risk that species may become extinct before they are even known (Demite *et al.* 2009). Some tenuipalpid show host preference (Mesa *et al.* 2009) and may occur only on a single genus of plants [e.g. *T. heveae* Baker that has only ever been recorded occurring on plants of the genus *Hevea* (Euphorbiaceae)]. Due to such host specificity, we believe that if a given plant becomes extinct, then the mites associated with it may also become extinct. This information highlights the importance of the conservation of biomes with endemics species, as the Cerrado.

The 39 known species of *Tenuipalpus* sensu stricto were collected on plants of 29 different families and were described mainly from Neotropical (19 spp.) and Nearctic regions (8 spp.) (Mesa *et al.* 2009; Castro *et al.* 2016). Of these species, four are known from Brazil. Two species were described from specimens collected from Brazil: *T. spinosaurus* (described herein), and *T. latiseta* Aranda collected on an unidentified plant of the family Celastraceae from São Paulo state (Flechtmann 1976); and another two species of the sensu stricto group were recorded in Brazil: *Tenuipalpus anacardii* De Leon was collected by Flechtmann (1976) on *Anacardium occidentale* (Anacardiaceae) from Ceará State, and *T. coyacus* De Leon was recorded by Vasconcelos *et al.* (2005) on *Cocos nucifera* (Arecaceae) from Pernambuco state.

Tenuipalpus spinosaurus bears a pair of lateral projections associated with setae c3 (synapomorphy of *Tenuipalpus* sensu stricto group), and another pair of lateral projections anterior to setae sc2 (present also in some other *Tenuipalpus* and *Ultratenuipalpus*). It also bears a longitudinal crest on the dorsal opisthosoma that occurs in four other species of the sensu stricto group (e.g. *T. caudatus* (Dugès) and *T. erbei* Kane, Castro & Ochoa). In addition, the presence of the pair of

projections anterior to setae *sc2* in the protonymphs and deutonymphs show that this character could be expressed during the ontogenetic development of *Tenuipalpus* sensu stricto.

Key to known species of *Tenuipalpus* sensu stricto (sensu Castro et al. 2016) (based on adult females)

1. Dorsum with one pair of lateral projections associated with setae *c3* and another pair of lateral projections anterior to setae *sc2*; lateral setae *sc2*, *c3*, *e3*, *f2*, *f3* and *h1* variable in shape from lanceolate, obovate to ovate; femora I and II with setae *d* inserted in lateral position on tubercles...*Tenuipalpus* sensu stricto (sensu Castro et al. 2016).....2
- Dorsum always without a pair of lateral projections associated with setae *c3* and usually without the lateral projection anterior to setae *sc2*; lateral setae not as mentioned above and usually setiform or minute; femora I and II with setae *d* usually inserted in dorsal position.....*Tenuipalpus* sensu lato (sensu Castro et al. 2016)
2. Opisthosoma with six pairs of dorsolateral setae (*f2* absent; *c3*, *d3*, *e3*, *f3*, *h1*, *h2* present).....*T. lalbaghensis* Channabasavanna & Lakkundi
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3. Three pairs of pseudanal setae (*ps1–3* present).....4
- Two pairs of pseudanal setae (*ps1–2* present, *ps3* absent).....6
4. Setae *c3* inserted on the associated lateral projections.....*T. banahawensis* Corpuz-Raros
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5. Palps two segmented; opisthosomal setae *c3* obovate; opisthosomal setae *e3* lanceolate; opisthosomal setae *f2* and *f3* ovate with broadly acute tips.....*T. mahoensis* Collyer
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respectively.....*T. coccolobicoloides* De Leon
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opisthosomal setae *h1* of similar length to setae *e3*, *f2* and
f3.....*T. podocarpus* Lawrence
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3, 3, 1, 0 setae, respectively.....*T. lucumae* De Leon

- Prodorsum and dorsal opisthosoma completely smooth; genua I–IV with 2, 2, 1, 0 setae, respectively.....*T. latiseta* Aranda

* = likely a junior synonym of *T. caudatus*.

Remarks: *T. proctori* De Leon was described based only on a male. Information on the following species were taken using illustrations and descriptions from the literature: *T. arbuti*, *T. cheladzeae*, *T. cupressoides*, *T. imias*, *T. inophylli*, *T. lalbaghensis*, *T. mahoensis*, *T. micheli*, *T. podocarp*i and *T. raphiae*.

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References

- Castro, E.B., Ochoa, R., Feres, R.J.F., Beard, J.J. & Bauchan, G.R. (2015) Reinstatement of the genus *Colopalpus* Pritchard and Baker (1958) and re-description of *Colopalpus matthyssei* Pritchard and Baker (1958), the type species of the genus (Acari, Tenuipalpidae). *International Journal of Acarology*, 41 (4), 310–328.
- Castro, E.B., Kane, E.C., Feres, R.J.F., Ochoa, R. & Bauchan, G.R. (2016) Definition of *Tenuipalpus* sensu stricto (Acari, Tenuipalpidae), with redescription of *Tenuipalpus caudatus* (Dugès) and description of a new species from Costa Rica. *International Journal of Acarology*, 42(2), 106–126.
- De Leon, D. (1965a) New Tenuipalpidae (False Spider Mites) from British Guiana with notes on four described species. *Florida Entomologist*, 48 (1), 65–75.
- De Leon, D. (1965b) False spider mites of Jamaica and the Dominican Republic (Acarina: Tenuipalpidae). *Annals of the Entomological Society of America*, 58 (4), 517–523.
- Demite, P.R., Feres, R.J.F., Lofego, A.C. & Oliveira, A.R. (2009) Plant inhabiting mites (Acari) from the Cerrado biome of Mato Grosso State, Brazil. *Zootaxa*, 2061, 45–60.
- Donnadieu, A.L. (1876) Recherches pour servir à l’histoire des Tétranyques. *Annales de la Societe Linneene de Lyon*, 135 pp., pls. 1–12.

- Dugès, A. (1834) Recherches pour servir a l'ordre des Acariens en general et la famille des Trombidies en particulier. *Annales des Sciences Naturelles Paris*, (ser. 2) 1, 5–46.
- Flechtmann, C.H.W. (1976) Preliminary report on the false spider mites (Acari: Tenuipalpidae) from Brazil and Paraguay. *Proceedings of the Entomological Society of Washington*, 78, 58–64.
- Klink, C.A. & Moreira, A.G. (2002) Past in current human occupation, and land use. In: Oliveira, O.S. & Marquis, R.J. (Eds), *The Cerrados of Brazil*. Columbia University Press, USA, pp. 69–88.
- Klink, C.A. & Machado, R.B. (2005) A conservação do Cerrado brasileiro. *Megadiversidade*, 1, 147–155.
- Lindquist, E.E. (1985) External anatomy. In: Helle, W. & Sabelis, M.W. (Eds), Spider mites: their biology, natural enemies and control. Vol. 1A. Chapter 1.1 Anatomy, Phylogeny and Systematics. *Elsevier Science Publishers, Amsterdam*, pp. 3–29.
- Lofego, A.C. & Moraes, G.J. (2006) Ácaros (Acari) associados a Mirtáceas (Myrtaceae) em áreas de Cerrado no Estado de São Paulo com Análise Faunística das famílias Phytoseiidae e Tarsonemidae. *Neotropical Entomology*, 35, 731–746.
- Mesa, N.C., Ochoa, R., Welbourn, W.C., Evans, G.A. & Moraes, G.J.de. (2009) A catalog of the Tenuipalpidae (Acari) of the World with a key to genera. *Zootaxa*, 2098, 1–185.
- Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B.da. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858.
- Rezende, J.M., Lofego, A.C., Nuvoloni, F.M. & Navia, D. (2014) Mites from Cerrado fragments and adjacent soybean crops: does the native vegetation help or harm the plantation? *Experimental and Applied Acarology*, 64 (4), 501–518. doi:10.1007/s10493-014-9844-5

- Seeman, O.D. & Beard, J.J. (2011) A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia. *Systematic and Applied Acarology*, 16, 73–89. doi:10.11158/saa.16.1.10
- Vasconcelos, G.J.N., Da Silva, F.R., Barbosa, D.G.F., Correa, M.G. & de Moraes, G.J. (2005) Ocorrência de Eriophyoidea, Tenuipalpidae, Tarsonemidae e Tukerellidae (Acari) em fruteiras no Estado de Pernambuco, Brasil. *Caatinga*, 18 (2), 98–104.
- Xu, Y. & Fan, Q.-H. (2010) *Tenuipalpus orilloi* Rimando, a new record to the Chinese fauna (Acari: Tenuipalpidae). *Systematic and Applied Acarology*, 15, 135–138.

Table 1. Ontogenetic development of leg setae in *Tenuipalpus spinosaurus* **sp. nov.** Setae are indicated in the stage in which they first appear. Setae in parentheses represent pairs.

	Coxa	Trochanter	Femur	Genu	Tibia	Tarsi
Leg I						
Larva	<i>1b</i>	-	<i>d, v', bv''</i>	<i>l'</i>	<i>d, (v), (l)</i>	<i>(u), (pζ), (ft), ω''</i>
Protonymph	<i>1c</i>	-	-	-	-	-
Deutonymph	-	<i>v'</i>	<i>l'</i>	<i>d, l''</i>	-	<i>(tc)</i>
Female	-	-	-	-	-	-
Leg II						
Larva	-	-	<i>d, v', bv''</i>	<i>l'</i>	<i>d, (v), (l)</i>	<i>(u), (pζ), (ft), ω''</i>
Protonymph	<i>2c</i>	-	-	-	-	-
Deutonymph	<i>2b</i>	<i>v'</i>	<i>l'</i>	<i>d, l''</i>	-	<i>(tc)</i>
Female	-	-	-	-	-	-
Leg III						
Larva	-	-	<i>d, ev'</i>	-	<i>d, (v)</i>	<i>(u), ft'</i>
Protonymph	<i>3b</i>	-	-	-	-	-
Deutonymph	-	<i>l', v'</i>	-	<i>d</i>	-	<i>(tc)</i>
Female	-	-	-	-	-	-
Leg IV						
Protonymph	-	-	<i>ev'</i>	-	<i>d, (v)</i>	<i>(u), ft'</i>
Deutonymph	<i>4b</i>	-	-	-	-	-
Female	-	<i>v'</i>	-	-	-	<i>(tc)</i>

Figures

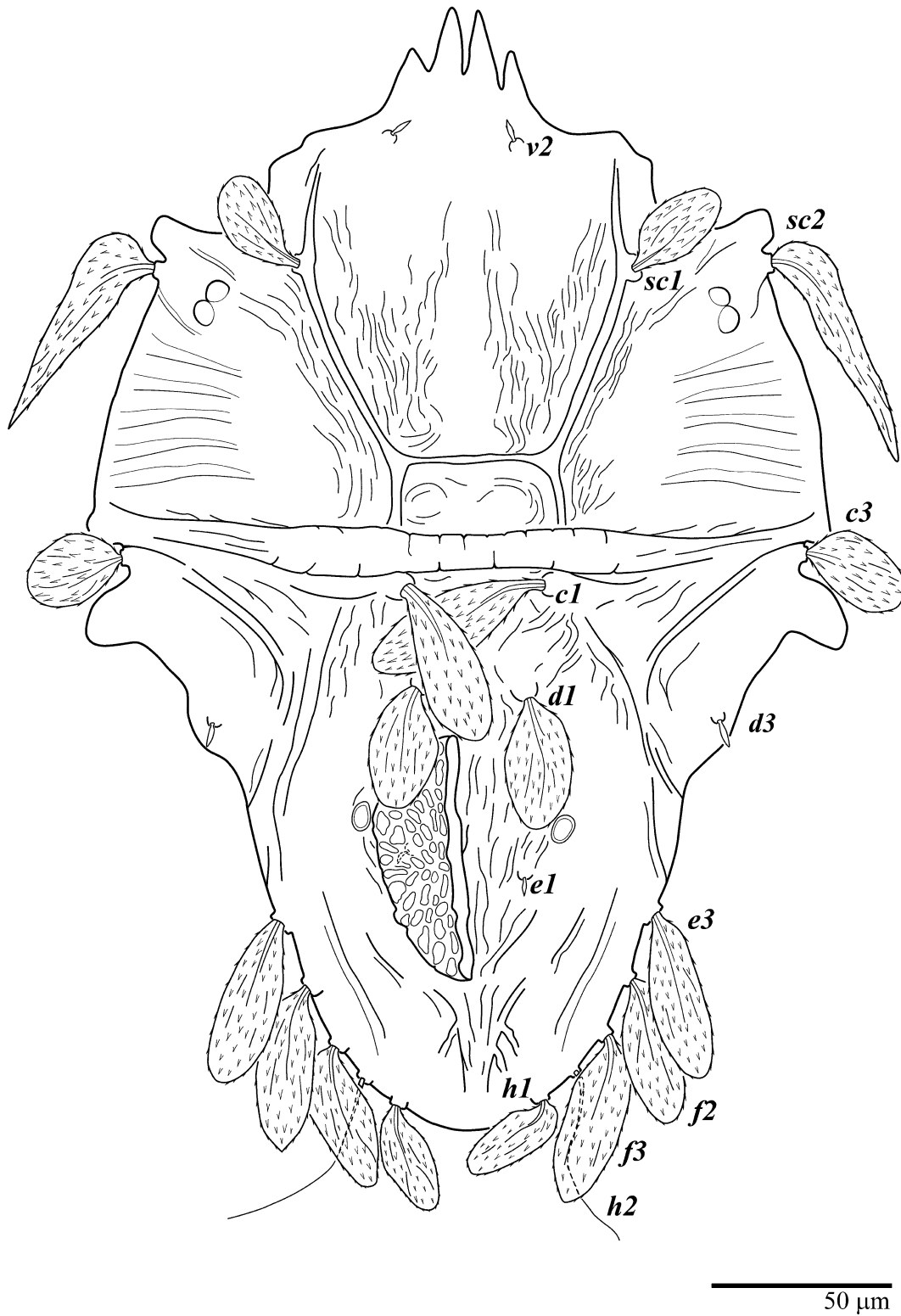


FIGURE 1. *Tenuipalpus spinosaurus* sp. nov. (Female): view of dorsum.

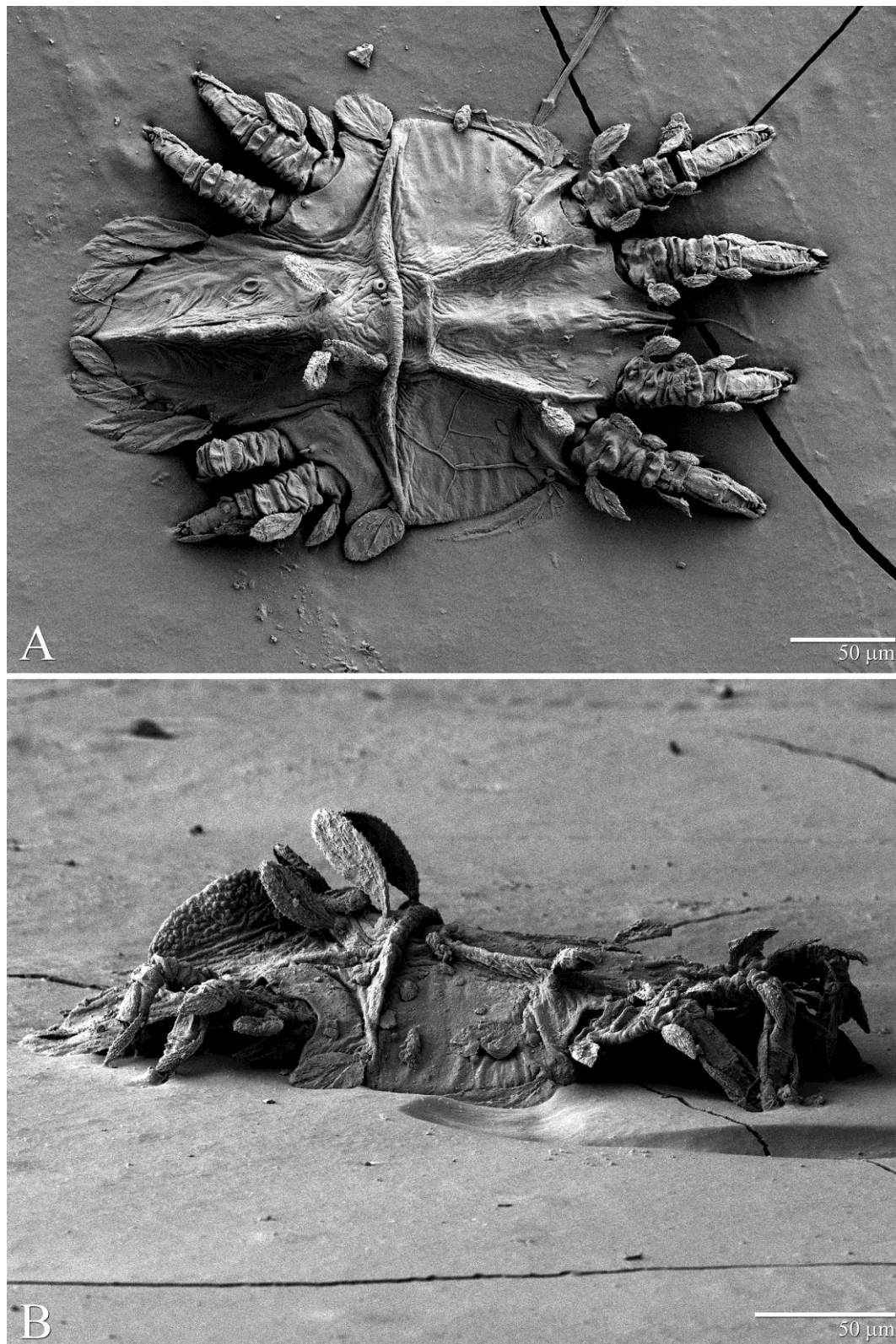


FIGURE 2. *Tenuipalpus spinosaurus* **sp. nov.** (Female): A. dorsal view; B. lateral view.

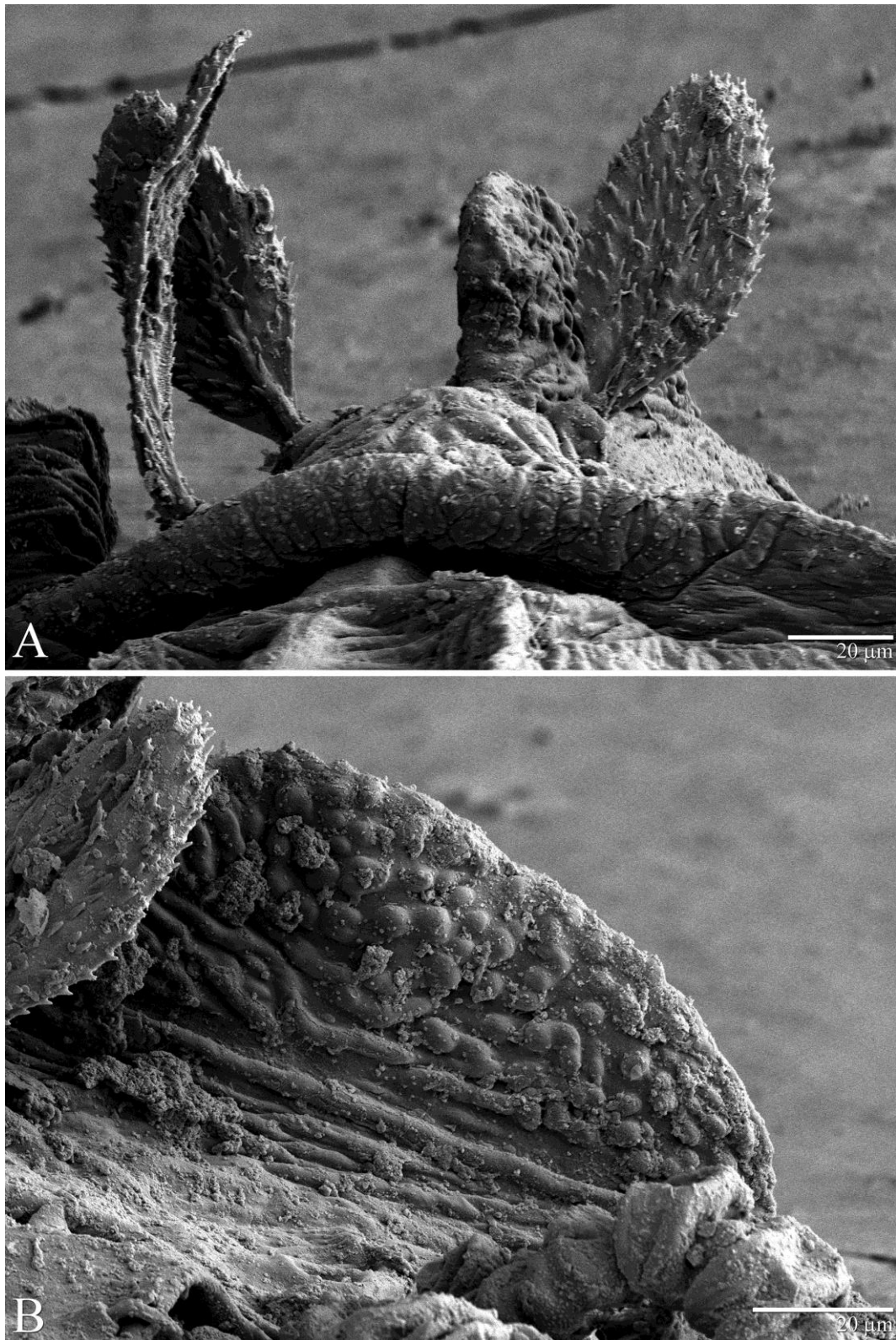


FIGURE 3. *Tenuipalpus spinosaurus* **sp. nov.** (Female): detail of crest. A. front view; B. lateral view.

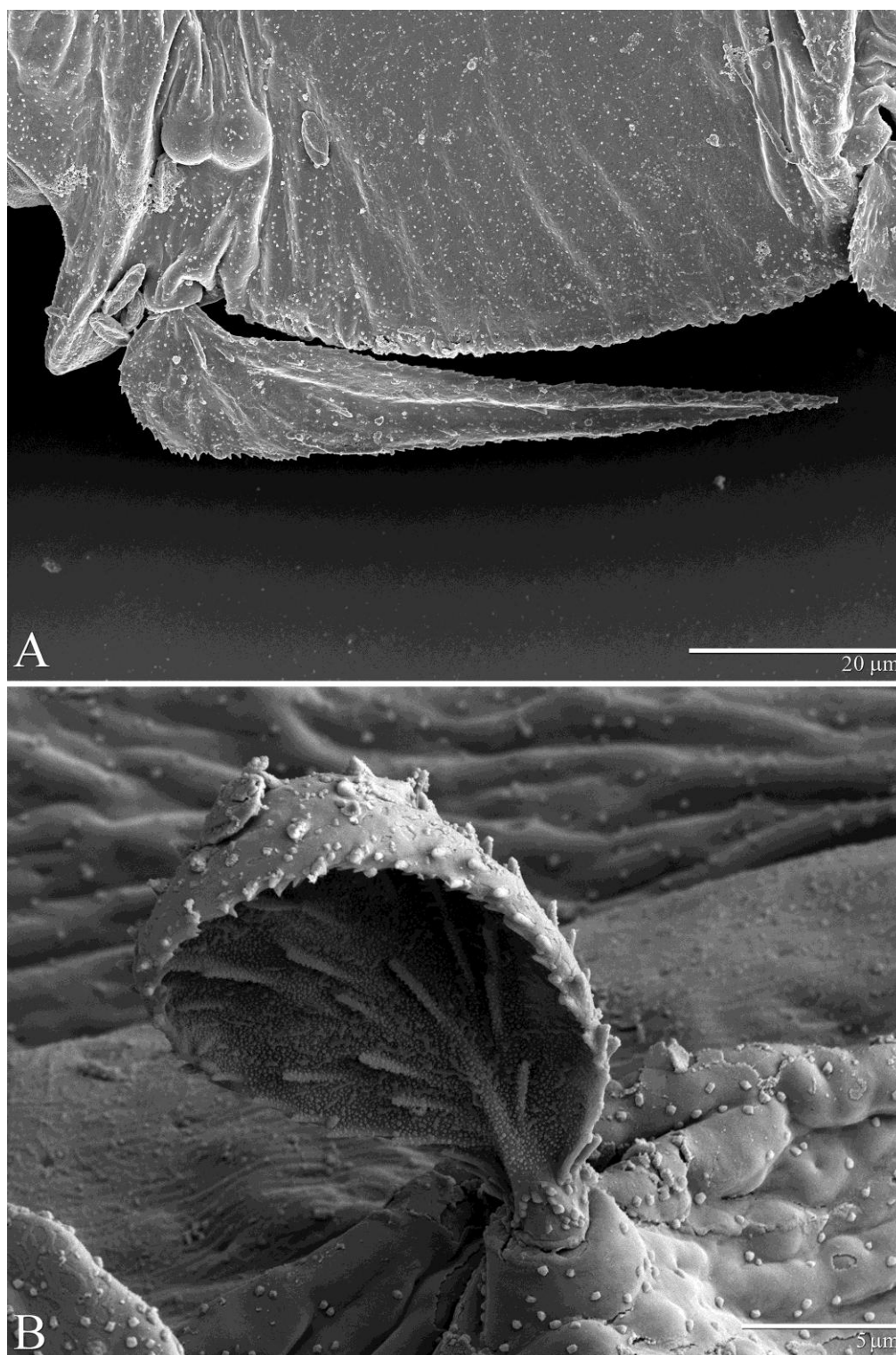


FIGURE 4. *Tenuipalpus spinosaurus* sp. nov. (Female): A. detail of the lateral region of prodorsum. Note the presence of body projection anterior to sc2 seta; B. sc1 seta inserted on tubercle.

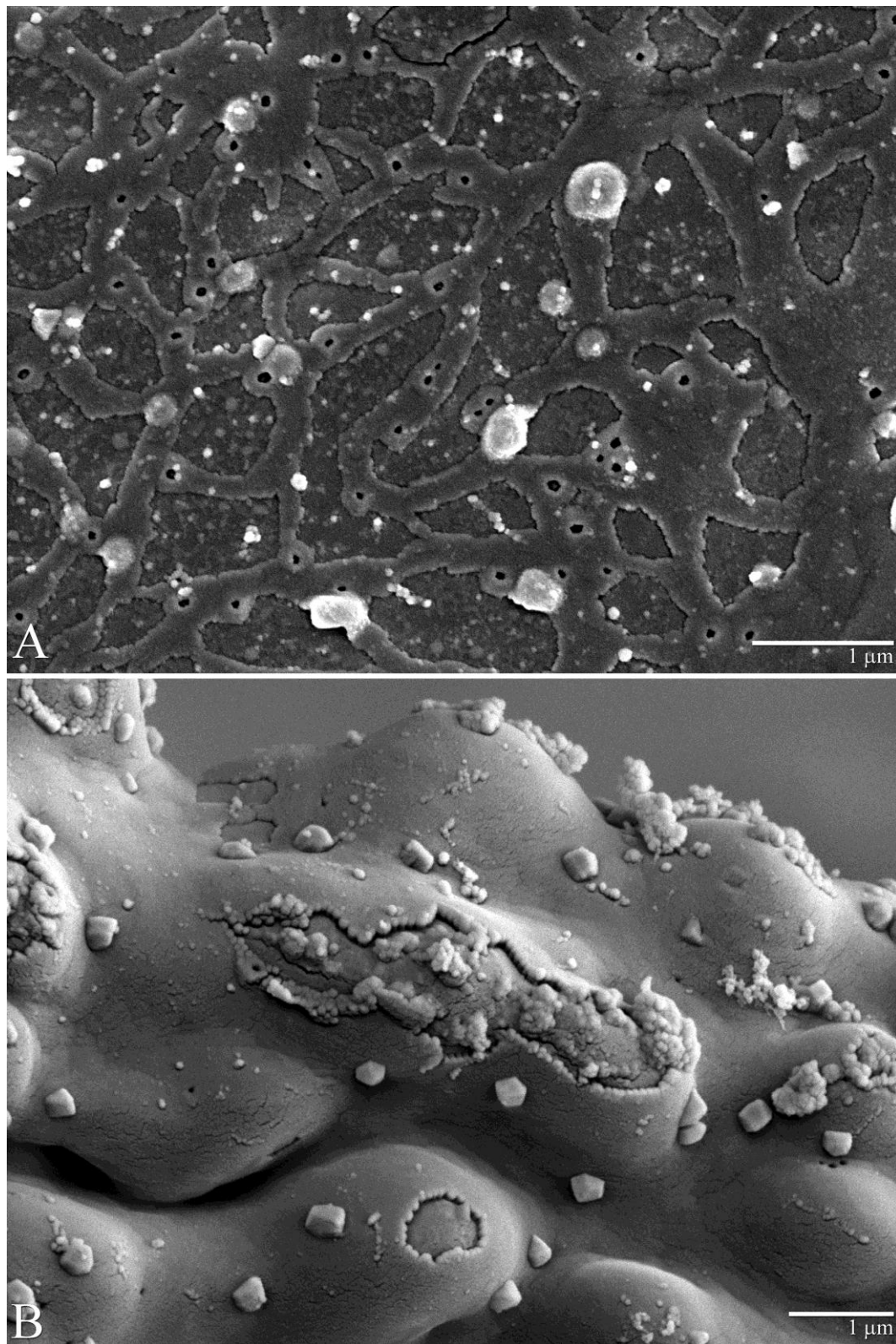


FIGURE 5. *Tenuipalpus spinosaurus* **sp. nov.** (Female): A. detail of microplate formation; B. view of microplate on integument of crest.



FIGURE 6. *Tenuipalpus spinosaurus* **sp. nov.** (Female): view of dorsum.

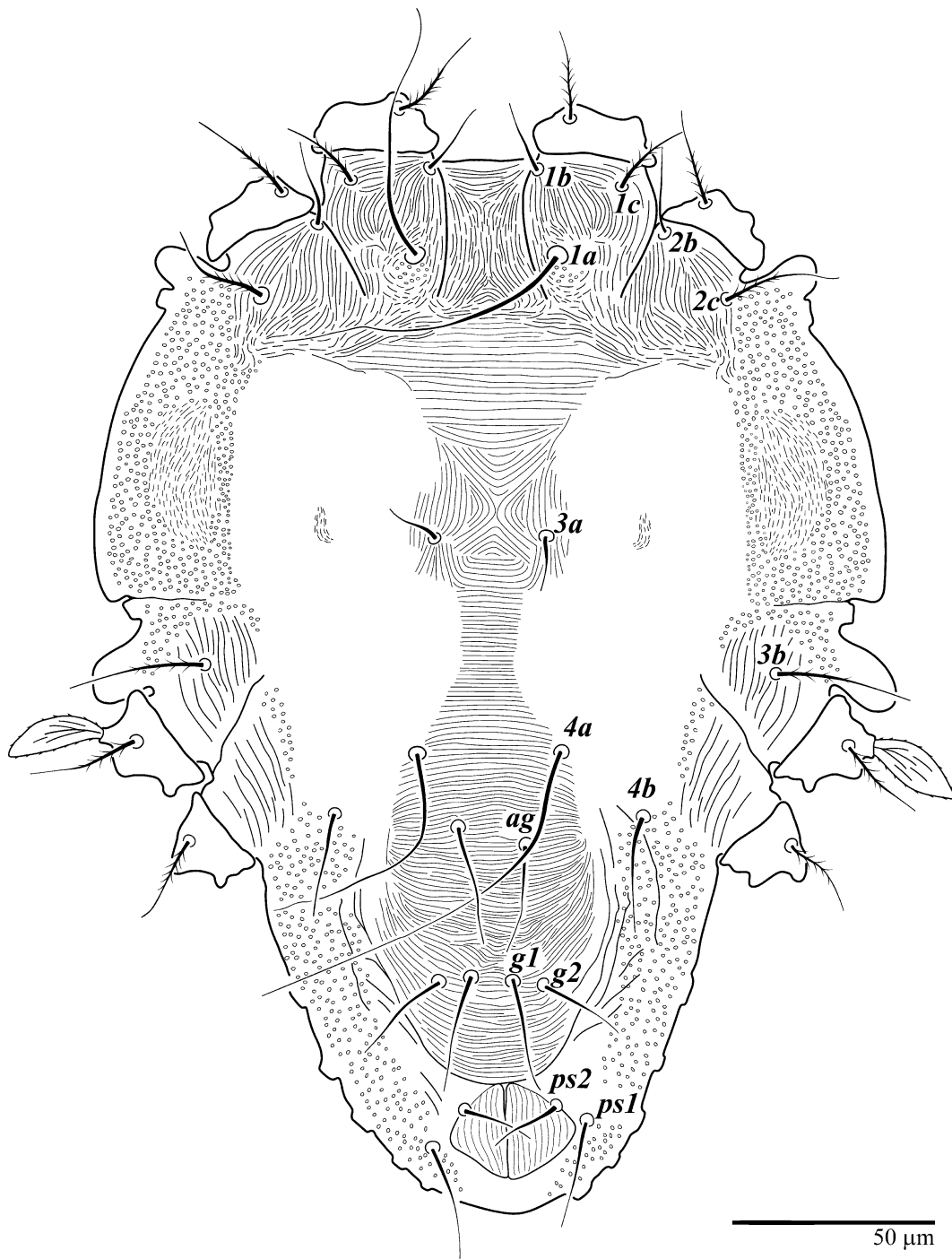


FIGURE 7. *Tenuipalpus spinosaurus* sp. nov. (Female): view of venter.

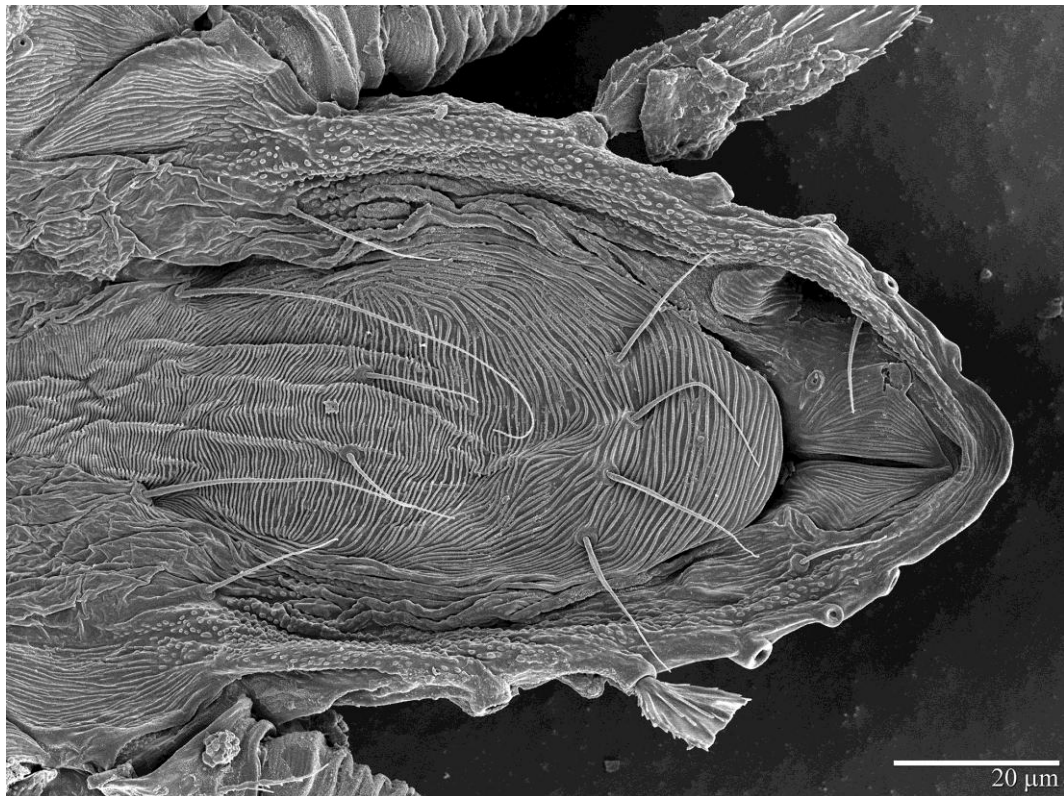


FIGURE 8. *Tenuipalpus spinosaurus* **sp. nov.** (Female): posterior ventral opisthosoma.

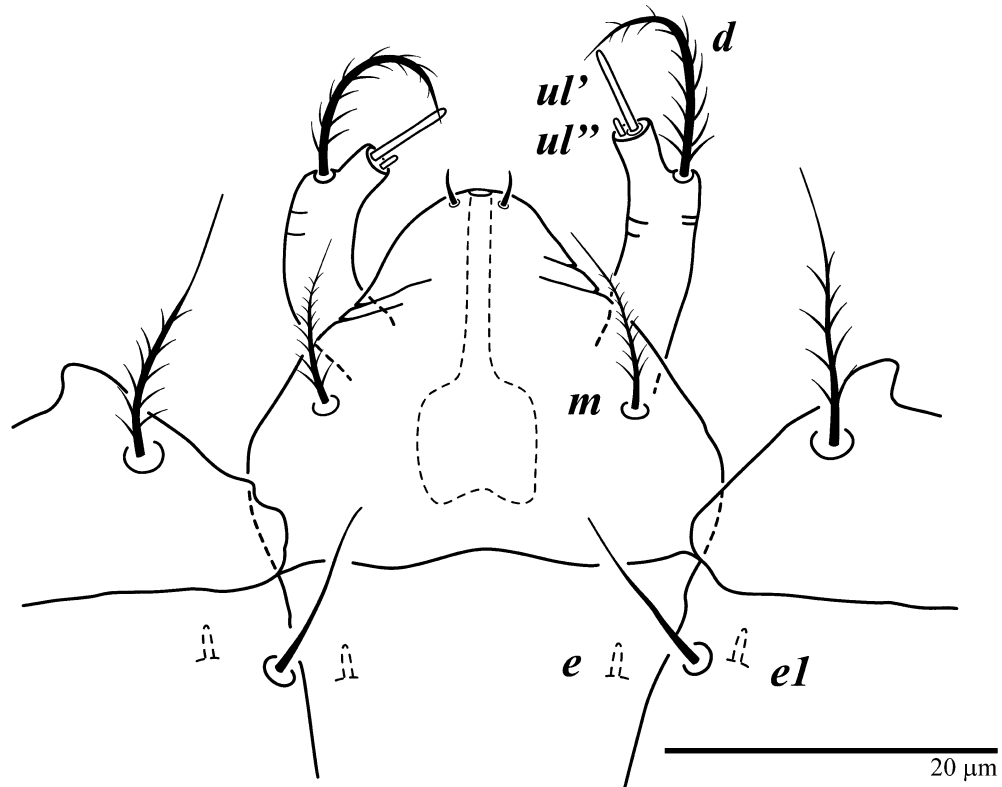


FIGURE 9. *Tenuipalpus spinosaurus* sp. nov. (Female): ventral infracapitulum.

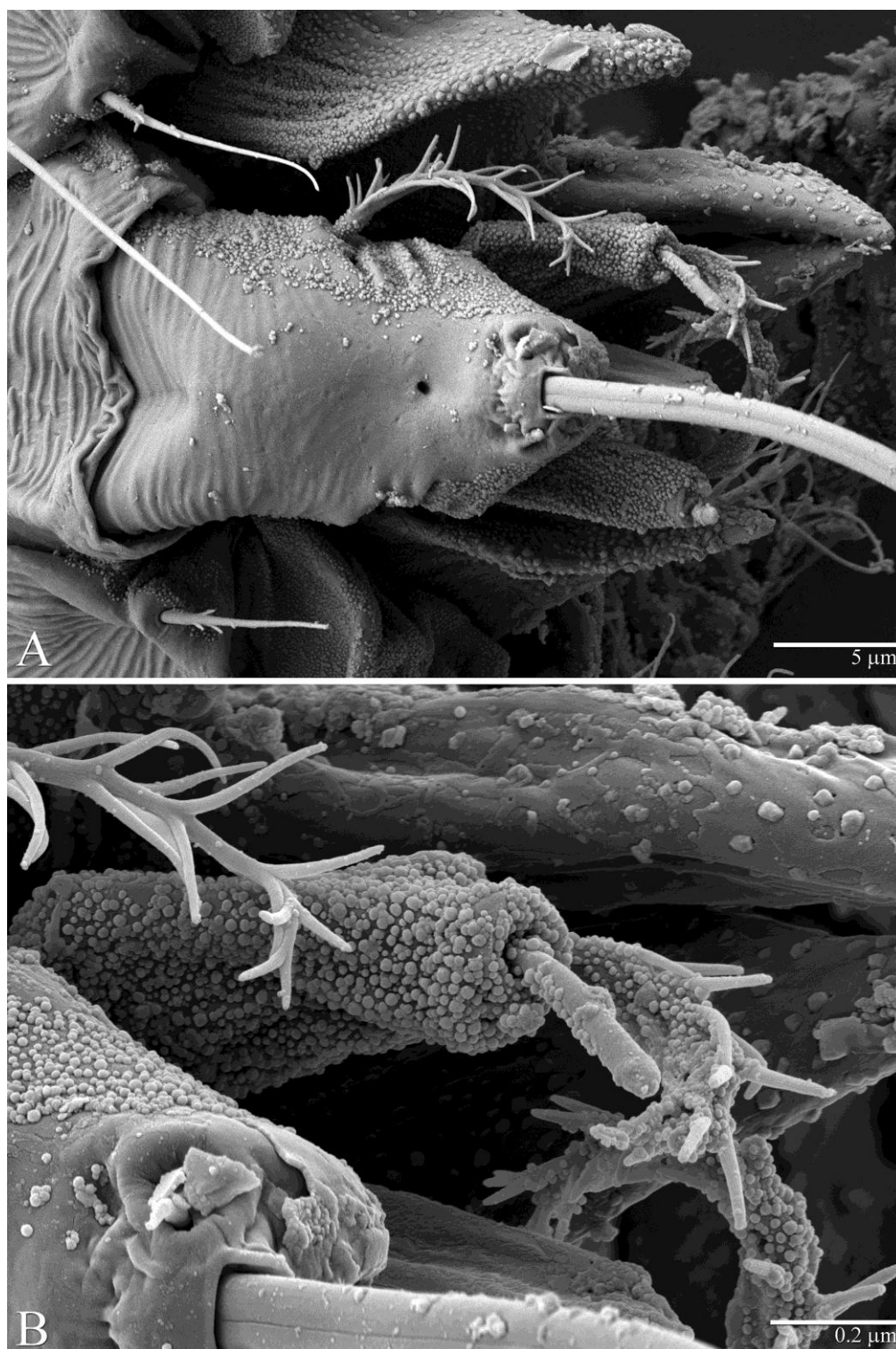


FIGURE 10. *Tenuipalpus spinosaurus* **sp. nov.** (Female): A. view of ventral infracapitulum, detail of protracted paired cheliceral stylets. Note the inferior oral commissure below oral orifice; B. detail of palp.

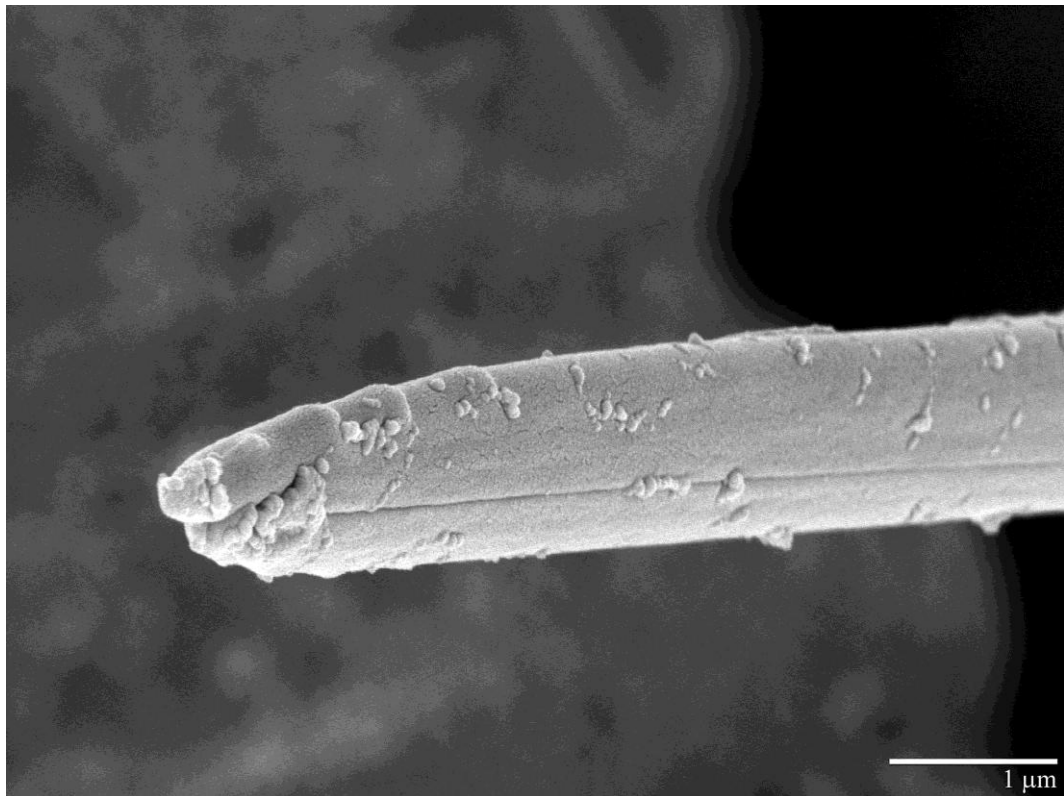


FIGURE 11. *Tenuipalpus spinosaurus* **sp. nov.** (Female): view of apex of chelicerae.

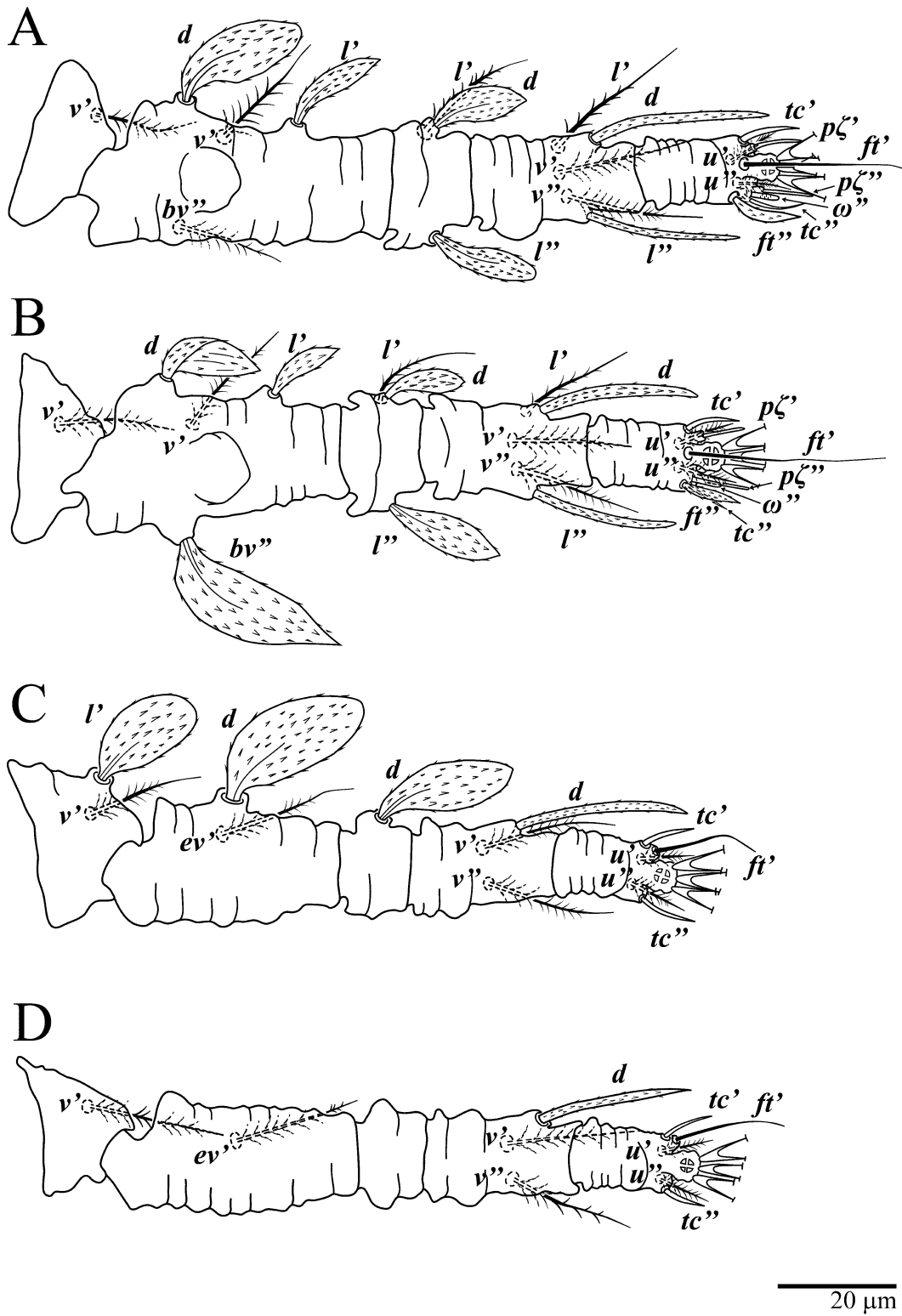


FIGURE 12. *Tenuipalpus spinosaurus* **sp. nov.** (Female): A. leg I; B. leg II; C. leg III; D. leg IV. (Right legs).

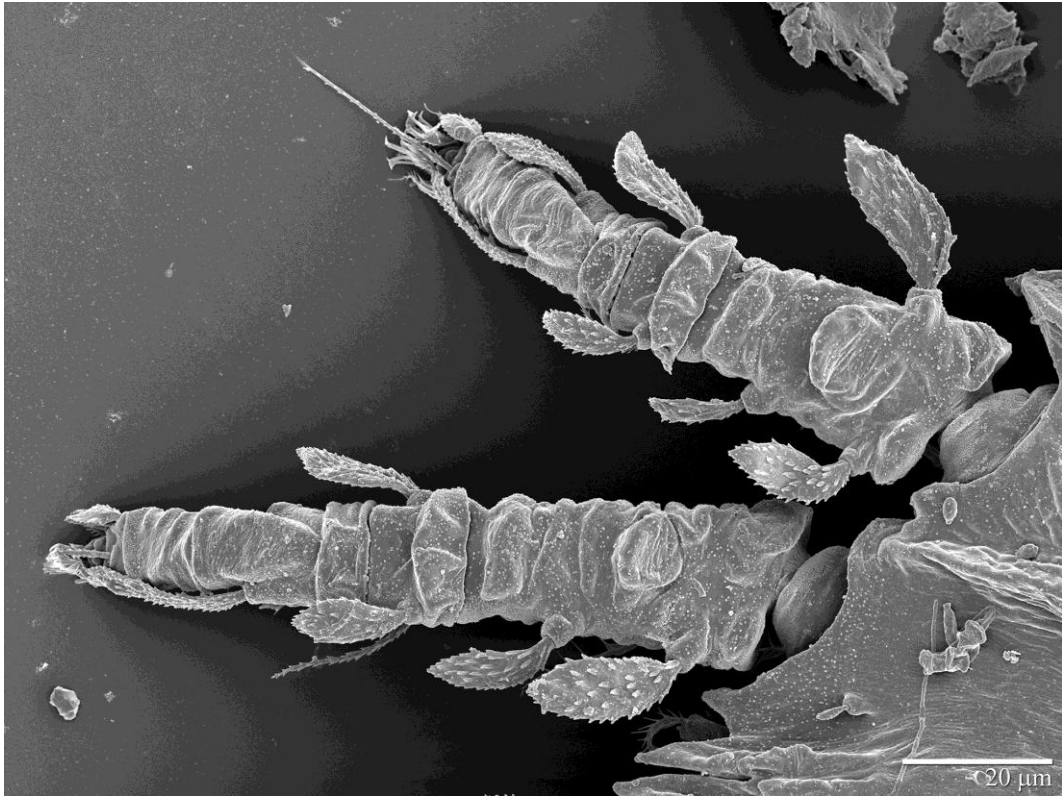


FIGURE 13. *Tenuipalpus spinosaurus* **sp. nov.** (Female): legs I and II (Right legs).

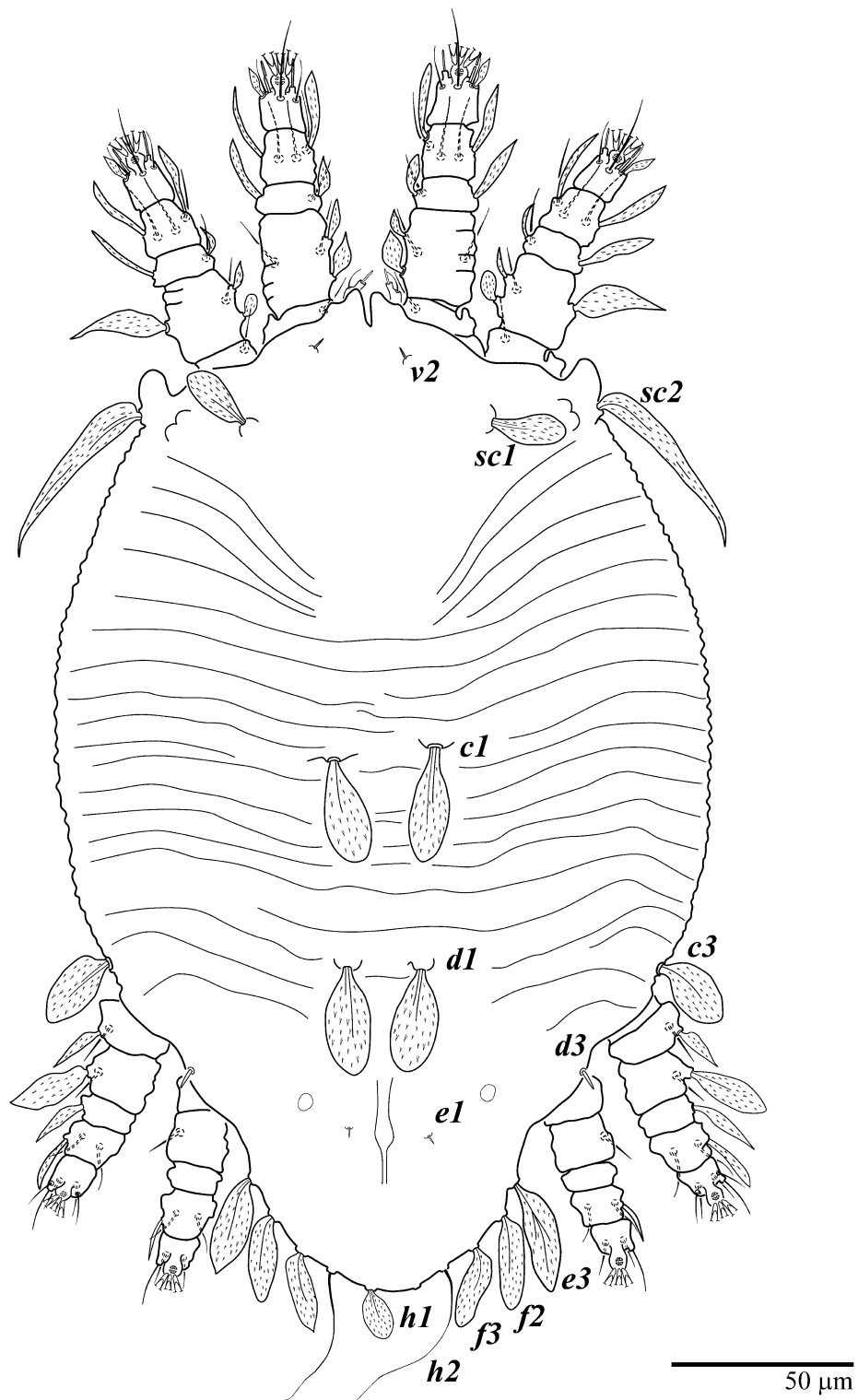


FIGURE 14. *Tenuipalpus spinosaurus* sp. nov. (Deutonymph): dorsum, with detail of legs. Unguinal setae u' – u'' on tarsus I and II are not included in the drawing.

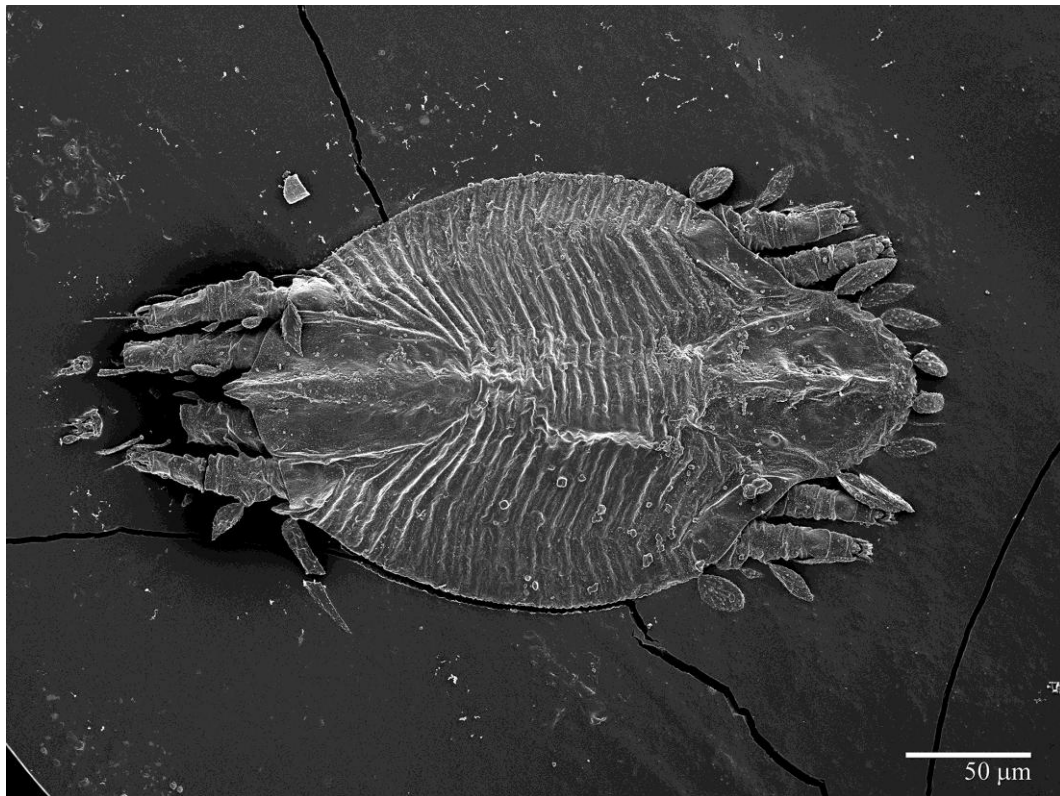


FIGURE 15. *Tenuipalpus spinosaurus* **sp. nov.** (Deutonymph): dorsal view.

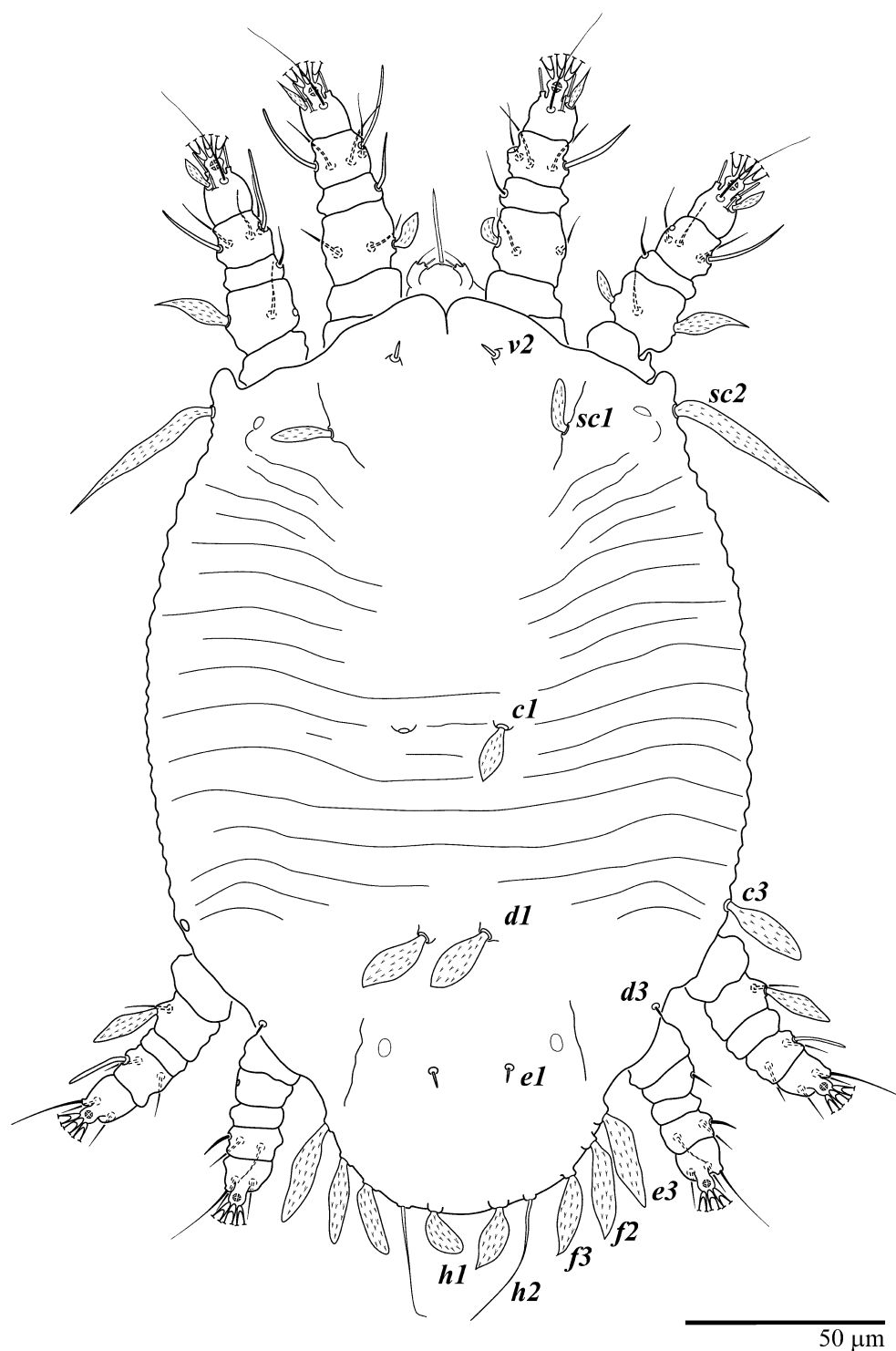


FIGURE16. *Tenuipalpus spinosaurus* sp. nov. (Protonymph): dorsum, with detail of legs. Unguinal setae *u'*–*u''* on tarsus I and II are not included in the drawing.

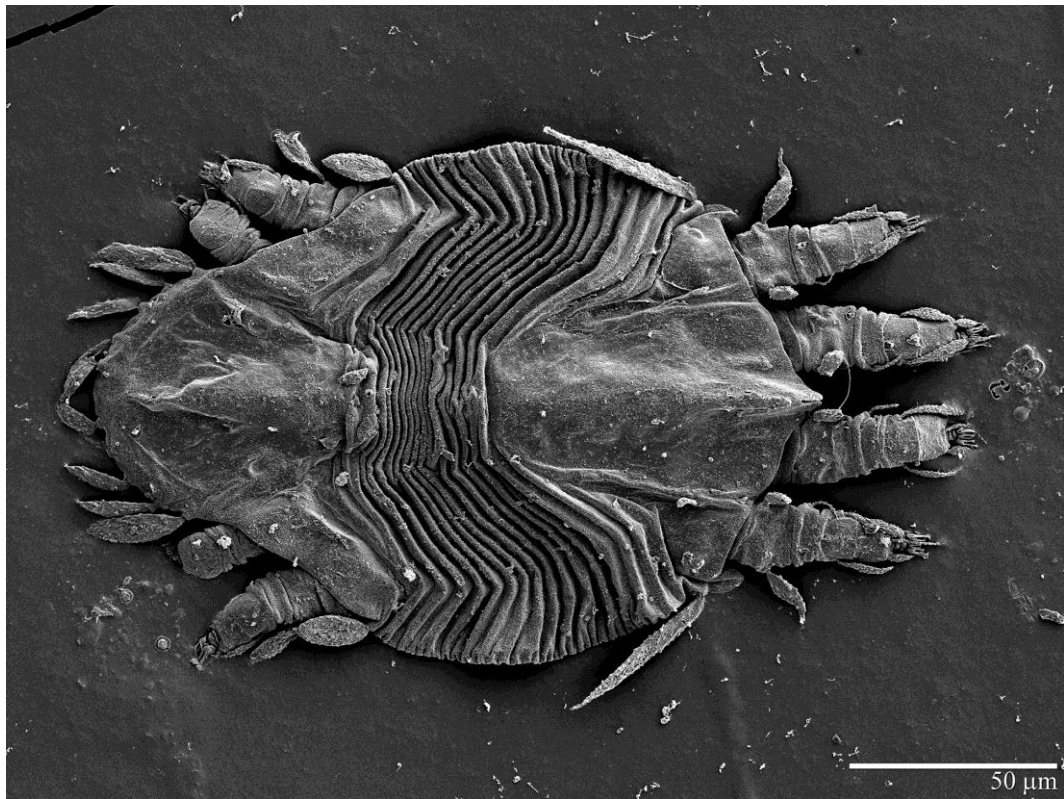


FIGURE 17. *Tenuipalpus spinosaurus* **sp. nov.** (Protonymph): dorsal view.

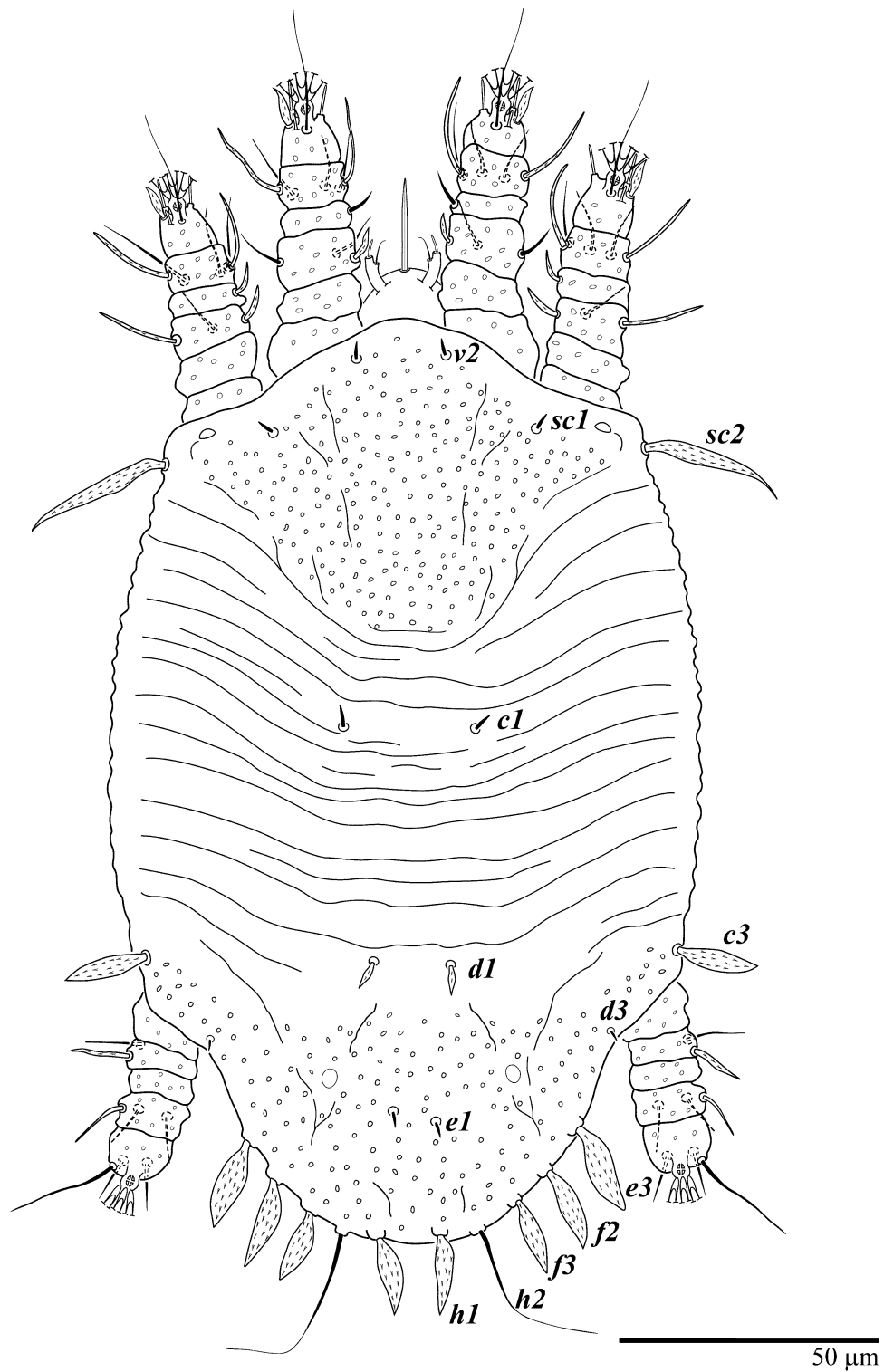


FIGURE 18. *Tenuipalpus spinosaurus* sp. nov. (Larva): dorsum, with detail of legs. Unguinal setae *u'*–*u''* on tarsus I and II are not included in the drawing.

CHAPTER 4

REDESCRIPTION OF *TENUIPALPUS HEVEAE* BAKER (ACARI: TENUIPALPIDAE) AND DESCRIPTION OF A NEW SPECIES COLLECTED ON RUBBER TREE FROM AMAZONIA, BRAZIL

Manuscript in preparation for submission

Abstract

Tenuipalpus heveae Baker, 1945 was described based only from female specimens collected on rubber trees from Belterra, State of Pará, Brazil. However, the original description does not provide essential information, and thus, it may be difficult to correctly identify the species. In this paper, we redescribe the female of *T. heveae* with additional data (e.g. dorsal and ventral ornamentation, leg chaetotaxy and setal measurements) in a standardized form. In addition, we describe *Tenuipalpus* **sp. nov.** based on females, deutonymphs, protonymphs and larvae collected on *Hevea brasiliensis* Muell. Arg. and *H. guianensis* Aubl. (Euphorbiaceae) from Manaus, State of Amazonas, Brazil. We include detail of ontogenetic changes for all stages of this new species.

Keywords: *Hevea*; sensu lato group; red false spider mite; pest mite; ontogeny; taxonomy; systematic.

Introduction

Some researchers have recorded a high abundance of *Tenuipalpus heveae* Baker (Acari, Tenuipalpidae) on the rubber tree, *Hevea brasiliensis* (Euphorbiaceae), plantations from different regions of Brazil (Hernandes & Feres 2006; Daud & Feres 2007; Castro *et al.* 2013). According to Pontier *et al.* (2000), high infestations of *T. heveae* may cause leaf rusting followed by plant defoliation. Currently, this species is considered to be a mite pest for this crop in several states of Brazil (Castro *et al.* 2013).

Tenuipalpus heveae was described based only on adult females collected on rubber trees in Belterra, State of Pará, Brazil (Baker 1945, Baker & Pritchard 1953). Recently, male and immatures were described by Pontier & Flechtmann (1999; 2000), respectively. However, the description available of the female does not provide essential information (e.g. dorsal and ventral ornamentation, leg chaetotaxy and setal measurements), and thus, it may be difficult to correctly identify the species. The objective of

this paper is to redescribe the female of *T. heveae* in a standardized form and to describe a new species collected on rubber tree from Manaus, State of Amazonas, Brazil.

Material and Methods

Measurements of the holotype are given in micrometers (μm), with the range of measurements for the paratypes shown in parentheses. Photographs taken using differential interference contrast (DIC) microscopy are included. The terminology used follows that of Lindquist (1985) and Mesa *et al.* (2009). Leg chaetotaxy is adapted from Lindquist (1985), Xu & Fan (2010) and Seeman & Beard (2011). Tarsal setae are presented as the total number followed by the number of solenidia in parentheses.

Specimens of *T. heveae* were collected on *Hevea brasiliensis* Muell. Arg. (Euphorbiaceae) from São José do Rio Preto, State of São Paulo, Brazil. These specimens were maintained in 70% ethanol and later used for low-temperature scanning electron microscopy (LT-SEM) studies. Mites for LT-SEM studied using the methodology previously described in Castro *et al.* (2015a). Non-type material of *T. heveae* was collected from rubber tree plantations of different regions of Brazil.

Type specimens and voucher of non-type material are deposited in the Collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRP, <http://www.splink.cria.org.br>) and in the National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located in the Systematic Entomology Laboratory (SEL), USDA, Beltsville, Maryland, USA (NMNH).

Family Tenuipalpidae Berlese, 1913

Genus *Tenuipalpus* Donnadieu, 1876

Type species *Tenuipalpus palmatus* Donnadieu, 1876 (= *T. caudatus* (Dugès), 1834)

Diagnosis. (According to Castro *et al.* 2016a). **Female:** Body shape with prodorsum wider than opisthosoma or elongate-ovate; prodorsum with three pairs of setae (*v2*, *sc1*, *sc2*, except *v2* absent in *T. elegans* (Collyer)); dorsal opisthosoma with eight to ten pairs of setae (*c3*, *d3*, *e3*, *f3*, *h1*, *h2* present; *c2*, *d2*, *e2* absent; *c1*, *d1*, *e1*, *f2* present or absent (*d1*, *e1* rarely absent); setae *h2* elongate, flagellate. Palp one to three segmented. Venter with one to two pairs of setae *3a* (*3a2* present or absent) and one to four pair of setae *4a* (*4a2*, *4a3*, *4a4* present or absent); ventral and genital plates not developed, membranous genital flap present; commonly two pairs of pseudanal setae *ps1–2* present (setae *ps3* rarely present). **Male:** Opisthosoma distinctly narrower than that of female; legs and dorsal setae usually similar to those of female; pseudanal setae *ps1* modified as accessory genital stylet.

Results

Tenuipalpus heveae Baker, 1945: 36

(Figures 1–13)

Tenuipalpus heveae Baker, 1945: 36; Baker & Pritchard, 1953: 319; Pontier & Flechtmann, 1999: 293; Pontier & Flechtmann, 2000: 77.

Diagnosis. Dorsum completely ornamented; prodorsum with 3 pairs of setiform and barbed setae; opisthosoma with 10 pairs of setiform and barbed setae; *f2* present. Palps three segmented. Ventral integument striated on central region, converging between *3a* setae; ventral prodorsum with margin longitudinally striate; striae surrounding coxae III and IV pointing to the center. Coxal setae *1b* and *2b* filiform and smooth, others barbed. Tarsi I–IV 8(1)-8(1)-4-4 (setae *tc'* absent on tarsus III-IV);

trochanters I–IV 1-1-1-1 (setae *l'* absent on tarsi III); setae *d* on tibia III and IV absent.

Type material examined: Holotype: female collected on a rubber tree, *Hevea brasiliensis* Muell. Arg. (Euphorbiaceae), Belterra, State of Pará, Brazil, 9 Aug. 1941, coll. J.A. Zilles, deposited in National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located at the SEL-USDA, Beltsville, Maryland, USA (USNM n. 1481a). Paratypes: 2 females with the same data that as holotype (USNM n. 1481b–1481c); and 1 female with the same data that as holotype, deposited in Collection of Acari, Departamento de Zoologia e Botânica, UNESP, located at the São José do Rio Preto, State of São Paulo, Brazil (USNM n. 1481d, DZSJRP n. 10145).

Remarks. Baker (1945) and Baker & Pritchard (1953) did not mention the number of specimens used in the description and redescription of the species. There were four type specimens in bad condition and had to be remounted by USNM staff. Now there are four slides, each with 1 female specimen. One of the paratypes was donated to Collection of Acari DZSJRP.

Non-type material examined: 5 females collected on *H. brasiliensis* from Igrapiúna, Bahia, Brazil, 2009; coll. E.B. Castro (DZSJRP n. 10146–10148); 2 females collected on *H. brasiliensis* from Manaus, Amazonas, Brazil, 20 Oct. 2000, coll. T.J. Izzo; 2 females collected on *H. guianensis* Aubl. (Euphorbiaceae) from Manaus, Amazonas, Brazil, Aug. 2012, coll. F.M. Nuvoloni (DZSJRP n. 10149–10151); 3 females collected on *H. brasiliensis* from Taquaritinga, São Paulo, Brazil, 14 Apr. 2000, coll. R.J.F. Feres; 2 females collected on *H. brasiliensis* from São José do Rio Preto, São Paulo, Brazil, 01 Jul. 2003, coll. R.J.F. Feres (DZSJRP n. 10152–

10154); and 5 females collected on *H. brasiliensis* from Goianésia, Goiás, Brazil, 05 Dec. 2000, coll. R.J.F. Feres (DZSJRP n. 10155–10157).

Redescription

Female (Figs. 1-13, n=4). Body measurements: distance between setae *v2–h1* 240 (230–250), *sc2–sc2* 150 (145–150); other measurements: *v2–v2* 32 (27–32), *sc1–sc1* 100 (95–105), *c1–c1* 25 (20–25), *c3–c3* 175 (167–175), *d1–d1* (2–7), *d3–d3* (130–145), *e1–e1* (1–5), *e3–e3* (85–112), *f2–f2* 82 (80–97), *f3–f3* 75 (72–75), *h2–h2* 60 (50–62), *h1–h1* 27 (22–27).

Dorsum (Figs. 1-4). Anterior margin of prodorsum with a pair of projections forming a notch. Dorsum completely ornamented; prodorsum with transverse to oblique striae. Mostly of dorsal setae setiform and barbed; setae *v2*, *c1*, *d1*, *d3* and *e1* short to minute, *h2* elongate and flagelliform. Setal lengths: *v2* 5 (4–5), *sc1* 10 (9–10), *sc2* 20 (20–23), *c1* 4 (3–4), *c3* 19 (16–19), *d1* 4 (3–4), *d3* 4 (4), *e1* 4 (4), *e3* 16 (17–20), *f2* 16 (13–18), *f3* 15 (14–17), *h1* 14 (10–13), *h2* 120 (100–125).

Venter (Figs. 5, 7). Ventral integument with oblique striations near to 3a setae; prodorsum with margin longitudinally striate. Striae surrounding coxae III and IV pointing to the center. Setae *1b* and *2b* smooth, others coxal setae barbed; *1a* and *4a* setae elongate and flagelliform; setae *ag*, *g1–2* and *ps1–2* barbed. Setal lengths: *1a* 70 (40–70), *1b* 10 (10–11), *1c* 14 (12–15), *2b* 16 (12–20), *2c* 21 (18–24), *3a* 12 (10–12), *3b* 20 (15–20), *4a* 70 (70–75), *4b* 17 (17–21), *ag* 17 (16–18), *g1* 16 (16–19), *g2* 19 (17–20), *ps1* 13 (12–16), *ps2* 14 (12–16).

Gnathosoma (Figs. 6, 8-9). Palps 3-segmented, second segment elongate bearing 1 long, barbed seta *d* (9-13); third segment short with 1 eupathidium *ul'* 8 (7-8). Ventral setae *m* 11 (10-12), barbed; distance between setae *m–m* 15 (12-14). Tips of cheliceral stylets laterally serrated (Fig 9).

Legs (Figs. 10-13) Chaetotaxy (from coxae to tarsi): I 2-1-4-1-5-8(1), II 2-1-4-1-5-8(1), III 1-1-2-0-2-4, IV 1-1-1-0-2-4. Setae *d* on femora I and II in

dorsal position; setae *l'* on trochanter III absent; setae *d* absent on tibiae III and IV; tarsi I and II each with 1 solenidion ω [tarsi I 4 (4–5) and tarsi II 3 (3–4) respectively] and 2 eupathidia *p'* and *p''* (7-8, 7-8 for both tarsi I and II).

Color. The body is reddish with the margin of prodorsum and opisthosoma dark red. The legs and dorsal setae are orange. Due to its color this species is known in the Brazil as the rubber tree red false spider mite or “falso-ácaro-vermelho-da-seringueira”.

Hosts and distribution. On rubber trees from several Brazilian states. This species occurs mainly on the lower surface of the leaflets.

Remarks. The non-type specimens examined in this study have similar body and setal measurements as those of the type specimens (Table 1). In addition, the pattern of dorsal ornamentation and the leg chaetotaxy of those specimens are similar to those of the type specimens.

***Tenuipalpus* sp. nov.** Castro, Ramos and Feres

Figures (14–24)

Diagnosis: Female: Dorsum completely smooth; prodorsal setae *v2* and *sc1* minute, *sc2* setiform, short and barbed; opisthosoma with 10 pairs of setae; *f2* present; setae *c1*, *c3*, *d1*, *d3*, *e1* and *e3* minute; setae *f2*, *f3* and *h1* lanceolate to obovate, short and barbed. Palps three segmented. Ventral integument with transverse to oblique striations between setae *1a* and *3a*; ventral prodorsum with lateral margin longitudinally striate. Tarsi I–IV 8(1)-8(1)-4-4 (setae *tc'* absent on tarsus III and IV); trochanters I–IV 1-1-2-1; setae *d* on tibia IV absent. Immatures: most of dorsal setae similar to those of the female.

Type material examined: Holotype: female collected on *Hevea brasiliensis* Muell Arg. (Euphorbiaceae) from Manaus, Amazonas, Brazil, 21 Dec. 2000, coll. T.J. Izzo, deposited in Acari Collection, Departamento

de Zoologia e Botânica, UNESP, located at the São José do Rio Preto, State of São Paulo, Brazil (DZSJRP no. 10158). Paratypes: 5 females, 1 deutonymph, 2 protonymphs and 2 larvae with the same data that as holotype (DZSJRP no. 10159–10164); 3 females, 1 deutonymph and 1 larva collected on *H. guianensis* Aubl. (Euphorbiaceae) from Manaus, Amazonas, Brazil, Aug. 2012, coll. F.M. Nuvoloni (DZSJRP n. 10165, USNM).

Description

Female (Figs. 14-21, n=9). Body measurements: distance between setae $v2-h1$ 232 (210–237), $sc2-sc2$ 135 (120–142); other measurements: $v2-v2$ 30 (27–30), $sc1-sc1$ 75 (72–77), $c1-c1$ 22 (17–27), $c3-c3$ 162 (152–167), $d1-d1$ 10 (10–12), $d3-d3$ 142 (130–142), $e1-e1$ 7 (5–10), $e3-e3$ 97 (82–102), $f2-f2$ 95 (80–97), $f3-f3$ 77 (67–80), $h2-h2$ 62 (37–62), $h1-h1$ 17 (15–22).

Dorsum (Figs. 14-15): Anterior margin of prodorsum with a pair of projections forming a notch; dorsum completely smooth; most dorsal setae minute; setae $sc2$ setiform and barbed; $f2$, $f3$ and $h1$ lanceolate to obovate, short and barbed; setae $e3$ distinctly smaller than setae $f2$ and $f3$. Setal lengths: $v2$ 4 (2–4), $sc1$ 4 (2–5), $sc2$ 15 (15–31), $c1$ 4 (3–4), $c3$ 6 (4–6), $d1$ 4 (2–4), $d3$ 5 (2–5), $e1$ broken (1–4), $e3$ 5 (5–9), $f2$ 13 (13–16), $f3$ 14 (12–18), $h1$ 12 (8–12), $h2$ 120 (95–120).

Venter (Fig. 16). Ventral integument with transverse to oblique striations between $1a$ and $3a$ setae; prodorsum with ventral margin longitudinally striate. Striae surrounding coxae III and IV pointing to the center. Setae $1b$ and $2b$ filiform and smooth, other coxal setae barbed; $1a$ and $4a$ setae elongate and flagelliform; setae ag , $g1-2$ and $ps1-2$ barbed. Setal lengths: $1a$ broken (65–80), $1b$ 7 (5–11), $1c$ 15 (10–17), $2b$ 11 (10–13), $2c$ 20 (16–24), $3a$ 10 (9–10), $3b$ 15 (12–22), $4a$ 90 (60–95), $4b$ 18 (13–20), ag 21 (14–21), $g1$ 17 (15–21), $g2$ 17 (14–17), $ps1$ 20 (13–20), $ps2$ 15 (10–15).

Gnathosoma (Fig. 17). Palps 3-segmented, second segment elongate bearing long, barbed *d* seta 10 (7-12); third segment short with 1 eupathidium *ul'* 7 (5-7). Ventral setae *m* 9 (5-9), barbed; distance between setae *m–m* 14 (11-14).

Legs (Figs. 18-21). Chaetotaxy (from coxae to tarsi): I 2-1-4-1-5-8(1), II 2-1-4-1-5-8(1), III 1-2-2-0-3-4, IV 1-1-1-0-2-4. Setae *d* distinctly dorsal on femora I-II, absent in tibiae IV; tarsi I and II each with 1 solenidion ω'' 4 (3–4) (for both tarsi I and tarsi II) and 2 eupathidia *p'* and *p''* (5-6, 4-7; 5-6, 4-7 respectively). See details of the development of leg chaetotaxy in Table 2.

Color. The body is dark red with some black spots. The legs are dark. Leg and dorsal setae are orange.

Male. Unknown.

Deutonymph (n=2). Body size measurements: distance between setae *v2–h1* 217-235, *sc2–sc2* 105–130; other measurements: *v2–v2* 25-27, *sc1–sc1* 75-80, *c1–c1* 22, *c3–c3* 142-160, *d1–d1* 10-12, *d3–d3* 107-122, *e1–e1* 2-5, *e3–e3* 70-87, *f2–f2* 65-80, *f3–f3* 52-62, *h2–h2* 32-40, *h1–h1* 12-15.

Dorsum (Fig. 22): Anterior margin of prodorsum with a small pair of projections, forming a notch; prodorsum with anterior region smooth; region between setae *sc2* and *d1* with spaced transverse to oblique folds; and region posterior to *d1* and *d3* smooth. Setal lengths: *v2* 2, *sc1* 3, *sc2* 36-37, *c1* 3-4, *c3* 8-14, *d1* 3, *d3* 2, *e1* 2, *e3* 12-15, *f2* 15–16, *f3* 15-17, *h1* 7-10, *h2* 70-110.

Venter: Ventral integument covered with transverse striae, weakly between setae *3a* and *4a*. Setal lengths: *1a* 75, *1b* 5, *1c* 5-9, *2b* 4, *2c* 8-9, *3a* 7–9, *3b* 5-7, *4a* 35-45, *4b* 5-6, *ag* 6-8, *g1* 5-6, *ps1* 5-6, *ps2* 4. Setae *g2* absent.

Gnathosoma: Palps similar to those of adults. Tibial seta *d* 5-6, tarsal eupathidium *ul'* 5. Ventral seta *m* 5–6; distance between setae *m–m* 5–11.

Legs: Chaetotaxy (from coxae to tarsi): I 2-1-4-1-5-8(1), II 2-1-4-1-5-8(1), III 1-2-2-0-3-4, IV 1-0-1-0-2-3. Setae *d* on tibia IV absent; tarsi I and II

each with 1 solenidion ω'' (tarsi I 2-3 and tarsi II 3) and eupathidia p' and p'' (5, 5–6; 5, 5 respectively). See details of the development of leg chaetotaxy in Table 2.

Protonymph (n=2). Body size measurements: distance between setae $v2-h1$ 174-176, $sc2-sc2$ 103-108; other measurements: $v2-v2$ 21-23, $sc1-sc1$ 65-67, $c1-c1$ 20, $c3-c3$ 120-124, $d1-d1$ 9-11, $d3-d3$ 91-95, $e1-e1$ 4-5, $e3-e3$ 69-72, $f2-f2$ 61-63, $f3-f3$ 45-48, $h2-h2$ 28-31, $h1-h1$ 10.

Dorsum (Fig. 23): Anterior margin of prodorsum with a pair of small projection, forming a notch; prodorsum with anterior region smooth; region between pair of setae $sc2$ and $d1$ with spaced transverse to oblique striations; region posterior to setae $d1$ and $c3$ smooth. Setal lengths: $v2$ 2, $sc1$ 2, $sc2$ 28-32, $c1$ 3-4, $c3$ 10, $d1$ 3-5, $d3$ 1-2, $e1$ 2-3, $e3$ 12-14, $f2$ 17-19, $f3$ 17-20, $h1$ 5-10, $h2$ 40-45.

Venter: Ventral integument covered with transverse striae. Setal lengths: $1a$ 55, $1b$ 4-5, $1c$ 4-5, $2c$ 6-7, $3a$ 5, $3b$ 6-8, ag 5–6, $ps1$ 5, $ps2$ 3. Setae $2b$, $4a$, $4b$, $g1$ and $g2$ absent.

Gnathosoma: Palps similar to those of adults. Tibial seta d 5, tarsal eupathidium ul' 3-4. Ventral seta m 4–5; distance between setae $m-m$ 9–10.

Legs: Chaetotaxy (from coxae to tarsi): I 2-0-3-0-5-6(1), II 1-0-3-0-5-6(1), III 1-1-2-0-3-3, IV 0-0-1-0-2-3. Tarsi I and II each with solenidion ω'' (tarsi I 2-3 and tarsi II 2) and eupathidia p' and p'' (5, 5; 5, 5 respectively).

Larva (n=3). Body measurements: distance between setae $v2-h1$ 138-150, $sc2-sc2$ 75-82; other measurements: $v2-v2$ 16–17, $sc1-sc1$ 59-60, $c1-c1$ 21–24, $c3-c3$ 79–94, $d1-d1$ 10–13, $d3-d3$ 53–65, $e1-e1$ 4, $e3-e3$ 53–55, $f2-f2$ 45–47, $f3-f3$ 31–35, $h2-h2$ 12–18, $h1-h1$ 5–8.

Dorsum (Fig. 24): Prodorsum with anterior region colliculate; area between $sc2$ and $c1$ with oblique to transverse striations; region between setae $c1$ and $d1$ with spaced transverse striation and posterior to setae $d1$ with longitudinal striations. Setal lengths: $v2$ 1–2, $sc1$ 1-2, $sc2$ 20, $c1$ 6-7, $c3$ 7-12, $d1$ 7, $d3$ 1, $e1$ 4, $e3$ 11-12, $f2$ 13-14, $f3$ 11-12, $h1$ 9, $h2$ 37-40.

Venter: Ventral integument with irregular striae. Setal lengths: *1a* 20, *1b* 4, *3a* 4–6, *ps1* 1-2, *ps2* 1. As is normal for tenuipalpids, setae *1c*, *2b*, *2c*, *3b*, *4a*, *4b*, *ag*, *g1* and *g2* absent.

Gnathosoma: Palps similar to that of adults. Tibial seta *d* 6, tarsal eupathidium *ul'* 4. Ventral setae *m* absent.

Legs: Chaetotaxy (from coxae to tarsi): I 1-0-3-0-5-6(1), II 0-0-3-0-5-6(1), III 0-0-2-0-3-3. Tarsi I and II each with solenidion ω'' 2 (for both tarsi I and tarsi II) and eupathidia *p'* and *p''* (4, 5; 5, 5 respectively). All legs covered with colliculate sculpturing.

Hosts and distribution. On rubber trees, *Hevea brasiliensis*, from the State of Amazonas, Brazil. This species occurs mainly on the upper surface of the leaflets.

Remarks. This new species belongs to the *Tenuipalpus* sensu lato group (Castro *et al.* 2016b). It resembles *Tenuipalpus heveae* Baker (1945) by the similar pattern of ventral striation and shape of leg setae, but differs mainly by features of the dorsum; In *T. sp. nov.* the dorsum is smooth versus heavily ornamented in *T. heveae*. The chaetotaxy of the trochanters and tibiae also are different between these two species: trochanter 1-1-2-1 in *T. sp. nov.* and 1-1-1-1 in *T. heveae*; tibia 5-5-3-2 in *T. sp. nov.* and 5-5-2-2 in *T. heveae*.

The new species also resembles *Tenuipalpus zanthus* De Leon (1965) because both species have a dorsum smooth, but the chaetotaxy of the genua, tibiae and tarsi are different between these two species: genua 1-1-0-0 in *T. sp. nov.* and 3-3-1-0 in *T. zanthus*; tibia 5-5-3-2 in *T. sp. nov.* and 5-5-3-3 in *T. zanthus* and; tarsi 8(1)-8(1)-4-4 in *T. sp. nov.* and 8(1)-8(1)-5-5 in *T. zanthus*.

Ontogeny. Coxal seta *1b* is present in the larva; setae *1c*, *2c* and *3b* are added in the protonymph and setae *2b* and *4b* are added in the deutonymph. Setae *v'* on trochanters I, II and III appears in the deutonymph; *l'* on trochanters III appears in the protonymph; the addition of *v'* to trochanters IV is delayed until the adult. This pattern of expression

of *v'* and *l'* is common in Tenuipalpidae, and is similar to that found in Tetranychidae (Lindquist 1985).

Setae *l'* are added to femora I and II in the deutonymph. This pattern of expression of setae to femora is common in *Tenuipalpus* (Castro *et al.* 2015b; Khanjani *et al.* 2013), and in the family (Lindquist 1985). Setae *d* appear to genua I and II in the deutonymph; setae to genua III and IV are suppressed and this may be considered a derived condition. Here, the number of tibial setae is 5-5-3-2, with setae *d* to tibia IV suppressed, while most common pattern of tibial setae to Tenuipalpidae is 5-5-3-3 (Baker & Tuttle 1987; Meyer 1979).

Pair of tectal setae are added to tarsus I and II in the deutonymphs; setae *tc''* on tarsus III are added in the deutonymph and to tarsus IV in the adult; setae *tc'* to tarsus III and IV are suppressed. The pattern of addition of tectal setae to tarsus I and II is common for the family, but the addition of setae *tc''* to tarsus III and IV is delayed one stage from the standard pattern (Lindquist 1985). The pattern of additions to the leg chaetotaxy during ontogeny is listed in Table 2.

The ventral setae changes as follows: *ag* is added in the protonymph, *4a* and *g1* appear in the deutonymph and *g2* is added in the adult. This pattern of ontogeny is similar that observed to Tetranychoida by Lindquist (1985). All setae of the gnathosoma are present in the larva, except setae *m* which are added in the protonymphs.

Discussion

Although *T. heveae* is considered a pest of rubber tree plantations in the Brazil (Pontier & Flechtmann 2000; Ferla & Moraes 2008), until now, details of the female (e.g. leg chaetotaxy and setal measurements) have not been described to allow its correct identification. The new species occurs on the same host plant as *T. heveae* and this increases the necessity and importance of a description that will allow a ready differentiation of these two species. It's important to note that *T. heveae*

occurs mainly on lower surface of the leaflets, while *T. sp. nov.* is found on upper surface of the leaflets (F.M. Nuvoloni, pers. comm.). This difference may be useful in the identification of these two species. In addition, *T. heveae* is recorded in rubber plantations from several states of Brazil (Daud & Feres 2007; Hernandez & Feres 2006), while *T. sp. nov.* is here described based only on specimens collected in the Amazonas state; there is no record of this species in other localities. We believe that this new species may be a species not adapted to climatic conditions (e.g. temperature and air humidity) present in the other regions of Brazil where the rubber tree is cultivated.

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References

- Baker E.W. 1945 --- Mites of the genus *Tenuipalpus* (Acarina: Trichadenidae) --- Proc. Entomol. Soc. Wash., 47(2): 33-38.
- Baker E.W., Pritchard A.E. 1953 --- A review of the false spider mite genus *Tenuipalpus* Donnadieu (Acarina: Phytoptipalpidae) --- Ann. Entomol. Soc. Amer., 46(3): 317-336.

- Baker E.W., Tuttle D.M. 1987 --- The false spider mites of Mexico (Tenuipalpidae: Acari) --- United States Department of Agriculture, Agricultural Research Service, Technical Bulletin, 1706: 1-236.
- Castro E.B., Nuvoloni F.M., Mattos C.R.R., Feres R.J.F. 2013 --- Population Fluctuation and Damage Caused by Phytophagous Mites on Three Rubber Tree Clones --- Neotropical Entomol., 42: 95-101.
- Castro E.B., Ochoa R., Feres R.J.F., Beard J.J., Baughan G.R. 2015a --- Reinstatement of the genus *Colopalpus* Pritchard and Baker (1958) and re-description of *Colopalpus matthyssei* Pritchard and Baker (1958), the type species of the genus (Acari, Tenuipalpidae) --- Intern. J. of Acarol., 41(4): 310-328.
- Castro E.B., Ramos F.A.M., Feres R.J.F., Ochoa R. 2015b --- A new species of *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Brazil, with ontogeny of chaetotaxy --- Syst. and Appl. Acarol., 20(3): 339-356.
- Castro E.B., Feres R.J.F., Ochoa R., Baughan G.R. 2016a --- A new species of *Tenuipalpus* sensu stricto (Acari: Tenuipalpidae) from Brazil, with ontogeny and a key to the known species --- Zootaxa, (in press).
- Castro E.B., Kane E.C., Feres R.J.F., Ochoa R., Baughan G.R. 2016b --- Definition of *Tenuipalpus* sensu stricto (Acari, Tenuipalpidae) with description of a new species from Costa Rica --- Intern. J. of Acarol., 42(2): 106-126..
- Daud R.D., Feres R.J.F. 2007 --- Dinâmica populacional de ácaros fitófagos (Acari, Eriophyidae, Tenuipalpidae) em seis clones de seringueira no sul do estado de Mato Grosso --- Rev. Bras. Entomol., 51: 377-381
- Ferla N.J., de Moraes G.J. 2008 --- Flutuação populacional e sintomas de danos por ácaros (Acari) em seringueira no estado do Mato Grosso, Brasil --- Rev. Árvore, 32(3): 65-376.

- Hernandes F.A., Feres R.J.F. 2006 --- Diversidade e Sazonalidade de Ácaros (Acari) em Seringal (*Hevea brasiliensis*, Muell. Arg.) no Noroeste do Estado de São Paulo --- Neotropical Entomol., 35(4): 523-535.
- Khanjani M., Khankani M., Owen O.D. 2013 --- The flat mites of the genus *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Iran --- Intern. J. of Acarol., 39(2): 97-129.
- Lindquist E.E. 1985 --- External anatomy. *In*: Helle W., Sabelis M.W. (Eds), Spider mites: their biology, natural enemies and control. Vol. 1A. Chapter 1.1 Anatomy, Phylogeny and Systematics. --- Elsevier Science Publishers, Amsterdam, pp. 3-29.
- Mesa N.C., Ochoa R., Welbourn W.C., Evans G.A., Moraes G.J.de. 2009 -- - A catalog of the Tenuipalpidae (Acari) of the World with a key to genera --- Zootaxa, 2098: 1-185.
- Meyer M.K.P.S. 1979 --- The Tenuipalpidae (Acari) of Africa with keys to the world fauna --- Entomology Memoir of the Department of Agriculture Republic South Africa, 50: 1-135.
- Pontier K.J.B., Flechtmann C.H.W. 1999 --- Description of male *Tenuipalpus heveae* Baker, 1945 (Acari: Prostigmata: Tenuipalpidae) --- Intern. J. of Acarol., 25(4): 293-296.
- Pontier K.J.B., Flechtmann C.H.W. 2000 --- Description of the immature life stages of *Tenuipalpus heveae* Baker, 1945 (Acari: Prostigmata: Tenuipalpidae) --- Syst. and Appl. Acarol., 5: 77-81.
- Pontier K.J.B., de Moraes G.J., Kreiter S. 2000 --- Biology of *Tenuipalpus heveae* (Acari, Tenuipalpidae) on rubber tree leaves --- Acarologia, 41(4): 423-427.
- Seeman O.D., Beard J.J. 2011 --- A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia --- Syst. and Appl. Acarol., 16: 73-89.

Xu Y., Fan Q.-H. 2010 --- *Tenuipalpus orilloi* Rimando, a new record to the Chinese fauna (Acari: Tenuipalpidae) --- Syst. and Appl. Acarol., 15: 135-138.

Table 1. Measurements of the body and dorsal setae for type and non-type females of *Tenuipalpus heveae* Baker. Measurements for the holotype with range for the paratypes are shown in parentheses.

	Pará state ¹	Amazonas state ²	Bahia state ³	Goiás state ⁴	São Paulo state ⁵
Body					
<i>v2-h1</i>	240 (230-250)	210-225	225-240	225-230	230-235
<i>sc2-sc2</i>	150 (145-150)	130-135	135-150	150	140-145
<i>c3-c3</i>	175 (165-170)	155-170	165-175	165-170	160-165
<i>f2-f2</i>	100 (95-100)	82-95	87-95	100	80-87
Dorsal setae					
<i>v2</i>	5 (4-5)	4	5-6	4	4-5
<i>sc1</i>	10 (9-10)	7	8-11	7-10	9
<i>sc2</i>	20 (20-23)	17-23	15-17	20-21	16-19
<i>c1</i>	4 (3-4)	3-5	4-6	4-5	5-6
<i>c3</i>	19 (16-19)	14-17	13-15	16-17	11-12
<i>d1</i>	4 (3-4)	3-4	3-5	4-5	5
<i>d3</i>	4 (4)	4-5	4-5	5	5
<i>e1</i>	4 (4)	4-6	3-5	4	5
<i>e3</i>	16 (17-20)	12-20	14-18	14-16	14-16
<i>f2</i>	16 (13-18)	11-15	14	15-16	14
<i>f3</i>	15 (14-17)	13-15	15	13-14	13-14
<i>h1</i>	14 (10-13)	11	12	10-12	10-11
<i>h2</i>	120 (100-125)	115-119	125-130	105-125	107-130

Type material measured: ¹four specimens: holotype and three paratypes;

Non-type material measured: ²five specimens; ³ four specimens; ^{4,5}five specimens.

Table 2. Ontogenetic development of leg setae in *Tenuipalpus* **sp. nov.** Setae are indicated in the stage in which they first appear. Setae in parentheses represent pairs.

	Coxa	Troch.	Femur	Genu	Tibia	Tarsi
Leg I						
Larva	<i>1b</i>	-	<i>d, v', bv''</i>	-	<i>d, (v), (l)</i>	<i>(u), (p), (ft), ω''</i>
Protonymph	<i>1c</i>	-	-	-	-	-
Deutonymph	-	<i>v'</i>	<i>l'</i>	<i>d</i>	-	<i>(tc)</i>
Female	-	-	-	-	-	-
Leg II						
Larva	-	-	<i>d, v', bv''</i>	-	<i>d, (v), (l)</i>	<i>(u), (p), (ft), ω''</i>
Protonymph	<i>2c</i>	-	-	-	-	-
Deutonymph	<i>2b</i>	<i>v'</i>	<i>l'</i>	<i>d</i>	-	<i>(tc)</i>
Adult	-	-	-	-	-	-
Leg III						
Larva	-	-	<i>d, ev'</i>	-	<i>d, (v)</i>	<i>(u), ft'</i>
Protonymph	<i>3b</i>	<i>l'</i>	-	-	-	-
Deutonymph	-	<i>v'</i>	-	-	-	<i>tc''</i>
Adult	-	-	-	-	-	-
Leg IV						
Protonymph	-	-	<i>ev'</i>	-	<i>(v)</i>	<i>(u), ft'</i>
Deutonymph	<i>4b</i>	-	-	-	-	-
Adult	-	<i>v'</i>	-	-	-	<i>tc''</i>

Figures

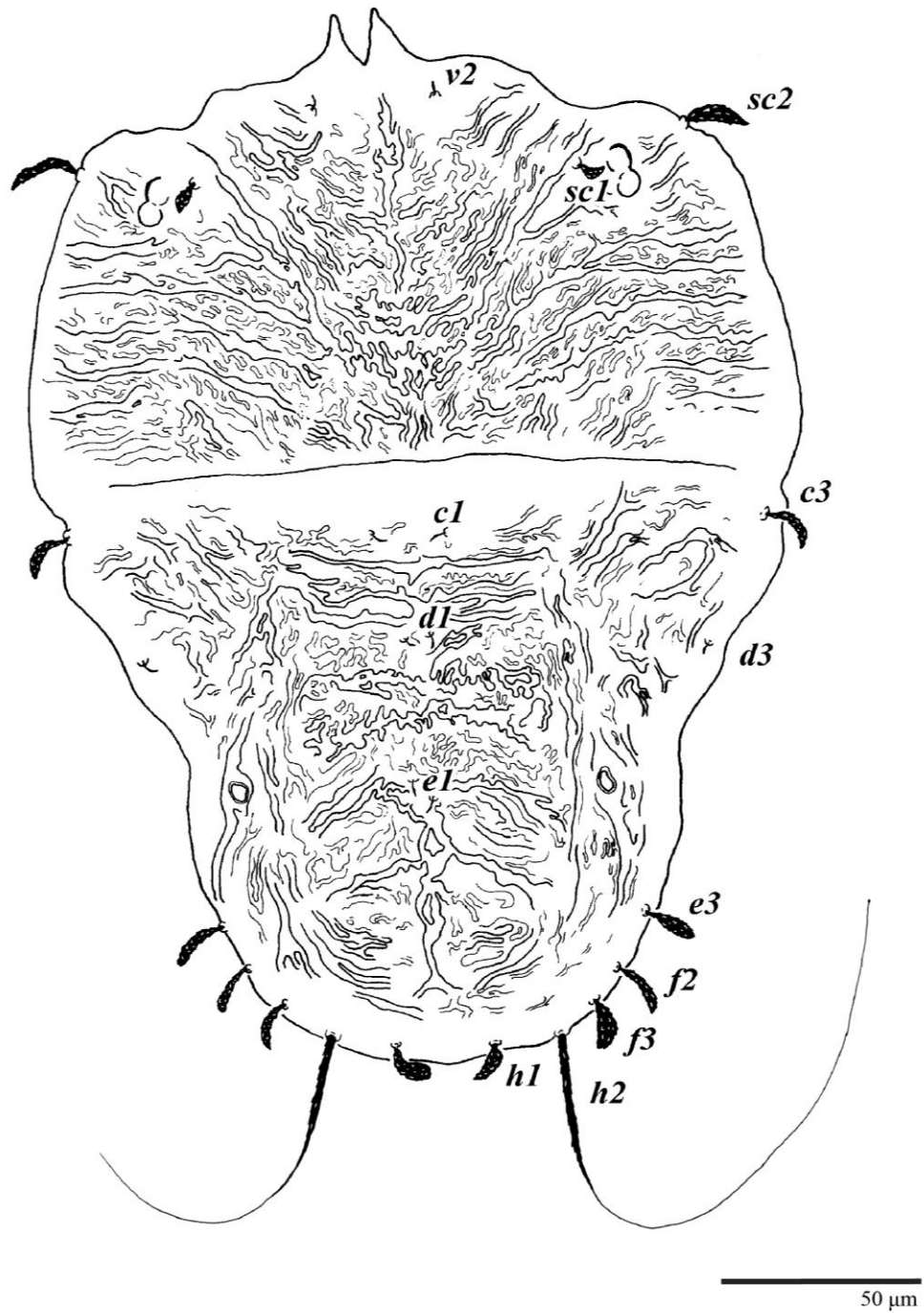


Figure 1. *Tenuipalpus heveae* Baker (Female): dorsum.

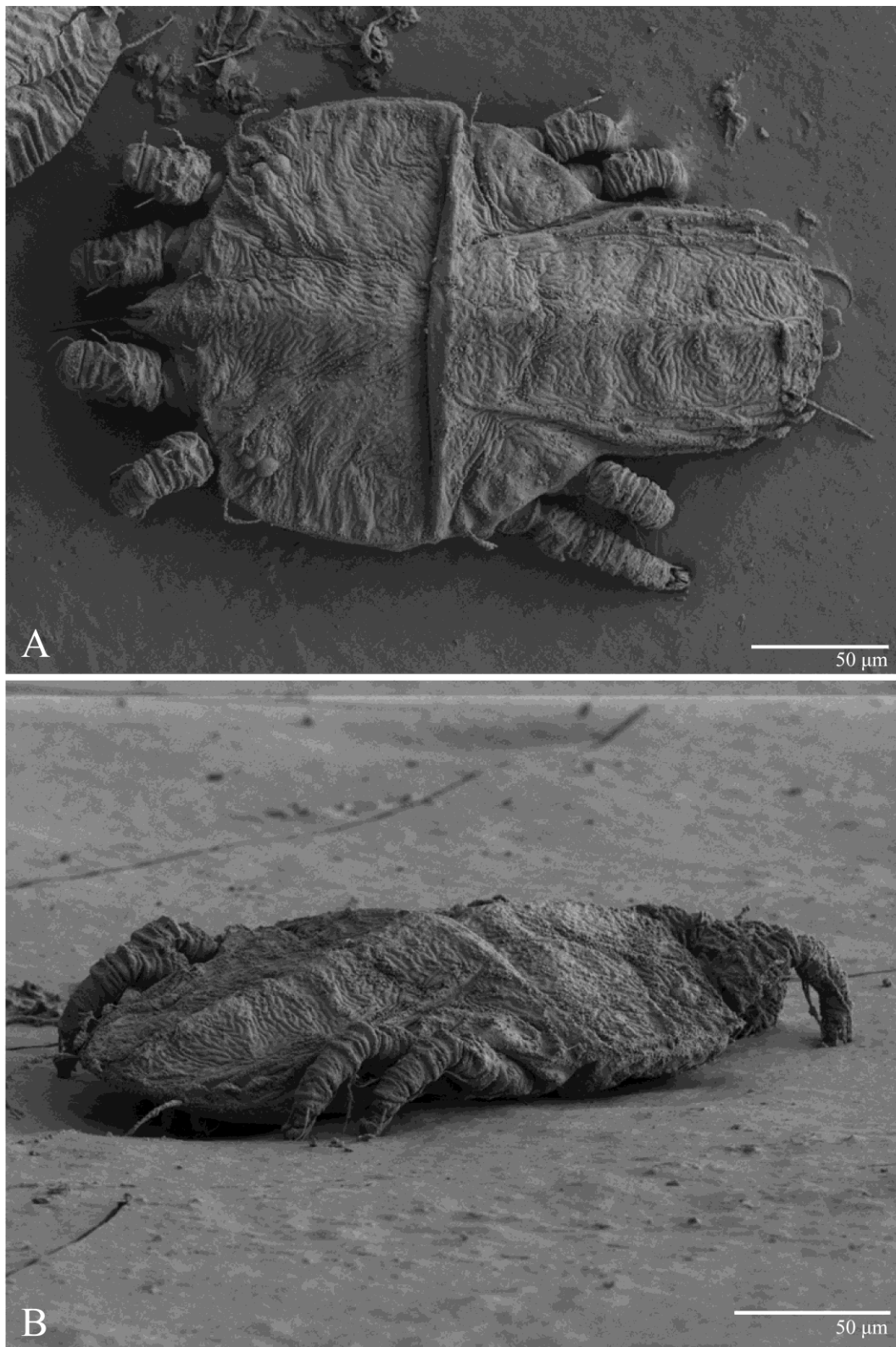


Figure 2. *Tenuipalpus heveae* Baker (Female): A. dorsal view. B. lateral view.

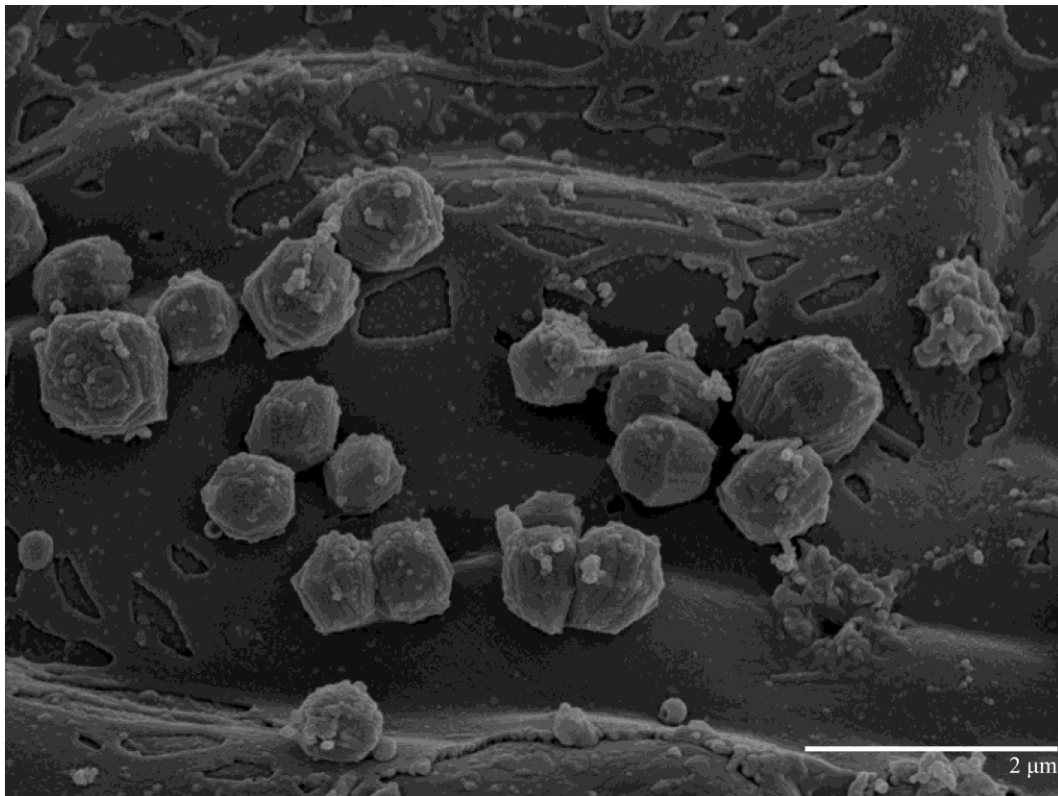


Figure 3. *Tenuipalpus heveae* Baker (Female): view of microplates on integument of dorsum.



Figure 4. *Tenuipalpus heveae* Baker (Female): dorsum.

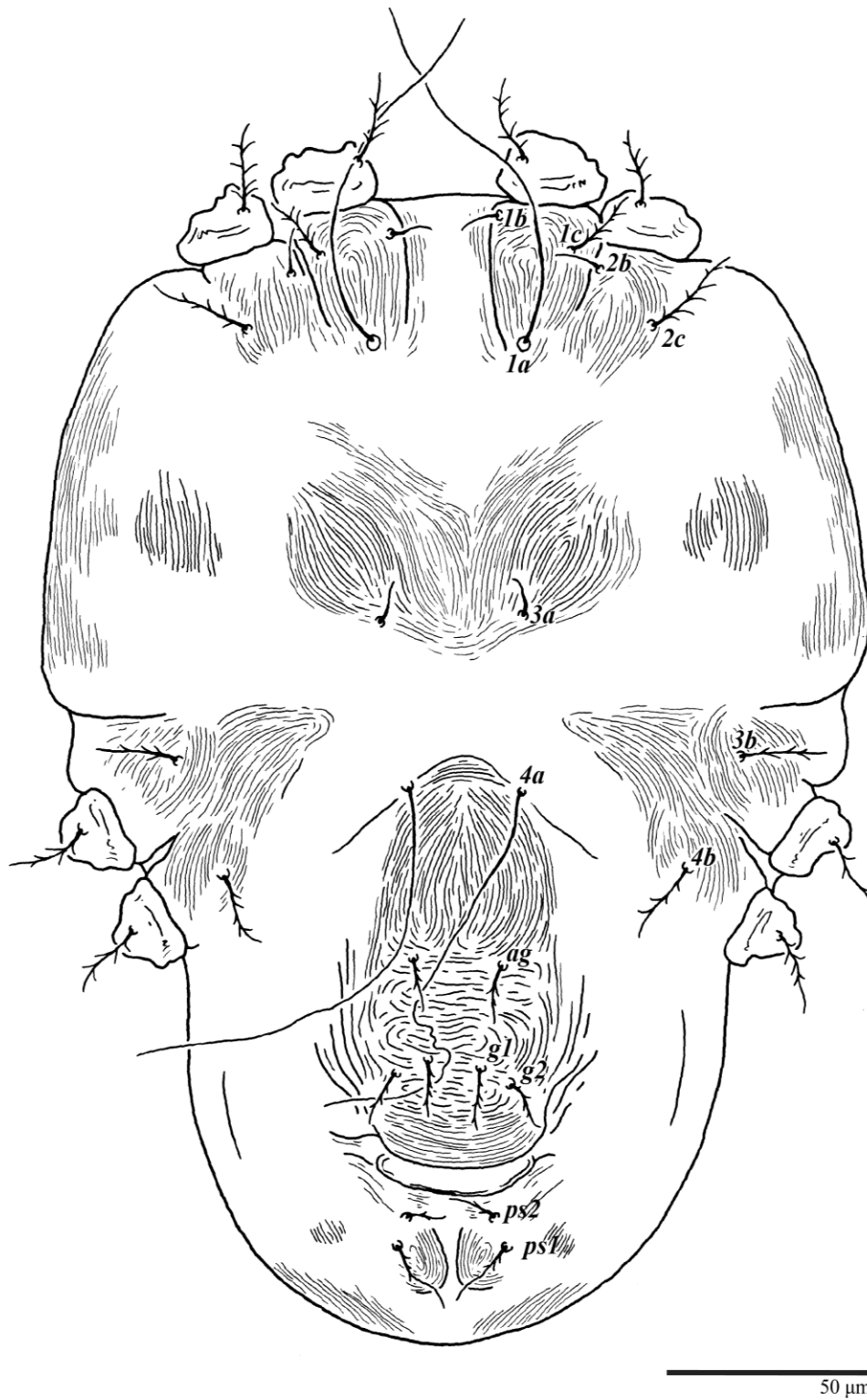


Figure 5. *Tenuipalpus heveae* Baker (Female): venter.

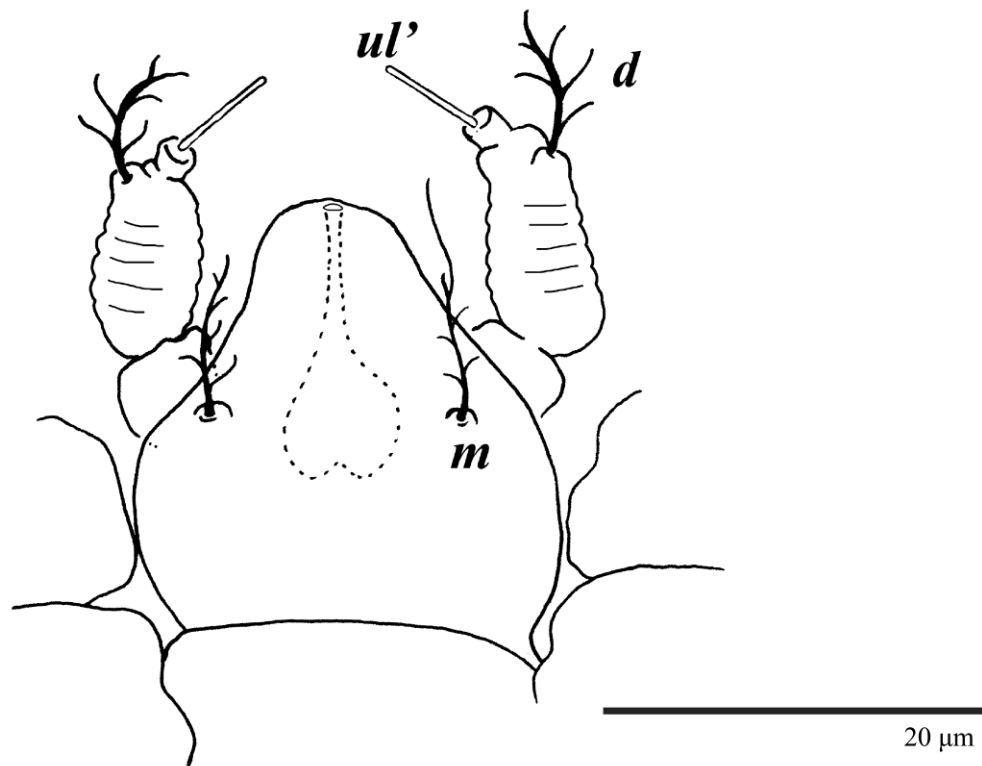


Figure 6. *Tenuipalpus heveae* Baker (Female): infracapitulum.

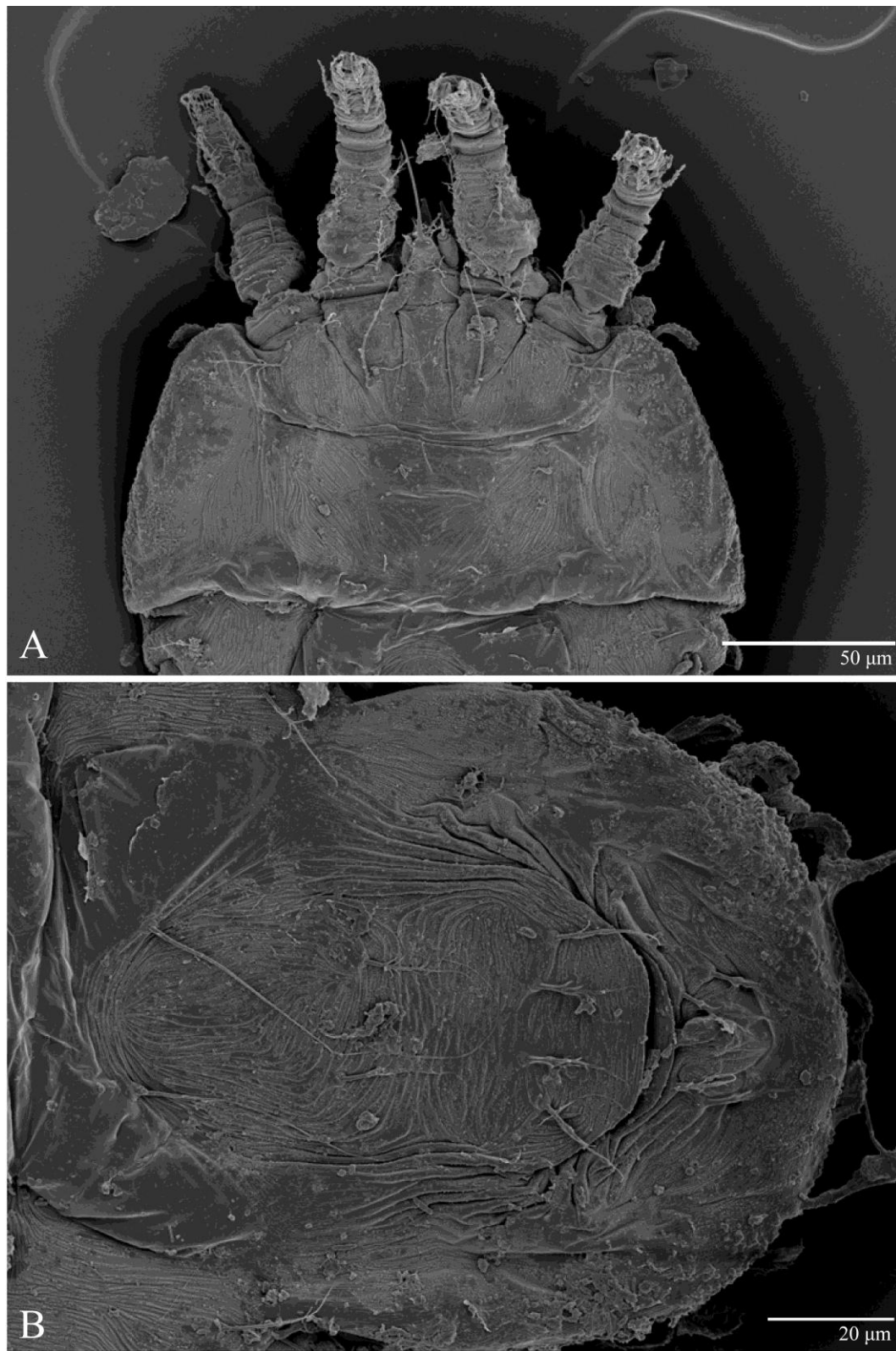


Figure 7. *Tenuipalpus heveae* Baker (Female): A. anterior ventral opisthosoma. B. posterior ventral opisthosoma.

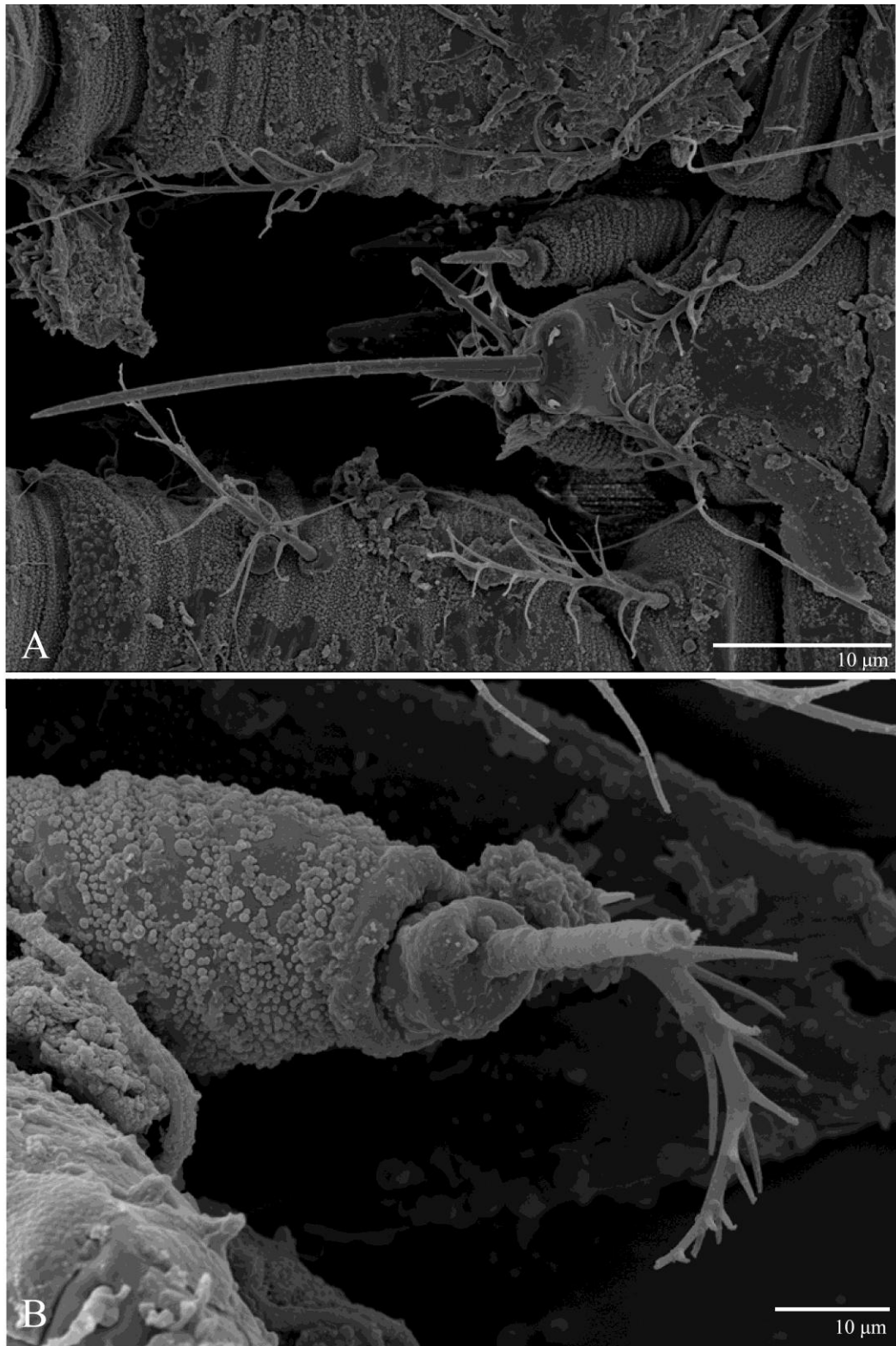


Figure 8. *Tenuipalpus heveae* Baker (Female): A. view of infracapitulum, detail of protracted paired cheliceral stylets. B. detail of palp.

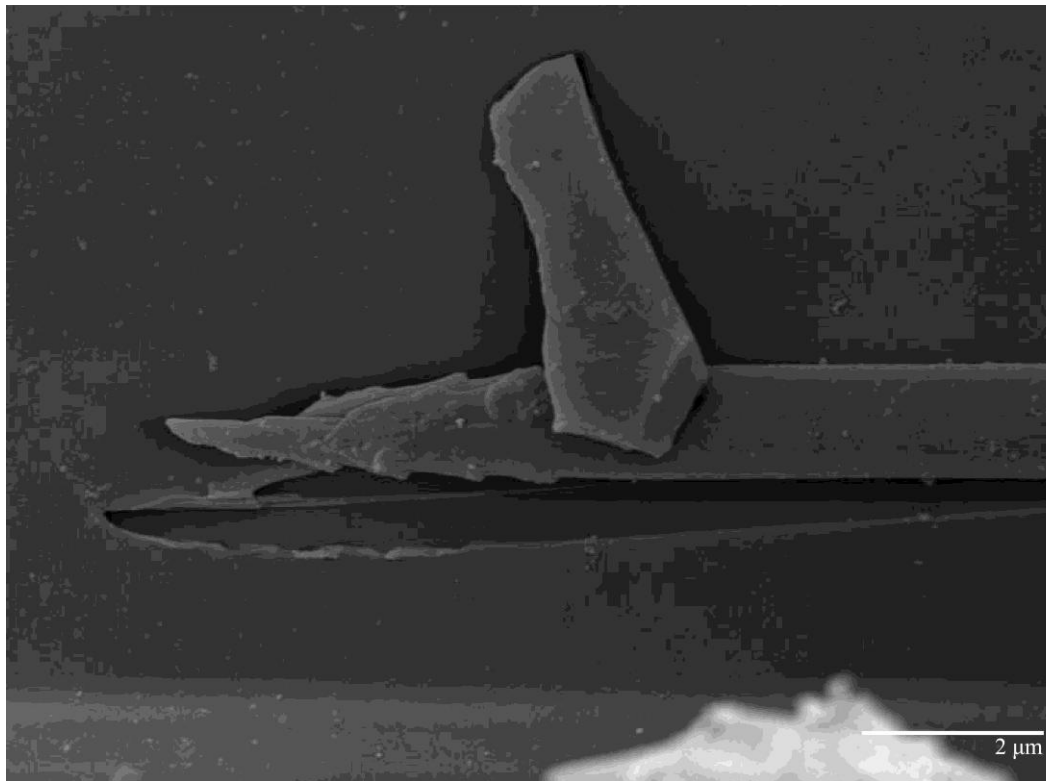
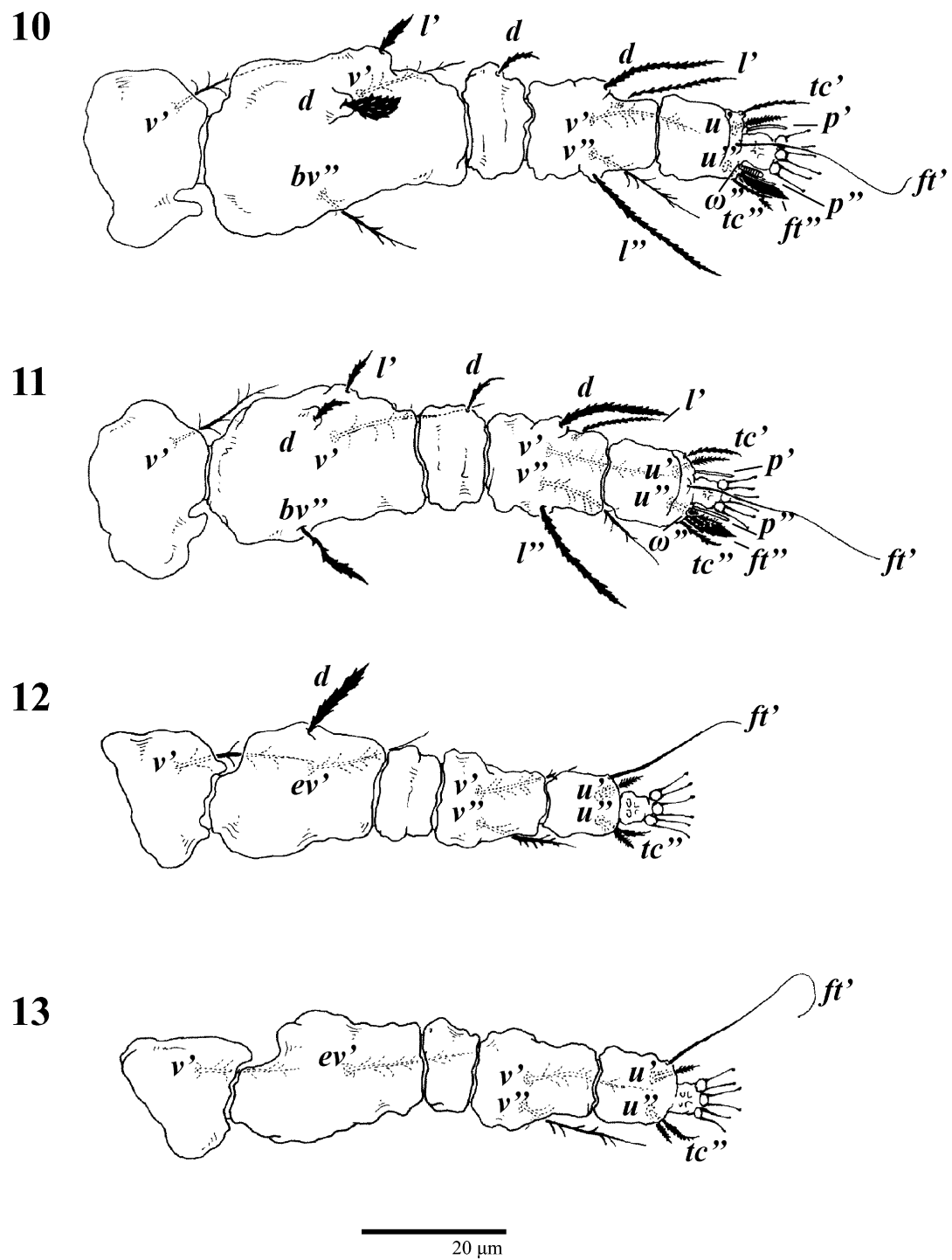


Figure 9. *Tenuipalpus heveae* Baker (Female): view of apex of chelicerae.



Figures 10–13. *Tenuipalpus heveae* Baker (Female): legs I–IV, respectively.

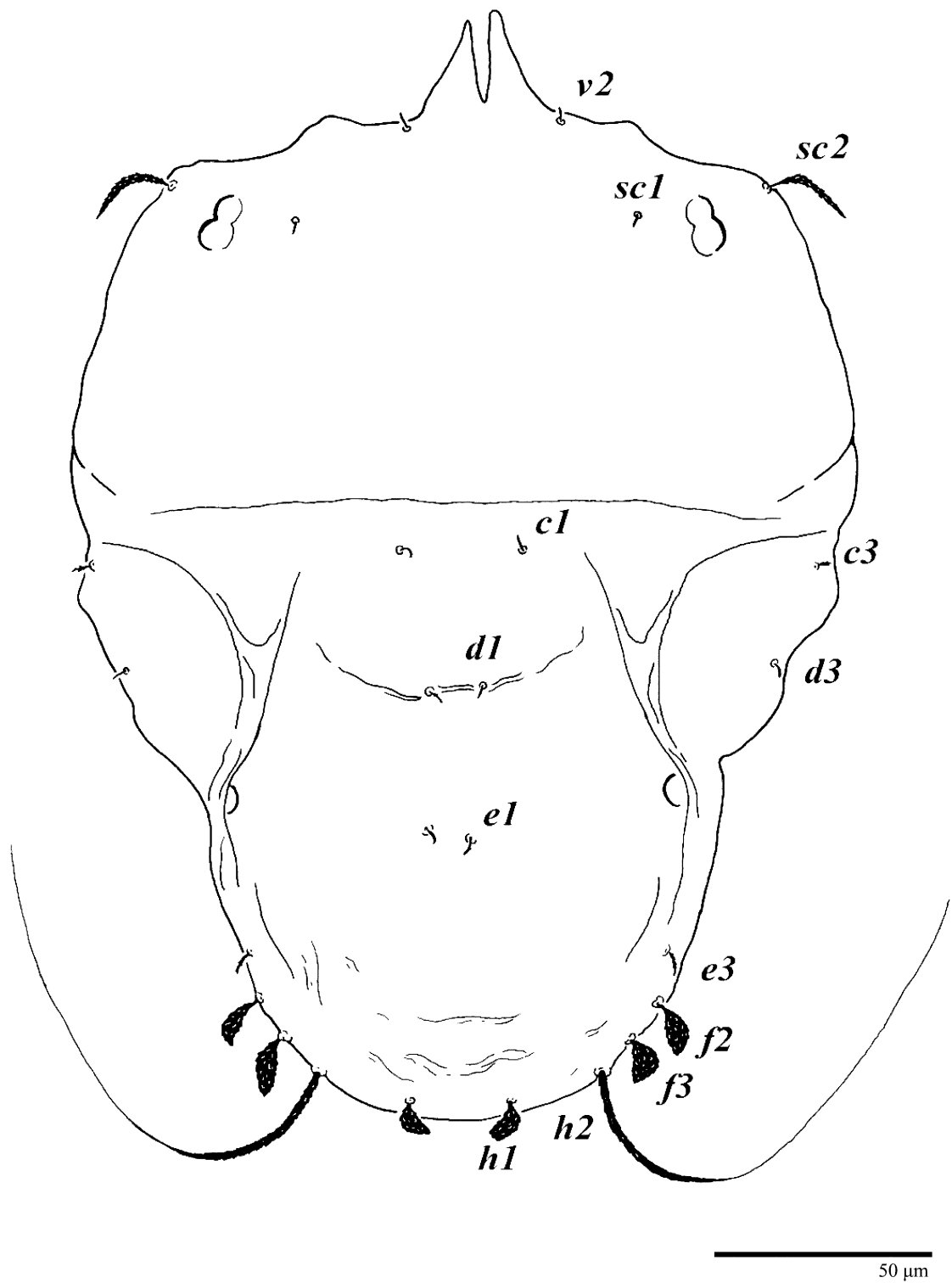


Figure 14. *Tenuipalpus* sp. nov. (Female): dorsum.

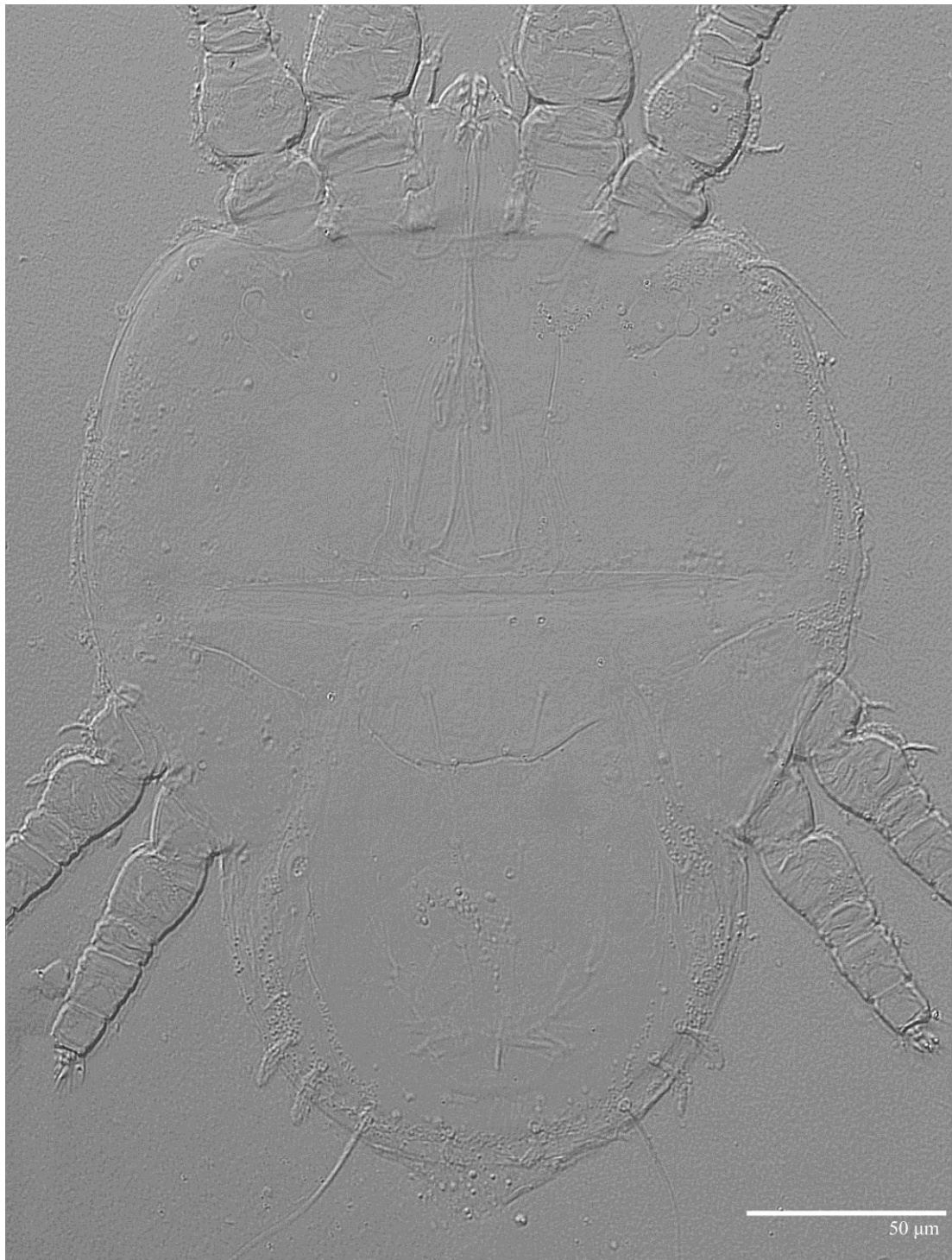


Figure 15. *Tenuipalpus* **sp. nov.** (Female): dorsum.

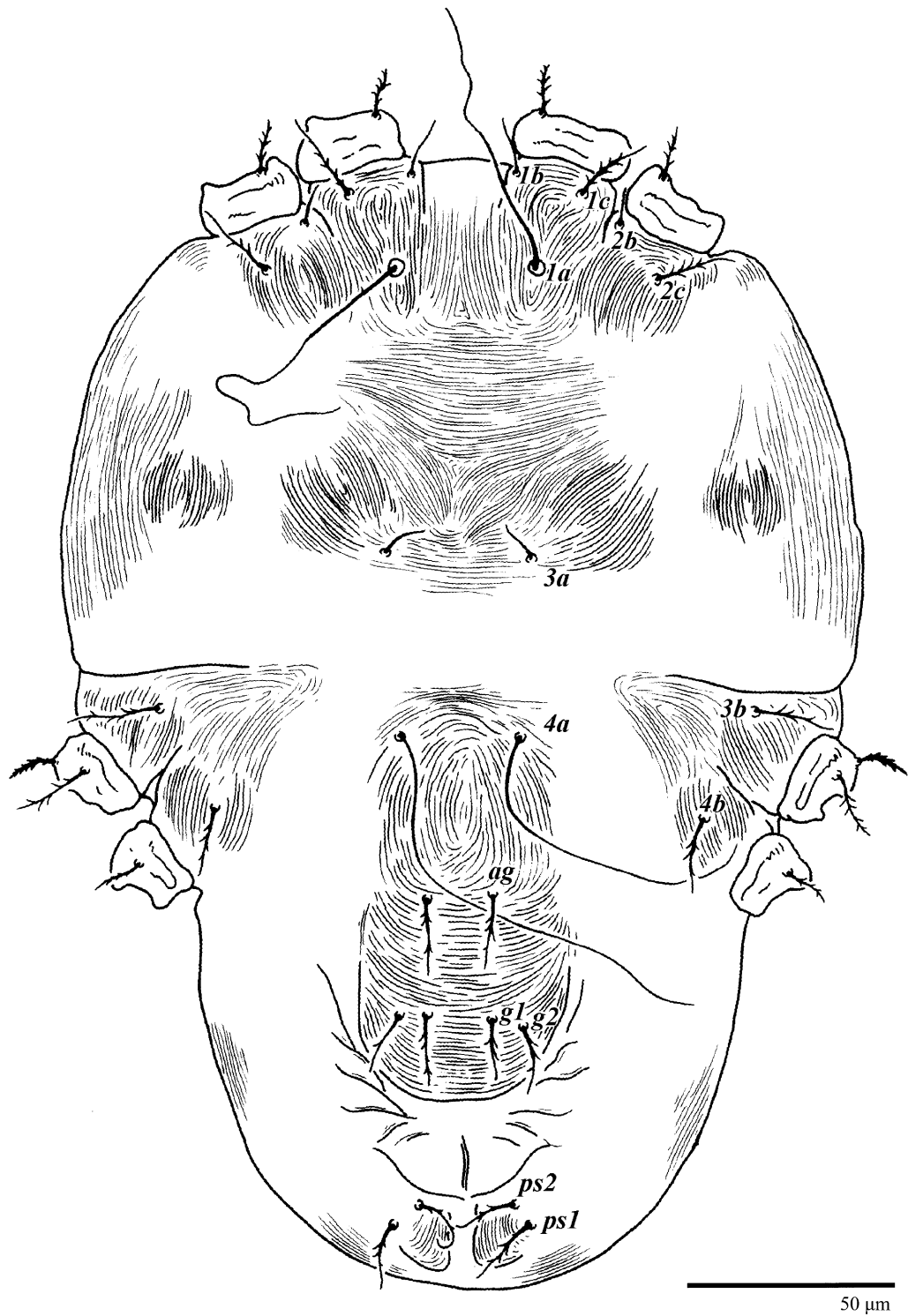


Figure 16. *Tenuipalpus* sp. nov. (Female): venter.

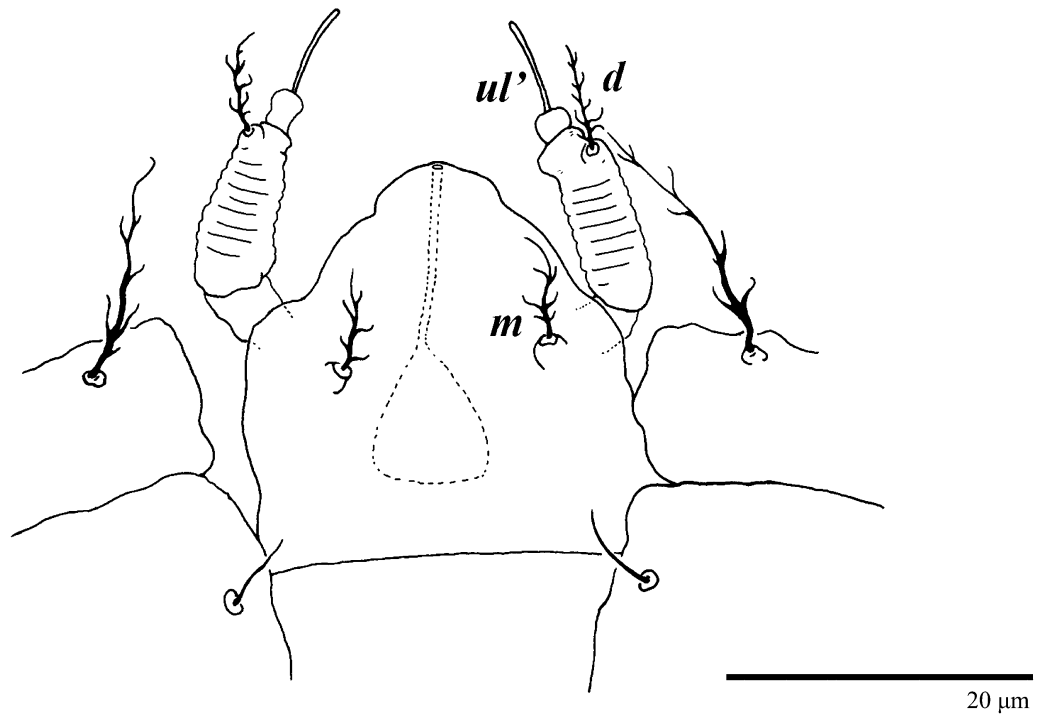
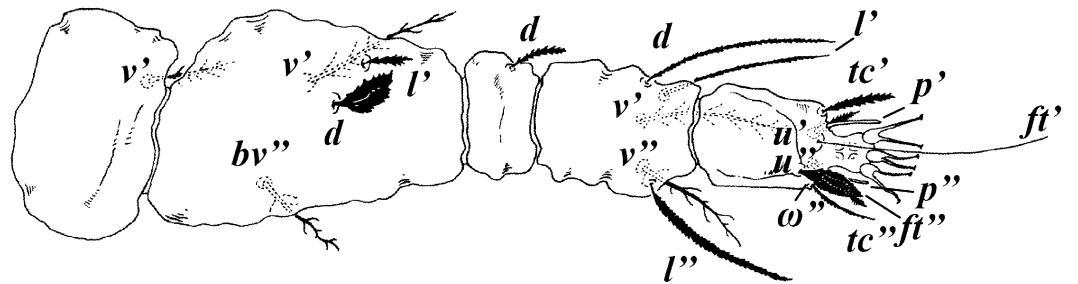
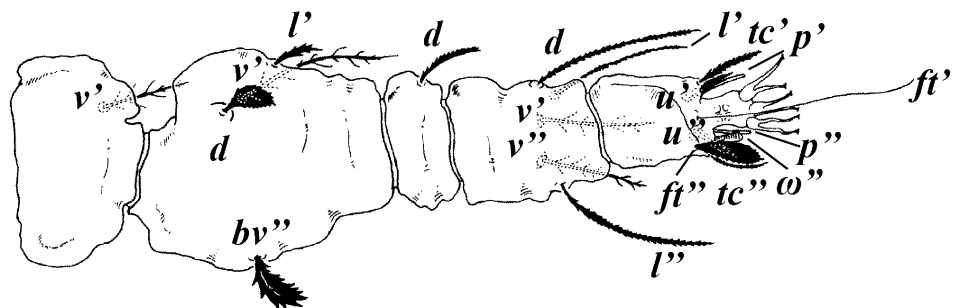


Figure 17. *Tenuipalpus* **sp. nov.** (Female): infracapitulum.

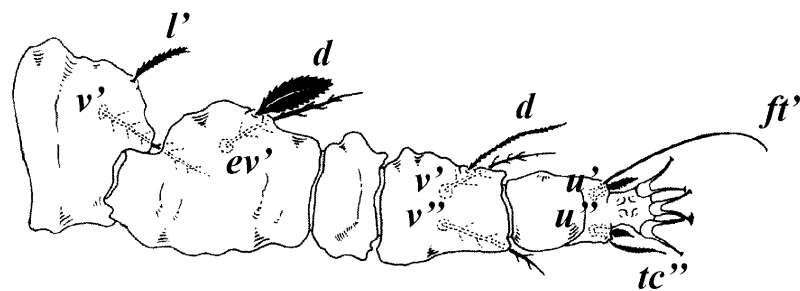
18



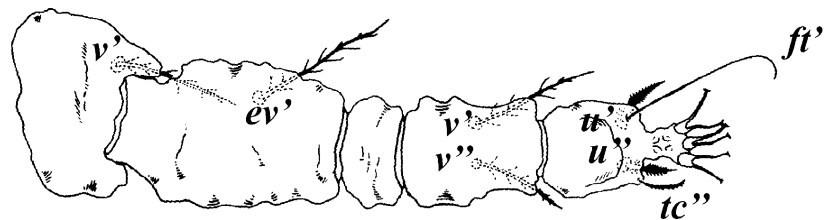
19



20



21



20 μm

Figures 18–21. *Tenuipalpus* sp. nov. (Female): legs I–IV, respectively.

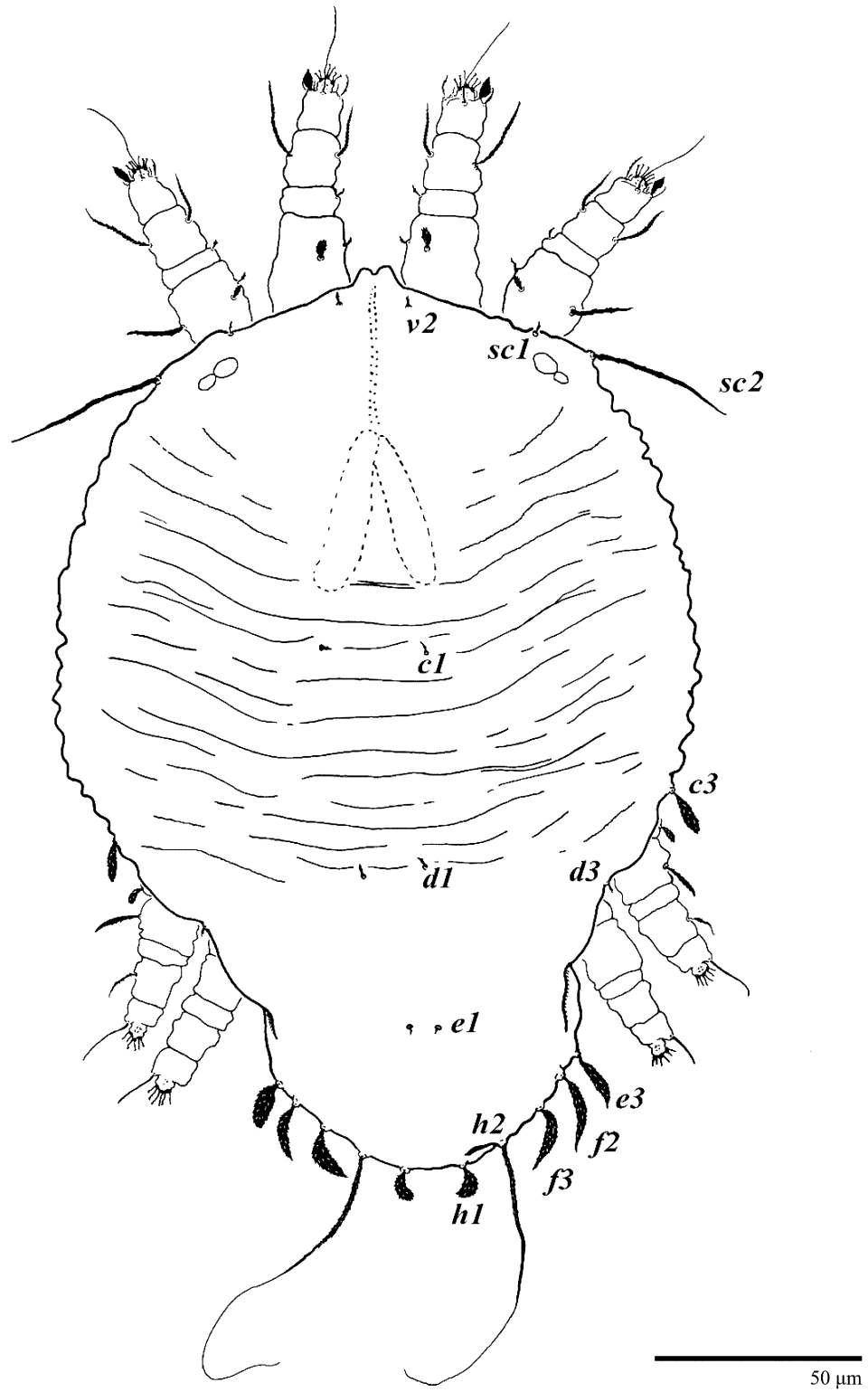


Figure 22. *Tenuipalpus* sp. nov. (Deutonymph): dorsum.

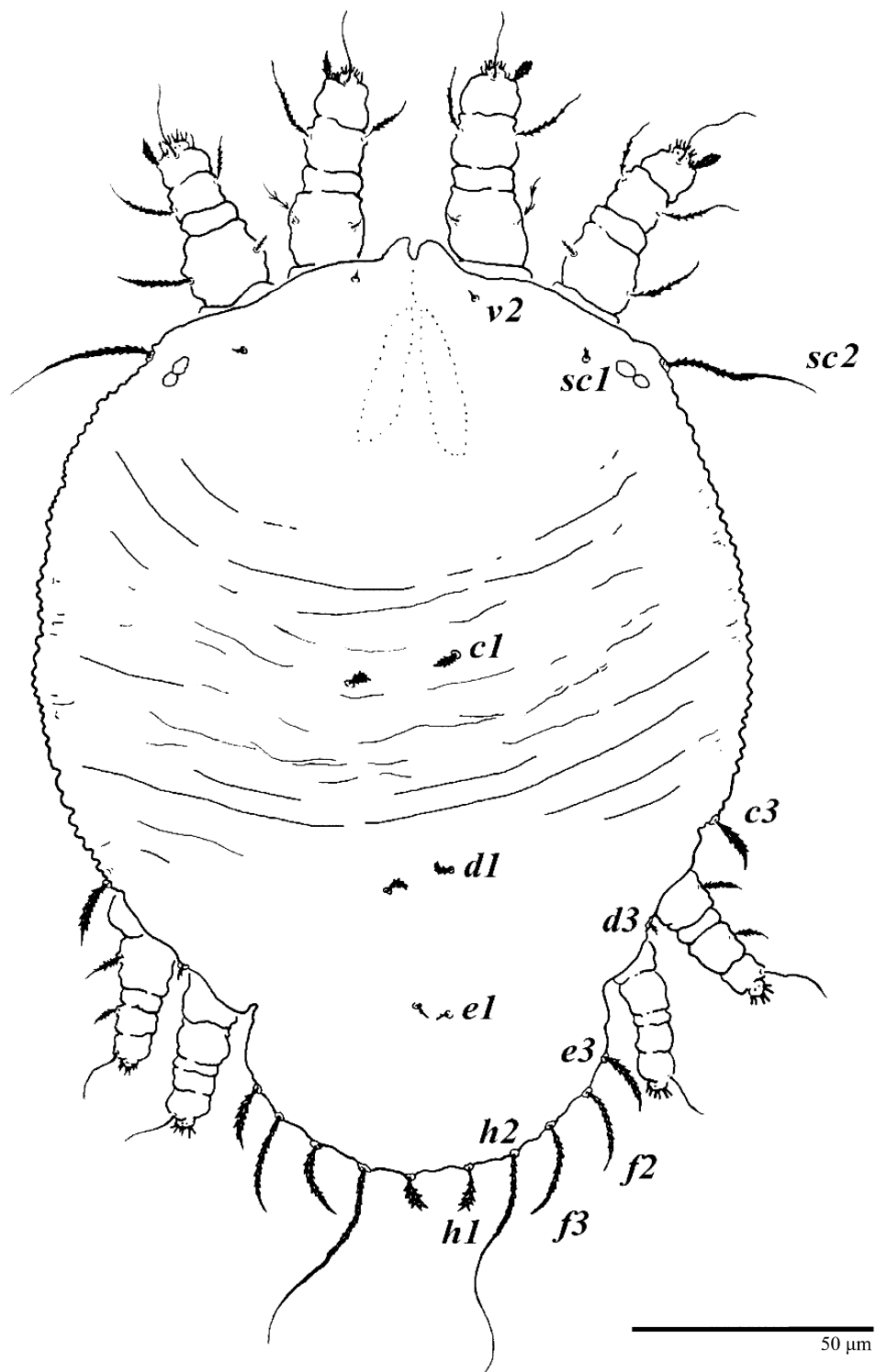


Figure 23. *Tenuipalpus* sp. nov. (Protonymph): dorsum.

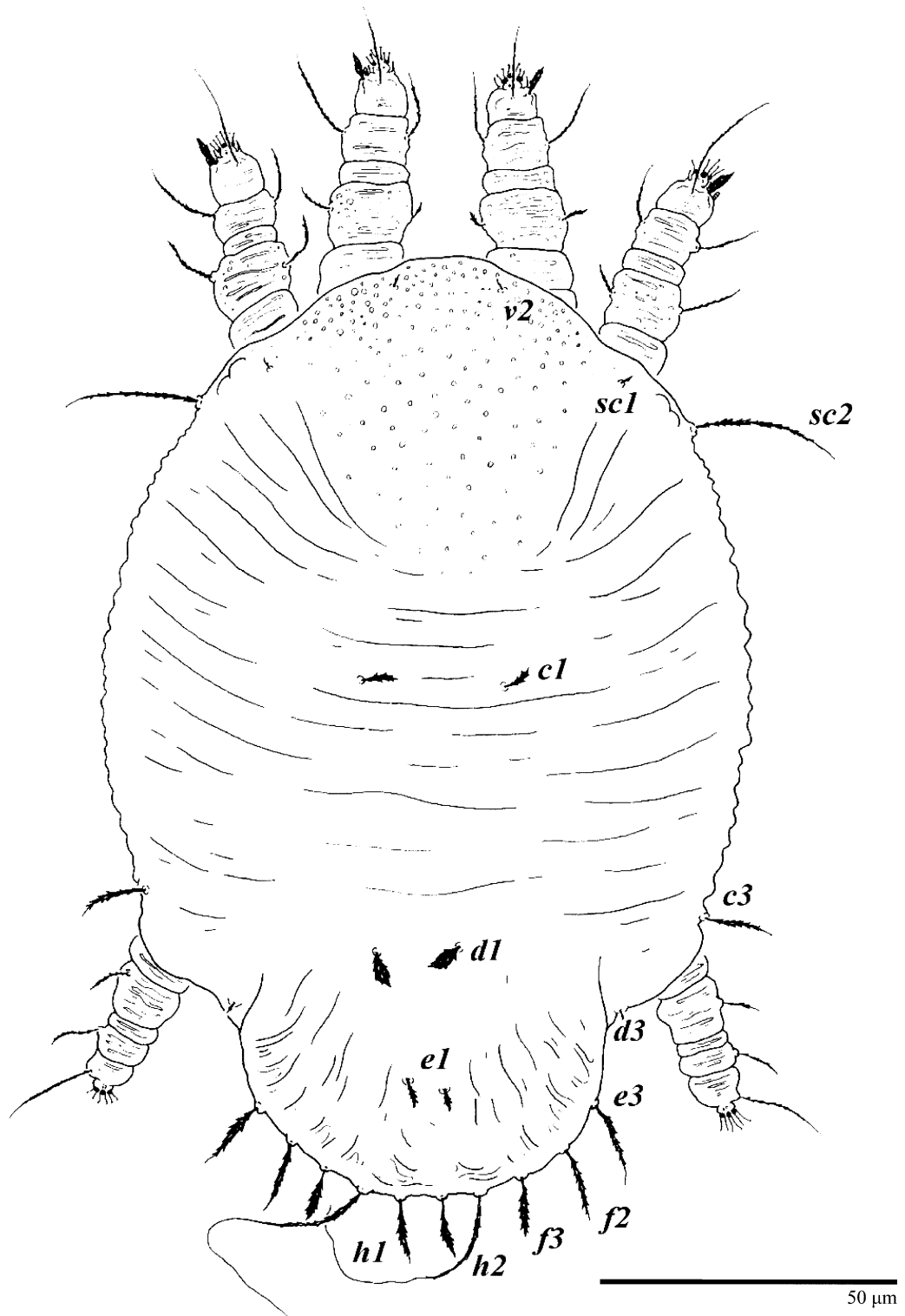


Figure 24. *Tenuipalpus sp. nov.* (Larva): dorsum.

CHAPTER 5

**REINSTATEMENT OF THE GENUS *COLOPALPUS*
PRITCHARD AND BAKER (1958) AND
RE-DESCRIPTION OF *COLOPALPUS MATTHYSSEI*
PRITCHARD AND BAKER (1958), THE TYPE SPECIES
OF THE GENUS (ACARI, TENUIPALPIDAE)**

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**Authors: Elizeu B. Castro, Ronald Ochoa, Reinaldo J.F. Feres,
Jennifer J. Beard and Gary R. Bauchan**

Abstract

We discuss the taxonomic history of the genus *Colopalpus* Pritchard and Baker 1958, and redescribe the female, male and deutonymph of the type species, *C. matthyssei* (Pritchard and Baker). We provide previously unknown morphological data for *C. matthyssei*, in addition to complementary information on the morphology of *C. nambii* (Castro and Feres) obtained using low temperature scanning electron microscopy (LT-SEM). Our results show that both *C. matthyssei* and *C. nambii* share characters with the genera *Tenuipalpus* and *Brevipalpus*. Based on these findings, we propose that *Colopalpus* be reinstated as a valid genus. We discuss the characters shared by *Colopalpus*, *Tenuipalpus* and *Brevipalpus*, and also provide a list of species that are transferred to the genus *Colopalpus*.

Keywords: *Tenuipalpus*; *Brevipalpus*; flat mites; taxonomy; systematics; Philippines

Introduction

The genus *Colopalpus* (Acari, Tenuipalpidae) was erected by Pritchard and Baker (1958, p. 258) with *Tenuipalpus matthyssei* as the type species, collected from *Melanolepis multiglandulosa* (Reinw. ex Blume) Rchb.f. and Zoll. (Euphorbiaceae) from Laguna, The Philippines. These authors noted that *Colopalpus* resembles *Brevipalpus* Donnadieu in the shape of the body and its dorsal chaetotaxy, and that it resembles *Tenuipalpus* Donnadieu due to the dorsal opisthosomal setae *h2* being elongate and flagelliform. Pritchard and Baker (1958) used the presence of a single genito-ventral plate in the female to distinguish *Colopalpus* from these two genera.

The diagnosis provided by Pritchard and Baker (1958) includes: body elongate-ovate with sculptured dorsum; palpus two-segmented, proximal segment without setae, and the second with two long setae;

rostral shield well developed, medially incised; propodosoma with three pairs of dorsal setae (v2, sc1, sc2); dorsal opisthosoma with three pairs of dorsocentrals, a pair of humerals and five pairs of dorsolaterals (i.e. setae c1, c3, d1, d3, e1, e3, f3, h1, h2 present); the dorsosublaterals absent (i.e. setae c2, d2, e2, f2 absent); female with large genito-ventral plate, bearing two pairs of genital setae (setae g1, g2) and the one pair of medioventral opisthosomals (i.e. setae ag); with two pairs of anal setae (i.e. pseudanal setae ps1, ps2). Male with three pairs of genito-anal setae (i.e. setae g1, g2, ps2; however, there are actually four pairs of setae, as the modified ps1 setae were overlooked).

Subsequently, several species were described in, or transferred from *Tenuipalpus* to, the genus *Colopalpus*. Manson (1963) described *C. pedrus* from Honduras; Baker and Tuttle (1972) transferred *T. eriophyoides* Baker to *Colopalpus*; Collyer (1973) described *C. elegans* from New Zealand and *C. masoni* from Australia; Flechtmann (1976) described *C. oxalis* from Brazil; Corpuz-Raros (1978) described *C. philippinensis* from The Philippines; Maninder and Ghai (1978) described *C. punjabensis* from India; Mitrofanov and Strunkova (1979) transferred *T. dubinini* Reck, *T. rosae* Kadzhaja, *Gnathopalpus tauricus* Mitrofanov and Strunkova, and *T. crassus* Andre to *Colopalpus*. Eventually, *Colopalpus* was made a junior synonym of *Tenuipalpus* by Meyer (1979) in her major revision of the family, discussed below.

In this paper, we re-describe *T. matthyssei*, the type species of the genus *Colopalpus*, with additional data (e.g. leg chaetotaxy and setal measurements). Additional morphological characters confirmed through of the study of LT-SEM imaging are presented for *T. nambii* Castro and Feres. Based on the study of these species, we consider *Colopalpus* Pritchard and Baker (1958) to be a valid genus and remove it from synonymy with *Tenuipalpus*. We also discuss the distinct characteristics of both genera *Colopalpus* and *Tenuipalpus* that differentiate these two

genera. Furthermore, a list is provided of the species reinstated or moved to *Colopalpus*.

Material and Methods

Measurements for the holotype are given in micrometres (μm), with the range of measurements for the paratypes shown in parentheses. Body size was measured by *v2–h1* (length) and *sc2–sc2* (width) (Saito et al. 1999). The numbers of leg setae are written as the total number of setae followed by number of solenidia in parentheses. Leg chaetotaxy is adapted from Lindquist (1985) and Seeman and Beard (2011). Photographs were obtained by using a Zeiss Axioscope™ microscope (Carl Zeiss Inc., Thornwood, NY) with differential interference contrast (DIC) 100x Plan Apochromatic objective with a NA 1.4.

Specimens of *T. nambii* were collected on *Sterculia striata* St. Hil. and Naud. (Sterculiaceae; formerly Malvaceae sensu lato), from the type locality São João do Itacema, São Paulo, Brazil. These specimens were maintained in 70% ethanol and were later used for low temperature SEM (LT-SEM) studies, utilizing the technique outlined by Bolton et al. (2014). Specimens were secured on 15 mm × 30 mm copper plates using ultra smooth, round (12 mm diameter), carbon adhesive tabs (Electron Microscopy Sciences, Inc., Hatfield, PA, USA). The specimens were frozen conductively, in a Styrofoam box, by placing the plates on the surface of a pre-cooled (–196°C) brass bar whose lower half was submerged in liquid nitrogen (LN2). After 20–30 s, the holders containing the frozen samples were transferred into a Quorum PP2000 cryo-prep chamber (Quorum Technologies, East Sussex, UK) attached to an S-4700 field emission scanning electron microscope (Hitachi High Technologies America, Inc., Dallas, TX, USA). The specimens were etched inside the cryotransfer system to remove any surface contamination (condensed water vapour) by raising the temperature of the stage to –90°C for 10–15 min. Following etching, the temperature inside the chamber was lowered

below -130°C , and the specimens coated with a 10 nm layer of platinum using a magnetron sputter head equipped with a platinum target. The specimens were transferred to a pre-cooled (-130°C) cryostage in the LTSEM for observation and an accelerating voltage of 5 kV was used for viewing. Images were captured using a 4 pi Analysis System (Durham, NC, USA). Adults, immatures and eggs of *Tenuipalpus* sp. and *Brevipalpus* sp. mounted for LT-SEM were compared to *Colopalpus*.

Family **Tenuipalpidae** Berlese, 1913

Genus ***Colopalpus*** Pritchard and Baker, 1958, **stat. rev.**

Type species: ***Colopalpus matthyssei*** Pritchard and Baker, 1958

Manson (1963, p. 222); Baker and Tuttle (1972, p. 35); Collyer (1973, p. 915); Mitrofanov (1973, p. 509); Chaudhri et al. (1974, p. 98); Flechtmann (1976, p. 63); Corpuz-Raros (1978, p. 216); Maninder and Ghai (1978, p. 111); Mitrofanov and Strunkova (1979, p. 59); Meyer (1979, p. 3); Al-Gboory (1987, p. 155); Mesa et al. (2009, p. 6).

Generic diagnosis

Female: Body elongate-ovate; prodorsum with three pairs of setae (*v2*, *sc1*, *sc2*); dorsal opisthosoma with nine or ten pairs of setae (*c1*, *c3*, *d1*, *d3*, *e1*, *e3*, *f3*, *h1*, *h2* present; setae *f2* present or absent); opisthosomal setae *h2* flagelliform and inserted on different plane to other hysterosomal setae. Gnathosoma not covered by the rostrum. Palps 1–3 segmented. Seta *d* on femora, genua and tibiae inserted in dorsal position (not lateral). Ventral integument smooth or striated; genital and ventral plates may be developed or not, but when developed they are fused into one genito-ventral plate. Tarsus I-II bearing elongate proral setae, $p\zeta'-p\zeta''$, each inserted on a lateral tubercle. *Male*: opisthosoma not distinctly narrower than the propodosoma; body shape resembles male *Brevipalpus*; form of

dorsal setae similar to those of female. Egg simple, oblong and without a wax-like ribbed shell cover.

Remarks

This generic definition is based on characteristics found in *C. matthyssei*, *C. pedrus* Manson, *C. nambii* (Castro and Feres), *C. zahirii* (Khanjani and Seeman), and *C. mansonculus* (Ghai and Shenhmar). The female body-shape for these species is elongate-ovate. Males are known only for *C. matthyssei*, *C. zahirii* and *C. mansonculus*, and have a body-shape resembling that of *Brevipalpus* males.

Colopalpus matthyssei Pritchard and Baker, 1958: 258 – **stat. rev.**

Colopalpus matthyssei Pritchard and Baker, 1958: 258; Meyer (1979, p. 3); Mitrofanov and Strunkova (1979, p. 59); Rimando (1962, p. 47).

Diagnosis

Female: Prodorsal setae *v2*, *sc1* and *sc2* long and strongly barbed; setae *sc2* inserted at level between the eyes; dorsal opisthosomal setae short, setiform and smooth; ventral integument smooth and delimited by soft furrows; *1a* setae elongate, *4a* setae short and similar in length to other ventral setae; *d* seta on femora, genua and tibiae inserted in dorsal position. *Male*: setae similar to those of female; opisthosoma not distinctly narrower than prodorsum; genito-ventral plate with two unusual circular folds resembling suckers; tarsi I and II each with two elongate solenidia (ω' paraxial, ω'' antiaxial). *Deutonymph*: prodorsal setae similar to those of adults; dorsal opisthosomal setae *c1*, *d1* and *d3* long, thick and strongly barbed; other dorsal opisthosomal setae minute; eyes not visible.

Material examined

Holotype: female collected on *Melanolepis multiglandulosa* (Reinw. ex Blume) Rchb. f. and Zoll. (Euphorbiaceae) from Laguna, The Philippines, 5 August 1955, coll. J. G. Matthysse, deposited in National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located at the SEL-USDA, Beltsville, Maryland, USA (USNM, no. 2343–01). Paratypes: three females, seven males and two deutonymphs with the same data as the holotype (USNM, nos. 2343–03–04, nos. 2343–06–08). Paratypes: four males with the same data as the holotype, deposited in the Collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRP no. 9513).

Re-description

Female ($n = 4$) (holotype: Figures 1–5). Body measurements: length $v2-h1$ 175 (175–180); width $sc2-sc2$ 85 (85–90), $c3-c3$ 100 (100–105), $e3-e3$ 67 (65–72).

Dorsum (Figures 1 and 2). Prodorsum smooth medially and faintly striate laterally. Setae $sc2$ inserted laterad and level with eyes. Prodorsal setae long, thick and strongly barbed. Opisthosomal pores vestigial. Opisthosomal setae short and smooth; setae $h2$ inserted on a lower plane to the other opisthosomal setae. Setal measurements: $v2$ 24 (24–27), $sc1$ 25 (29–30), $sc2$ 20 (21–22), $c1$ 10 (9–10), $c3$ 5 (4–6), $d1$ 5 (6–7), $d3$ 7 (7–8), $e1$ 5 (4–5), $e3$ 5 (4–6), $f3$ 4 (4–5), $h1$ 4 (4–5), $h2$ 185 (175–220).

Venter (Figure 3). Integument smooth and delimited by longitudinal and transversal soft furrows. All setae fine and smooth. Setae $3a$ and $4a$ short; $4a$ inserted anterad genito-ventral shield. Genito-ventral shield well delimited; ag , $g1$ and $g2$ setae similar in length, inserted on genitoventral shield; two pairs of pseudanal setae, $ps1$ and $ps2$ present. Setal measurements: $1a$ 95 (74–97), $1b$ 23 (23–25), $1c$ 13 (13–17), $2b$ 22 (18–24), $2c$ 14 (14–16), $3a$ 9 (8–12), $3b$ 15 (14–17), $4a$ 10 (11–12), $4b$ 12 (12–

14), *ag* 11 (10–12), *g1* 10 (9–12), *g2* 12 (10–13), *ps1* 10 (11–12), *ps2* 10 (10–11).

Gnathosoma (Figure 4). Gnathosoma extends to genua I. Ventral setae *m* present, distance between setae *m-m* 14 (12–14). Palps 2-segmented, distal segment bearing one long, slightly barbed *d* seta and one long solenidion *ul'* 14 (12–15).

Legs (Figure 5). Setation (from coxae to tarsi): I 2–1–4–3–5–8(1), II 2–1–4–3–5–8(1), III 1–2–2–0–2–5, IV 1–1–1–0–2–5; femora, tibiae and genua I and II, each with one barbed dorsal setae; tibiae I and II with long barbed setae *v'* and *v''*; tarsi I and II each with long *ft'* setae, one antiaxial solenidion (ω''), and two elongate eupathidia, *pζ'–pζ''* inserted on distinct lateral tubercles.

Male (*n* = 11) (Figures 6–9). Body measurements: length *v2–h1* 150–160; width *sc2–sc2* 70–80, *c3–c3* 75–85, *e3–e3* 45–55.

Dorsum (Figures 6 and 7). Prodorsum smooth medially and faintly striate laterally. Dorsal opisthosoma divided into two shields by a transverse suture posterad *d3–d3* and at level of leg IV (the point at which the body folds upwards during copulation): anterior shield bears setae *c1*, *c3*, *d1* and *d3*; posterior shield, tapering posteriorly, bears setae *e1*, *e3*, *f3*, *h1*, *h2*. Shape of the dorsal setae similar those of female, except *h1* and *e3* slightly barbed. Setal measurements: *v2* 23–28, *sc1* 26–33, *sc2* 21–25, *c1* 7–9, *c3* 4–6, *d1* 6–8, *d3* 7–9, *e1* 5–6, *e3* 6–8, *f3* 4–7, *h1* 4–6, *h2* 155–220.

Venter (Figure 8). Cuticle on ventral propodosoma smooth and delimited by folds. Setae *3a* and *4a* short. Coxae I and II well delimited and separate; coxal fields III and IV fused. Genito-ventral shield bearing two unusual circular structures that resemble suckers; setae *g1*, *g2*, *ps2*

aligned along medial margin of the genito-anal valves. Setae *ps1* modified and inserted posterior to the genito-anal valves. Setal measurements: *1a* 60–75, *1b* 19–25, *1c* 12–14, *2b* 25–30, *2c* 10–13, *3a* 8–11, *3b* 9–10, *4a* 6–8, *4b* 7–10, *ag* 7–9, *g1* 12–16, *g2* 9–11, *ps1* 8–10, *ps2* 9–10.

Gnathosoma. Similar to that of female.

Legs (Figure 9). Setation (from coxae to tarsi): I 2–1–4–3–5–8(2), II 2–1–4–3–5–8(2), III 1–2–2–0–2–5, IV 1–1–1–0–2–5; tarsi I and II each with two elongate solenidia (ω' paraxial, inserted ventro-laterally; ω'' antiaxial); other setae, and eupathidia similar to those of female.

Deutonymph ($n = 2$). (Figures 10 and 11). The two studied specimens are different in size, probably because one is an immature male (smaller specimen) and the other a female (female specimen illustrated). Body measurements: length *v2–h1* 135–160; width *sc2–sc2* 65–75, *c3–c3* 75–85, *e3–e3* 50–57.

Dorsum. Prodorsal setae similar to female; opisthosomal setae *c1*, *d1* and *d3* thick, strongly barbed and similar to prodorsal setae; other opisthosomal setae are minute; setae *h2* are missed on both the studied specimens. Setal measurements: *v2* 18–22, *sc1* 25–26, *sc2* 22–25, *c1* 35–43, *c3* 3–4, *d1* 45–46, *d3* 30–35, *e1* 2, *e3* 2, *f3* 2, *h1* 2.

Venter. Cuticle covered with fine, mostly transverse striae, except smooth area posterior to coxa IV. Setae *1a*, *1b*, *1c*, *2b*, *2c*, *3a*, *3b*, *4a*, *4b*, *ag*, *g1*, *ps1* and *ps2* present; setae *g2* absent.

Gnathosoma. Similar to that of female.

Legs. Setation (from coxae to tarsi): I 2–1–3–3–5–8(1), II 2–1–3–3–5–8(1), III 1–1–2–0–2–5, IV 1–0–1–0–2–3. The analysed specimens' legs are not in good condition, and the actual number of setae on some segments may differ from that provided here.

***Colopalpus nambii* (Castro and Feres 2013) – comb. nov.**

Tenuipalpus nambii Castro and Feres 2013:48: holotype female collected on *Sterculia striata* St. Hil. And Naud. (Sterculiaceae; formerly Malvaceae sensu lato) from São João de Iracema, São Paulo State, Brazil, March 2008, coll. P.R. Demite, deposited in the Collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRP no. 9513).

Diagnosis

Female: Body elongate-ovate; with 13 pairs of dorsal setae (*f*₂ present); ventral integument smooth; gnathosoma elongate and not completely covered by the rostrum; palps 2-segmented; *d* setae on femora, genua and tibiae inserted in dorsal position; tarsi I and II each with setae *p*_{ζ'}–*p*_{ζ''} inserted on tubercles. Deutonymph: *sc*₂ setae inserted posterad level of eyes; setae *h*₂ short and inserted slightly ventrally. Additional information can be found in Castro and Feres (2013).

Remarks

Castro and Feres (2013) described *C. nambii* from Brazil based only on the females. Here, we present additional morphological characters for this species based on new observations of females, deutonymphs and eggs that were imaged using LT-SEM.

The body shape of the female is elongate-ovate, and the dorsal integument is covered with wax and small spherical structures (Figure 12A and B). The mites are yellow in colour when alive. All dorsal setae are

setiform and slightly barbed (except *h2* elongate and flagelliform). The setae *sc2* are inserted at a level between the eyes on adult female. The ventral integument is smooth (Figure 13A). The genitoventral shield is developed, undivided and smooth.

The gnathosoma of *C. nambii* is elongate and not completely covered by the rostrum. The palps are 2-segmented, bearing one slightly barbed *d* seta on first segment and one elongate solenidion on second segment (Figures 13B and 14A). The *d* seta on femora, genua and tibiae is inserted in dorsal position. The tarsi I and II with setae $p\zeta'-p\zeta''$ are inserted on tubercles (Figure 14A and B).

The eggs are yellow in colour, smooth and oblong. Most of the eggs were found individually on the trichome tips (Figure 15A), and this behaviour may be a strategy to protect the eggs from predation.

The prodorsal setae on deutonymph, *v2* and *sc1* are minute, while the setae *sc2* are of similar length to those of the female and inserted posterior to level with the eyes.

The setae *c1*, *d1*, *e1*, *c3*, *d3* and *e3* are minute. The setae *f2*, *f3*, *h1* and *h2* are similar in length; setae *h2* are not flagelliform (Figures 15B and 16). We were unable to verify the form of setae *h2* on *C. matthyssei* because these setae are missing on the available specimens.

The use of LT-SEM imaging allowed the verification of characters otherwise not observable using phase contrast and differential interference contrast (DIC) microscopy. These data helped us verify and better understand some characters shared by *C. matthyssei* and *C. nambii*. Based on these new data, we have transferred *C. nambii* from *Tenuipalpus* to *Colopalpus*.

Discussion

Colopalpus and relative genera

In the description of *Colopalpus*, Pritchard and Baker (1958) indicated the similarity of this genus to the genera *Brevipalpus* and *Tenuipalpus*. These

authors indicated the presence of a single genito-ventral shield in the female of *Colopalpus* as a distinct character separating it from these other genera. However, we observed that the development and shape of the genito-ventral plate is variable in *Colopalpus* and *Tenuipalpus*, and to separate these two genera it may be necessary to use a combination of features. Besides the similar body shape of females and males, *Colopalpus* shares with *Brevipalpus* the dorsal position of the *d* setae on femora, genua and tibiae (*d* are inserted in lateral position in *Tenuipalpus*, Figure 17). In addition, *Colopalpus* shares the elongate, flagelliform *h2* setae and pad-like true claws and empodium with *Tenuipalpus*. Lastly, we observed that the eggs of *C. nambii* are oblong and smooth, and enclosed in a thin wax-like coating (as seen in hatched egg Figure 18B), similar to many observed eggs of *Brevipalpus* species (as seen in Figure 18D where thin coating is cracked); whereas the eggs of *Tenuipalpus* spp. are enclosed in a thick wax-like ribbed or striated case (as seen in Figure 18F) that is produced into a flange at one end of the egg during oviposition (Figure 18E). Further observations of eggs of other *Colopalpus* species would be necessary for the understanding and potential use of this characteristic in diagnosis.

Synonymy of *Colopalpus* as *Tenuipalpus*

Baker and Tuttle (1972) transferred *T. eriophyoides* to *Colopalpus*, based on body shape and presence of a single genito-ventral shield of the female, even though the male has a distinctly narrow opisthosoma. Meyer (1979) concluded that the inclusion of *T. eriophyoides* in *Colopalpus* would open it up to the placement of other species having a narrow opisthosoma within the genus, including species of *Tenuipalpus*. If so, then the only remaining character that would separate *Colopalpus* from *Tenuipalpus* would be the single genito-ventral shield. Meyer considered this character to be variable, and synonymized the two genera instead of simply moving *T. eriophyoides* to a different genus. As the males of *C. matthyssei*, *T.*

mansonculus and *T. zahirii* all have a body shape similar to that of *Brevipalpus*, we believe that species in which the male bears a distinctly narrow hysterostoma, like that found in *T. eriophyoides*, cannot be placed in *Colopalpus*.

Conclusion

Our results show that *Colopalpus* can be differentiated from *Brevipalpus* by the shape of the setae *h*₂, the lack of uncinat true claws on the tarsi and the single genitoventral shield (when developed). Likewise, the main differences between *Colopalpus* and *Tenuipalpus* are the body shape of the females and males, the position of the *d* setae on segments of legs and the characteristics of the eggs. This combination of morphological features places *Colopalpus* as apparently intermediate between *Brevipalpus* and *Tenuipalpus*, and based on these characteristics, we consider *Colopalpus* to be a valid genus of the family Tenuipalpidae.

Other species of Colopalpus

Based on our examination of type specimens of *T. pedrus*, a recent description of *T. zahirii*, and a re-description of *T. mansonculus*, we consider these species to be better placed within the genus *Colopalpus*. Other species currently placed in the genus *Tenuipalpus* may need to be transferred to *Colopalpus*. We highly recommend that a detailed study of the type specimens of the species which appear to be intermediate between *Brevipalpus* and *Tenuipalpus* be conducted before making such decisions, since of the current descriptions and/or illustrations lack sufficient detail.

Species transferred here to Colopalpus

1. *Colopalpus matthyssei* Pritchard and Baker, 1958: 259 – **stat. rev.**
Tenuipalpus matthyssei (Pritchard and Baker); Meyer 1979: 3.
2. *Colopalpus pedrus* Manson, 1963: 222 – **stat. rev.**

Tenuipalpus pedrus (Manson); Meyer 1979: 3.

3. *Colopalpus masoni* Collyer, 1974: 531 – **stat. rev.**

Tenuipalpus masoni (Collyer); Meyer 1979: 3.

Tenuipalpus mansonculus Ghai and Shenhmar, 1985: 117; replacement to *Colopalpus masoni* Collyer (1973), name preoccupied by *Tenuipalpus masoni* De Leon (1965). (Article 58.7 4th Edition International Code of Zoological Nomenclature).

4. *Colopalpus nambii* (Castro and Feres 2013) – **comb. new.**

Tenuipalpus nambii Castro and Feres 2013: 485.

5. *Colopalpus zahirii* (Khanjani and Seeman, 2013); (in Khanjani et al. 2013) – **comb. new.**

Tenuipalpus zahirii Khanjani and Seeman, 2013: 389.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

- Al-Gboory I. 1987. Taxonomic studies of false spider mites (Acari: Tenuipalpidae) in central Iraq [dissertation]. Bonn (Germany): Institut für Angewandte Zoologie der Rheinischen Friedrich-Wilhelms-Universität, Bonn University; p. 205.
- Baker EW, Tuttle DM. 1972. New species and further notes on the Tetranychoidae mostly from the Southwestern United States (Acarina: Tetranychidae and Tenuipalpidae). *Smithsonian Contributions to Zoology* 116:1–37.
- Bolton SJ, Klompen H, Bauman GR, Ochoa R. 2014. A new genus and species of Nematalycidae (Acari: Endeostigmata). *Journal of Natural History* 48:1359–1373.
- Chaudhri WM, Akbar S, Rasool A. 1974. Taxonomic studies of the mites belonging to the families Tenuipalpidae, Tetranychidae, Tuckerellidae,

- Caligonellidae, Stigmaeidae and Phytoseiidae Project No. A17-Ent-26. Lyallpur (Pakistan): University of Agriculture; p. 1–250.
- Collyer E. 1973. Two new species of the genus *Colopalpus* (Acarina: Tenuipalpidae). New Zealand Journal of Science 16:529–532.
- Corpuz-Raros LA. 1978. New Philippine Tetranychoida (Acarina). Kalikasan, Philippines Journal of Biology 7:211–230.
- Castro EB de, Feres RJF. 2013. New species of *Tenuipalpus* (Acari: Tenuipalpidae) from Semidecidual Forest remnants in the State of São Paulo, Brazil. Zootaxa 3716:475–493.
- Flechtmann CHW. 1976. Preliminary report on the false spider mites (Acari: Tenuipalpidae) from Brazil and Paraguay. Proceedings of the Entomological Society of Washington 78:58–64.
- Khanjani M, Alvandy S, Khanjani M, Seeman OD. 2013. A new species of *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Iran. Systematic and Applied Acarology 18:389–395.
- Lindquist EE. 1985. External anatomy. In: Helle W, MW S, editors. Spider mites: their biology, natural enemies and control. Vol. 1A. Amsterdam: Elsevier Science Publishers B.V.; p. 3–28.
- Maninder M, Ghai S. 1978. Indian species of *Tenuipalpus* (Acarina: Tenuipalpidae). Oriental Insects 12:243–258.
- Manson DC. 1963. Seven new species of false spider mites (Tenuipalpidae: Acarina). Acarologia 5:213–224.
- Mesa NC, Ochoa R, Welbourn WC, Evans GA, Moraes G. 2009. A catalog of the Tenuipalpidae (Acari) of the World with a key to genera. Zootaxa 2098:1–185.
- Meyer MKP. 1979. The Tenuipalpidae (Acari) of Africa with keys to the world fauna. Pretoria (South Africa): Entomology Memoir Department of Agriculture Republic South Africa 50(1):1–133.
- Mitrofanov VI. 1973. Revision of the subfamily Brevipalpinae (Trombidiformes, Tenuipalpidae). Zoologicheskii Zhurnal 52:507–512.

- Mitrofanov VI, Strunkova ZI. 1979. A key to false spider mites. *Operdelitl`Kleshchei-ploskotelok*, USSR 148:1–148.
- Pritchard AE, Baker EW. 1958. The false spider mites (Acarina: Tenuipalpidae). *University of California Publications in Entomology* 14:175–274.
- Rimando LC. 1962. The tetranychoid mites of the Philippines. *University of Philippines, College Agricultural. Laguna, Technical Bulletin* 11:1–52.
- Saito Y, Kotaro M, Chittenden AR. 1999. Body characters reflecting the body size of spider mites in flattened specimens (Acari, Tetranychidae). *Applied Entomology and Zoology* 34:383–386.
- Seeman OD, Beard JJ. 2011. A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia. *Systematic and Applied Acarology* 16:73–89.

Figures

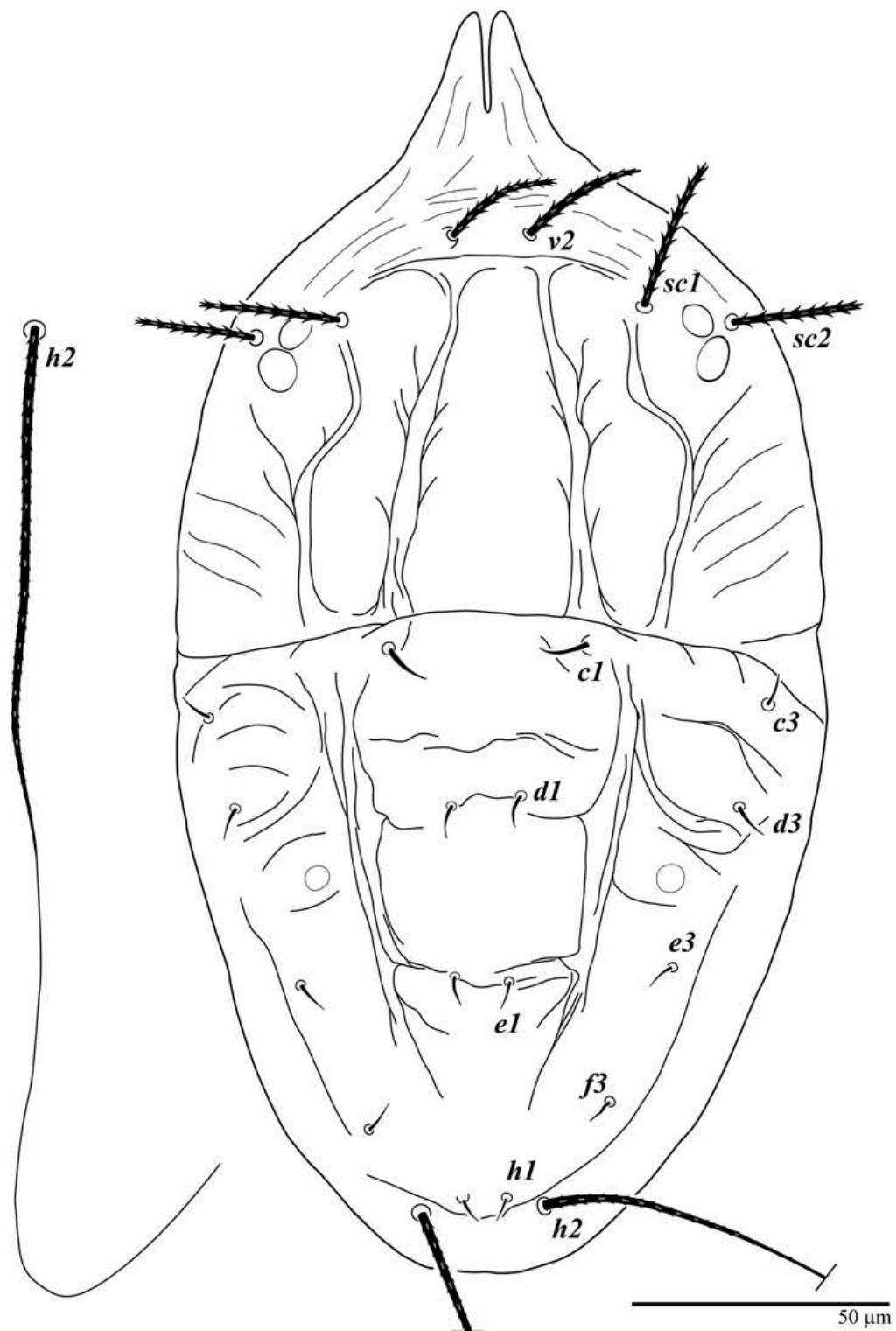


Figure 1. *Colopalpus matthyssei* Pritchard and Baker (Female): dorsum, with detail of *h2* seta.



Figure 2. *Colopalpus matthyssei* Pritchard and Baker (Female): dorsum.



Figure 3. *Colopalpus matthyssei* Pritchard and Baker (Female): venter.

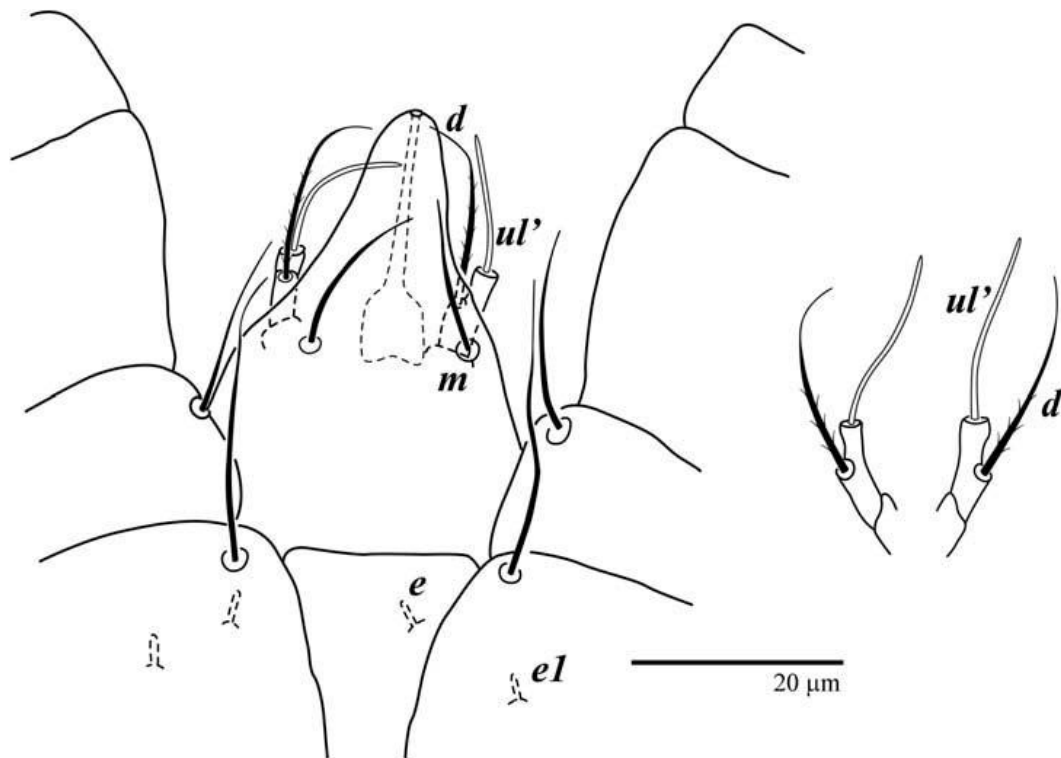


Figure 4. *Colopalpus matthyssei* Pritchard and Baker (Female): hypostome and palpi.

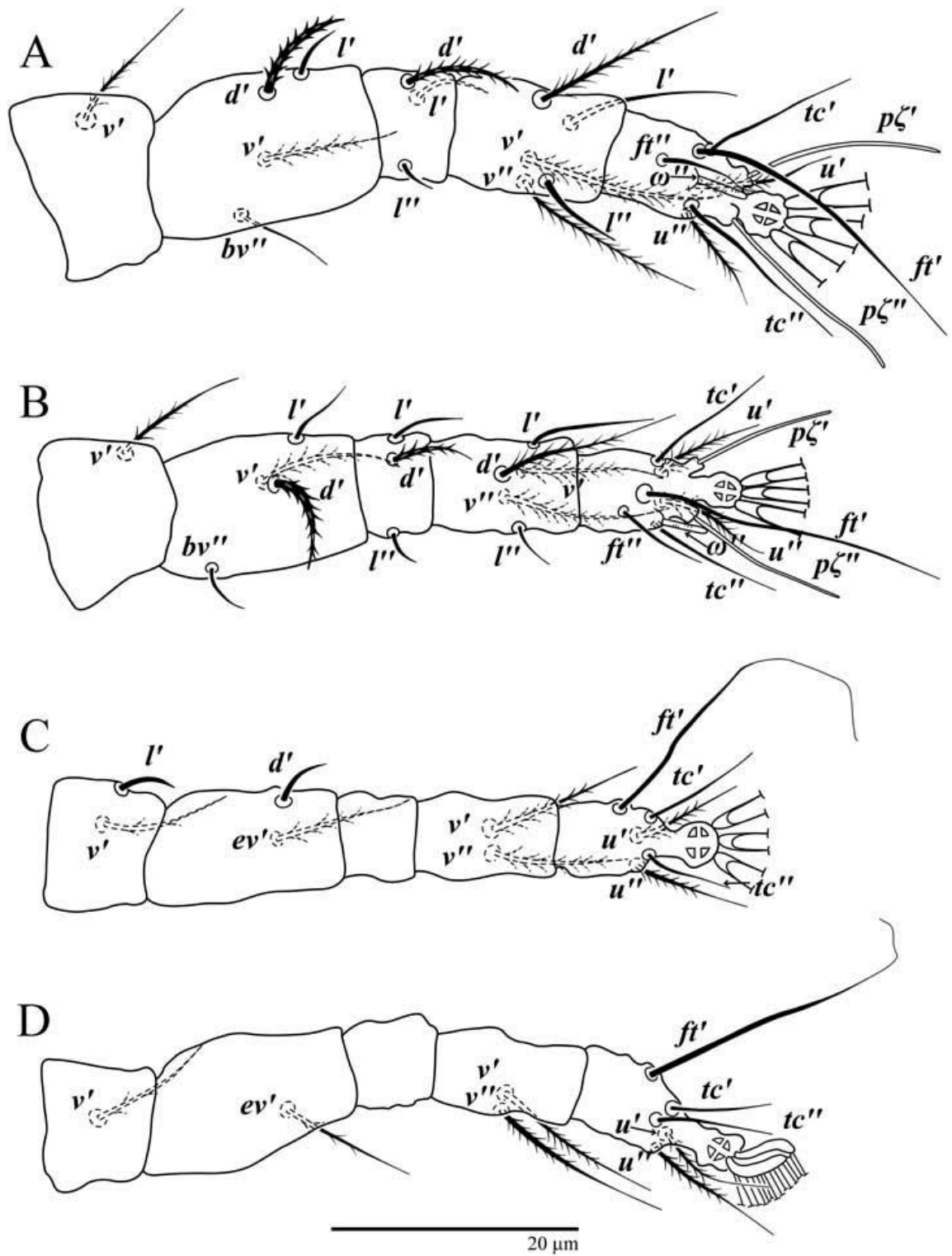


Figure 5. *Colopalpus matthyssei* Pritchard and Baker (Female): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

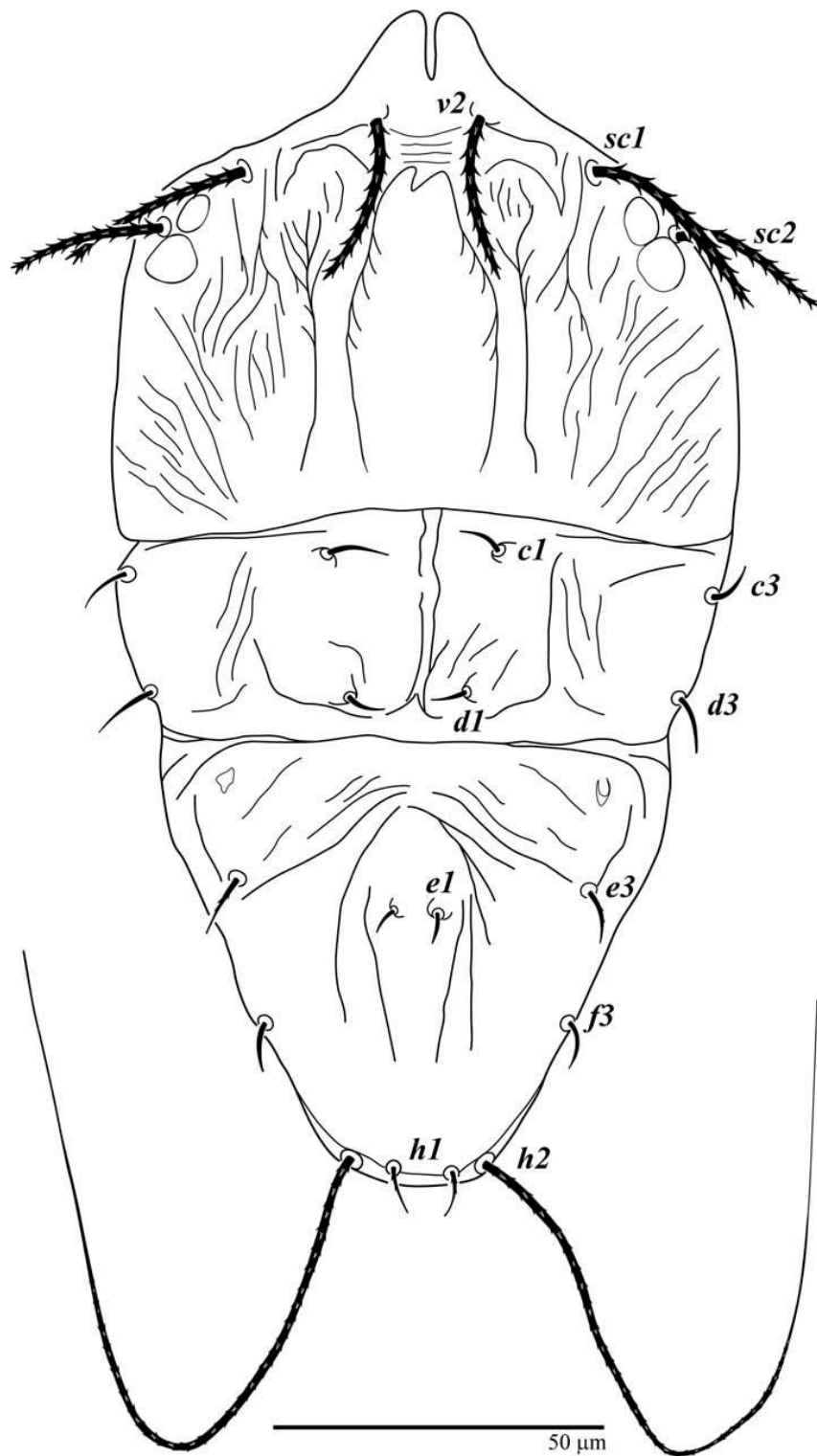


Figure 6. *Colopalpus matthyssei* Pritchard and Baker (Male): dorsum.



Figure 7. *Colopalpus matthyssei* Pritchard and Baker (Male): dorsum.

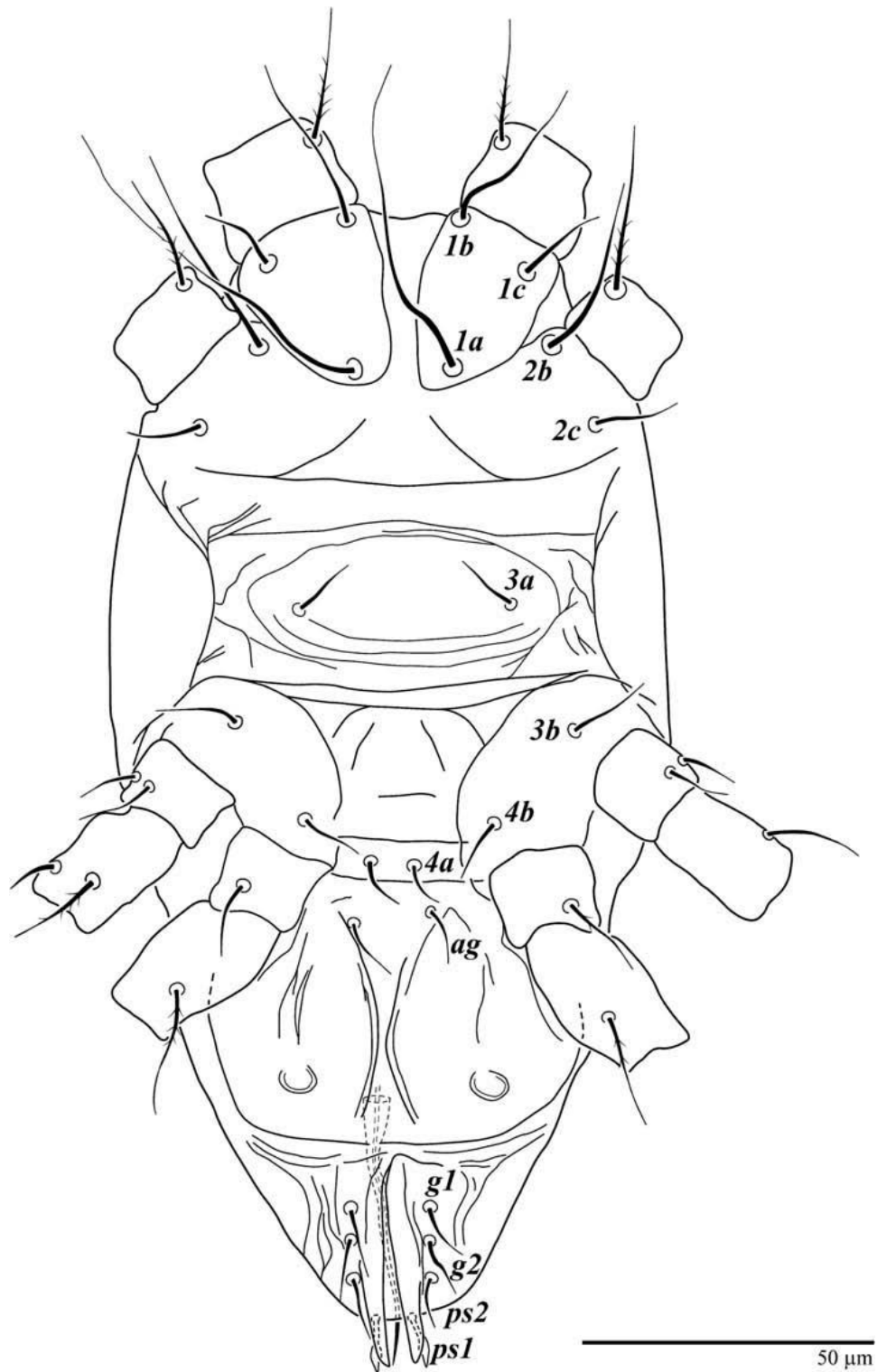


Figure 8. *Colopalpus matthyssei* Pritchard and Baker (Male): venter.

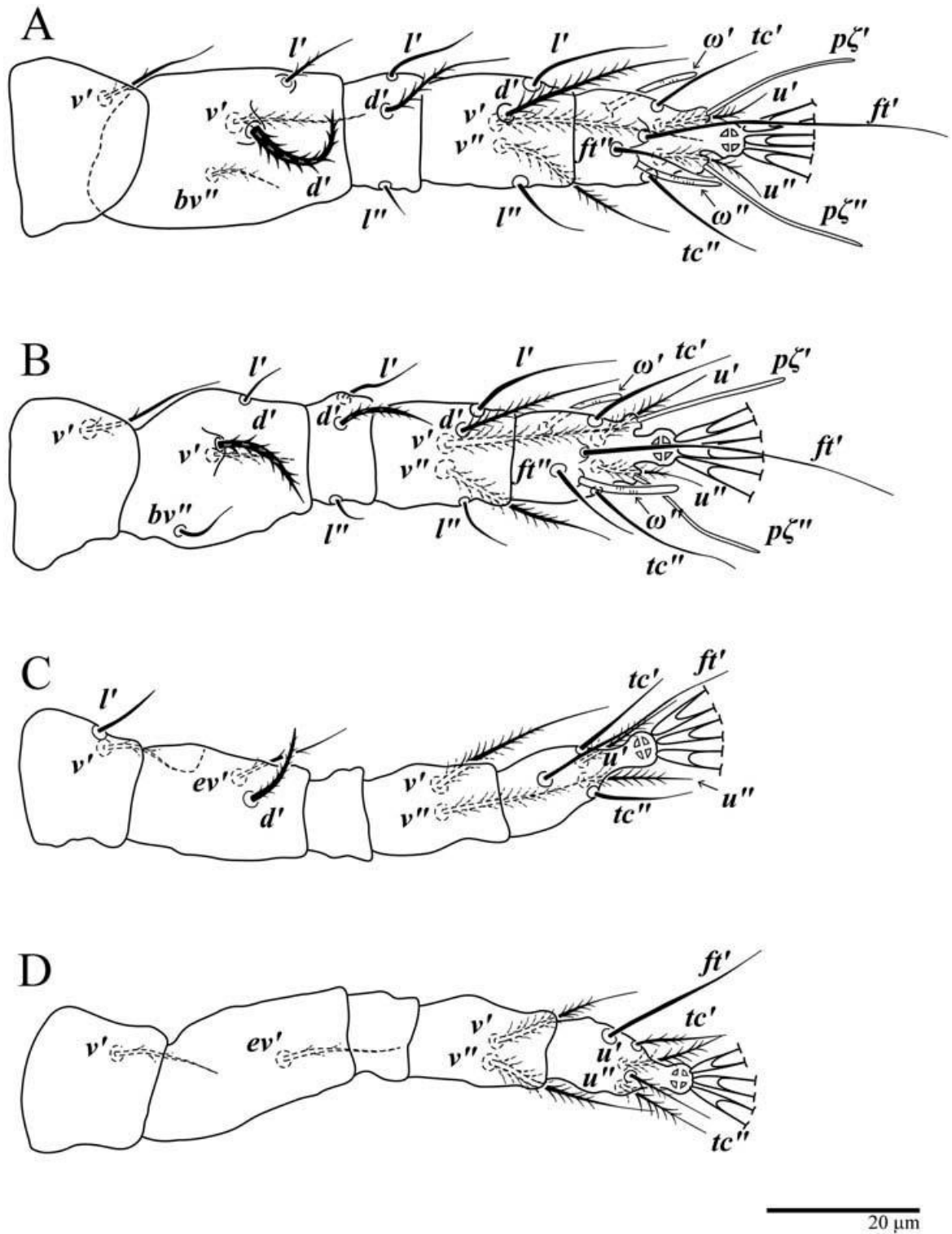


Figure 9. *Colopalpus matthyssei* Pritchard and Baker (Male): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

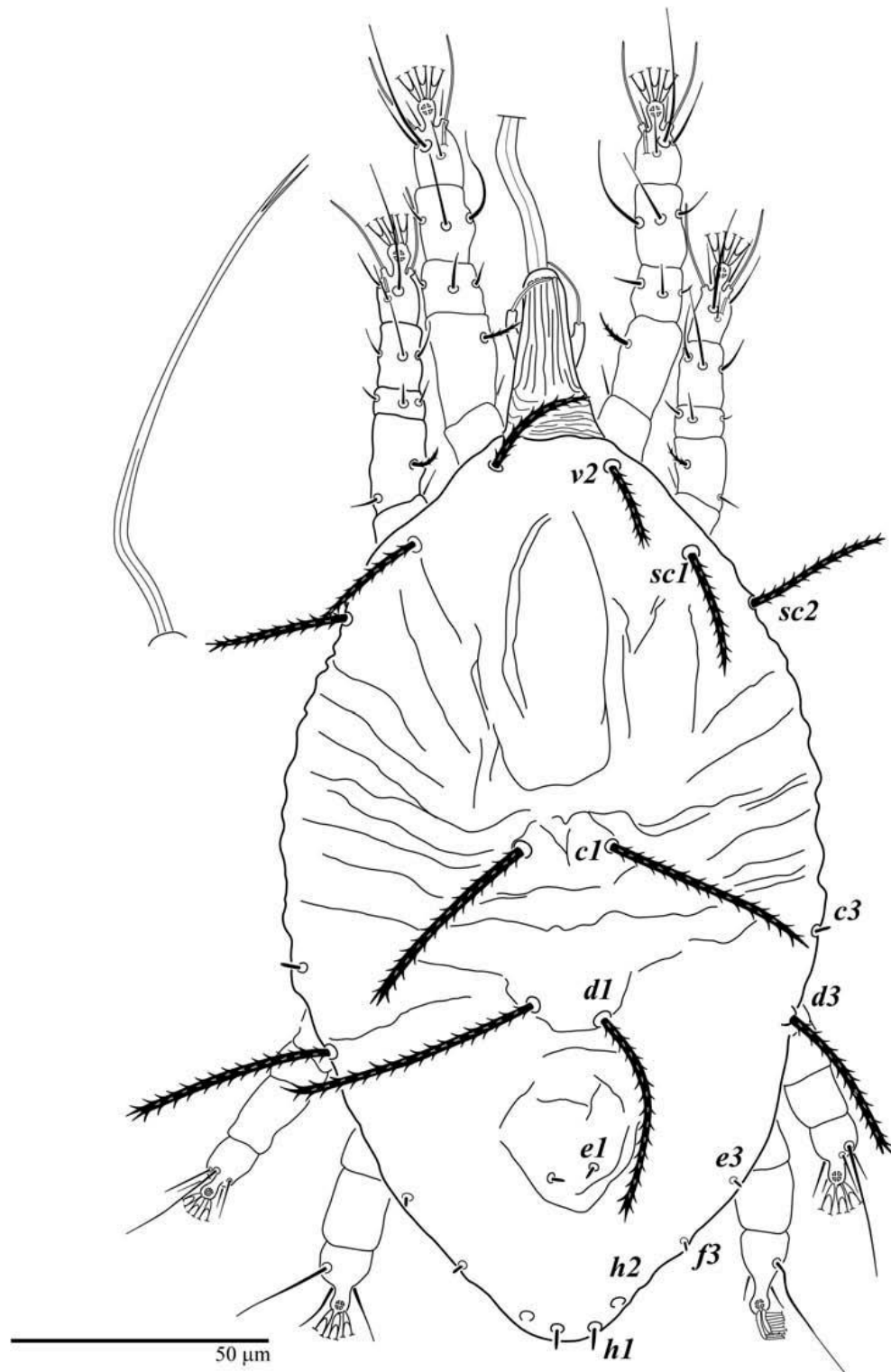


Figure 10. *Colopalpus matthyssei* Pritchard and Baker (Deutonymph):
dorsum, with details of legs and chelicerae.



Figure 11. *Colopalpus matthyssei* Pritchard and Baker (Deutonymph):
dorsum.

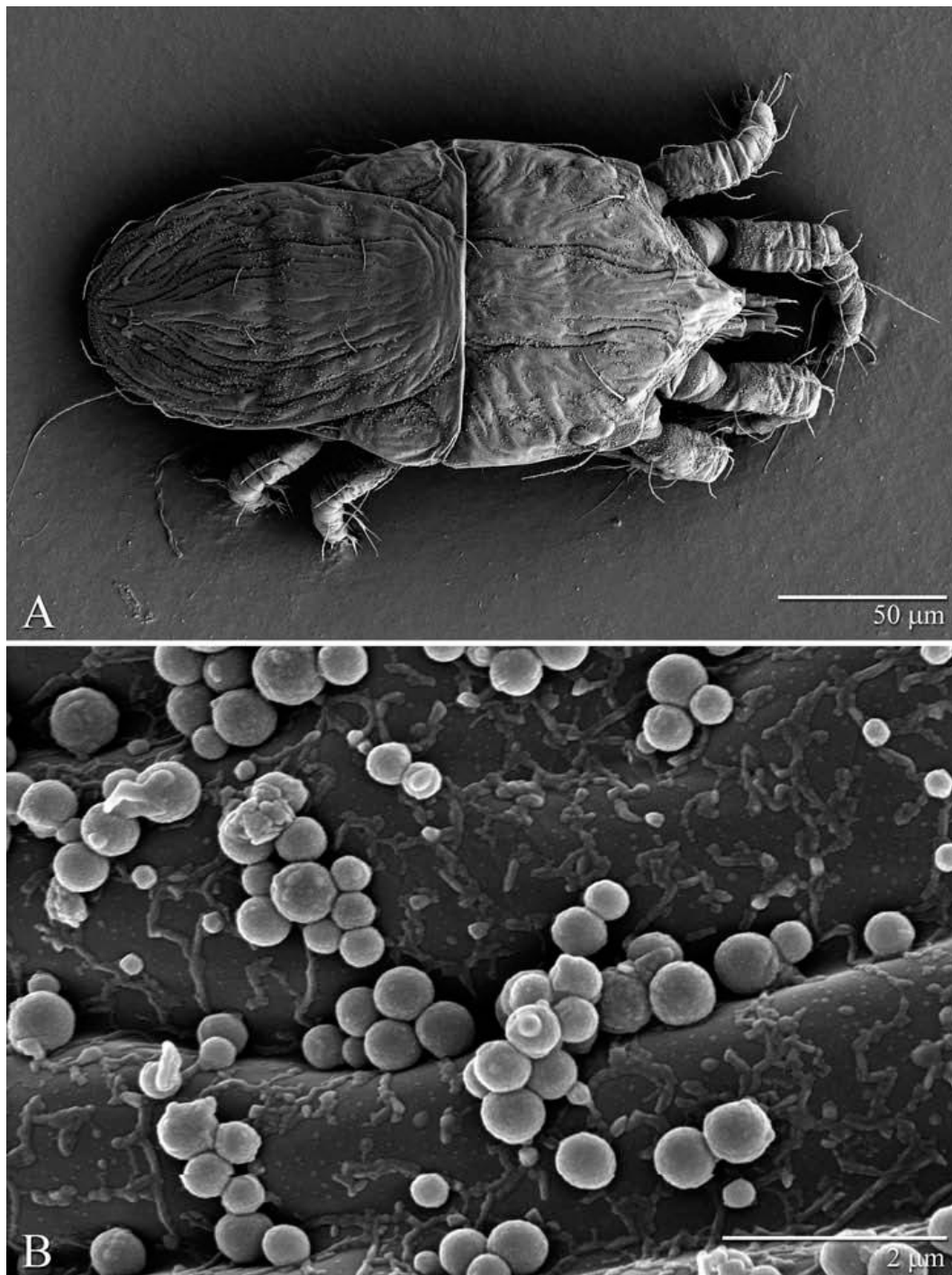


Figure 12. *Colopalpus nambii* (Castro and Feres) (Female): (A) dorsum; (B) detail of dorsal integument.

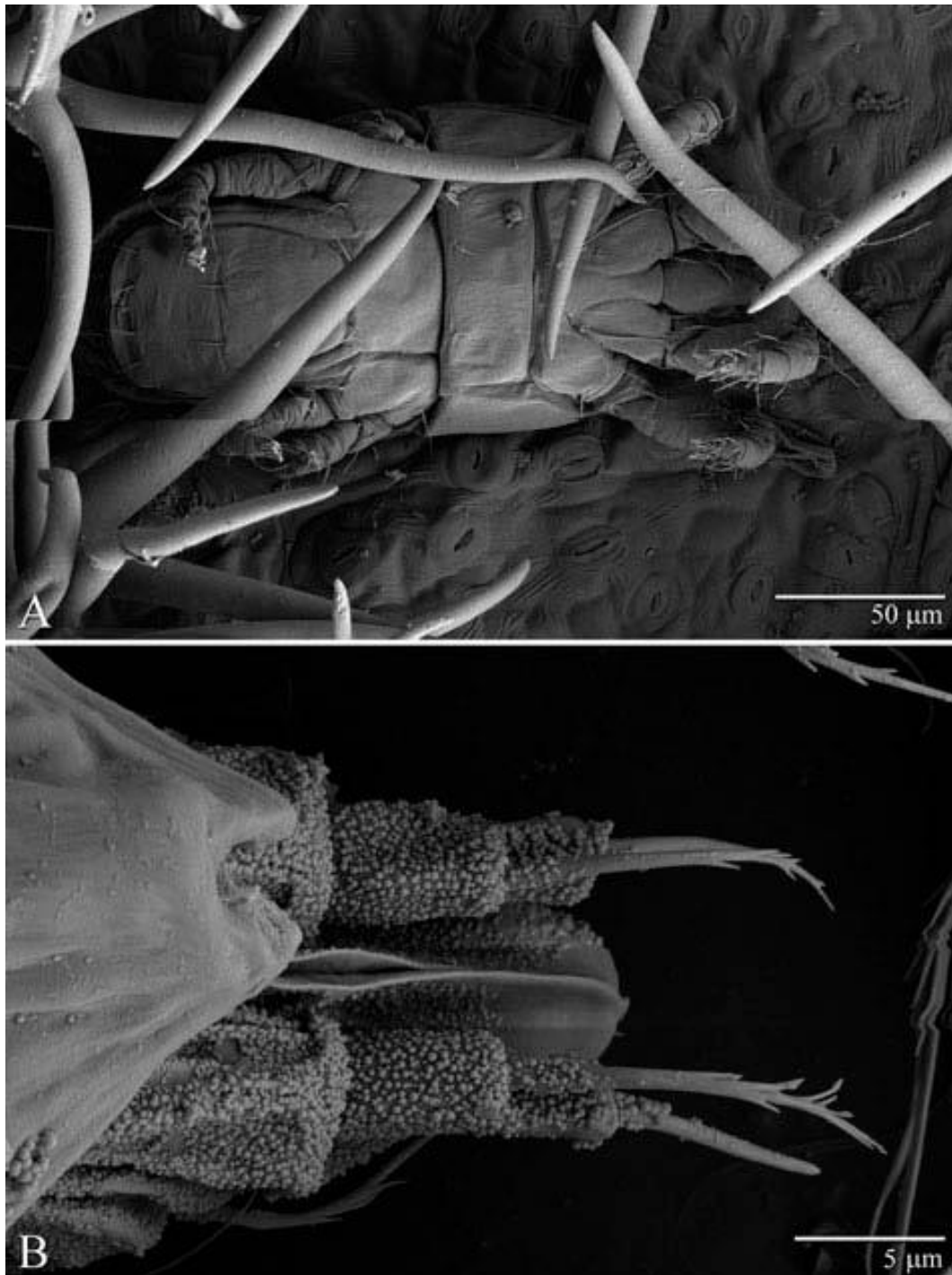


Figure 13. *Colopalpus nambii* (Castro and Feres) (Female): (A) venter; (B) palps.

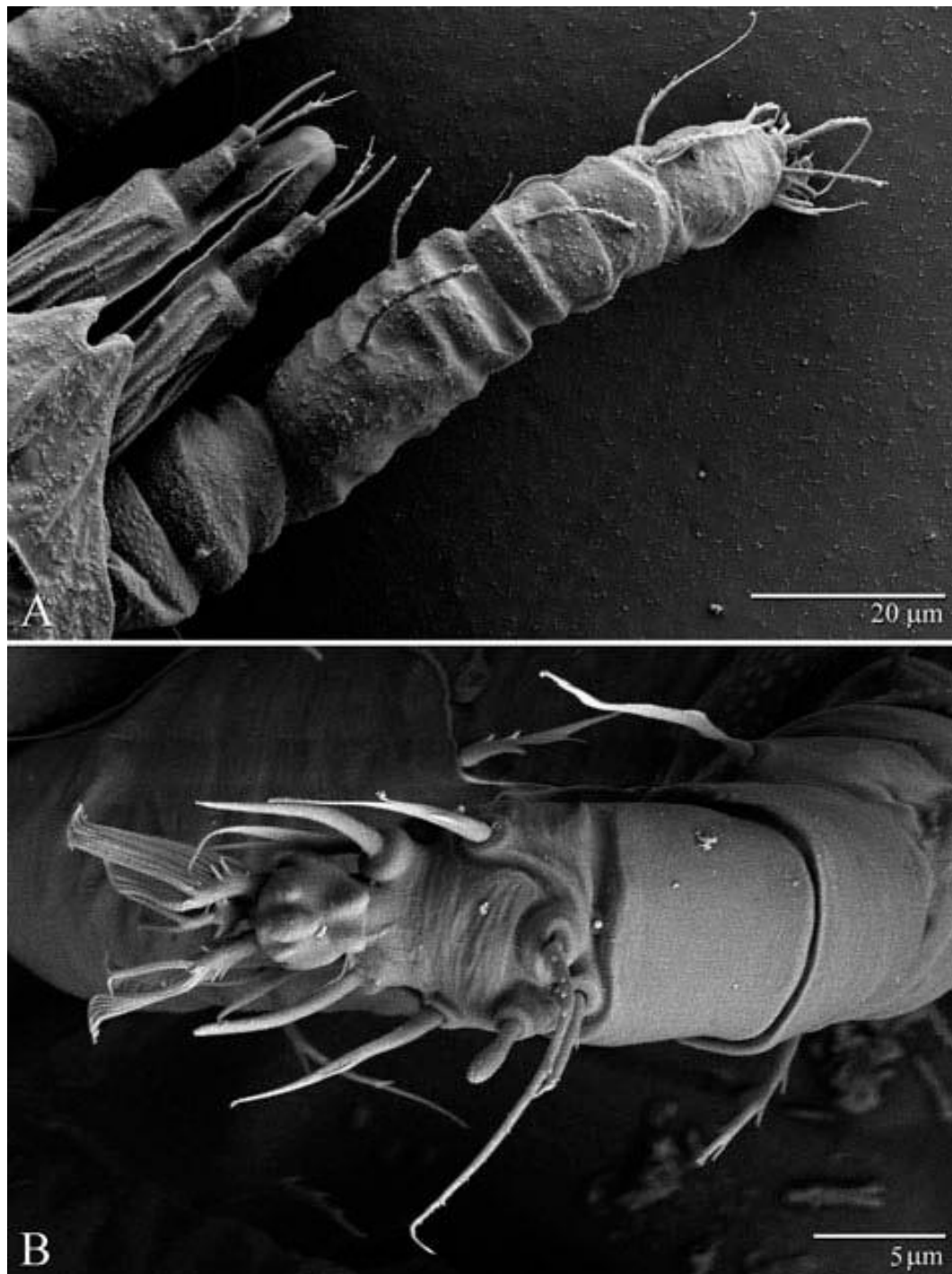


Figure 14. *Colopalpus nambii* (Castro and Feres) (Female): (A) gnathosoma and leg I; (B) detail of tarsus II.

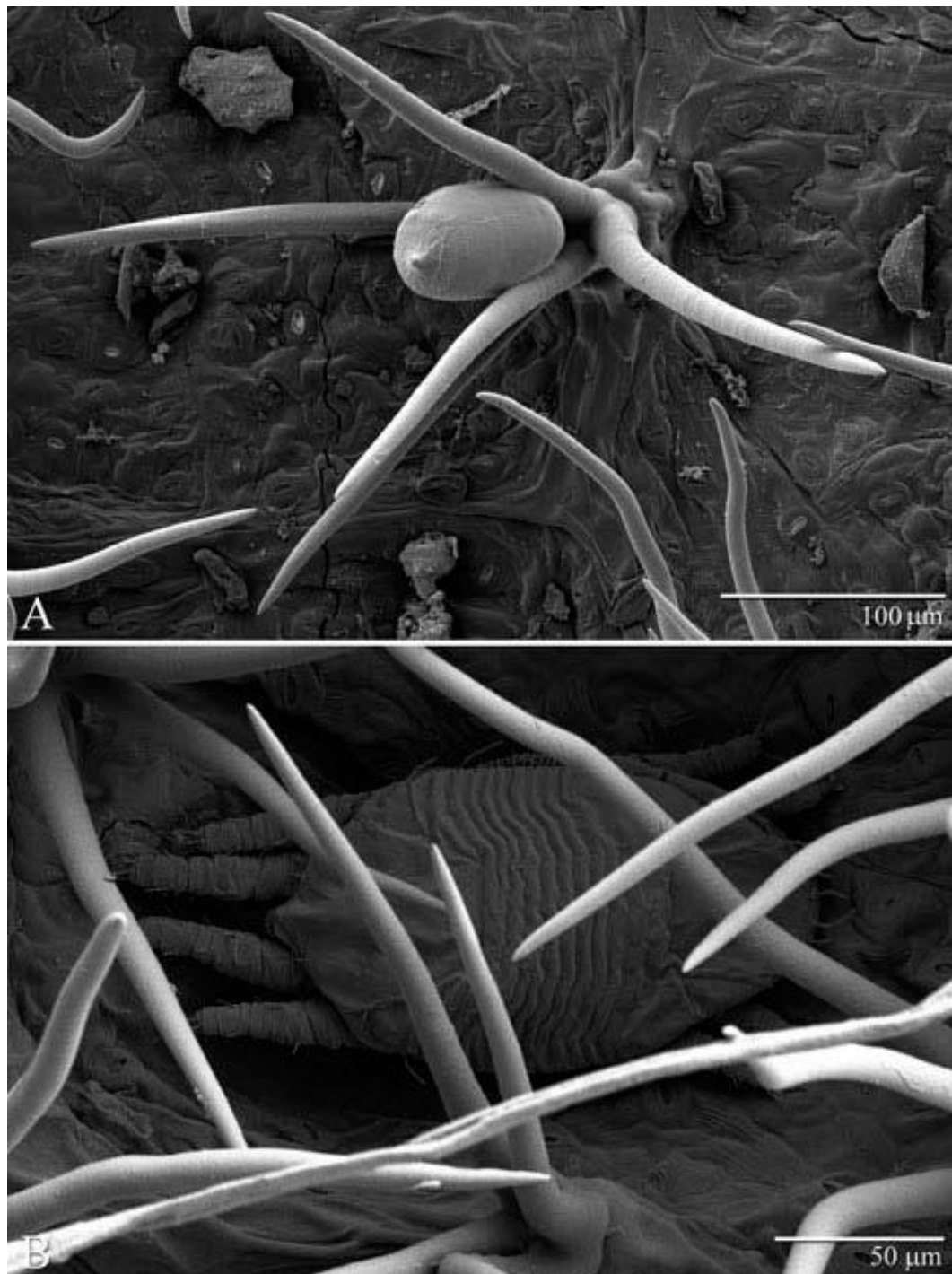


Figure 15. *Colopalpus nambii* (Castro and Feres) (A) egg on trichome. (B) deutonymph, dorsal view.

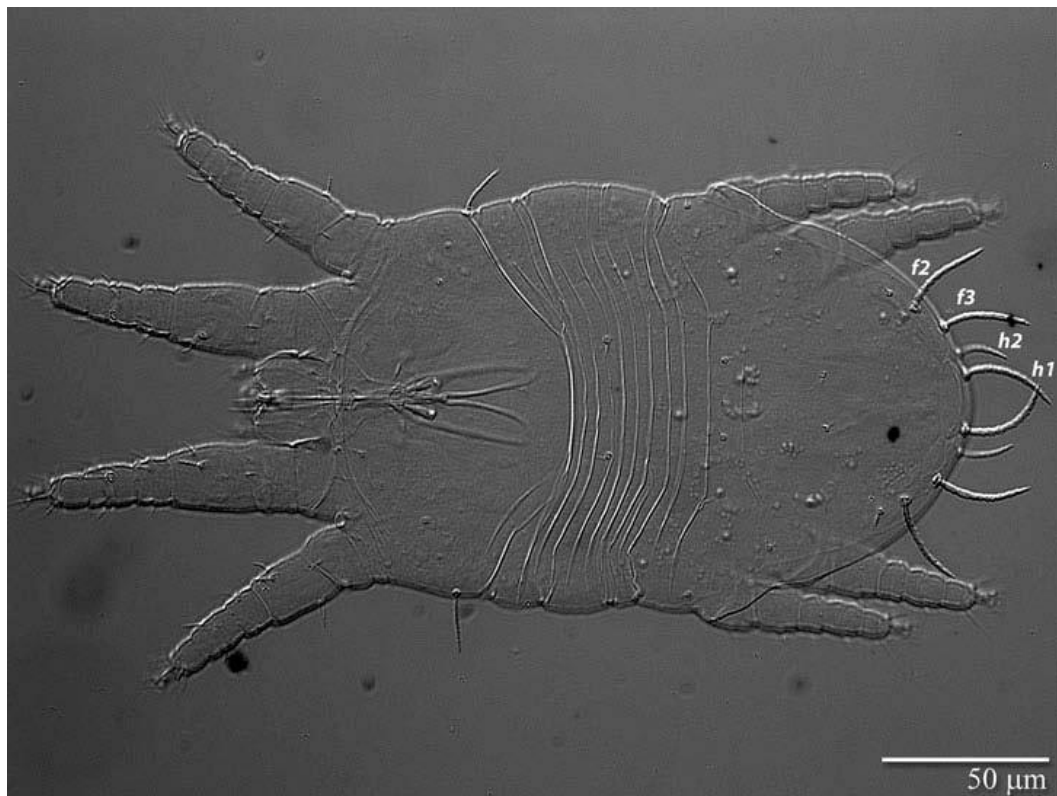


Figure 16. *Colopalpus nambii* (Castro and Feres) (Deutonymph): dorsal view. Note the *h2* setae short and inserted slightly ventrally.

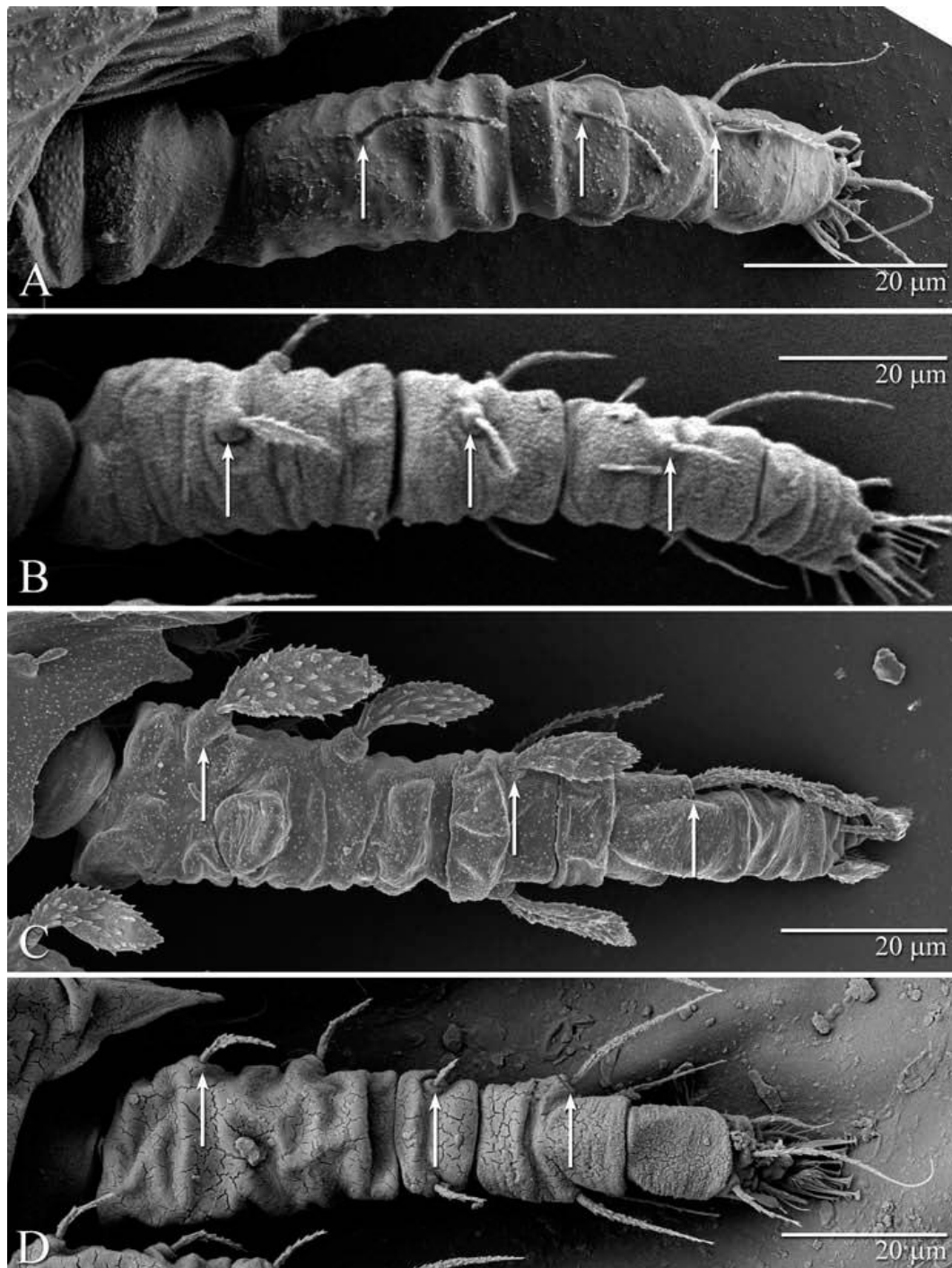


Figure 17. Leg I of females. The arrows indicate the position of d setae on femora, genua and tibiae: (A) *Colopalpus nambii* (Castro and Feres); (B) *Brevipalpus* sp.; (C) *Tenuipalpus* sp. (sensu stricto). (D) *Tenuipalpus granati* Sayed (sensu lato).

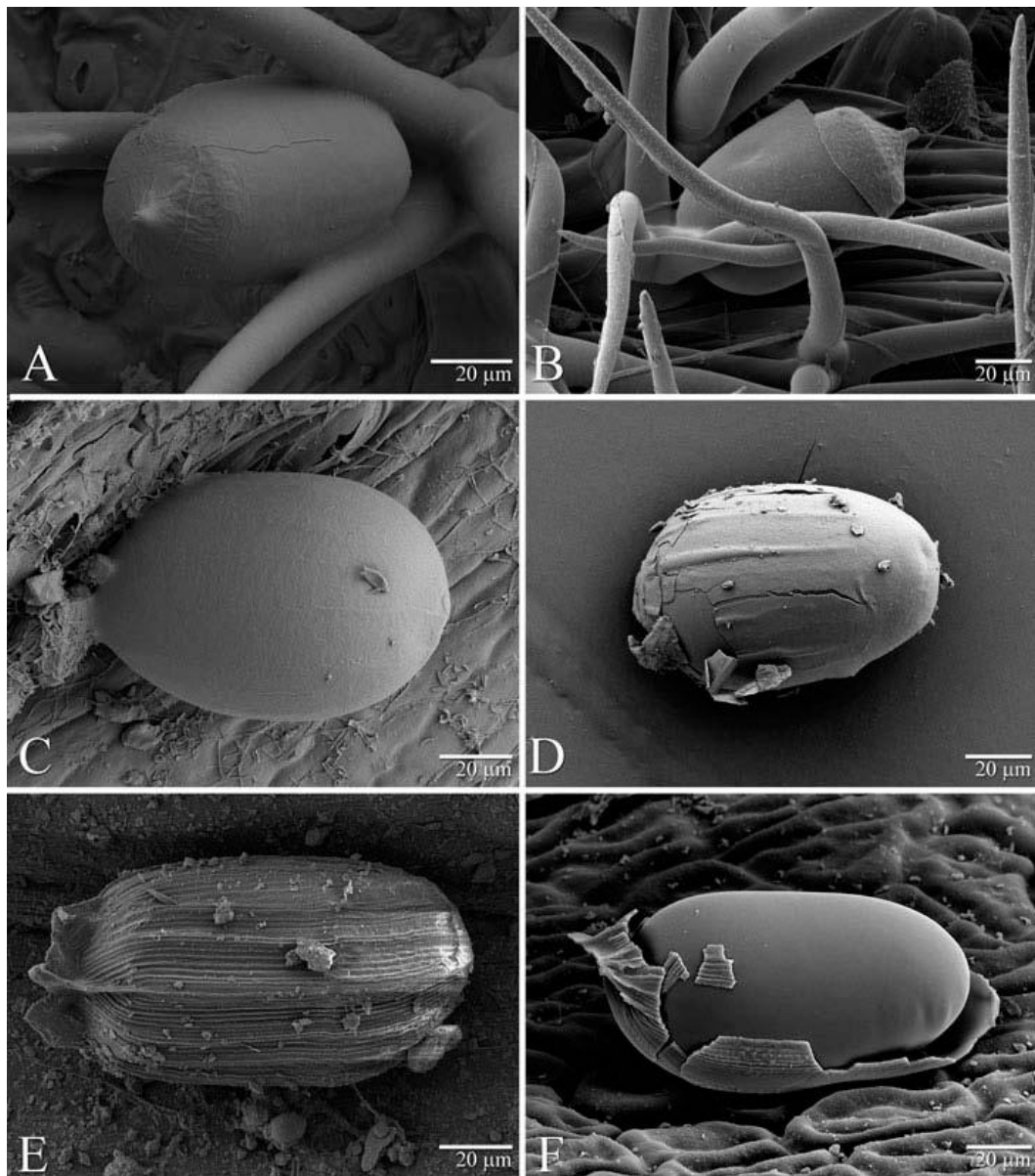


Figure 18. Eggs: (A–B) *Colopalpus nambii* (Castro and Feres); (C–D) *Brevipalpus* sp.; (E–F) *Tenuipalpus* sp.

CHAPTER 6

DEFINITION OF *TENUIPALPUS* SENSU STRICTO (ACARI, TENUIPALPIDAE), WITH REDESCRIPTION OF *TENUIPALPUS CAUDATUS* (DUGÈS) AND DESCRIPTION OF A NEW SPECIES FROM COSTA RICA

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**Authors: Elizeu B. Castro, Ethan C. Kane, Reinaldo J.F. Feres, Ronald
Ochoa and Gary R. Bauchan**

Abstract

The taxonomic history of the genus *Tenuipalpus* Donnadieu is discussed and *Tenuipalpus caudatus* (Dugès) (= *Tenuipalpus palmatus* Donnadieu) is redescribed based on specimens from Portugal intercepted at ports of entry in the United States, and references including photographic records of the neotype of *T. caudatus*. In addition, a proposed new species, *Tenuipalpus erbei* **sp. nov.** is described from Costa Rica. Our results show that *T. caudatus*, *T. erbei* **sp. nov.** and another 36 known species of *Tenuipalpus* share a pair of lateral body projections associated with setae c3, considered a synapomorphy for the newly defined group, *Tenuipalpus* sensu stricto. We also show that its members share other character states, although these features are found elsewhere in *Tenuipalpus* and also in *Ultratenuipalpus*, indicating their origins are within *Tenuipalpus*. A list of *Tenuipalpus* sensu stricto species is presented.

Keywords: Flat mites; taxonomy; systematics; *Tenuipalpus palmatus* Donnadieu; body projections; crests; remote-sampling; low-temperature scanning electron microscopy

Introduction

Donnadieu (1876) erected the new genus *Tenuipalpus* and placed three species within it, *Tenuipalpus palmatus*, *Tenuipalpus spinosus* and *Tenuipalpus glaber*, but he did not designate a type species. Later, Vitzthum (1929) designated *T. palmatus* as the type species for the genus. Baker (1945), McGregor (1949) and Baker and Pritchard (1953) mentioned *T. palmatus* as the type species of the genus and provided a redescription based on specimens from the Berlese Collection. The main characteristics used by these authors to define *Tenuipalpus* were the presence of a broad prodorsum and a narrow opisthosoma. Based on these simple characteristics, many species have been described under this broad concept of *Tenuipalpus* (De Leon 1961; Manson 1963; Collyer

1964, 1973; González 1968). Although the broader concept of *Tenuipalpus* would have included their new species, Pritchard and Baker (1958) erected a new genus *Colopalpus* to accommodate *Colopalpus matthyssei*, thus providing a more precise genus diagnosis to distinguish it from *Tenuipalpus*.

Tenuipalpus has undergone some previous division, beginning with Reck (1959), who erected *Extenuipalpus* as a monospecific genus and designated *Tenuipalpus quadrisetosus* Lawrence as the type species. Mitrofanov (1973) followed with the proposed division of *Tenuipalpus* into seven genera. Of these, two have setae *h2* non-flagelliform – *Ultratenuipalpus* (*f2* present; four segmented palp); *Extenuipalpus* (*f2* absent; three segmented palp); and five have setae *h2* flagelliform – *Tuttlepalpus* (*c1*, *d1*, *f2* present; *e1* absent; three pairs 3a, three pairs 4a2); *Aegyptopalpus* (*c1*, *f2* present; *d1*, *e1* absent; one pair 3a, two pairs 4a); *Gnathopalpus* (*c1*, *d1*, *e1* present; *f2* absent; two pairs 3a, four pairs 4a); *Deleonipalpus* (*c1* present; *d1*, *e1*, *f2* absent; one pair 3a, two pairs 4a); and *Tenuipalpus* (*c1*, *d1*, *e1*, *f2* present; one to two pairs 3a, one pair 4a). For purposes of these divisions, this study mainly considered the number of lateral setae (i.e. the presence/ absence of setae *f2*) and central setae (i.e. the presence of setae *d1* and *e1*) on the dorsal opisthosoma. Mitrofanov and Strunkova (1979) transferred several species from *Tenuipalpus* to *Tuttlepalpus*, *Colopalpus* and *Extenuipalpus*.

Meyer (1979) did not consider the characteristics used by Mitrofanov important enough to separate genera, and proposed the division of *Tenuipalpus* into six species groups instead based primarily on character states similar to those used by Mitrofanov (1973). The six species groups proposed by Meyer were *caudatus*, *trisetosus*, *albae*, *elegans*, *granati* and *quadrisetosus*. Thus, the genera erected by Mitrofanov (1973) were synonymized with *Tenuipalpus* – with the exception of *Ultratenuipalpus*, which she considered a valid genus based on the presence of non-flagelliform setae *h2*, three pairs of ps setae

(apparently not considered by Mitrofanov) and a four segmented palp. We feel that Meyer considered the presence of setae *ps3* in *Ultratenuipalpus* to be more significant than the form of *h2*, because *Extenuipalpus* also included species with non-flagelliform setae *h2* and four segmented palp, but this genus was included in her mass synonymy with *Tenuipalpus*, which also included *Colopalpus* Pritchard & Baker.

Baker and Tuttle (1987) revised the false spider mites of Mexico and grouped the species of *Tenuipalpus* into either the *caudatus* (*f2* present) or the *proteae* (*f2* absent) species groups. They also further divided the *caudatus* species group into three subgroups: *anoplus* (one pair 3a, one pair 4a), *bakeri* (two pairs 3a, one pair 4a) and *annonae* (one pair 3a, two pairs 4a) subgroups. Meyer (1993) accepted the division proposed by Baker and Tuttle (1987), and added two new subgroups to the *caudatus* group, namely the *pacificus* (two pairs 3a, two pairs 4a) and *eriophyoides* (one pair 3a, four pairs 4a) subgroups; and divided the *proteae* group into three subgroups: *rhusi* (one pair 3a, one pair 4a), *keiensis* (one pair 3a, two pairs 4a) and *xerocolus* (two pairs 3a, two pairs 4a) subgroups. Meyer (1993) also synonymized *Amblypalpus* Mitrofanov & Strunkova, 1978 (with a non-flagelliform *h2*) with *Tenuipalpus*, again indicating that she did not see the form of *h2* as phylogenetically significant.

After this somewhat recent regrouping, *Tenuipalpus* was broken up once more. Mesa et al. (2009) published the catalogue of Tenuipalpidae and considered *Amblypalpus* and *Tenuipalpus* to be distinct and valid genera. They also transferred several species bearing setae *h2* non-flagelliform from *Tenuipalpus* to *Ultratenuipalpus*. Furthermore, Castro et al. (2015a) reinstated the genus *Colopalpus* from *Tenuipalpus* based on differences of the body shape and position of the leg setae. These authors presented *C. pedrus* Manson and *C. masoni* Collyer as valid species of *Colopalpus*, and transferred *C. nambii* (Castro & Feres) and *C. zahirii* (Khanjani & Seeman) from *Tenuipalpus* to *Colopalpus*.

Currently, *Tenuipalpus* includes over 300 described species (Mesa et al. 2009; Beard et al. 2012a; Castro et al. 2015b). As defined by Beard et al. (2012a), all *Tenuipalpus* have setae *h2* flagelliform, lack the dorsosublateral setae (*c2*, *d2*, *e2*), have reduced palpal segmentation (one to three segments), a broad flat projection over the gnathosoma and coxae I–II that is strongly forked medially, poorly developed anal plates, and usually lack one pair of *ps* setae (i.e. *ps1*–*2* present). All these character states can be found in other flat mite genera; thus, no single character state is a synapomorphy, suggesting that *Tenuipalpus* is a polyphyletic or paraphyletic group. Furthermore, some variable character states present within *Tenuipalpus* are used to define other genera in the Tenuipalpidae. For example, the absence of all dorsocentral setae defines the related genus *Tenuilichus*, but one or two of these three setae may be absent within *Tenuipalpus* (i.e. *c1*, *d1*); and duplicated setae *4a*, found in many *Tenuipalpus*, are also found in *Prolixus*, *Acaricis*, *Cyperacarus* and *Gahniacarus* (Beard et al. 2005; Beard and Gerson 2009; Beard and Ochoa 2011).

We studied specimens of *Tenuipalpus caudatus* (Dugès), and identified a novel character state present within *Tenuipalpus* that supports a monophyletic subgroup. Based on this findings, *T. caudatus* is redescribed and new proposed species *Tenuipalpus erbei* **sp. nov.** is described from Costa Rica. A morphological survey of additional type specimens and descriptions available in the literature identified 36 previously described species which also share this character state and thus justify their inclusion in the newly defined *Tenuipalpus* sensu stricto.

Taxonomic history about the type species of Tenuipalpus

The type species of the genus *Tenuipalpus* has a complicated taxonomic history and we cite some important records present in the literature that may help clarify its history. Dugès (1834) described *Tetranychus caudatus*, within the family Trombidiei [sic] but did not

illustrate his description. Donnadieu (1876) erected the genus *Tenuipalpus* and placed three species in this genus, but did not designate a type species. Under his new species *T. palmatus*, he listed two synonyms (*Trombidium caudatus*, Gervais and *Tetranychus caudatus*, Dugès), each followed by a question mark. Perhaps the question marks indicate that, even at this point in time, there was uncertainty about the identity of these species, or that Donnadieu did not examine the specimens.

Vitzthum (1929) designated *T. palmatus* as the species type for the genus, but did not consider the possible synonymy of *T. palmatus* and *T. caudatus*. Baker (1945, p. 37) redescribed the male of *T. palmatus* based on specimens from the Berlese Collection and McGregor (1949, p. 5) redescribed the female of *T. palmatus* based on the same specimens used by Baker, and presented a drawing of the dorsal view of the female. Baker and Pritchard (1953, p. 325) also redescribed the female of *T. palmatus*, again from the same specimens, and presented a drawing with good details of the dorsal view. These latter authors highlighted the fact that the illustration of *T. palmatus* presented in Donnadieu (1876), Vitzthum (1929) and Baker (1945) were all similar. They also recognized the synonymy of *Caligonus calyx* Canestrini & Fanzago with *T. palmatus*, as proposed by Canestrini (1890).

Pritchard and Baker (1958) transferred *Tetranychus caudatus* Dugès to *Tenuipalpus* and cited incorrectly this species as *Trombidium caudatus* Dugès. These authors regarded *Acarus tini* Boisduval, *Tenuipalpus palmatus* Donnadieu and *Caligonus calyx* Canestrini & Fanzago as new synonyms of *Tenuipalpus caudatus* (Dugès). This synonymy created confusion, because although now a synonym of *T. caudatus*, the name *T. palmatus* remains the type species for the genus. Subsequently, several authors have cited the type species of *Tenuipalpus* in different ways: Meyer (1979) cited *Tenuipalpus caudatus* (Dugès) (= *T. palmatus* Donnadieu); Baker and Tuttle (1987) and Meyer (1993) cited *T. palmatus* Donnadieu = *Trombidium caudatus* Dugès; and Mesa et al.

(2009) cited the type species of *Tenuipalpus* as *Tenuipalpus palmatus* Donnadieu (p. 71), and it is also cited as a junior synonym of *T. caudatus* (p. 75). André (2011) redescribed *T. caudatus* and also followed the synonymy proposed by Pritchard and Baker (1958). This author designated a neotype for the species because the type specimen is lost (Mesa et al. 2009). The photographs of the neotype match previous descriptions and illustrations of *T. palmatus*, and was collected on *Viburnum tinus*, the same host species as specimens described by Baker (1945) and McGregor (1949). Therefore, we concur that the neotype designated by André (2011) is a suitable neotype for *T. caudatus* (Dugès, 1834) (= *T. palmatus* Donnadieu, 1876).

According to the International Code of Zoological Nomenclature, article: 61.1.3: “Once fixed, name-bearing types are stable and provide objective continuity in the application of names”, and by the subsequent designation of Vitzthum (1929), *T. palmatus* will always be the type species of *Tenuipalpus*, even if later work, such as that of Pritchard and Baker (1958), shows that it is a junior synonym of another species (B. Halliday, J.J. Beard and O. Seeman, pers. comm.). Therefore, the correct citation for the type species of the genus is *T. palmatus* Donnadieu, 1876 (= *T. caudatus* (Dugès), 1834).

Materials and Methods

Measurements for the holotype of each species are given in micrometres (µm), with the range of measurements for the paratypes shown in parentheses. Leg setal numbers are written as the total number of tactile setae and eupathidia, followed by number of solenidia in parentheses. Leg chaetotaxy is adapted from Lindquist (1985) and Seeman and Beard (2011). Photographs were obtained using a Zeiss Axioscope™ microscope with differential interference contrast (DIC) 100x Plan Apochromate objective with a NA 1.4.

We refer to all the species of the genus *Tenuipalpus* that do not have lateral body projections associated with setae *c3* as *Tenuipalpus* sensu lato. This group can be defined as follows: Body shape with prodorsum wider than opisthosoma or elongate-ovate; lateral body projections associated with setae *sc2* usually absent; prodorsum with three pairs of setae (*v2*, *sc1*, *sc2*; except *v2* absent in *T. elegans* (Collyer)); opisthosoma with 8–10 pairs of setae; (*c3*, *d3*, *e3*, *f3*, *h1*, *h2* present; *c2*, *d2*, *e2* absent; *c1*, *d1*, *e1*, *f2* present or absent (*d1*, *e1* rarely absent); setae *h2* elongate, flagelliform. Palp one to three segmented. Venter with one to two pairs of setae *3a* (*3a2* present or absent) and one to four pair of setae *4a* (*4a2*, *4a3*, *4a4* present or absent); ventral and genital plates not developed, membranous genital flap present; two pairs of pseudanal setae.

Specimens of *T. erbei* **sp. nov.** were collected using the remote-sampling techniques outlined in Erbe et al. (2003) whereby freshly collected specimens and host material are cryopreserved *in situ* in the field (in this case at field sites in Costa Rica) and subsequently transported to the Electron and Confocal Microscopy Unit (ARS-USDA, BARC, Beltsville, MD) in the United States for imaging and analysis. Additional specimens of *T. erbei* **sp. nov.** were collected and maintained in 70% ethanol and used for low-temperature scanning electron microscopy (LT-SEM) studies. Mites for LT-SEM were studied using the methodology previously described in Castro et al. (2015a).

Abbreviations

DEES – Reference Collection of Departamento de Entomologia, Fitopatologia e Zoologia Agrícola, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba, SP, Brazil.

DZSJRP – Collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil.

NMNH – National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located in the Systematic Entomology Laboratory, USDA, Beltsville, Maryland, USA.

MCZ – Museum of Comparative Zoology, Cambridge, Massachusetts, USA.

QM – Queensland Museum, South Brisbane, Queensland, Australia.

SANC – National Collection of Acari, Plant Protection Research Institute, Department of Agricultural Technical Services, Pretoria, South Africa.

Family **Tenuipalpidae** Berlese, 1913

Genus **Tenuipalpus** Donnadieu, 1876

Type species: *Tenuipalpus palmatus* Donnadieu, 1876 (= *Tenuipalpus caudatus* Dugès, 1834)

Aegyptopalpus Mitrofanov 1973: 1318; type-species: *Tenuipalpus granati* Sayed, 1946, by original designation – Meyer 1979: 3 – **synonymy**.

Deleonipalpus Mitrofanov 1973: 1319; type-species: *Tenuipalpus barticanus* De Leon, 1965, by original designation – Meyer 1979: 5 – **synonymy**.

Gnathopalpus Mitrofanov 1973: 1318; type-species: *Tenuipalpus rosae* Kadzhaja, 1955, by original designation – Meyer 1979: 5 – **synonymy**.

Tuttlepalpus Mitrofanov 1973: 1318; type-species: *Tenuipalpus trisetosus* Baker & Tuttle, 1964, by original designation – Meyer 1979: 3 – **synonymy**.

Diagnosis – *Tenuipalpus sensu stricto*

Female. Prodorsum semicircular, wider than opisthosoma with lateral margins extended beyond margins of opisthosoma; dorsum with one pair of lateral projections anterior to setae sc2 and another pair of lateral projections associated with setae c3; prodorsum with a pair of weakly to strongly developed longitudinal converging ridges running from sc1 to sejugal furrow or near shield posterior margin; prodorsum with three pairs

of setae (v2, sc1, sc2); dorsal opisthosoma with 10 pairs of setae (c1, c3, d1, d3, e1, e3, f2, f3, h1, h2 present; except f2 absent in *T. lalbaghensis* Channabasavanna and Lakkundi); lateral setae sc2, c3, e3, f2, f3 and h1 variable in shape from lanceolate, obovate to ovate; central setae c1, d1, e1 variable in shape from oblanceolate to minute; setae h2 elongate, flagellate; semicircular cuticular crests on opisthosoma present or absent. Palp one to three segmented (palp one segmented only in *T. chiclorum* De Leon). Venter with one to two pairs of setae 3a (3a2 present or absent) and one pair of setae 4a; ventral and genital plates not developed, membranous genital flap present; two to three pairs of pseudanal setae (commonly ps1–2 present; setae ps3 present only in *T. banahawensis* Corpuz-Raros, *T. mahoensis* Collyer and *T. inophylli* Gutierrez and Bolland). Femora, genua and tibiae with setae d inserted in lateral position on tubercles; tarsi I–II bearing one antiaxial solenidion.

Male. Opisthosoma distinctly narrower than that of female; legs and dorsal setae usually similar to those of female; tarsi I–II bearing two solenidia (one paraxial, one antiaxial); tarsus III bearing zero to one solenidia. Setae ps1 modified as an accessory genital stylet.

Immatures. Protonymphs and deutonymphs usually bearing one pair of body projections anterior to setae sc2.

Remarks

This definition is based on the study of *T. caudatus*, *T. erbei* **sp. nov.**, 26 type specimens deposited in USNM, MCZ and DEES (see list below), and descriptions of another 10 known *Tenuipalpus* species. The group sensu stricto shares morphological characters with several other flat mite genera, but are bound by one putative synapomorphy: the presence of a pair of lateral body projections associated with setae c3 (see latter discussion about the shape and size of these projections).

Priscopalpus cherretti De Leon bears a pair of lateral body projections near setae c3 that arise from the ventral region, and are most likely not homologous to those projections present in *T. sensu stricto*, which arise dorsally. Furthermore, several other characteristics can be used to differentiate these two groups (e.g. *Priscopalpus* species have setae *h2* non-flagelliform and empodia claw-like; while *Tenuipalpus sensu stricto* have *h2* flagelliform and empodia pad-like).

The flagelliform setae *h2* are found in several other genera than *Tenuipalpus*, including *Acaricis*, *Colopalpus*, *Cyperacarus*, *Gahniacarus*, *Lisaepalpus*, *Prolixus* and *Tenuilichus*. This character state would define a larger group of flat mite genera if it is considered to be a synapomorphy. The presence of a pair of lateral body projections associated with setae *sc2* present in *Tenuipalpus sensu stricto* is shared with some species of *Tenuipalpus sensu lato* group, as well as some species of *Ultratenuipalpus* (e.g. *U. meekeri* (De Leon), the type species of the genus). Palp segmentation is often reduced in flat mites, but amongst genera allied to *Tenuipalpus*, the palps are two to three segmented in *Tenuipalpus sensu stricto*, one to three segmented in *Tenuipalpus sensu lato*, and three, but more often, four segmented in *Ultratenuipalpus*.

As noted, *Tenuipalpus sensu stricto* and *Ultratenuipalpus* share several character states such as those mentioned above, as well as the semicircular, laterally extended propodosoma that is wider than the opisthosoma (in some *Ultratenuipalpus*), converging ridges running from near *sc1* to the sejugal furrow (in a few *Ultratenuipalpus*), poorly developed genital plates, several large ovate to obovate dorsal and leg setae, and the laterally placed dorsal setae on the legs. However, no *Ultratenuipalpus* have setae *h2* flagelliform or lateral projections associated with setae *c3*.

They also have three pseudanal setae, which is a plesiomorphy found in only three species of *Tenuipalpus*, and these three are all members of the *Tenuipalpus sensu stricto* group.

Tenuipalpus caudatus (Dugès, 1834)

(Figures 1–10)

Tetranychus caudatus Dugès, 1834: 29 – **original designation**.

Tenuipalpus caudatus (Dugès); Pritchard and Baker, 1958: 244 – **new combination**.

Tenuipalpus palmatus Donnadieu, 1876: 112; Pritchard and Baker, 1958: 244 – **synonymy**.

Acarus tini Boisduval, 1867: 91; Pritchard and Baker, 1958: 244 – **synonymy**.

Caligonus calyx Canestrini & Fanzago, 1876: 134; Canestrini, 1890: 457 – **synonymy**.

Redescription

André (2011), Baker (1945), Baker and Pritchard (1953), Ehara and Masaki (2001), McGregor (1949).

Diagnosis

Female. Dorsal opisthosoma with 10 pairs of setae (*c1*, *c3*, *d1*, *d3*, *e1*, *e3*, *f2*, *f3*, *h1*, *h2*; note *f2* present); most dorsal setae narrowly obovate to lanceolate; lateral body projections anterior to setae *sc2* and associated with setae *c3* present; prodorsum with pair of strong longitudinal ridges from *sc1* to sejugal furrow; prodorsum cuticle with broken longitudinal striations and opisthosoma with irregular striations, mostly longitudinal to oblique; opisthosoma with one transverse cuticular crest posterior to setae *d1* and longitudinal crest between setae *e1*; palp two segmented; two pairs of setae *ps*; one pair setae *3a* and *4a*.

Male. Opisthosoma narrower than that of female and without crests; lateral body projections present near setae *sc2* and *c3* similar to that of female; tarsi I–II each with two solenidia (ω' paraxial and ventrolateral; ω'' antiaxial); tarsus III with one solenidion ω' paraxial and ventrolateral.

Protonymph: With small lateral body projection anterior to setae *sc2* (lateral body projection posterior to *c3* absent); setae *tc'* and *tc''* absent on tarsi I–IV.

Material examined

Four females, one male, and one protonymph collected on *Laurus nobilis* L. (Lauraceae), from Portugal, intercepted in Boston, USA, 21 April 1974. These specimens are deposited in USNM, no. 6028. The females were compared with photographs of the neotype presented by André (2011).

Redescription – female

Female ($n = 4$) (Figures 1–5). Body size measurements: length *v2–h1* 275–290; width *sc2–sc2* 180–195, *c3–c3* 215–230, *f2–f2* 110–120.

Dorsum (Figures 1 and 2). Anterior margin of prodorsum with three paired median projections, central pair much longer than two lateral pairs, central pair forming notch. Prodorsum with one pair of lateral projections anterior to and conjunct with setae *sc2* and opisthosoma with one pair of lateral triangular projections associated with setae *c3*. Opisthosoma bearing two cuticular crests: one transverse crest immediately posteriad setae *d1* and another longitudinal crenulate crest running between pair of setae *e1*; prodorsum with pair of strong longitudinal ridges from *sc1* to sejugal furrow; prodorsum with fine longitudinal striations in central region, and opisthosoma with irregular, though mostly longitudinal to oblique, striations. Prodorsal setae *v2* and *sc1* short and weakly barbed; *sc2* narrowly falcate, narrow, acutely tapered; opisthosomal setae *d3* and *e1* minute, similar to prodorsal setae *v2* and *sc1*; opisthosomal setae *c1*, *d1* narrowly obovate; setae *c3* ovate to broadly lanceolate; setae *e1* minute; setae *e3*, *f2*, *f3* and *h1* narrowly lanceolate, almost parallel-sided; setae *h2* flagelliform, barbed basally; central setae *c1*, *d1* with obtuse tips, lateral setae with acute tips. Setal measurements: *v2* 5–6, *sc1* 6–8, *sc2* 79–86,

c1 52–60, *c3* 43–46, *d1* 52–57, *d3* 6–7, *e1* 7–8, *e3* 61–69, *f2* 55–62, *f3* 51–58, *h1* 35–38, *h2* 125–135.

Venter (Figure 3). Ventral integument with central band of weak transverse striae from setae *1a* to *g1–g2*; longitudinal striae between coxa I; band of densely finely pustulate cuticle on lateral margin of idiosoma; setae *1a* elongate and flagelliform, extending beyond base of setae *3a*; setae *3a* short; setae *4a* elongate and flagelliform, extending beyond bases of setae *ag*; setae *ag* and *g1–2* of similar length and longer than setae *ps1–2*. Ventral and genital shields not developed, entire region membranous; genital flap membranous and well defined. Spermatheca not visible.

Gnathosoma (Figure 4). Palps two segmented, basal segment elongate, with one long, seta *d* barbed; distal segment short bearing two eupathidia *ul'–ul''*, 5, 2, respectively. Infracapitular setae *m* present, barbed.

Legs (Figure 5). Setation (from coxae to tarsi): I 2–1–4–3–5–8(1), II 2–1–4–3–5–8(1), III 1–2–2–1–3–5, IV 1–1–1–0–3–5. Setae *d* on femora, genua and tibiae lanceolate (tibial *d* setae narrow) and inserted in lateral position on tubercles; tarsi I–II each with one antiaxial solenidion (ω'') and two eupathidia *pζ'–pζ''*; setae *ft''* on tarsi I–II lanceolate (*ft''* absent on tarsi III–IV); setae *ft'* on tarsi I–IV flagelliform.

Redescription – male

Male (*n* = 1) (Figures 6–9). Body size measurements: length *v2–h1*: 250; width *sc2–sc2*: 170, *c3–c3*: 185, *f2–f2*: 87.

Dorsum (Figures 6 and 7). Most dorsal setae similar in shape to female, except *c1* and *d1* minute (not obovate), similar to setae *v2*, *sc1*, *d3* and *e1*; lateral body projections on prodorsum and opisthosoma similar to female; setae *sc2* inserted anterior to level of eyes. Prodorsum with pair of weak

longitudinal ridges from *sc1* to sejugal furrow. Opisthosoma distinctly narrower than prodorsum. Setal measurements: *v2* 6, *sc1* 8, *sc2* 58, *c1* 7, *c3* 33, *d1* 6, *d3* 8, *e1* 7, *e3* 46, *f2* 43, *f3* 41, *h1* 31, *h2* 130.

Venter (Figure 8). Integument with central band of fine transverse striations and lateral region densely finely pustulate. Setae *1a* flagelliform; setae *3a* short; setae *4a* flagelliform, extending beyond base of setae *g*; setae *g1–2* of similar length and longer than setae *ps 2*. With one aberrant additional seta *g* on right side of anal plate. Setae *ps1* a blunt rod, modified as an accessory genital stylet, inserted posteroventrally on anal valves.

Gnathosoma. Similar to that of female.

Legs (Figure 9). Setation (from coxae to tarsi): I 2–1–4–3–5–8(2), II 2–1–4–3–5–8(2), III 1–2–2–1–3–5(1), IV 1–1–1–0–3–5. Tarsi I–II each with two solenidia (ω' paraxial, inserted ventrolaterally; ω'' antiaxial); other setae, and eupathidia, similar to those of female. Tarsus III with one antiaxial solenidium ω' , inserted ventrolaterally; other setae, and tarsus IV, similar to those of female.

Protonymph (*n* = 1) (Figure 10). Body size measurements: length *v2–h1*: 210; width *sc2–sc2*: 120, *c3–c3*: 140, *f2–f2*: 67.

Dorsum. Anterior margin of prodorsum with small median triangular projections. Prodorsum bearing one pair of small rounded lateral projections anterior to and associated with setae *sc2*; prodorsal ridges not developed; central region of idiosoma covered by series of transverse integumental folds. Lengths of dorsal setae are as follows: *v2* 5, *sc1* 3, *sc2* 45, *c1* 4, *c3* 21, *d1* 3, *d3* 4, *e1* 3, *e3* 31, *f2* 26, *f3* 26, *h1* 17, *h2* 28 (broken).

Venter. Integument covered with transverse striate between setae *1a* and *ag*. Setae *1a*, *1b*, *1c*, *2b*, *3a*, *3b*, *ag*, *ps1* and *ps2* present. Setae *2c*, *4a*, *4b* and *g1–2* absent.

Gnathosoma. Similar to that of female.

Legs. Setation (from coxae to tarsi): I 2–0–3–1–5–6(1), II 1–0–3– 1–5–6(1), III 1–0–2–0–3–3, IV 0–0–1–0–3–3; setae *2c* on coxae II absent; setae *4b* absent; trochanters I–IV bare; setae *l'* on femora I–II absent; setae *l'* and *l''* on genua I–II absent; seta *d* on genua III absent (genua III–IV nude); tectal pair of setae *tc'–tc''* on tarsi I–IV absent.

***Tenuipalpus erbei* sp. nov.**, Kane, Castro & Ochoa

(Figures 11–27)

Diagnosis

Female. Dorsal opisthosoma with 10 pairs of setae (*c1*, *c3*, *d1*, *d3*, *e1*, *e3*, *f2*, *f3*, *h1*, *h2*; note *f2* present); most of dorsal setae narrowly lanceolate; small rounded lateral body projections anterior to setae *sc2* and longer obtuse lateral projection associated with setae *c3*; prodorsum with pair of strong, converging ridges from *sc1* to sejugal furrow; prodorsum and opisthosoma with transverse to oblique striations; dorsal opisthosoma bearing two large cuticular crests, one transverse crest between setae *c1* and *d1*, and another longitudinal crest between setae *d1* and *e1*; with raised longitudinal ridge or thickening along entire idiosomal midline; palps two segmented; two pairs of *ps* setae; one pair *3a* and *4a* setae; setae *ag* and *g1–2* barbed.

Male. Opisthosoma narrower than that of female and without crests, but with raised longitudinal ridge or thickening along entire idiosomal midline; lateral body projections similar to that of female; tarsi I–II each with two

solenidia (ω' paraxial and ventrolateral; ω'' antiaxial). *Deutonymph*: With small lateral body projections anterior to setae *sc*₂; leg chaetotaxy similar to that of female, except trochanter IV without seta *v'* and tarsus IV without setae *tc'* and *tc''*.

Material examined

Holotype: female collected on *Piper glabratum* Kunth (Piperaceae), from La Selva, Heredia, Sarapiquí, Costa Rica, 10°26'0"N, 84°1'0"W, 7 September 2005, coll. H. Aguilar, deposited in NMNH, located at the SEL-USDA, Beltsville, Maryland, USA. Paratypes: two females and one male, same slide as holotype; nine females and three males, same data as holotype; one female collected on Myrsinaceae, from Heredia, Sarapiquí, Costa Rica, 17 May 1994, coll. C. Vargas; six females and one deutonymph, collected on *P. multiplinerium* C. DC. (Piperaceae), from La Selva, Heredia, Puerto Viajo, Costa Rica, 6 November 1992, coll. C. Vargas (NMNH); one female, collected on *P. glabratum* Kunth (Piperaceae), 16 June 2005, coll. R. Ochoa, deposited in DZSJRP, located at the UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRP n. 9549–9550); and one deutonymph collected on *P. glabratum* Kunth (Piperaceae), from La Selva, Heredia, Sarapiquí, Costa Rica, 16 March 2002, coll. E. Kane, deposited in holdings of the Electron and Confocal Microscopy Unit, ARSUSDA, BARC, Beltsville, Maryland, USA (ECMU) (Imaged 8 August 2002: Image number #1381).

Description – female

Female (*n* = 20) (Figures 11–18). Body size measurements: length *v*₂–*h*₁ 245 (240–260); width *sc*₂–*sc*₂ 160 (150–165), *c*₃–*c*₃ 190 (180–195), *f*₂–*f*₂ 90 (85–95).

Dorsum (Figures 11–14). Anterior margin of prodorsum produced centrally into paired triangular projections forming notch between them. Prodorsum

with one pair of small rounded lateral projections anterior to setae *sc2* and another pair of obtuse lateral projections associated with setae *c3*; prodorsum with pair of strong, converging ridges from *sc1* to sejugal furrow. Opisthosoma with two large cuticular crests, one transverse immediately posterior to setae *c1* and another longitudinal between setae *d1* and *e1* (Figures 12B and 13A). On slides, transverse crest tends to fold posteriorly and cover setae *d1* and longitudinal crest folds over left or right onto opisthosoma. Prodorsal setae *v2* minute, and *sc1* short, obovate or spatulate; *sc2* narrowly falcate, elongate and acutely tapered (Figure 13B). Opisthosomal setae *d1*, *d3* and *e1* minute, similar to prodorsal setae *v2*; other opisthosomal setae narrowly lanceolate, except *c3* broadly lanceolate to oblanceolate and *h2* flagelliform. Setal measurements: *v2* 8 (5–8), *sc1* 15 (13–17), *sc2* 62 (57–67), *c1* 39 (35–41), *c3* 30 (28–32), *d1* 14 (12–16), *d3* 10 (10–13), *e1* 7 (6–9), *e3* 40 (35–42), *f2* 40 (35–42), *f3* 33 (29–33), *h1* 20 (19–21), *h2* 140 (125–150).

Venter (Figure 15). Integument with central band of weak broken transverse striations, and lateral margin of idiosoma with broad band of pustulate integument. Setae *1a* flagelliform, extending beyond base of setae *3a*; setae *3a* short; setae *4a* flagelliform, extending beyond bases of setae *g*; setae *ag* and *g1–2* of similar length and longer than setae *ps1–2*. Setae *1c*, *2c*, *3b*, *4b*, *ag* and *g1–2* barbed. Ventral and genital plates not developed, entire region membranous; membranous genital flap present, well defined.

Gnathosoma (Figure 16). Palps two segmented, basal segment elongate and with setae *d* barbed; distal segment short bearing two eupathidia *ul'–ul''*, 6, 2, respectively; infracapitular setae *m* present, barbed.

Legs (Figures 17 and 18A). Setation (from coxae to tarsi): I 2–1–4–3–5–8(1), II 2–1–4–3–5–8(1), III 1–2–2–1–3–5, IV 1–1–1–0–3–5. Femora,

genua and tibiae with setae *d* inserted in lateral position on tubercles; setae *d* on femora and genua broadly lanceolate; setae *d* on tibiae thick, acutely tapered distally. Tarsi I–II each with one antiaxial solenidion ω'' and two eupathidia $p\zeta'-p\zeta''$. Setae *ft'* on tarsi I–IV flagelliform, and setae *ft''* on tarsi I–II lanceolate (absent on tarsi III–IV).

Egg (Figure 18B). Length 80–90. Elongate, with three longitudinal broad bands, intercalated with five to six longitudinal fine ridges.

Description – male

Male ($n = 4$) (Figures 19–23). Body size measurements: length $v2-h1$ 190–195; width $sc2-sc2$ 130–135, $c3-c3$ 130–135, $f2-f2$ 50–60.

Dorsum (Figures 19, 20A and 21). Anterior margin of prodorsum with pair of narrow triangular projections forming central notch. Opisthosoma distinctly narrower than prodorsum. Prodorsum with one pair of small lateral projections anterior to setae $sc2$ setae and another pair associated with setae $c3$; prodorsum with pair of weakly converging ridges from $sc1$ to near posterior margin of shield. Opisthosoma without cuticular crests, but with raised longitudinal ridge or thickening along entire midline. Prodorsal and opisthosomal setae similar to those of female, except most setae much smaller. Setal measurements: $v2$ 5–6, $sc1$ 10, $sc2$ 40–46, $c1$ 16–17, $c3$ 18–20, $d1$ 5–6, $d3$ 8–9, $e1$ 5–6, $e3$ 12–13, $f2$ 14–17, $f3$ 15–16, $h1$ 13–15, $h2$ 120–130.

Venter (Figure 22). Integument with central band of weak transverse striae; lateral margin prodorsum with broad band of finely pustulate integument; broken fine transverse striae between setae *ag* and $g1-2$; setae *1a* flagelliform; setae *3a* short; setae *4a* flagelliform and extend beyond bases of setae $g1-2$; setae *ag*, $g1-2$ and *ps2* of similar length and longer than setae *ps1*. Setae *ps1* short blunt rod-like seta, modified as

accessory genital stylet and inserted posteroventrally to genito-anal valves.

Gnathosoma. Similar to that of female.

Legs (Figures 20B and 23). Setation (from coxae to tarsi): I 2–1–4–3–5–8(2), II 2–1–4–3–5–8(2), III 1–2–2–1–3–5, IV 1–1–1–0–3–5. Tarsi I–II each with two solenidia (ω' paraxial, inserted ventrolaterally; ω'' antiaxial) (Figure 20B); setae *d* on femora and genua narrower than those of female; other setae of similar shape and location to those of female.

Deutonymph ($n = 1$) (Figures 24 and 25). Body size measurements: length $v2-h1$ 240; width $sc2-sc2$ 135, $c3-c3$ 160, $f2-f2$ 65.

Dorsum (Figures 24 and 25). Anterior margin of prodorsum with two short triangular projections forming short central notch. Prodorsum with small rounded lateral projections anterior to setae *sc2* (lateral body projection associated with setae *c3* absent); prodorsum with pair of weakly converging ridges from *sc1* to posterior margin of shield. Dorsal idiosoma with raised longitudinal ridge or thickening along entire midline; from *sc2* to *c3* and *c1* to *d1* covered with series of transverse integumental folds. Prodorsal setae *v2* minute, *sc1* short, oblanceolate; *sc2* narrowly falcate (almost linear), acutely tapered distally; opisthosomal setae *c1*, *c3* short, lanceolate, finely barbed; setae *d1*, *d3* and *e1* minute and finely barbed; other opisthosomal setae narrowly lanceolate, acutely tapered, except *h2* flagelliform. Setal measurements: *v2* 4, *sc1* 12, *sc2* 45, *c1* 14, *c3* 21, *d1* 5, *d3* 5, *e1* 4, *e3* 27, *f2* 29, *f3* 23, *h1* 11, *h2* 55.

Venter. Integument covered with transverse striae between setae *1a* and *ag*; setae *1a* and *4a* flagelliform; setae *3a* short; setae *ag* and *g1* of similar length and longer than setae *ps1–2*; setae *g2* absent.

Gnathosoma. Similar to that of female.

Legs. Setation (from coxae to tarsi): similar to female, except seta *v'* on trochanter IV absent; setae *tc'* and *tc''* absent on tarsus IV.

Protonymph (Figure 26). Anterior margin of prodorsum with two short triangular projections forming short central notch. Prodorsum appears to have pair weak longitudinal ridges from *sc1* to posterior margin of shield. Dorsal idiosoma with raised longitudinal ridge or thickening along entire midline; with series of transverse integumental folds from setae *sc2*–*c3* and *c1*–*d1*. Dorsal setae similar to those of deutonymph, except narrower. Setal measurements and chaetotaxy of legs not taken as specimen was observed under LT-SEM only.

Larva (Figure 27A and B). Dorsum without projections on anterior margin or associated with setae *sc2* and *c3*. Ridges on prodorsum not developed. Integument of central region of prodorsum, posterior region of opisthosoma and legs covered with fine pustulate coating. Setal measurements and chaetotaxy of legs not taken as the specimens were observed under LT-SEM only. The larva was observed at two stages of development: after leaving the egg but prior to feeding, where the integument is concertinaed into many folds (Figure 27A), and after feeding, where the mite has expanded and the folds are not as strong (Figure 27B). These observations indicate that the folds of the integument in immature stages allow an increase in body size during feeding. In addition, the presence of a prodorsal shield and a pygidial shield are indicated by regions of thickened unfolded cuticle. These shields are also indicated in the protonymph and deutonymph.

Etymology

The specific name is in honour to Eric F. Erbe, retired USDA-ARS electron microscopist extraordinaire, who perfected the use of low-temperature scanning electron microscopy for the study of mites.

Remarks

Tenuipalpus erbei **sp. nov.** is morphologically similar to *T. caudatus*, but these two species can be differentiated by the pattern of the dorsal striation of the prodorsum, which is transverse to oblique in *T. erbei* and longitudinal in *T. caudatus*; the shape of several dorsal setae is lanceolate in *T. erbei* and obovate in *T. caudatus*; and the morphology of the dorsal opisthosomal crests present in the females is large in *T. erbei* and reduced in *T. caudatus*. *Tenuipalpus erbei* bears a transverse crest anterior to setae *d1*, while that in *T. caudatus* the transverse crest is posterior to setae *d1*. The male of *T. erbei* **sp. nov.** does not have solenidion on tarsus III, while the male of *T. caudatus* has one antiaxial solenidion, ω' , on tarsus III.

Discussion

Groups and subgroups of species

The presence of many species within a single genus makes it difficult to compare the potentially new species with all previously known taxa, and this in turn increases the chance of creating synonyms (Seeman and Beard 2011). The division of *Tenuipalpus* into numerous smaller species groups is a practical means to make a large genus more manageable, and in *Tenuipalpus* these are based on the presence of setae *f2* and the number of setae *3a* and *4a* (Meyer 1979, 1993; Baker and Tuttle 1987). However, by creating a new group based on a different putative synapomorphy, we may cast doubt on the ability of these previous two features to form natural groups.

First, the loss of seta *f2* may still prove informative within *Tenuipalpus*, as it is lost in only one species of *Tenuipalpus* sensu stricto,

i.e. *T. lalbaghensis*. Nevertheless, this seta has been lost independently on several occasions within the Tenuipalpidae: for example, it is sometimes absent within *Brevipalpus*, *Colopalpus* and *Ultratenuipalpus*, and Beard et al. (2014) presented phylogenetic evidence that this seta has been lost twice within the Tegopalpinae. Therefore, some homoplasy is expected elsewhere in the Tenuipalpidae.

Second, the duplication of setae 3a and 4a is peculiar to *Tenuipalpus* and some of its allied genera, yet this unusual character state is considered homoplasious under Meyer (1993) because it is present in the *caudatus* and *proteae* groups (i.e. species with and without setae f2). Our *Tenuipalpus* sensu stricto group also treats the duplication of setae 3a as homoplasious. For example, the *bakeri* subgroup comprises the original four members of this group – *T. bakeri* McGregor, *T. chiclorum*, *T. coccolobicolus* De Leon and *T. rhysus* Baker & Pritchard – which we consider members of *Tenuipalpus* sensu stricto. However, the *bakeri* subgroup also includes morphologically dissimilar species that are not part of *Tenuipalpus* sensu stricto, such as the three African species placed into the group by Meyer (1993), and several others such as *T. daneshvari* Khosrowshahi & Arbabi, and *T. orchidofilo* Moraes & Freire.

Regarding setae 4a, the duplication of this seta was also considered homoplasious under Meyer's (1993) species groupings. We note that this seta is not duplicated within *Tenuipalpus* sensu stricto, and may therefore be a synapomorphy. However, the duplication or not of setae 4a is present in several species of *T.* sensu lato, and it is always duplicated in the sedge-associated genera *Acaricis*, *Cyperacarus*, *Gahniacarus* and *Prolixus*, suggesting that the duplication or not of these setae appear several times in different groups, and therefore can be considered as homoplasy.

Body projections

The lateral body projections anterior to and conjunct with setae *sc2* and those associated with setae *c3* have been mentioned and illustrated previously in past descriptions of *Tenuipalpus* species (e.g. Lawrence 1943; McGregor 1949; De Leon 1956; Collyer 1964; Ehara and Masaki 2001). These projections have been referred to as a “broad sub-quadrate lateral body-projection” (De Leon 1956, p. 59), a “conical projection of body” (Collyer 1964, p. 438), and a “distinct expansion anterior to coxa III” (Ehara and Masaki 2001, p. 256). In addition, these projections have been used as characters in keys for separation of species (e.g. Collyer 1973 (couplet 20), Meyer 1993 (couplet 6)).

The pair of lateral body projections anterior to setae *sc2* vary from prominent (as in *T. caudatus*) to more reduced (as in *T. coccolobicolus*), and the shape and development of these projections also varies in the immatures. This pair of body projections is shared with some species of *Tenuipalpus* sensu lato (e.g. *T. dimensus* Chaudhri, *T. senecionis* Collyer, *T. stefani* Meyer) and *Ultratenuipalpus* (e.g. *U. avarua* Xu, Fan & Zhang, *U. coprosmae* Collyer, *U. rubi* Collyer), and in conjunction with other shared characters (e.g. prodorsum wider than opisthosoma in *T.* sensu stricto and *Ultratenuipalpus*, and in most of the species of *Tenuipalpus* sensu lato) indicates that these three groups are closely related.

There is also variation in the position and shape of the lateral body projections associated with setae *c3*. Setae *c3* may be anterior to the projection as in *T. caudatus* and *T. erbei*, or inserted on the projection itself, as in *T. coccolobicolus* and *T. coccolobicoloides* De Leon. Due to this variation, we prefer to refer to these projections as being associated with setae *c3*. Their shape can be broad (as in *T. micheli*) to narrow (as in *T. podocarpi*), but they are always large and angulate, as opposed to small bulges found in some other species of *Tenuipalpus* sensu lato, such as *T. orilloi* Rimando, *T. apichai* Castro & Feres, and *T. couroupita* De Leon, and in some species of *Ultratenuipalpus*, such as *U. coprosmae*.

These lateral body projections were observed in some immature specimens of two species described from Africa, *T. micheli* and *T. podocarp*i, whereas they are absent on the immatures of most other species in the group.

Opisthosomal crests

The cuticular crests on the opisthosoma are present in five species of *T.* sensu stricto: *T. caudatus*, *T. boyani* De Leon, *T. erbei*, *T. eugeniae* De Leon and *T. sandyi* De Leon. They may be reduced as in *T. caudatus* (Figures 1 and 2) or prominent as in *T. erbei* (Figures 11, 12 and 14). *Tenuipalpus caudatus* and *T. erbei* have two crests, one transverse and another longitudinal, while *Tenuipalpus boyani* and *T. eugeniae* have only a single longitudinal crest on the opisthosoma positioned between the pair of setae *e1*. *Tenuipalpus sandyi* has a single transverse crest immediately posterior to setae *d1*, which is an autapomorphy.

De Leon (1965a) failed to illustrate or describe the longitudinal crest present on the opisthosoma of *T. boyani* in the original description, and only illustrated the transverse crest of *T. sandyi* without mentioning it in the description. In the description of *T. eugeniae*, De Leon (1965a, p. 521) did, however, illustrate and describe the longitudinal crest as a non-bilateral “semioval area extending anteriorly and posteriorly of dorsocentral hysterosomal seta 3”, and that the male hysterosoma is “without semioval area”. The reference to the crest as an asymmetrical “semioval area” indicates the difficulty in interpreting this structure when it is folded over on a slide-mounted specimen, without the use of LT-SEM images.

The presence of the crests on the opisthosoma in these species may form a subgroup in *Tenuipalpus* sensu stricto, but the position of the crests is different between species and further consideration is necessary to confirm if they are actually homologous.

Low-temperature scanning electron microscopy

LT-SEM techniques provide a means to more accurately visualize the in vivo morphology of these mites and uncover delicate structures that are destroyed or seriously altered as a result of traditional SEM preparation methods, and of the clearing and mounting procedures associated with light microscopy. Using this technology to survey a broader selection of *Tenuipalpus* sensu lato species will prove fruitful in establishing a more natural classification. In addition, the demonstrated ability to use remote-sampling techniques to cryopreserve these delicate, soft-bodied arthropods in a field setting for later examination in the laboratory, without intermediary storage in ethanol or other preservatives, offers additional opportunities to facilitate the accurate documentation of the morphology of these organisms, while providing insight into the mite host associations (Beard et al. 2012b). We see exciting opportunities for applying such an approach to this and other groups of mites.

List of *Tenuipalpus* sensu stricto

- 1.* *Tenuipalpus anacardii* De Leon, 1965a: 67; about 4.8 km S Bartica, Potaro Road, Guyana (= British Guiana), ex *Anacardium* sp. (probably officinale) (Anacardiaceae) – Type depository: NMNH.
- 2.** *Tenuipalpus arbuti* Mitrofanov & Sharonov, 1983: 948; Ukraine, ex *Arbutus unedo* L. (Ericaceae) – Type depository: Unknown.
- 3.* *Tenuipalpus argus* Baker & Pritchard, 1953: 328; Pomona Park, Florida, USA, ex *Yucca gloriosa* L. (Agavaceae) – Type depository: USNM.
- 4.* *Tenuipalpus bakeri* McGregor, 1949: 7; Cocoa Beach, Florida, USA, ex *Magnolia* sp. (Magnoliaceae), oak, *Sobralia macrantha* Lindl. (Orchidaceae) and *Yucca gloriosa* L. (Agavaceae) – Type depository: USNM.
- 5.* *Tenuipalpus banahawensis* Corpuz-Raros, 1978: 221; Mount Banahaw, Sariaya, Quezon, Philippines, ex (Myrsinaceae) – Type depository: USNM.

- 6.*** *Tenuipalpus boyani* De Leon, 1965a: 67; Bartica Nature Reserve, Guyana (= British Guiana), ex *Pouteria* sp. (Sapotaceae) – Type depository: MCZ.
- 7.*** *Tenuipalpus chamaedorea* Salas & Ochoa, 1985: 171; at Las Nubes de Coronado, San José, Costa Rica, ex *Chamaedorea* sp. (Arecaceae) – Type depository: USNM.
- 8.** *Tenuipalpus cheladzeae* Gomelauri, 1960: 77; Ukraine, ex *Taxus baccata* L. (Taxaceae) – Type depository: Unknown.
- 9.*** *Tenuipalpus chiclorum* De Leon, 1957: 91; Tuxtla Gutierrez, Chiapas, Mexico, ex *Achras sapota* L. (Sapotaceae) – Type depository: MCZ.
- 10.*** *Tenuipalpus coccolobicoloides* De Leon, 1965b: 519; Bath Fountain, Saint Thomas Parish, Jamaica, ex *Psychotria grandis* Sw. (Rubiaceae) – Type depository: MCZ.
- 11.*** *Tenuipalpus coccolobicolus* De Leon, 1956: 58; Coral Gables, Florida, USA, ex *Coccoloba laurifolia* Jacq. (Polygonaceae) – Type depository: USNM.
- 12.*** *Tenuipalpus coyacus* De Leon, 1957: 83; San Blas, Nayarit, Mexico, ex oil palm (Arecaceae) – Type depository: MCZ.
- 13.** *Tenuipalpus cupressoides* Meyer & Gerson, 1980: 68; Kabri, Israel, ex *Cupressus sempervirens* L. (Cupressaceae) – Type depository: Collection of the Department of Entomology, Faculty of Agriculture, Rehovot, Israel.
- 14.*** *Tenuipalpus dasples* Baker & Pritchard, 1953: 324; Oviedo, Florida, USA, ex *Sabal megacarpa* (Chapm.) Small (Arecaceae) – Type depository: USNM.
- 15.*** *Tenuipalpus eugeniae* De Leon, 1965b: 521; Green Hills, Portland, Jamaica, ex *Eugenia biflora* (L.) DC. (Myrtaceae) – Type depository: MCZ.
- 16.*** *Tenuipalpus hastaligni* De Leon, 1956: 57; Coral Gables, Florida, USA, ex *Ocotea coriacea* Britton (Lauraceae) – Type depository: USNM.
- 17.** *Tenuipalpus imias* Cao, 1982: 14; Imias, Guantanamo, Cuba, ex *Hippomane mancinella* L. (Euphorbiaceae) – Type depository: Col·lecció·n

de la Estación Biologica Docente (EBD) de la Facultad de Biologia, Universidad de La Habana.

18. *Tenuipalpus inophylli* Gutierrez & Bolland, 1981: 26; NE Koumac, New Caledonia, ex *Codiaeum inophyllum* Mull. Arg. (Euphorbiaceae) – Type depository: Museum National d’Histoire Naturelle de Paris, France.

19.*** *Tenuipalpus lalbaghensis* Channabasavanna & Lakkundi, 1977: 19; Bangalore, Lalbagh, Karnataka, India, ex *Artocarpus integrifolia* L. (Moraceae) – Type Depository: Zoological Survey of India and Department of Entomology, University of Agricultural Sciences, Bangalore, India.

20.* *Tenuipalpus latiseta* Aranda, in: Flechtmann, 1976: 61; Corumbatai, São Paulo, Brazil, ex (Celastraceae) – Type depository: DEES.

21.* *Tenuipalpus lucumae* De Leon, 1957: 84; Tuxtla Gutierrez, Chiapas, Mexico, ex *Lucuma salicifolia* H.B. and K. (Sapotaceae) – Type depository: MCZ.

22. *Tenuipalpus mahoensis* Collyer, 1964: 438; Waitakeres, near Auckland, North Island, New Zealand, ex *Melicytus ramiflorus* J. R. Forst. & G. Forst. (Violaceae) – Type Depository: BMNH.

23. *Tenuipalpus micheli* Lawrence, 1940: 111; Durban, Umhloti Beach, Natal, South Africa, ex *Chaetachme aristata* (Ulmaceae) – Type depository: SANC.

24.* *Tenuipalpus masoni* De Leon, 1965b: Palisadoes Park, Kingston, Jamaica, ex *Tabebuia* sp. (Bignoniaceae) – Type depository: USNM.

25.* *Tenuipalpus pigrus* Pritchard & Baker, 1952: 43; Mount Diablo, California, USA, ex *Umbellularia californica* (Hook. & Arn.) Nutt. (Lauraceae) – Type depository: USNM.

26. *Tenuipalpus podocarp*i Lawrence, 1943: 40; Cathkin Peak, Drakensberg Mountains, South Africa, ex *Podocarpus falcatus* (Thunb.) R.Br. ex Mirb. (Podocarpaceae) – Type depository: SANC.

27.* *Tenuipalpus proctori* De Leon, 1965b: 521; Ipswich, Saint Elizabeth, Jamaica, ex *Hohenbergia proctori* L.B. Sm. (Bromeliaceae) – Type depository: MCZ.

- 28.** *Tenuipalpus raphiae* Meyer & Bolland, 1984: 219; Bamenda, Cameroon, ex *Raphia* sp. (Arecaceae) – Type depository: SANC.
- 29.*** *Tenuipalpus rhagicus* Pritchard & Baker, 1952: 42; Crescent Lake, California, USA, ex *Vaccinium ovatum* Pursh (Ericaceae) – Type depository: USNM.
- 30.*** *Tenuipalpus rhysus* Baker & Pritchard, 1953: 330; Glen Saint Mary, Florida, USA, ex *Cyrilla racemiflora* L. (Cyrillaceae) – Type depository: USNM.
- 31.*** *Tenuipalpus sandyi* De Leon, 1965a: 69; near Bartica Nature Reserve, Guyana (= British Guiana), ex *Humiria balsamifera* Mart. var. *floribunda* (Mart.) Cuatrec. (Humiriaceae) – Type depository: MCZ.
- 32.*** *Tenuipalpus tuttlei* Ochoa, 1988: 225; replacement to *Tenuipalpus chamaedoreae* (Baker & Tuttle, 1987), name preoccupied by *Tenuipalpus chamaedorea* (Salas & Ochoa, 1985). (Article 58.7 4th Edition International Code of Zoological Nomenclature) 6: 125; Mexico, intercepted at New York City, USA, ex *Chamaedorea* sp. (Arecaceae) – Type depository: USNM.
- 33.*** *Tenuipalpus unonopsonis* De Leon, 1965a: 66; Bartica Nature Reserve, Guyana (= British Guiana), ex *Unonopsis guatteriioides* (DC.) R.E. Fr. (Annonaceae) – Type depository: MCZ.
- 34.*** *Tenuipalpus vexus* De Leon, 1965b: 520. Santo Domingo, Dominican Republic, ex *Tabebuia* sp. (Bignoniaceae) – Type depository: MCZ.
- 35.*** *Tenuipalpus victoriae* De Leon, 1967: 43; Cleaver Reserve, Arima, Trinidad and Tobago, ex an unidentified shrub or young tree – Type depository: MCZ.
- 36.*** *Tenuipalpus xylosmae* De Leon, 1965b: 519; Bath Fountain, Saint Thomas, Jamaica, ex *Xylosma* G. Forst. aff. *Nitida* (Salicaceae) – Type depository: MCZ.

* Types studied (26).

** Likely a junior synonym of *T. caudatus*.

*** The unique species with five pairs of dorsolateral setae.

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Note

1. The cover of Annales de la Societe Linneene de Lyon, volume 22, says “Annee 1875”, but the publisher’s imprint says 1876, so 1876 is the date of publication of *palmatus*. The original combination is *T. palmatus* Donnadieu, 1876 (B. Halliday pers. comm.).

References

- André HM. 2011. Dugès` *caudatus* is a Tenuipalpidae and not a Tydeidae (Acari). *Acarologia* 51:69–85.
- Baker EW. 1945. Mites of the genus *Tenuipalpus* (Acarina: Trichadenidae). *Proceedings of the Entomological Society of Washington* 47:33–38.
- Baker EW, Pritchard AE. 1953. A review of the false spider mite genus *Tenuipalpus* Donnadieu (Acarina: Phytoptipalpidae). *Annals of the Entomological Society of America* 46:317–336.
- Baker EW, Tuttle DM. 1987. The false spider mites of Mexico (Tenuipalpidae: Acari). United States Department of Agriculture, Agricultural Research Service, Technical Bulletin 1706:1–236.
- Beard JJ, Fan QH, Walter DE. 2005. A new genus and two new species of Tenuipalpidae (Prostigmata: Tetranychoida) from an Australian sedge. *Acarologia* 45:161–181.
- Beard JJ, Gerson U. 2009. A new flat mite genus, *Acaricis* (Prostigmata: Tenuipalpidae), from Australian sedges (Cyperaceae). *Zootaxa* 2073:31–44.
- Beard JJ, Ochoa R. 2011. New flat mite genera (Acari: Trombidiformes: Tenuipalpidae) associated with Australian sedges (Cyperaceae). *Zootaxa* 2941:1–37.

- Beard JJ, Ochoa R, Bauchan GR, Trice MD, Redford AJ, Walters TW, Mitter C. 2012a. Flat mites of the world. 2nd ed. Fort Collins, CO: Identification Technology Program, CPHST, PPQ, APHIS, USDA [cited 2015 Jul 26]. Available from: www.idtools.org/id/mites/flatmites/index.php
- Beard JJ, Ochoa R, Bauchan GR, Welbourn WC, Pooley C, Dowling APG. 2012b. External mouthpart morphology in the Tenuipalpidae (Tetranychoidae): *Raoiella* a case study. *Experimental and Applied Acarology* 57:227–255.
- Beard JJ, Seeman OD, Bauchan GR. 2014. Tenuipalpidae (Acari: Trombidiformes) from Casuarinaceae (Fagales). *Zootaxa* 3778:1–157.
- Canestrini G. 1890. Prospetto dell'Acarofauna Italiana, Famiglie: Tetranychini. Atti delle adunanze dell' I.R. Istituto Veneto di Scienze, Lettere ed Arti, Italy. Serie 6/7:491–537.
- Cao J. 1982. Una nueva especie del género *Tenuipalpus* (Acarina: Tenuipalpidae) sobre *Hippomane mancinella*. *Agrotecnia de Cuba, La Habana* 14:13–20.
- Castro EB, Ochoa R, Feres RJF, Beard JJ, Bauchan GR. 2015a. Reinstatement of the genus *Colopalpus* Pritchard and Baker (1958) and re-description of *Colopalpus matthyssei* Pritchard and Baker (1958), the type species of the genus (Acari, Tenuipalpidae). *International Journal of Acarology* 41:1–19.
- Castro EB, Ramos FEM, Feres RJF, Ochoa R. 2015b. A new species of *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Brazil, with ontogeny of chaetotaxy. *Systematic and Applied Acarology* 20:339–356.
- Channabasavanna GP, Lakkundi NH. 1977. *Tenuipalpus lalbaghensis* (Acarina: Tenuipalpidae), a new species from Southern India. *Indian Journal of Acarology* 1:19–22.

- Collyer E. 1964. New species of *Tenuipalpus* (Acarina: Tenuipalpidae) from New Zealand. *Acarologia* 6:432–440.
- Collyer E. 1973. New species of the genus *Tenuipalpus* (Acari: Tenuipalpidae) from New Zealand, with a key to the world fauna. *New Zealand Journal of Science* 16:915–955.
- Corpuz-Raros LA. 1978. New Philippine Tetranychoida (Acarina). *Kalikasan, Philippines Journal of Biology* 7:211–230.
- De Leon D. 1956. Six new false spider mites from southern Florida (Acarina: Tenuipalpidae). *The Florida Entomologist* 39:55–60.
- De Leon D. 1957. The genus *Tenuipalpus* in Mexico (Acarina: Tenuipalpidae). *The Florida Entomologist* 40:81–93.
- De Leon D. 1961. New false spider mites with notes on some previously described species (Acarina: Tenuipalpidae). *The Florida Entomologist* 44:167–179.
- De Leon D. 1965a. New Tenuipalpidae (false spider mites) from British Guiana with notes on four described species. *The Florida Entomologist* 48:65–75.
- De Leon D. 1965b. False spider mites of Jamaica and the Dominican Republic (Acarina: Tenuipalpidae). *Annals of the Entomological Society of America* 58:517–523.
- De Leon D. 1967. Some mites of the Caribbean Area. Lawrence (Kansas): Allen Press, Inc.; p. 1–46.
- Donnadieu AL. 1876. Recherches pour servir à l'histoire des Tétranyques. Soc. Linn. Lyon, Lyon. 135 pp., pls. 1–12.
- Dugès A. 1834. Recherches pour servir à l'ordre des Acariens en general et la famille des Trombidies en particulier. *Annales des Sciences Naturelles Paris* (ser. 2) 1:5–46.
- Ehara S, Masaki M. 2001. Three species of exotic mites (Acari: Tetranychoida) recently intercepted at Japanese plant quarantine. *Applied Entomology Zoology* 36:251–257.

- Erbe EF, Rango A, Foster J, Josberger EG, Pooley C, Wergin WP. 2003. Collecting, shipping, storing, and imaging snow crystals and ice grains with low-temperature scanning electron microscopy. *Microscopy Research and Technique* 62:19–32.
- Flechtmann CHW. 1976. Preliminary report on the false spider mites (Acar: tenuipalpidae) from Brazil and Paraguay. *Proceedings of the Entomological Society of Washington* 78:58–64.
- Gomelaurov LA. 1960. New species in the genus *Tenuipalpus* from the Georgia, Gruzia, SSR (Acarina: Tenuipalpidae). *Reports of the Academy of Science of the Georgian SSR. Soobshcheniya Akademii Nauk Gruzinskoi* 24:77–79.
- González RH. 1968. Acaros plantícolas del género *Tenuipalpus* en Chile (Acarina: Tenuipalpidae). *Revista Chilena de Entomología* 6:37–46.
- Gutierrez J, Bolland HR. 1981. Un acarien Tenuipalpidae de Nouvelle-Calédonie *Tenuipalpus inophylli* n. sp.: description et premières données biologiques. *Entomologische Berichten* 41:26–30.
- Lawrence RF. 1940. Three new parasitic mites (Acarina) from South Africa. *Journal of the Entomological Society of Southern Africa* 3:109–119.
- Lawrence RF. 1943. New South African mites of the genus *Tenuipalpus* Donnadieu (Tetranychidae). *Transactions of the Royal Society of South Africa* 30:35–48.
- Lindquist EE. 1985. External anatomy. In: Helle W, Sabelis MW, editors. *Spider mites: their biology, natural enemies and control*. Amsterdam: Elsevier Science Publishers. B.V.; p. 3–28.
- Manson DC. 1963. Seven new species of false spider mites (Tenuipalpidae: Acarina). *Acarologia* 5:213–224.
- McGregor EA. 1949. Nearctic mites of the family Pseudoleptidae. *Memoir of the Southern California Academy of Sciences* 3:1–45.

- Mesa NC, Ochoa R, Welbourn WC, Evans GA, Moraes GJde. 2009. A catalog of the Tenuipalpidae (Acari) of the World with a key to genera. *Zootaxa* 2098:1–185.
- Meyer MKP. 1979. The Tenuipalpidae (Acari) of Africa with keys to the world fauna. *Entomology Memoir*, Department of Agriculture Republic South Africa, Pretoria 50:1–133.
- Meyer MKP. 1993. A revision of the genus *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) in the Afrotropical region. *Entomology Memoir of the Department of Agriculture Republic South Africa* 88:1–84.
- Meyer MKP, Bolland HR. 1984. Tetranychoid mites (Acari: Prostigmata) from Cameroun and a survey of their chromosome complements. *Phytophylactica* 16:209–220.
- Meyer MKP, Gerson U. 1980. Some false spider mites (Prostigmata: Tenuipalpidae) from Israel. *Israel Journal of Entomology* 15:67–81.
- Mitrofanov VI. 1973. Revision of the system of phytophagous mites of the subfamily Tenuipalpinae s. str. (Trombidiformes, Tenuipalpidae). *Zoologicheskii Zhurnal* 52:1315–1320.
- Mitrofanov VI, Sharonov AA. 1983. A contribution to the fauna of plant-feeding mites (Acariformes: Tetranychidae) of Crimea. *Zoologicheskii Zhurnal* 62:947–950.
- Mitrofanov VI, Strunkova ZI. 1978. A new genus and species of the family Tenuipalpidae (Trombidiformes). *Zoologicheskii Zhurnal* 52:1095–1099.
- Mitrofanov VI, Strunkova ZI. 1979. A key to false spider mites. *Operdelitl' Kleshchei-ploskotelok*, USSR 148:1–148.
- Ochoa R. 1988. Homonymy in Tenuipalpidae (Acarina). *International Journal of Acarology* 14:225.
- Pritchard AE, Baker EW. 1952. The false spider mites of California (Acarina: Phytoptipalpidae). *University of California Publications in Entomology* 9:1–94.

- Pritchard AE, Baker EW. 1958. The false spider mites (Acarina: Tenuipalpidae). University of California Publications in Entomology 14:175–274.
- Reck G. 1959. On the chaetological basis of the systematics of tetranychid mites. Soobshcheria Akademi Nauk Gruzinskoi SSR 23:465–471.
- Salas LA, Ochoa R. 1985. *Tenuipalpus chamaedorea*, una nueva especie de falsa arañita roja (Acari: Tenuipalpidae) em pacaya (*Chamaedorea* spp.). Agronomia Costarricense 9:171–174.
- Seeman OD, Beard JJ. 2011. A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia. Systematic and Applied Acarology 16:73–89.
- Vitzthum HG. 1929. Spinnentiere, 5. Ordnung: Milben, Acari. Tierwelt Mitteleuropas II, Leipzig 3:1–112.

Figures

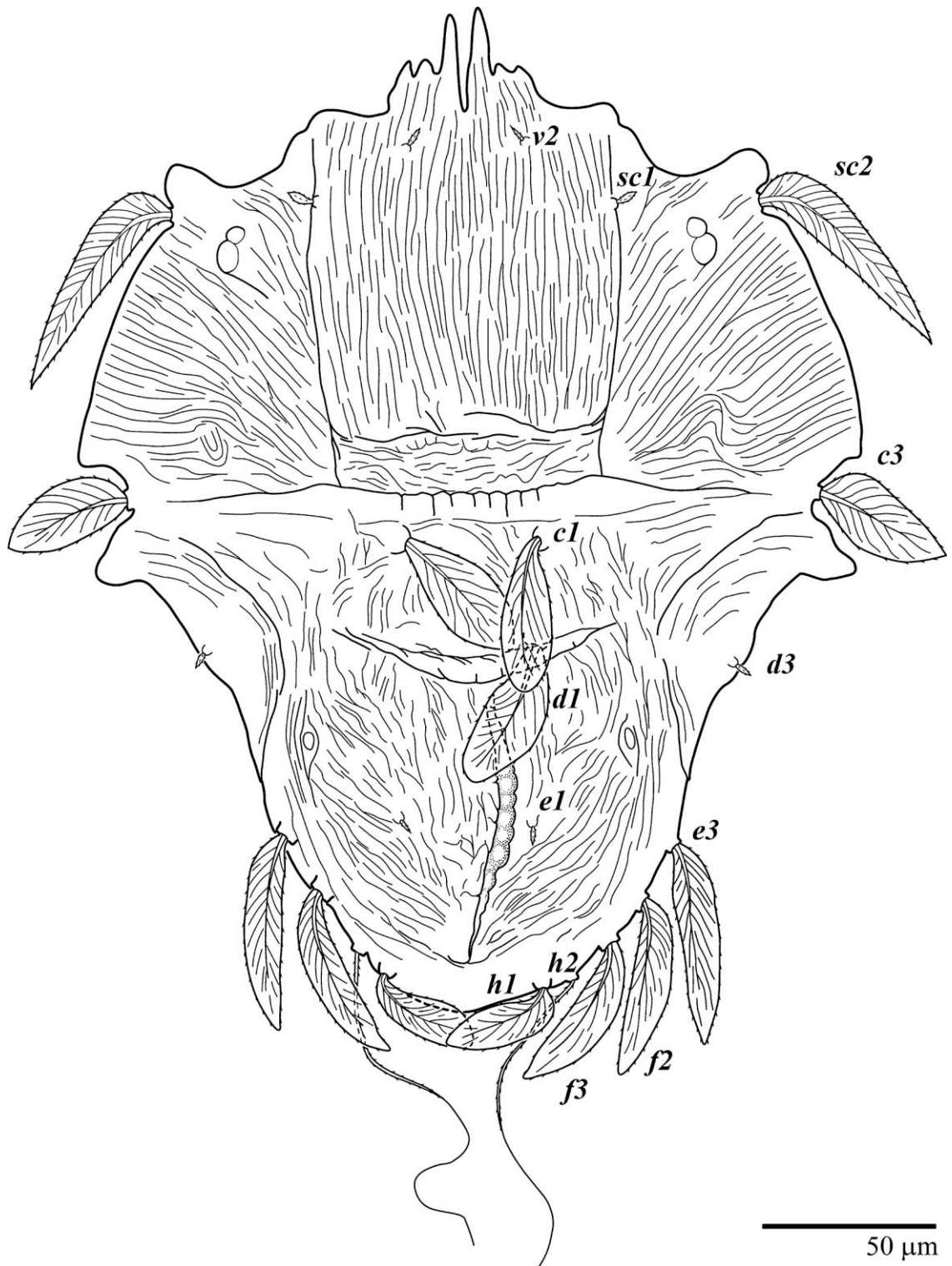


Figure 1. *Tenuipalpus caudatus* (Dugès) (female): dorsum. Note setae *d1* and *e3* missing on the left side of the drawn specimen.



Figure 2. *Tenuipalpus caudatus* (Dugès) (female): dorsum.

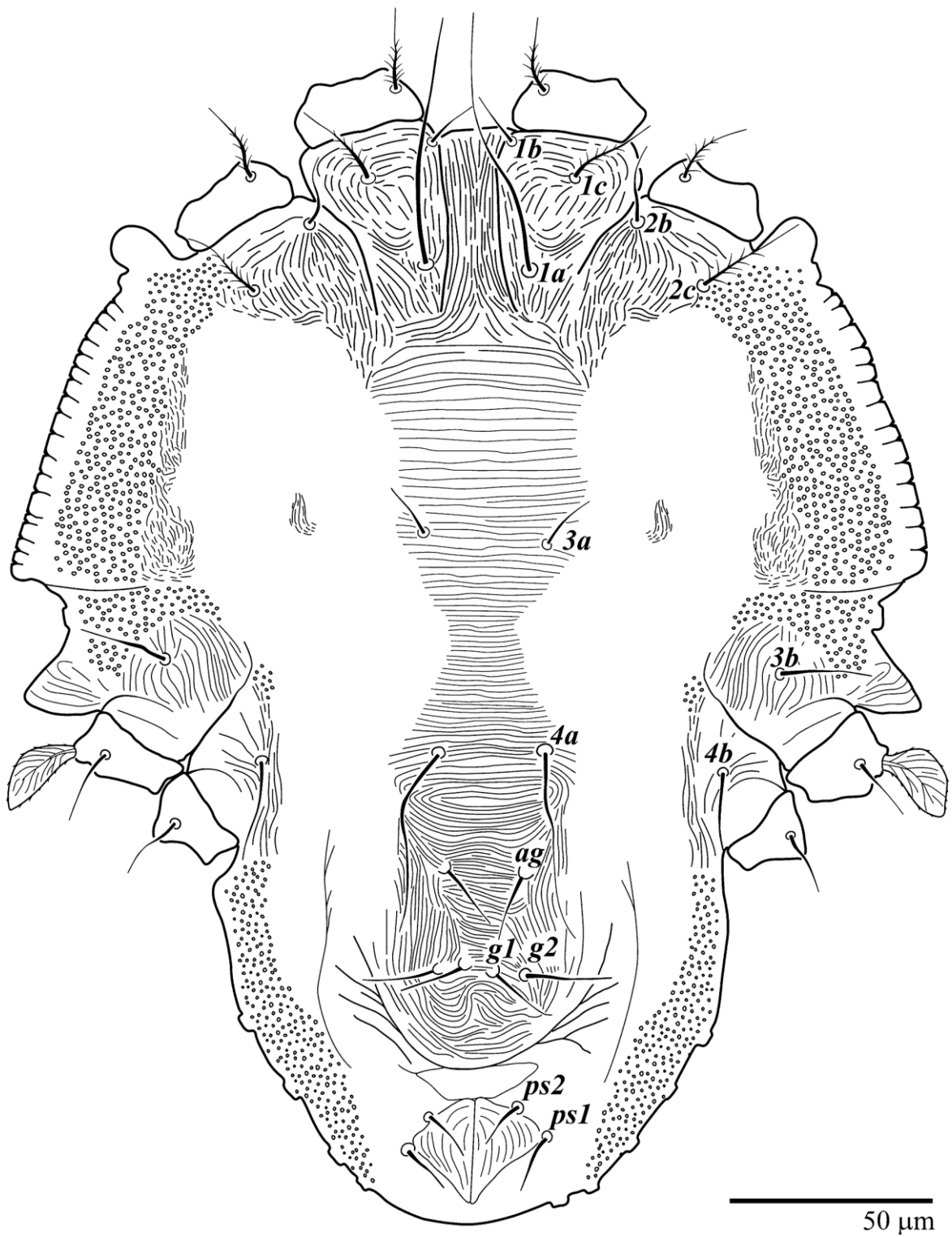


Figure 3. *Tenuipalpus caudatus* (Dugès) (female): venter.

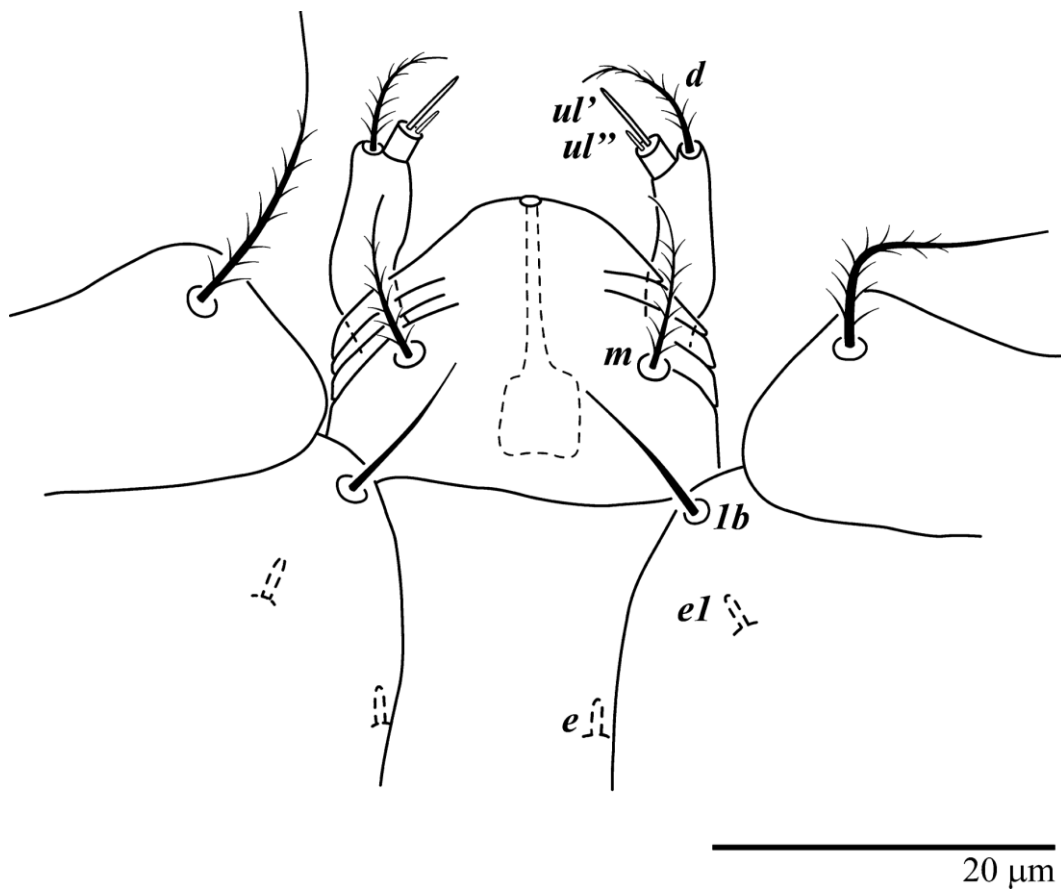


Figure 4. *Tenuipalpus caudatus* (Dugès) (female): hypostome.

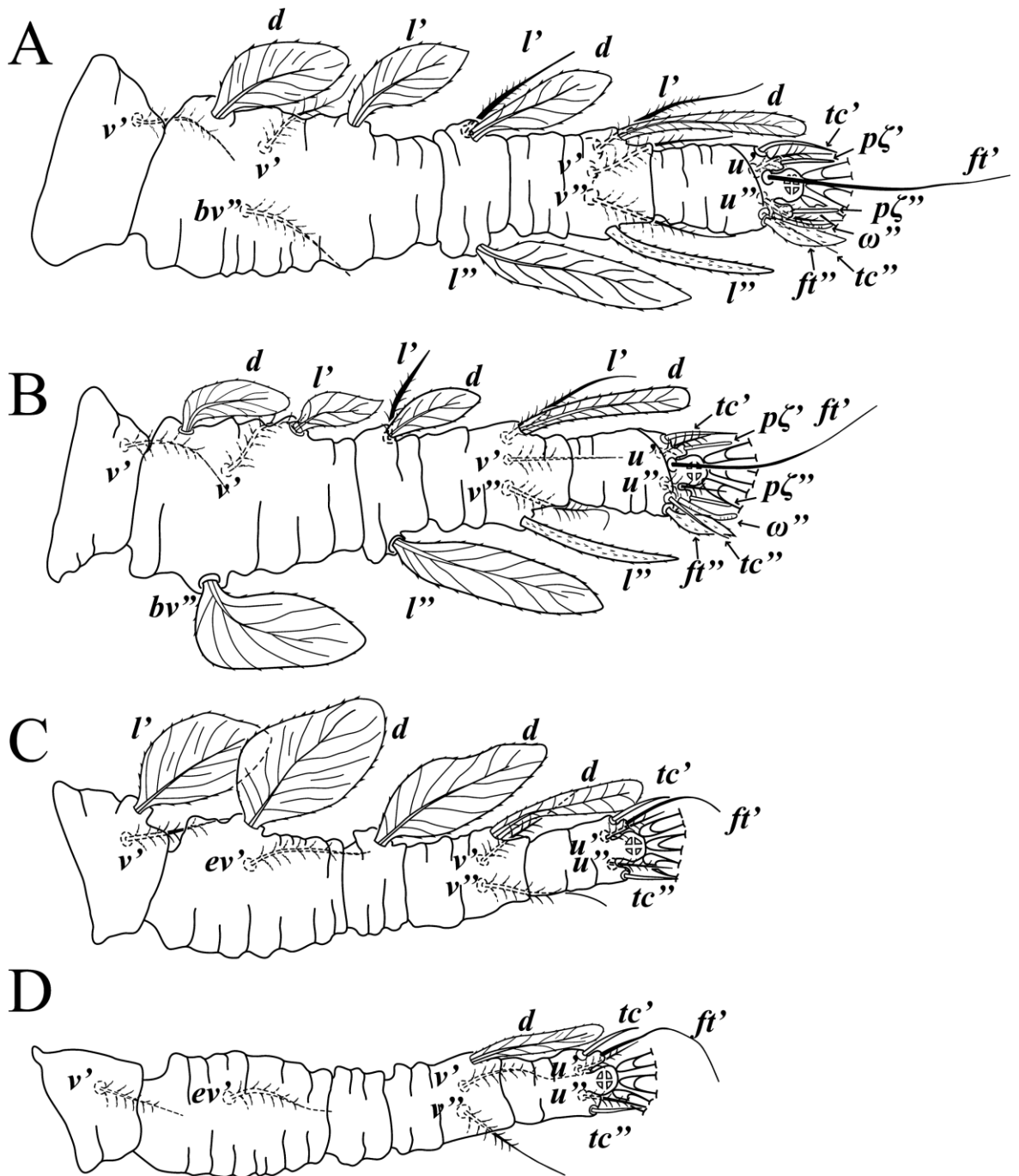


Figure 5. *Tenuipalpus caudatus* (Dugès) (female): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

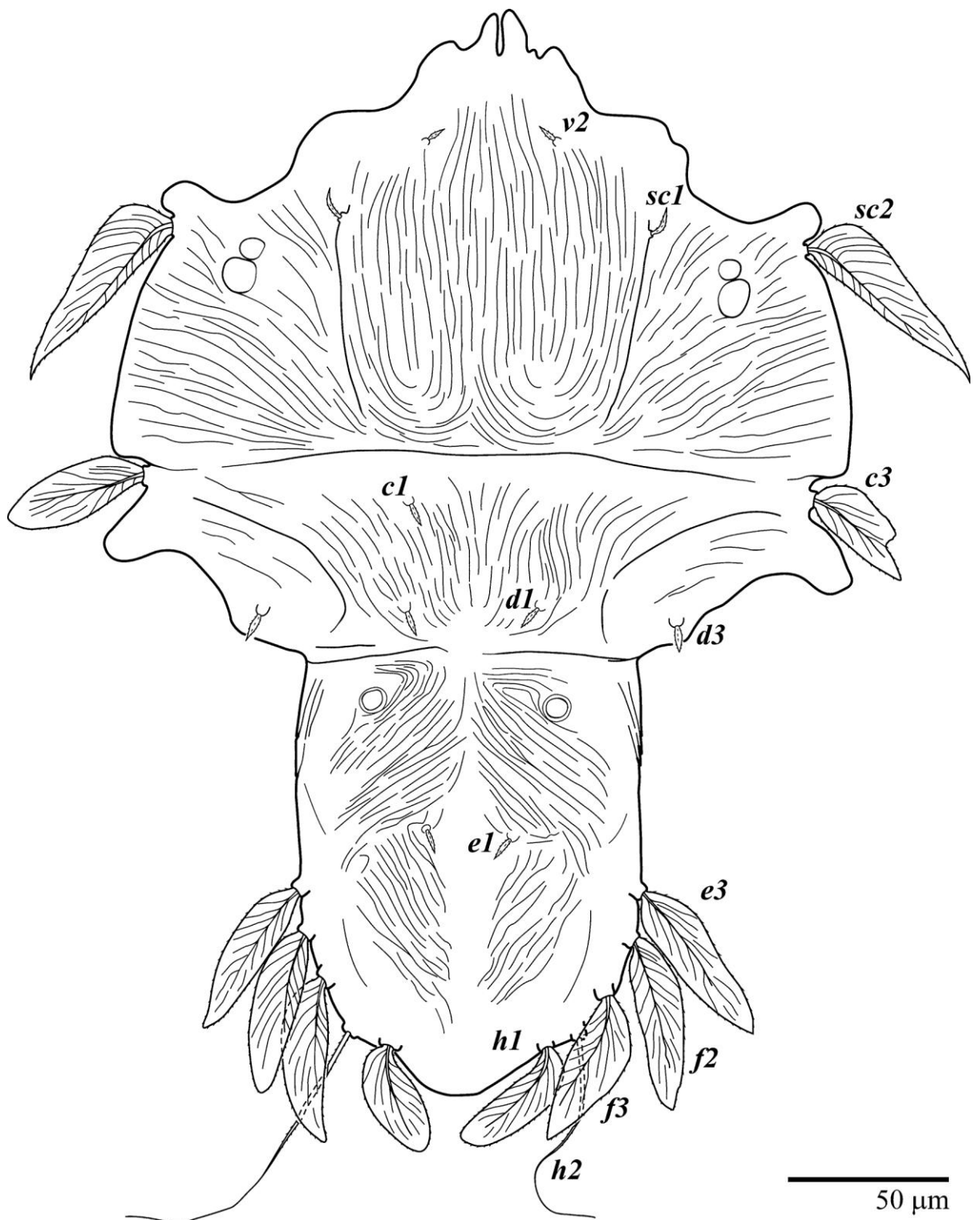


Figure 6. *Tenuipalpus caudatus* (Dugès) (male): dorsum.

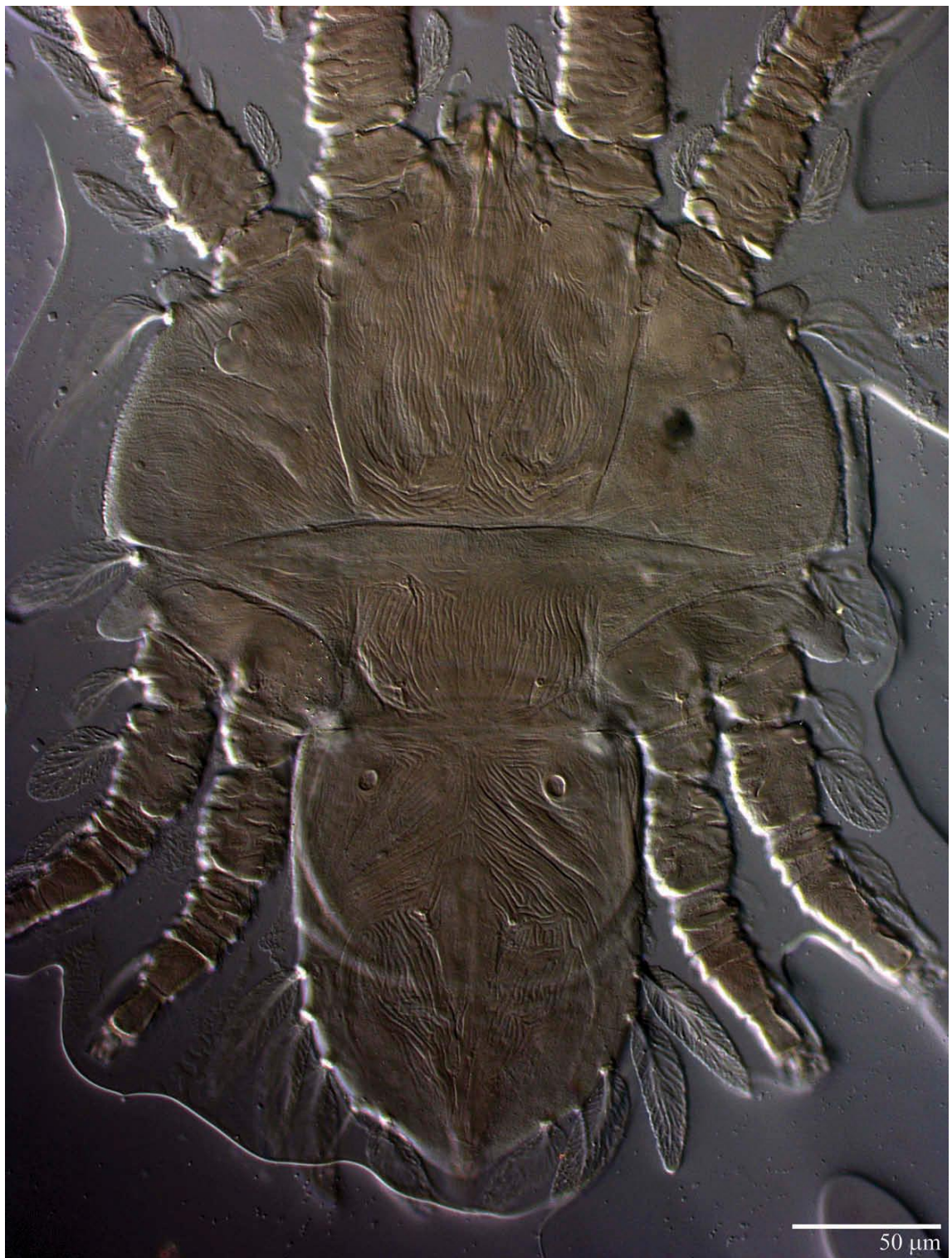


Figure 7. *Tenuipalpus caudatus* (Dugès) (male): dorsum.

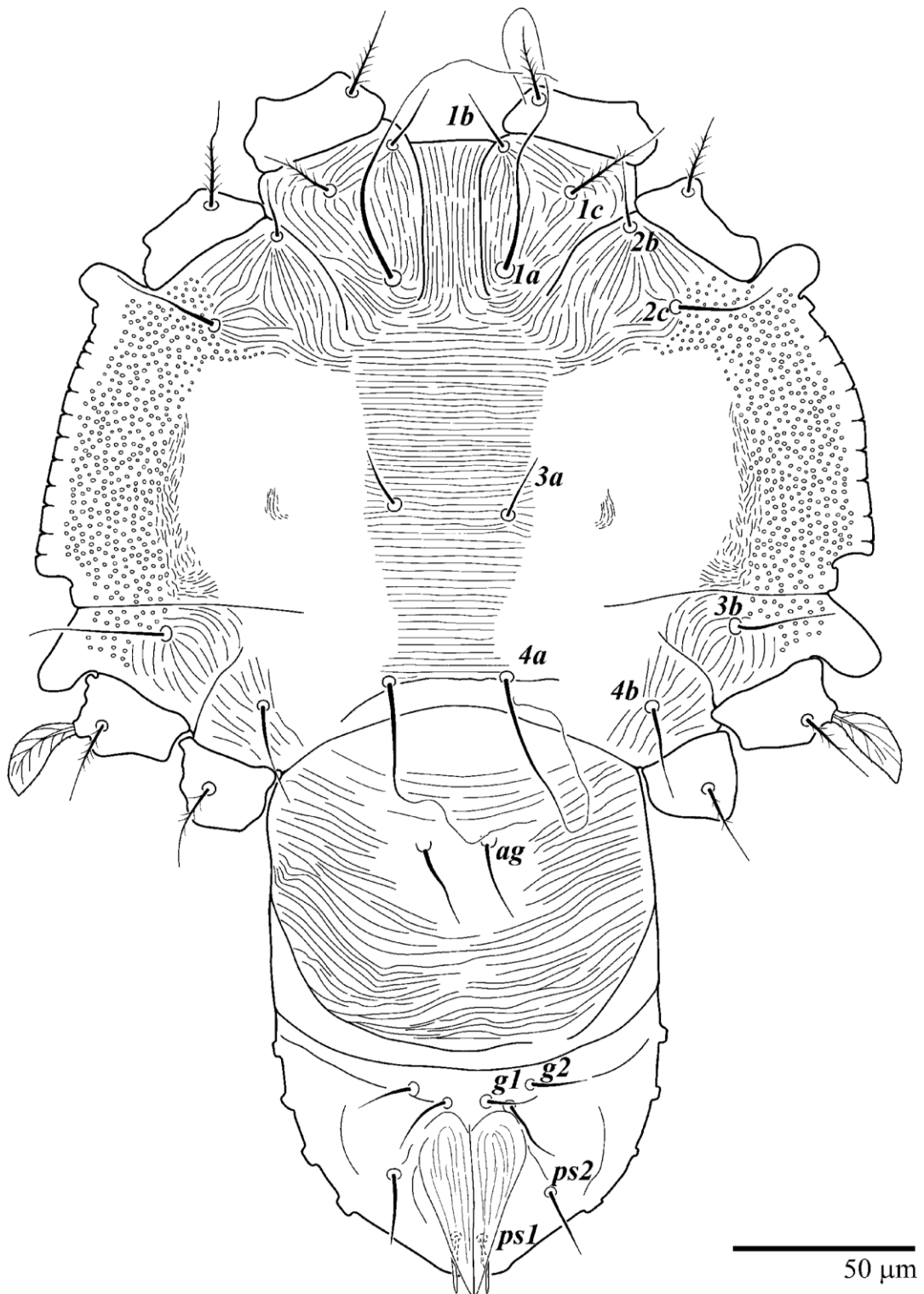


Figure 8. *Tenuipalpus caudatus* (Dugès) (male): venter. Note one aberrant additional seta *g* on right side of anal plate.

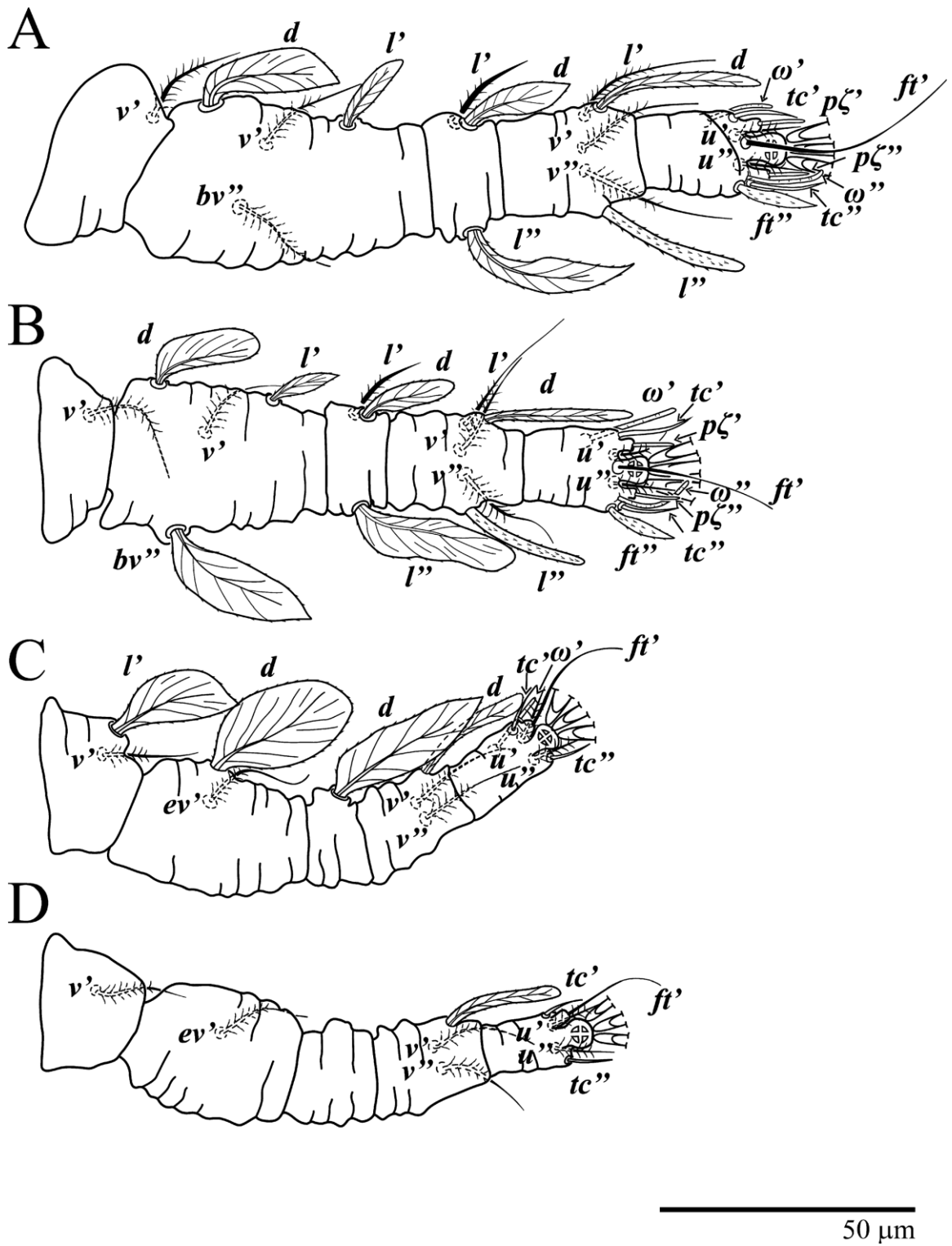


Figure 9. *Tenuipalpus caudatus* (Dugès) (male): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

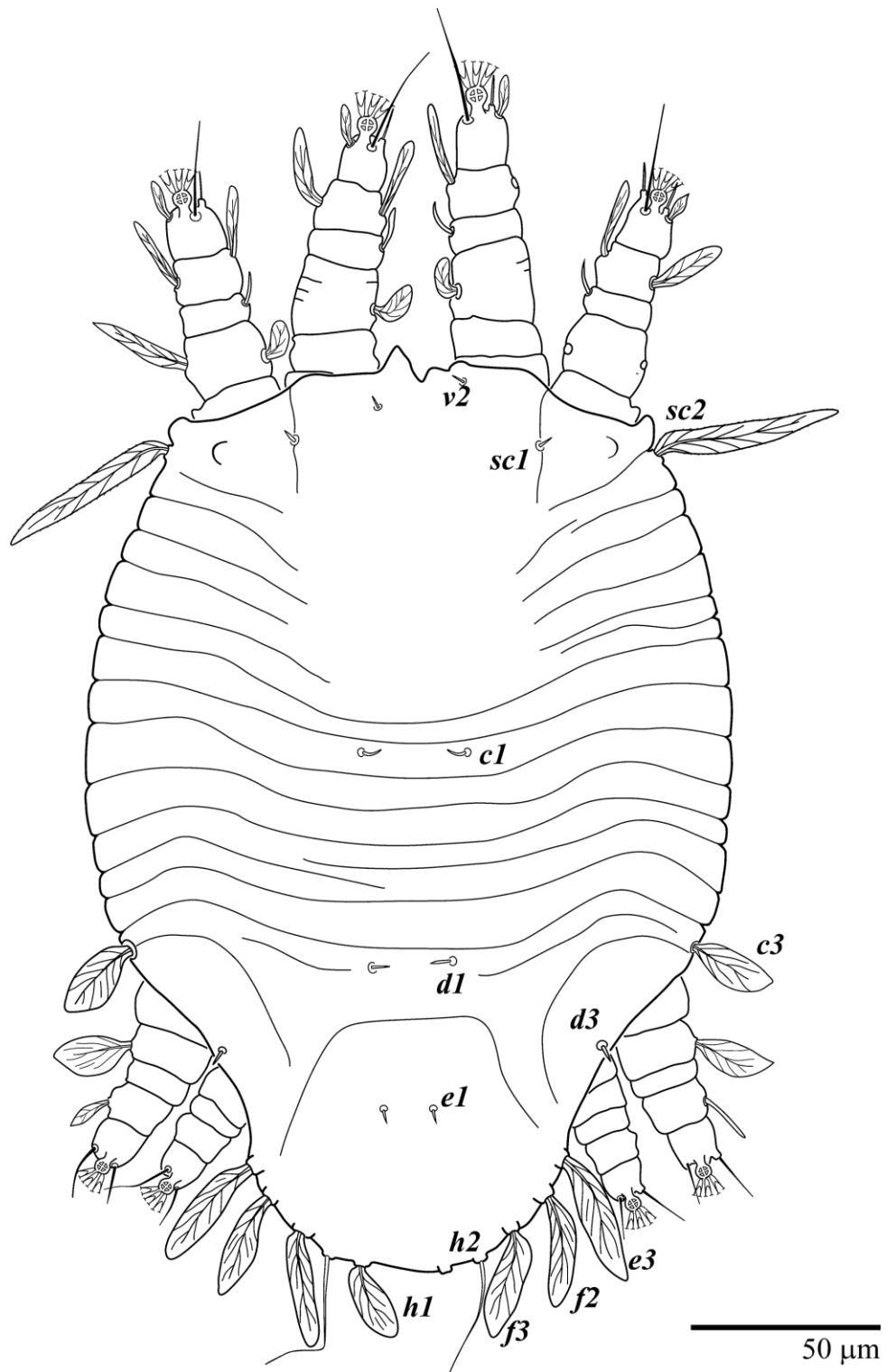


Figure 10. *Tenuipalpus caudatus* (Dugès) (protonymph): dorsum, with details of legs.

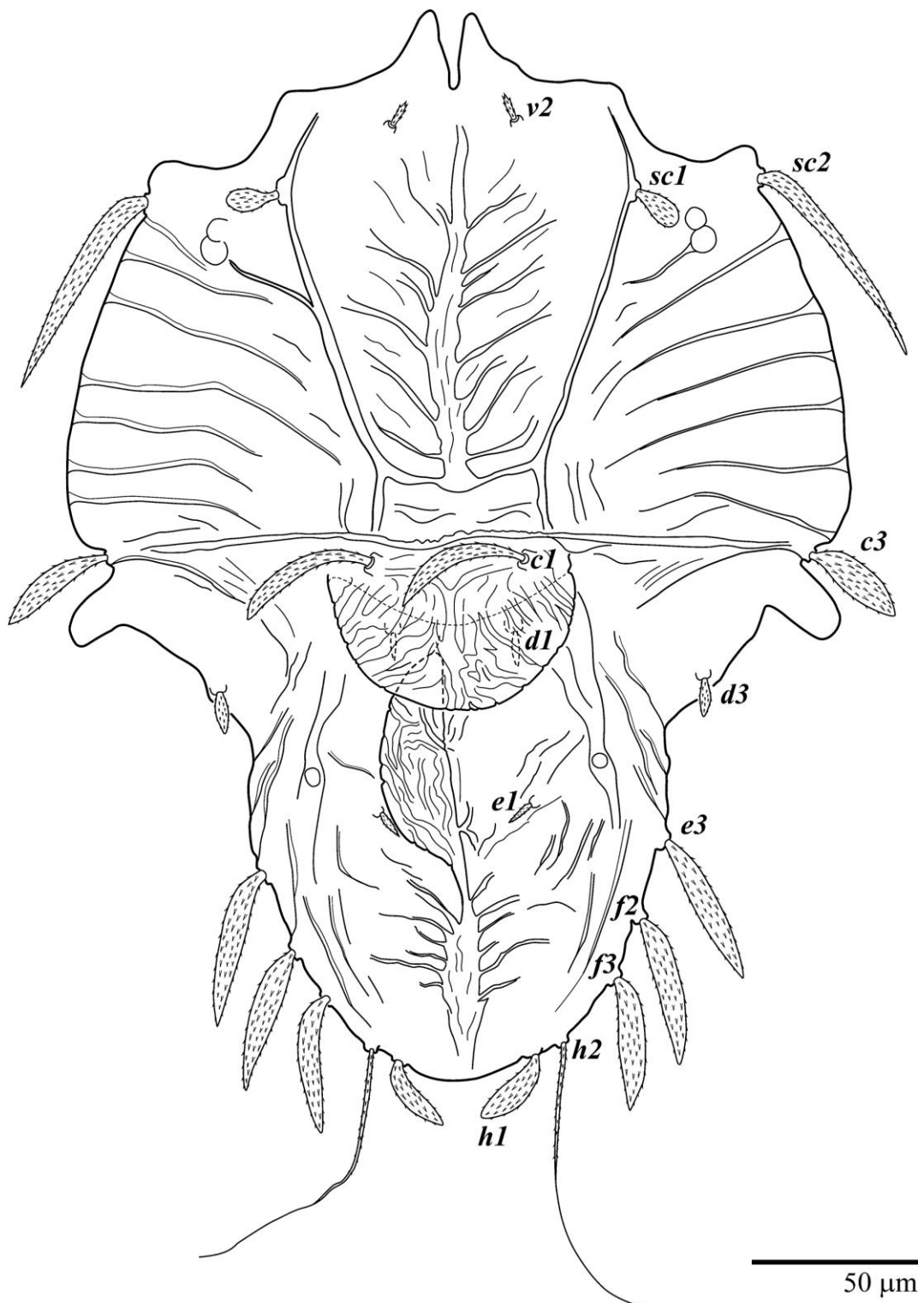


Figure 11. *Tenuipalpus erbei* **sp. nov.** (female): dorsum.

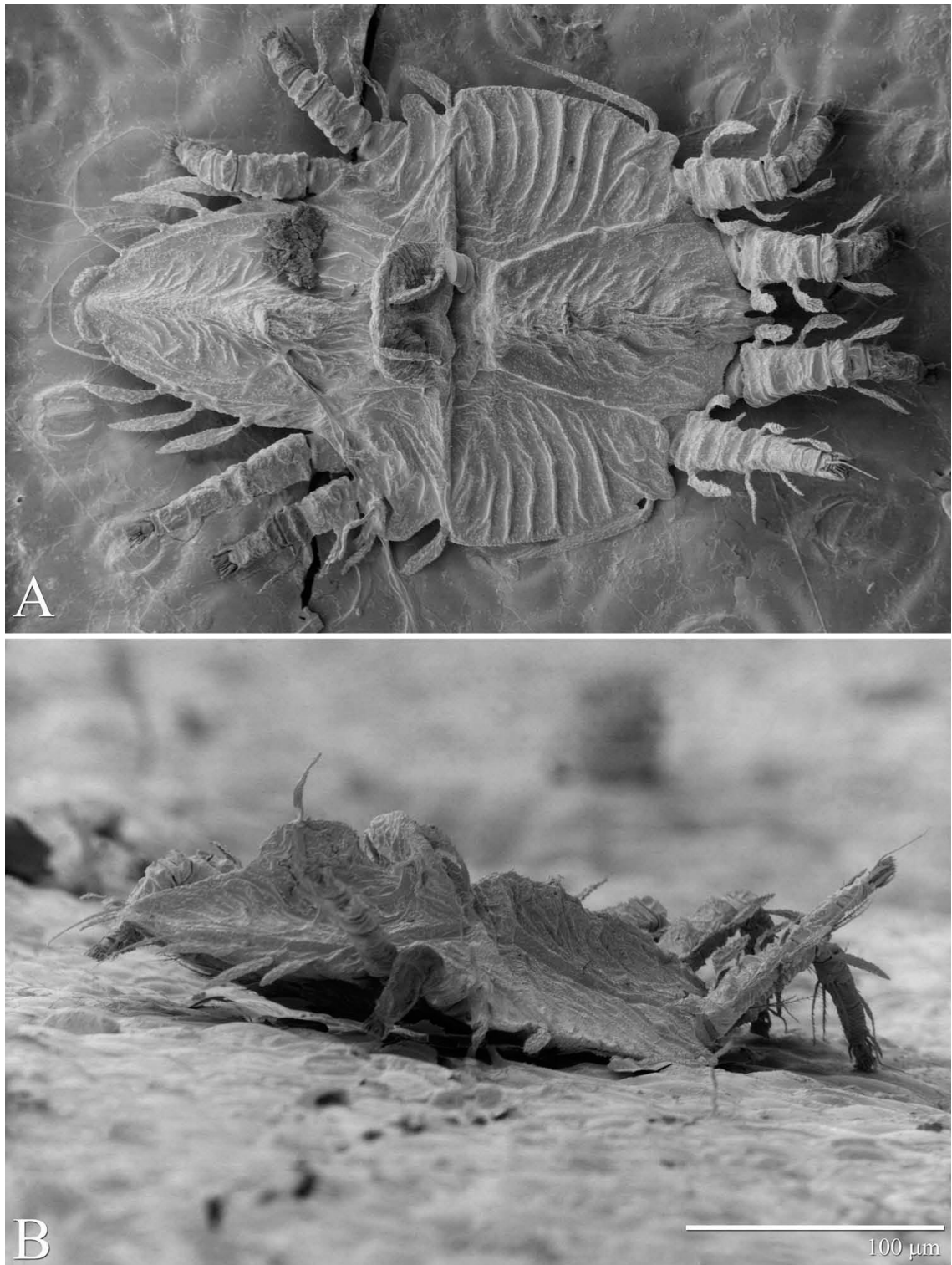


Figure 12. *Tenuipalpus erbei* **sp. nov.** (female): (A) dorsal view; (B) lateral view.

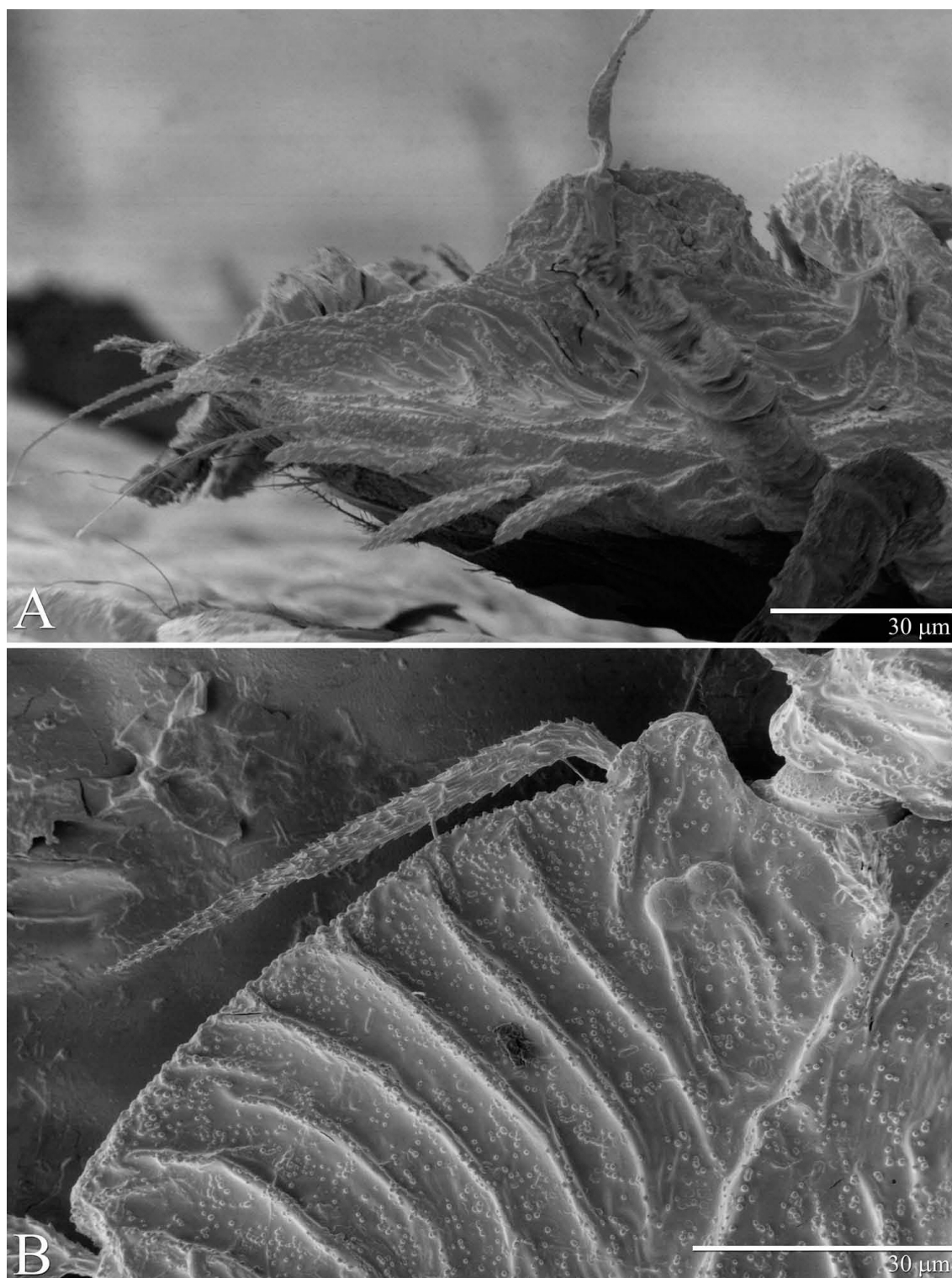


Figure 13. *Tenuipalpus erbei* **sp. nov.** (female): (A) detail of crests; (B) detail of the lateral region of prodorsum. Note the presence of body projection anterior to setae sc2.



Figure 14. *Tenuipalpus erbei* **sp. nov.** (female): dorsum.

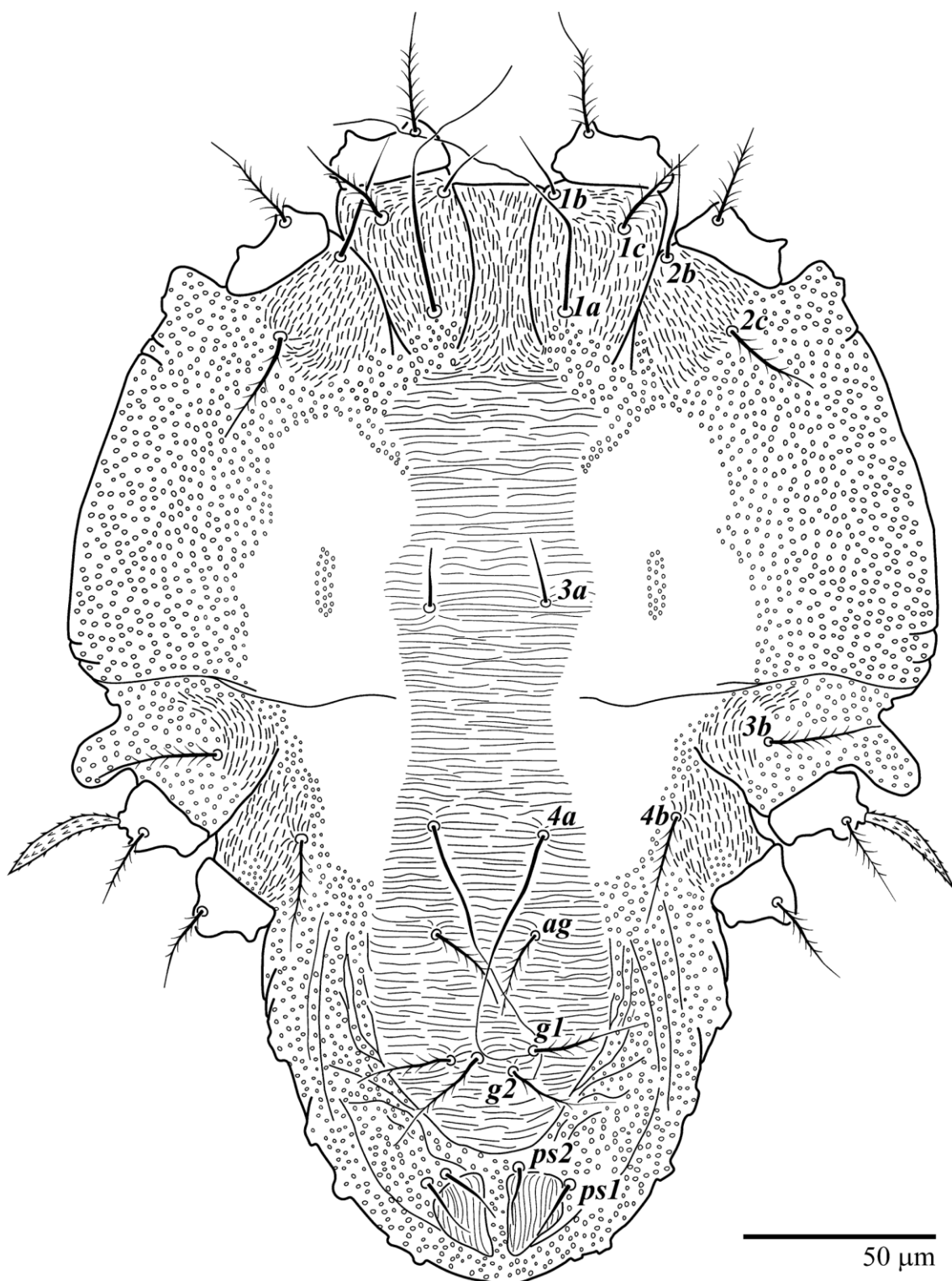


Figure 15. *Tenuipalpus erbei* **sp. nov.** (female): venter.

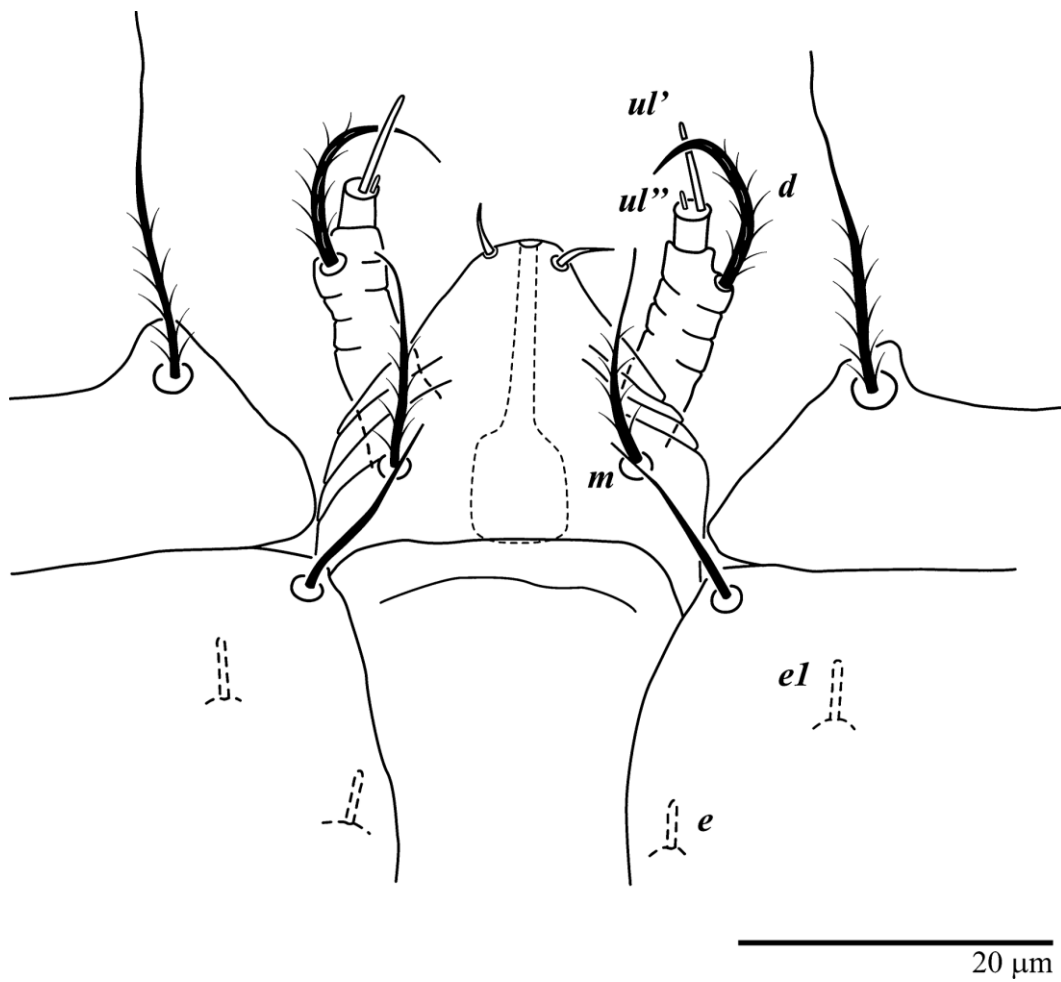


Figure 16. *Tenuipalpus erbei* **sp. nov.** (female): hypostome.

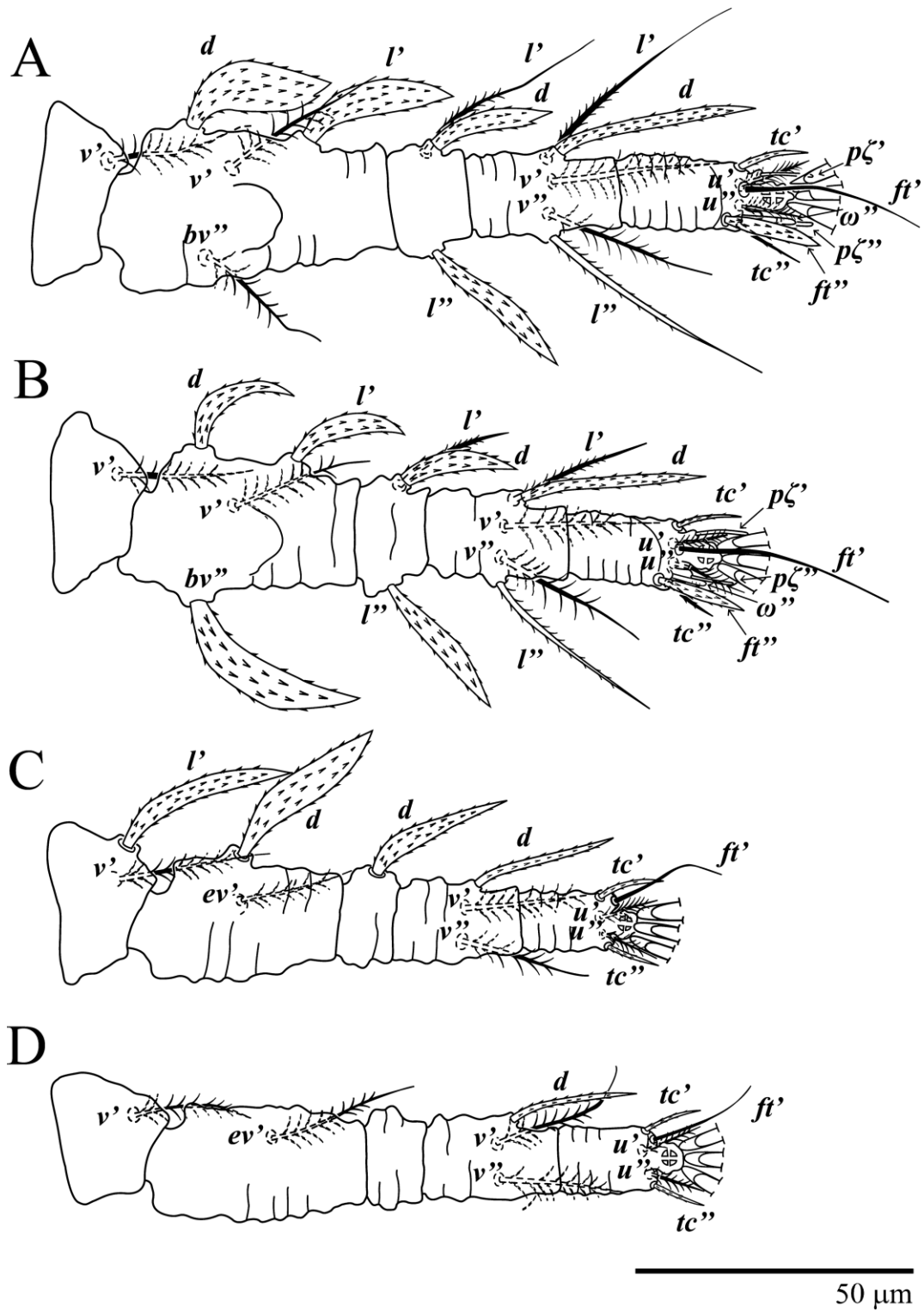


Figure 17. *Tenuipalpus erbei* **sp. nov.** (female): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

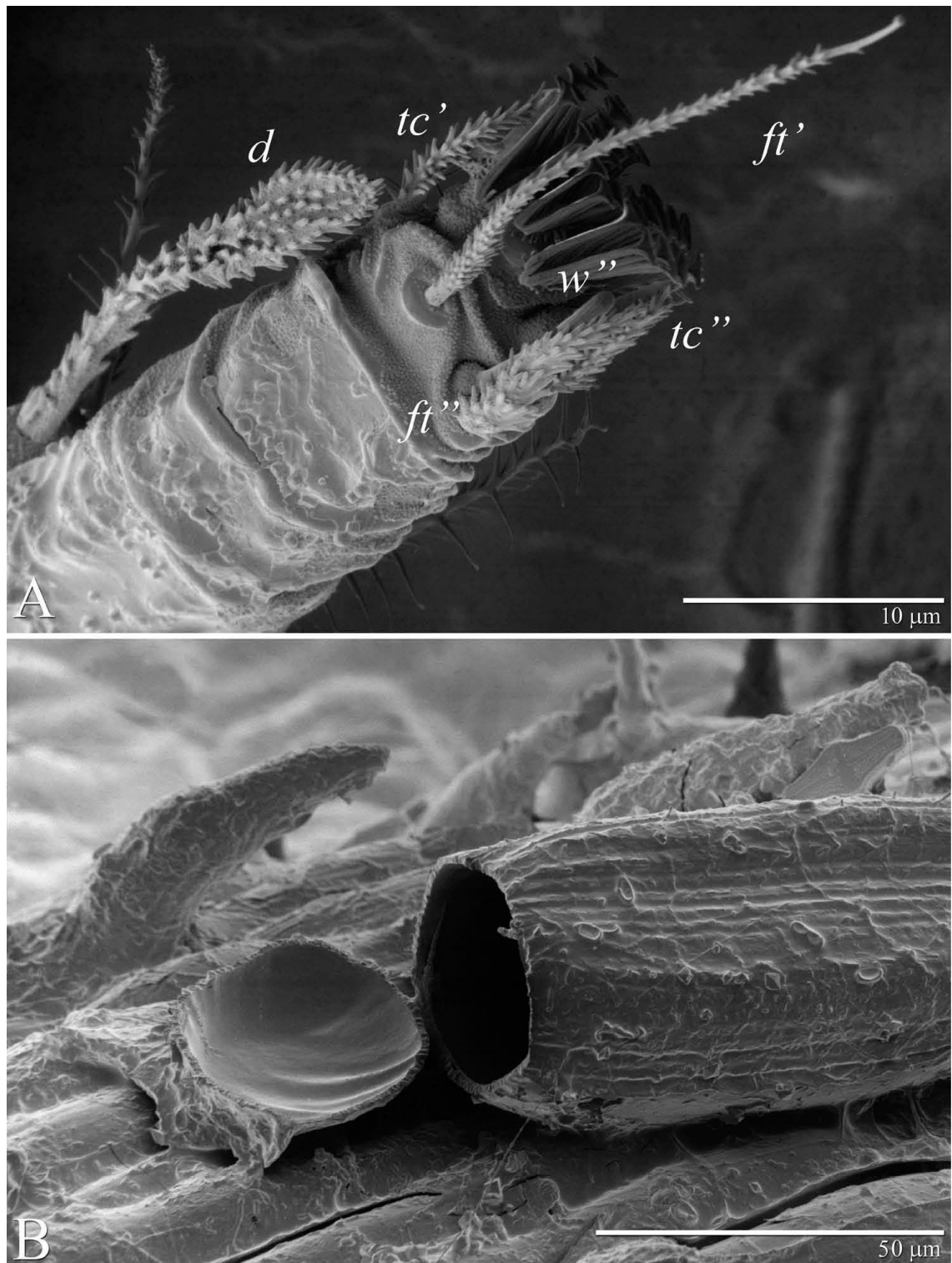


Figure 18. *Tenuipalpus erbei* sp. nov. (female): (A) detail of tarsus II; (B) egg.

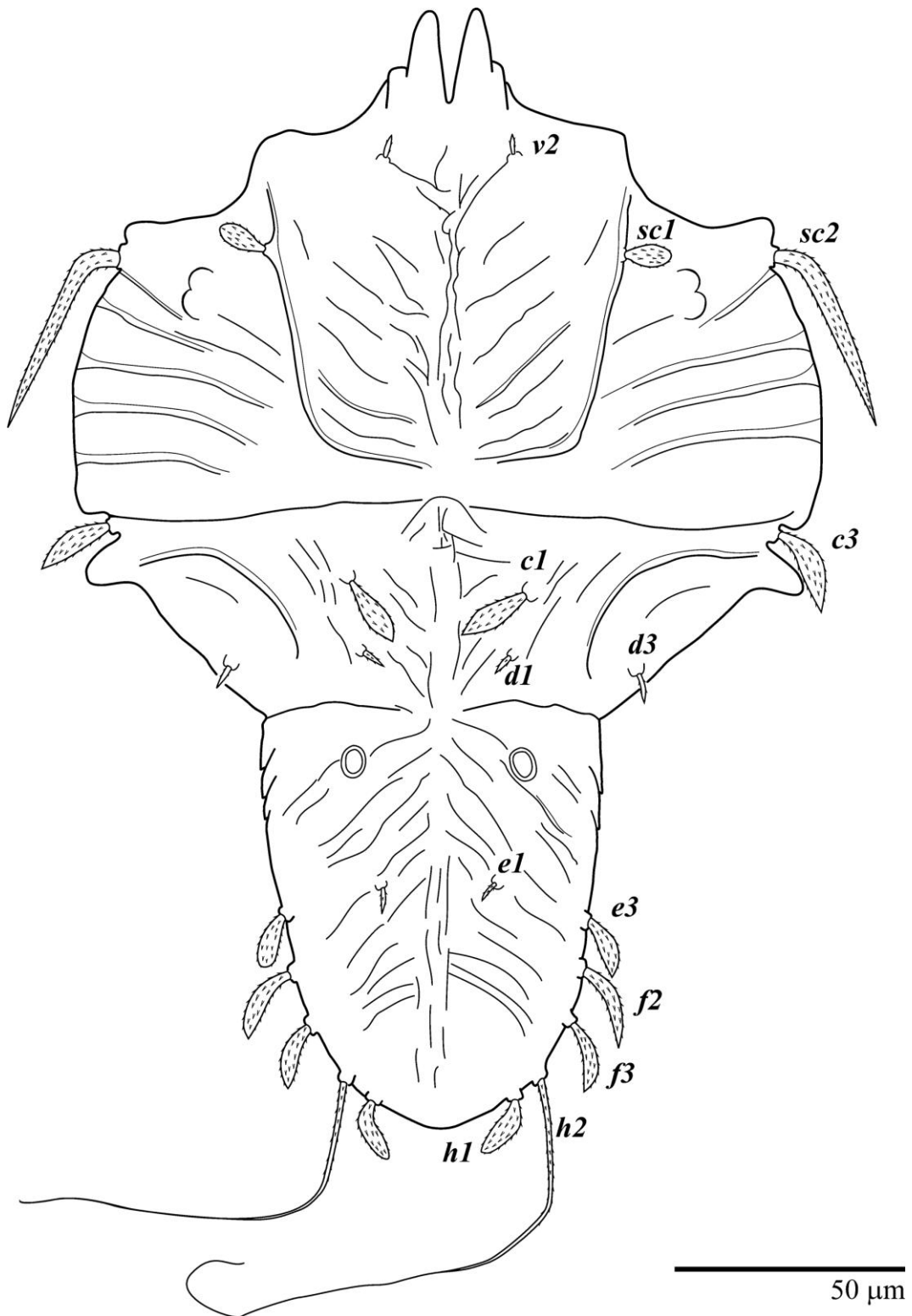


Figure 19. *Tenuipalpus erbei* **sp. nov.** (male): dorsum.

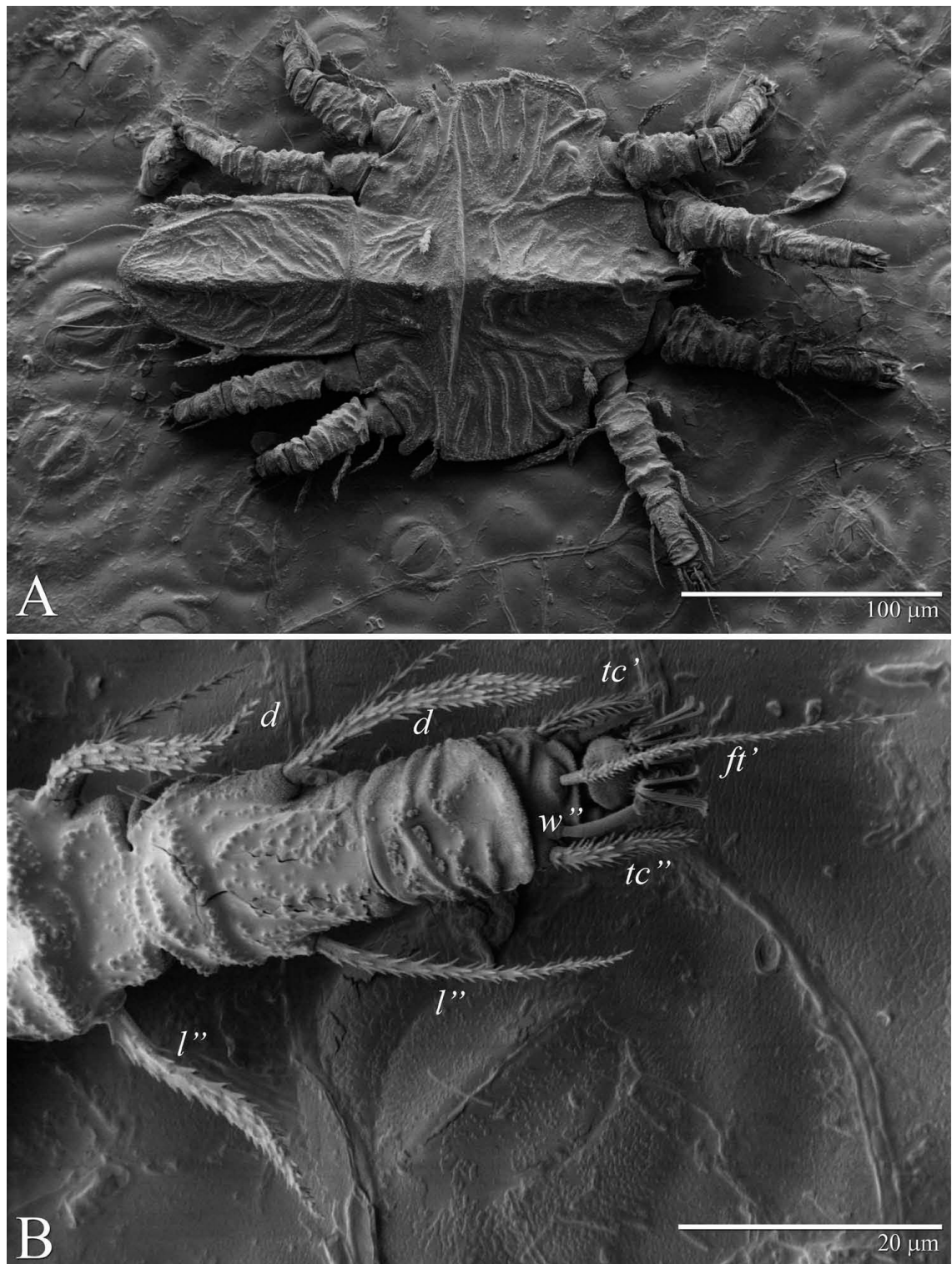


Figure 20. *Tenuipalpus erbei* **sp. nov.** (male): (A) dorsum; (B) detail of tibia and tarsus II.

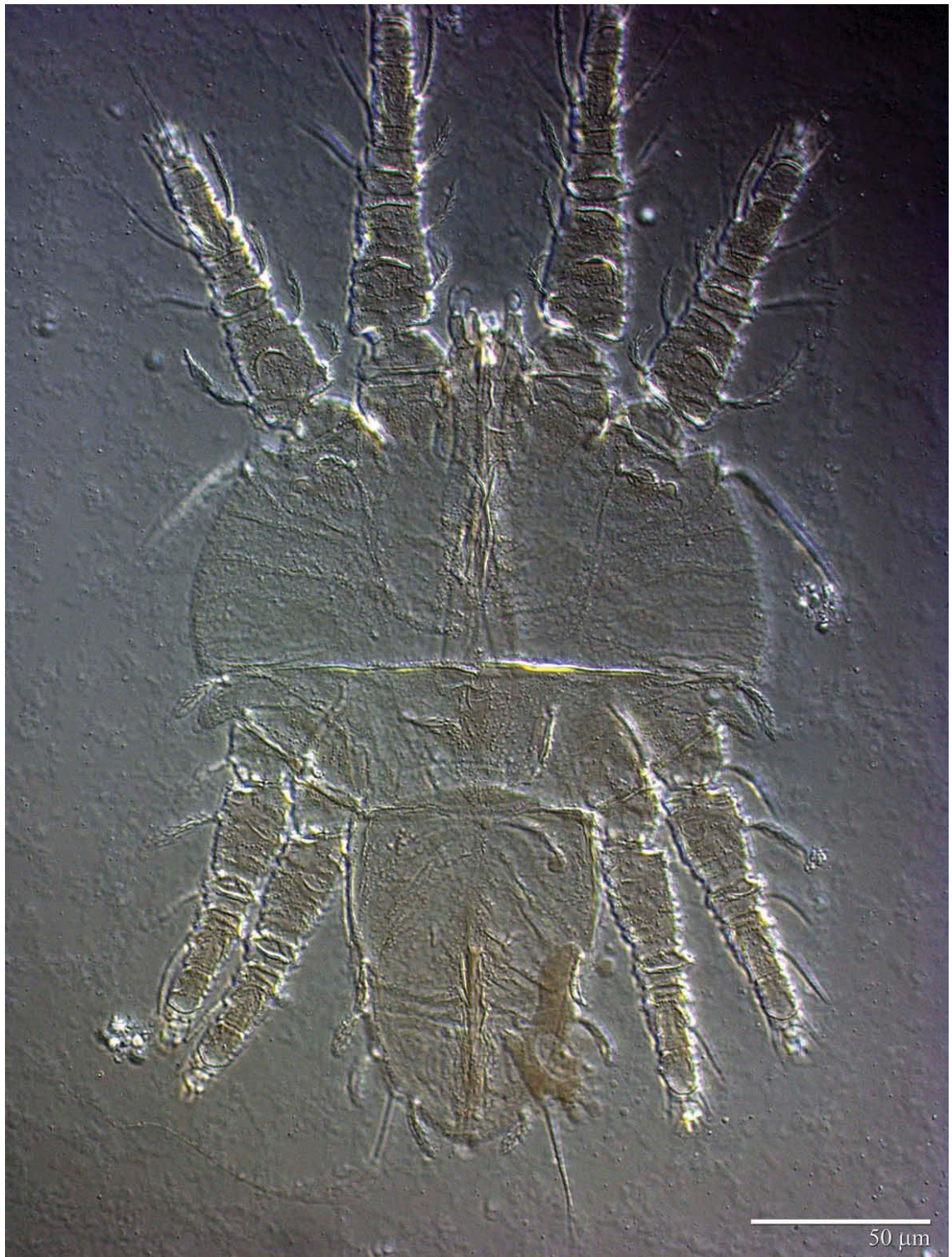


Figure 21. *Tenuipalpus erbei* **sp. nov.** (male): dorsum.

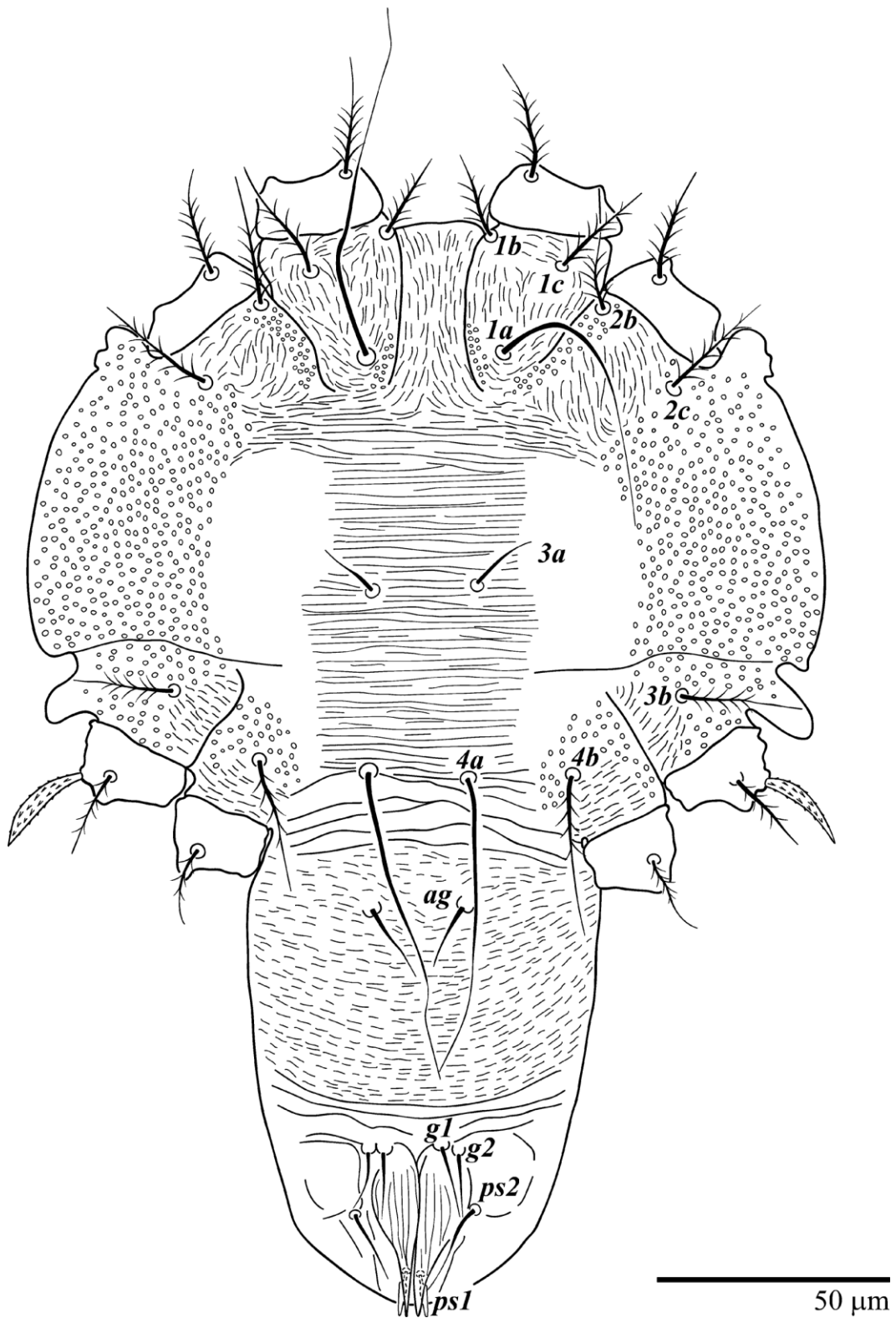


Figure 22. *Tenuipalpus erbei* **sp. nov.** (male): venter.

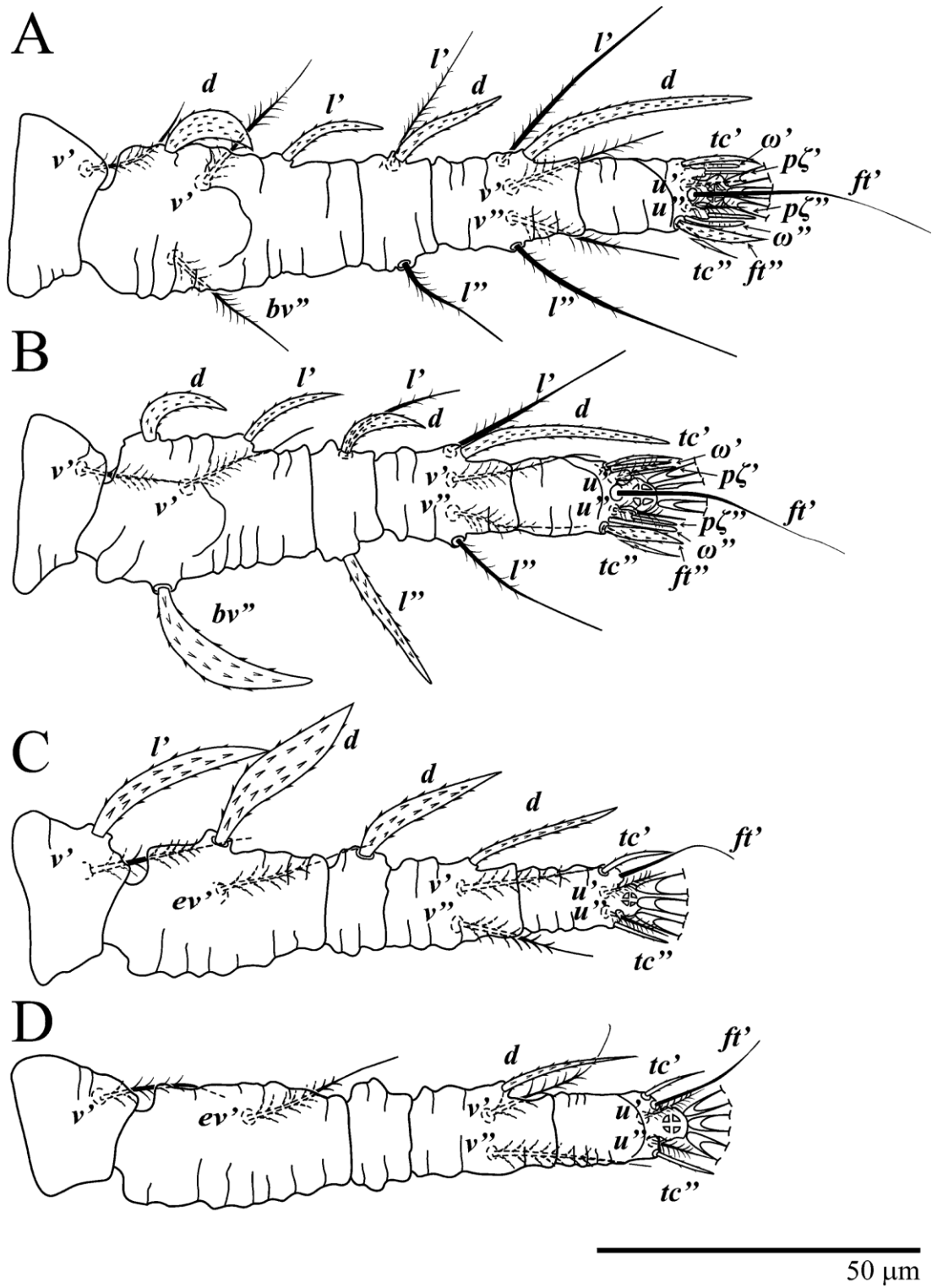


Figure 23. *Tenuipalpus erbei* sp. nov. (male): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

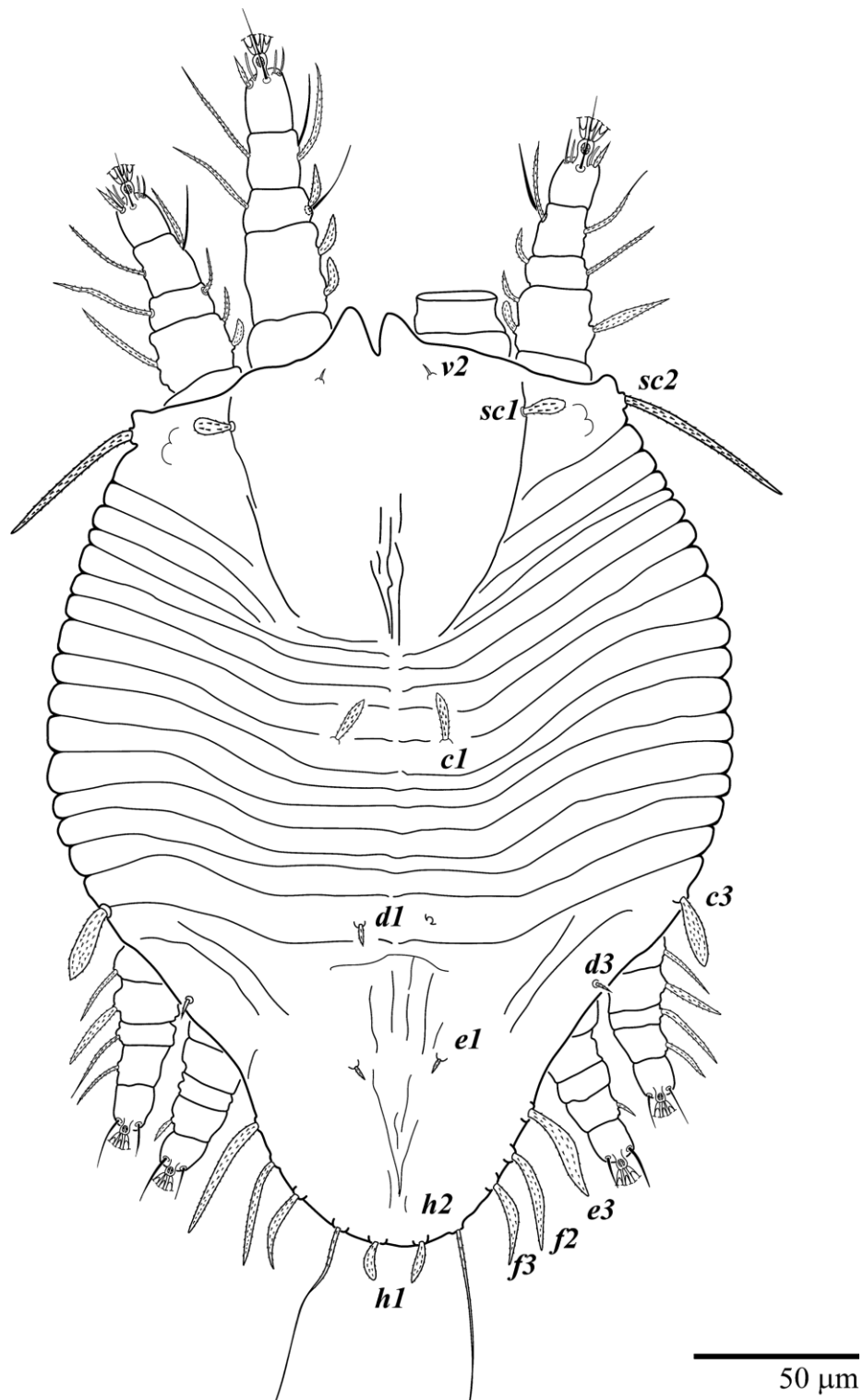


Figure 24. *Tenuipalpus erbei* **sp. nov.** (deutonymph): dorsum, with detail of legs.

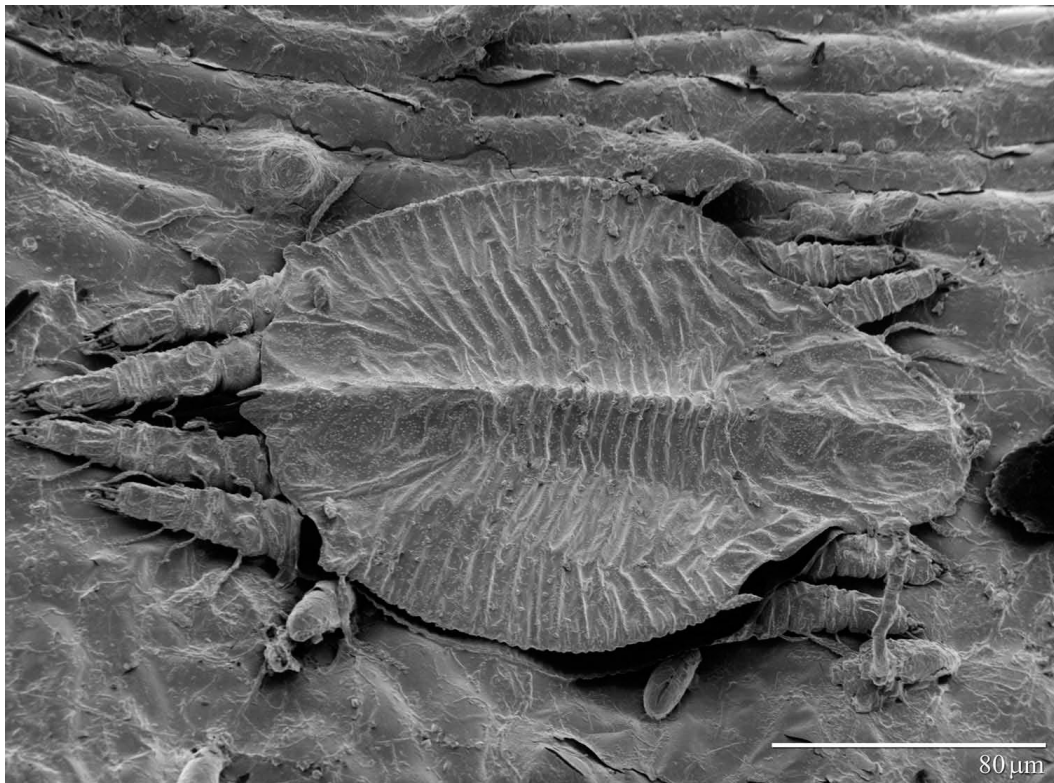


Figure 25. *Tenuipalpus erbei* **sp. nov.** (deutonymph): dorsum of caste skin.



Figure 26. *Tenuipalpus erbei* **sp. nov.** (protonymph): dorsum.

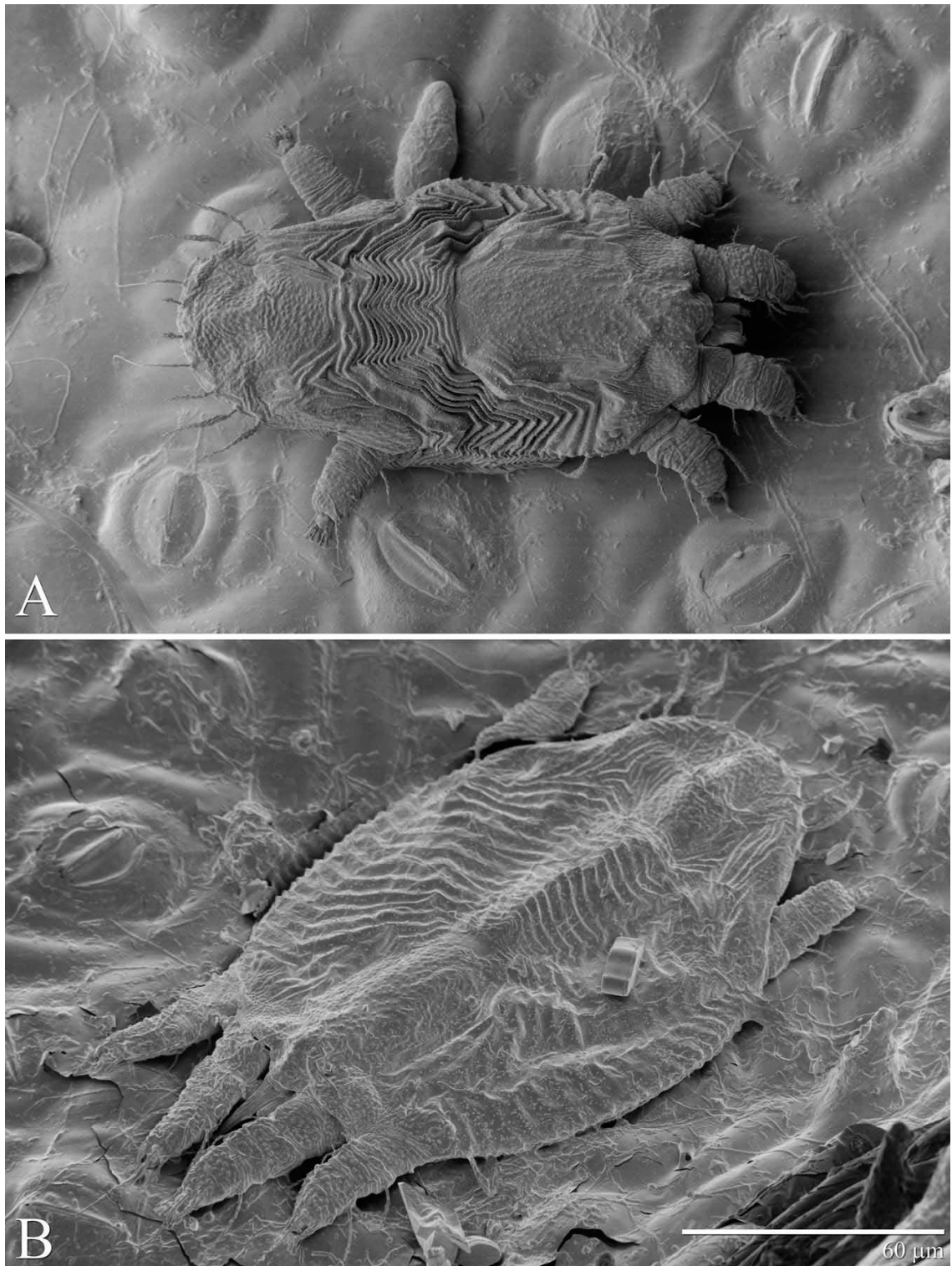


Figure 27. *Tenuipalpus erbei* **sp. nov.** (larva): (A) soon after out of the egg; (B) dorsum of caste skin.

CHAPTER 7

PHYLOGENY OF *TENUIPALPUS* DONNADIEU (SENSU STRICTO AND SENSU LATO GROUPS) AND *COLOPALPUS* PRITCHARD AND BAKER (ACARI, TENUIPALPIDAE)

Manuscript in preparation for submission

Abstract

We performed a cladistic analysis including species of the genera *Tenuipalpus* Donnadieu (sensu stricto and sensu lato groups) and *Colopalpus* Pritchard and Baker (Acari, Tenuipalpidae). The analysis indicates a monophyletic branch including species of *Tenuipalpus* sensu stricto group supported by presence of one pair of lateral body projections associated with setae *c*₃, a synapomorphy for this group. The second major branch indicates *Tenuipalpus* sensu lato as sister group of *Colopalpus*. It includes one monophyletic clade with the species of sensu lato group supported by one non-homoplasious synapomorphy (i.e. ornamentation of the venter); the other branch including species of *Colopalpus* was supported by the body shape of female and male, and the position of setae *d* on genua and tibiae I and II. These results support the division of genus *Tenuipalpus* into sensu stricto and sensu lato groups, as well as the reinstatement of the genus *Colopalpus*. The inclusion of more species in the analysis may improve the understanding about the relationships between the species of these three groups.

Key words: Prostigmata; cladistic; synapomorphy; body shape; lateral body projections.

Introduction

The flat mites (Acari: Tenuipalpidae) comprise over 1,100 described species of obligately phytophagous mites, including some of most important pests of cultivate plants worldwide (Mesa *et al.* 2009; Walter *et al.* 2009; Beard *et al.* 2012). As a result, greater attention has been given to its biological aspects, and studies on phylogenetic relationships among representatives of this family are incipient. The few studies about the phylogeny of flat mites were performed by Quirós-González (1985), Kane (2003), two unpublished thesis, and more recently by Beard *et al.* (2014),

which conducted a cladistic analysis to test the monophyly of the subfamily Tegopalpinae.

Tenuipalpus Donnadieu is the largest genus of Tenuipalpidae, with over than 300 known species (Mesa *et al.* 2009; Beard *et al.* 2012; Castro *et al.* 2016a). Recently, this genus was divided into two groups: sensu stricto and sensu lato (Castro *et al.* 2016a). These authors indicated the presence of one pair of lateral body projections associated with setae c3 as a synapomorphy for this group. The sensu stricto group comprises 40 known species described mainly from Neotropical and Nearctic regions (Castro *et al.* 2016a; 2016b). On the other hand, the sensu lato group includes morphologically dissimilar species and there is no synapomorphy to support the monophyly of this group.

Pritchard and Baker (1958) erected the genus *Colopalpus* to accommodate *Colopalpus matthyssei*, a new species that they described from The Philippines. These authors noted that *Colopalpus* resembles *Brevipalpus* by the elongate-ovate body shape, and that it resembles *Tenuipalpus* by the presence of setae h2 flagelliform. Subsequently, species from different regions of the world were described in this genus (Collyer 1973; Flechtmann 1976). Meyer (1979), in her major revision of the family, considered *Colopalpus* a junior synonymy of *Tenuipalpus*. Recently, Castro *et al.* (2015) reinstated *Colopalpus* based on difference of body shape present in females and males, and on the position of leg setae.

Despite the latest changes and advances about the knowledge of the systematic of the genera *Tenuipalpus* and *Colopalpus*, a cladistic analysis is needed to confirm these recent proposals. In this study, we present a cladistic analysis including species of the genera *Tenuipalpus* (sensu stricto and sensu lato groups) and *Colopalpus*, and we discuss the main morphological characters currently used to support these groups.

Material and Methods

The ingroup consists of 28 species of *Tenuipalpus* (14 of each sensu stricto and sensu lato groups) and five species of *Colopalpus* (Table 1). The outgroups is composed by two species: *Ultratenuipalpus avarua* Xu, Fan and Zhang, 2013 and an undescribed Brazilian species of *Ultratenuipalpus* (Tenuipalpidae). The characters included on the analysis were taken from study of type specimens and description available in the literature (Table 1). Characters were treated as hypotheses of homology following Nixon and Carpenter (2012). Most characters were treated as binary, but some present more than two states (multistate characters) (Scotland and Pennington 2000; Wiley and Lieberman 2011).

The dataset consisted of 105 morphological characters (Appendix A) treated as non-additive. These characters were extracted mainly from gnathosoma and dorsal, ventral and leg chaetotaxy. Terminals with unobserved states were coded with a '?', and those with inapplicable states with '-'. The matrix (Appendix B) was created using software Mesquite 3.04 (Maddison and Maddison 2015) and the parsimony searches were performed using software TNT and algorithms: *Ratchet*, with 200 iterations and the perturbation phase adjusted to 4 for both up-weighting and down-weighting; *Tree-Drifting*, with 20 iterations per replication; and *Sectorial Searching*, with sectors chosen by *Random sectorial search* (RSS) (Goloboff *et al.* 2008). The Bremer decay analysis (Bremer 1988) was calculated for the topology obtained.

The terminology of dorsal setae used follows that of Lindquist (1985) and Mesa *et al.* (2009). Leg chaetotaxy is adapted from Lindquist (1985), Xu and Fan (2010) and Seeman and Beard (2011).

Abbreviations

DEES – Reference Collection of Departamento de Entomologia, Fitopatologia e Zoologia Agrícola, Escola Superior de Agricultura “Luiz de Queiroz”, Universidade de São Paulo, Piracicaba, SP, Brazil.

DZSJRP – Collection of Acari, Departamento de Zoologia e Botânica, UNESP, São José do Rio Preto, State of São Paulo, Brazil.

NMNH – National Insect and Mite Collection, National Museum of Natural History, Smithsonian Institution, located in the Systematic Entomology Laboratory, USDA, Beltsville, Maryland, USA.

MCZ – Museum of Comparative Zoology, Cambridge, Massachusetts, USA.

Results and Discussion

The analysis returned 16 equally parsimonious trees of 265 steps (CI: 41, RI: 79). In the strict consensus tree (Fig. 1), a branch including the ingroup was supported by five synapomorphies (characters 6, 42, 73, 76 and 78). Among these characters are the presence of flagelliform setae *h2* and the absence of body projection between the setae *h1*. The monophyly of the branch including the species of *Tenuipalpus* sensu stricto group was supported by one synapomorphy (character 4). The second major branch including *Tenuipalpus* sensu lato group and *Colopalpus* was supported by 11 synapomorphies (characters 3, 20, 32, 47, 56, 61, 68, 82, 98, 100 and 103), most related to shape of dorsal setae.

The analysis revealed that the presence of a pair of lateral body projections associated with setae *c3* (character 4, Fig. 2B), previously mentioned by Castro *et al.* (2016a) as a synapomorphy to *Tenuipalpus* sensu stricto, is a appropriate character to diagnosis of this group and supported its monophyly. One of its clusters, formed by *T. sandyi*, *T. eugeniae*, *T. caudatus*, *T. spinosaurus*, *T. boyani*, *T. lucumae*, *T. erbei* and *T. victoriae*, was supported by the following characters: palps two-segmented (character 0, state 3) and one pair of ridges from setae *sc1* to sejugal furrow (characters 9). One small cluster of species was supported by presence of longitudinal and transverse crests on opisthosoma (characters 7 and 8). These crests are only known in some species of

sensu stricto group, and Castro *et al.* (2016a) suggested that their presence could form a subgroup in *Tenuipalpus* sensu stricto.

The second major branch included *Tenuipalpus* sensu lato and *Colopalpus* species. This branch was supported by a prodorsum without the pair of lateral body projections associated with setae *sc2* and the dorsal and leg setae not inserted on tubercles (see Fig. 2C-D). The setiform shape of dorsal setae *sc2*, *c3*, *f2*, *f3*, *e3* and *h1* were also considered synapomorphies to this branch. In comparison, in the sensu stricto group these dorsal setae are lanceolate, obovate to ovate, and most of setae are inserted on tubercles. Furthermore, in the *Tenuipalpus* sensu lato group and in *Colopalpus* the setae *d* on femora I and II (character 82) are inserted in dorsal position, while in *Tenuipalpus* sensu stricto these setae are inserted in lateral position on tubercles.

The branch including the species of *Colopalpus* was supported by four synapomorphies (characters 1, 88, 91 and 104). The elongate-ovate body shape of the female (character 1, Fig. 2D) and the opisthosoma not distinctly narrower than prodorsum in males (character 104) were used by Castro *et al.* (2015) to differentiate *Colopalpus* from *Tenuipalpus*. Besides body shape, these authors mentioned the position of setae *d* on genua and tibiae of legs I and II (characters 88 and 91, respectively) to differentiate these two genera. In *Colopalpus*, the setae *d* on genua and tibiae I and II are inserted on dorsal position (similar to condition found in *Brevipalpus*), while these setae are inserted on lateral position in *T.* sensu stricto and sensu lato groups (Castro *et al.* 2015).

The branch including *Tenuipalpus* sensu lato group was supported by one synapomorphy (character 102), related to ornamentation of the venter. Along this branch, there is a group supported by three synapomorphies (characters 29, 85 and 87), related to presence of leg setae. Herein, we include in the analysis only 14 of approximately 250 known species belonging to this group (Castro *et al.* 2016a). Besides the small number of taxons included in the analysis, *T.* sensu lato includes

several morphologically dissimilar species, being necessary the study of more taxons to reveal possible novel characters that allow the establishment of a more natural and better supported classification for this large group of *Tenuipalpus*.

Although the analysis indicates *Colopalpus* as sister group of *Tenuipalpus* sensu lato, we highlight that future studies may reveal *Colopalpus* as a group more related with *Brevipalpus* than *Tenuipalpus*, since these three groups share several characteristics. In the classification proposed by Mitrofanov (1973), *Colopalpus* and *Brevipalpus* are included in the subfamily Brevipalpinae. In a subsequent paper, this author presents *Colopalpus* and *Tenuipalpus* in the subfamily Tenuipalpinae (Mitrofanov and Strunkova 1978). This example indicates a dubious position for *Colopalpus* in relation to the genera *Brevipalpus* and *Tenuipalpus*. Furthermore, the flagelliform shape of the setae *h2* present in *Tenuipalpus* and *Colopalpus* also occurs in other tenuipalpid genera (e.g. *Prolixus* and *Acaricis*), and may be considered as a homoplastic condition. We believe that results and questions here presented will provide support to future investigations about the relationships between *Colopalpus* and the genera *Tenuipalpus* and *Brevipalpus*.

Conclusion

Our results support the recent division of the genus *Tenuipalpus* in the sensu stricto and sensu lato groups. The analysis indicated the presence of one pair of lateral body projections associated with setae *c3* as a synapomorphy to sensu stricto group, confirming the results presented by Castro *et al.* (2016a). The analysis also indicates the monophyly of *Colopalpus* and confirms the reinstatement of this genus, although a broader study is necessary to understand its relation with the genera *Brevipalpus* and *Tenuipalpus*. We expect that the inclusion of more taxa in the analysis will reveal novel characters to *Tenuipalpus* sensu lato, and

also collaborate for a better understanding about the relationships between the species of these groups of Tenuipalpidae.

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References

Beard, J.J., Ochoa, R., Bauchan, G.R., Trice, M.D., Redford, A.J., Walters, T.W., Mitter, C. 2012. Flat mites of the world. 2nd ed. Fort Collins, CO: Identification Technology Program, CPHST, PPQ, APHIS, USDA

- [cited 2016 Feb 22]. Available from: www.idtools.org/id/mites/flatmites/index.php
- Beard, J.J., Seeman, O.D., Baughan, G.R. 2014. *Tenuipalpidae* (Acari: Trombidiformes) from *Casuarinaceae* (Fagales). *Zootaxa*, 3778: 1–157.
- Baker, E.W., Tuttle, D.M. 1987. The false spider mites of Mexico (*Tenuipalpidae*: Acari). United States Department of Agriculture, Agricultural Research Service, Technical Bulletin, 1706: 1–236.
- Bremer K. 1988. The limits of amino acid sequence data in angiosperm phylogenetic reconstruction. *Evolution*, 42: 795–803.
- Castro, E.B., Feres, R.J.F. 2013. New species of *Tenuipalpus* (Acari: *Tenuipalpidae*) from Semidecidual Forest remnants in the State of São Paulo, Brazil. *Zootaxa*, 3716 (3): 475–493.
- Castro, E.B., Ochoa, R., Feres, R.J.F., Beard, J.J., Baughan, G.R. 2015. Reinstatement of the genus *Colopalpus* Pritchard and Baker (1958) and re-description of *Colopalpus matthyssei* Pritchard and Baker (1958), the type species of the genus (Acari, *Tenuipalpidae*). *International Journal of Acarology*, 41(4): 310–328.
- Castro, E.B., Kane, E.C., Feres, R.J.F., Ochoa, R., Baughan, G.R. 2016a. Definition of *Tenuipalpus* sensu stricto (Acari, *Tenuipalpidae*), with redescription of *Tenuipalpus caudatus* (Dugès), the type species of the genus, and description of a new species from Costa Rica. *International Journal of Acarology*, 42(2): 106–126.
- Castro, E.B., Feres, R.J.F., Ochoa, R., Baughan, G.R. 2016b. A new species of *Tenuipalpus* sensu stricto (Acari: *Tenuipalpidae*) from Brazil, with ontogeny and a key to the known species. *Zootaxa*, (in press).
- Collyer, E. 1973. Two new species of the genus *Colopalpus* (Acarina: *Tenuipalpidae*). *New Zealand Journal of Science*, 16: 529–532.

- Flechtmann, C.H.W. 1976. Preliminary report on the false spider mites (Acari: Tenuipalpidae) from Brazil and Paraguay. *Proceedings of the Entomological Society of Washington*, 78: 58–64.
- Goloboff, P.A., Farris, J.S., Nixon, K.C. 2008. TNT, a free program for phylogenetic analysis. *Cladistics*, 24: 774–786.
- Kane, E.C. 2003. A maximum parsimony phylogeny of the mite family Tenuipalpidae (Acari: Tetranychoidae) based on setal characters. Master of Science Thesis, University of Maryland, USA.
- Khanjani, M., Alvandy, S., Khanjani, M., Seeman, O.D. 2013. A new species of *Tenuipalpus* Donnadieu (Acari: Tenuipalpidae) from Iran. *Systematic and Applied Acarology*, 18: 389–395.
- Lindquist, E.E. 1985. External anatomy. In: Helle W., Sabelis M.W., editors. *Spider mites: their biology, natural enemies and control*. Vol. 1A. Amsterdam: Elsevier Science Publishers B.V., pp. 3–28.
- Maddison, W.P., Maddison, D.R. 2015. Mesquite: a modular system for evolutionary analysis. Version 3.04 <http://mesquiteproject.org>
- Mesa, N.C., Ochoa, R., Welbourn, W.C., Evans, G.A., Moraes, G.J.de. 2009. A catalog of the Tenuipalpidae (Acari) of the World with a key to genera. *Zootaxa*, 2098: 1–185.
- Meyer, M.K.P. 1979. The Tenuipalpidae (Acari) of Africa with keys to the world fauna. *Entomology Memoir, Department of Agriculture Republic South Africa, Pretoria*, 50: 1–133.
- Mitrofanov, V.I. 1973. Revision of the system of phytophagous mites of the subfamily Tenuipalpinae s. str. (Trombidiformes, Tenuipalpidae). *Zoologicheskii Zhurnal*, 52: 1315–1320.
- Mitrofanov, V.I., Strunkova, Z.I. 1978. A new genus and species of the family Tenuipalpidae (Trombidiformes). *Zoologicheskii Zhurnal*, 52: 1095–1099.
- Nixon, C.C., Carpenter J.M. 2012. More on homology. *Cladistics*, 28(3): 225–226.

- Pritchard, A.E., Baker, E.W. 1958. The false spider mites (Acarina: Tenuipalpidae). University of California Publications in Entomology, 14: 175–274.
- Quirós-González, M. 1985. A systematic and phylogenetic analysis of the world genera of Tenuipalpidae Berlese (Acari: Tetranychoidae). PhD Dissertation, University of Maryland, pp. 429.
- Scotland, R.W., Pennington, R.T. 2000. Homology in systematics: coding characters for phylogenetic analysis. London: Taylor and Francis, pp. 217.
- Seeman, O.D., Beard J.J. 2011. A new species of *Aegyptobia* (Acari: Tenuipalpidae) from Myrtaceae in Australia. Systematic and Applied Acarology, 16: 73–89.
- Walter, D.E., Lindquist E.E., Smith I.M., Cook D.R., Krantz G.W. 2009. Order Trombidiformes. In: Krantz G.W., Walter D.E. (Eds). A manual of Acarology. 3 ed.; Lubbock: Texas Tech University Press, pp. 233–420.
- Wiley, E.O., Lieberman, B.S. 2011. Phylogenetics: Theory and Practice of Phylogenetic Systematics 2 ed., Hoboken: Wiley-Blackwell, pp. 432.
- Xu, Y., Fan, Q.-H. 2010. *Tenuipalpus orilloi* Rimando, a new record to the Chinese fauna (Acari: Tenuipalpidae). Systematic and Applied Acarology, 15(2): 135–138.
- Xu, Y., Fan, Q.-H., Zhang, Z.-Q. 2013. A new species of *Ultratenuipalpus* (Acari: Tenuipalpidae) from Cook Islands, with a key to the known species. Zootaxa, 3731(2): 223–233.
- Xu, Y., Zhang, Z.-Q., 2014. *Tenuipalpus mansonculus* (Acari: Tenuipalpidae) of Australia: redescription of the holotype. Systematic and Applied Acarology, 19(3): 322–328.

Table 1. Species included in the phylogeny; * = type specimens examined; ** = data were taken from literature.

1. <i>Ultratenuipalpus avarua</i> Xu, Fan and Zhang, 2013 ** (data taken from Xu <i>et al.</i> 2013)
2. <i>Ultratenuipalpus</i> sp. <i>Tenuipalpus</i> Donnadieu, 1876 - sensu stricto group
3. <i>Tenuipalpus anacardii</i> De Leon, 1965 * (MCZ holotype)
4. <i>Tenuipalpus bakeri</i> McGregor, 1949 * (NMNH holotype)
5. <i>Tenuipalpus boyani</i> De Leon, 1965 * (MCZ paratype)
6. <i>Tenuipalpus caudatus</i> (Dugès, 1834) ** (data taken from Castro <i>et al.</i> 2016a)
7. <i>Tenuipalpus coccolobicoloides</i> De Leon, 1965 * (NMNH paratype)
8. <i>Tenuipalpus coyacus</i> De Leon, 1957 * (NMNH paratype)
9. <i>Tenuipalpus eugeniae</i> De Leon, 1965 * (MCZ paratype)
10. <i>Tenuipalpus herbei</i> Kane, Castro and Ochoa, 2016 * (NMNH)
11. <i>Tenuipalpus latiseta</i> Aranda, 1976 * (DEES paratype)
12. <i>Tenuipalpus lucumae</i> De Leon, 1957 * (MCZ paratype)
13. <i>Tenuipalpus sandyi</i> De Leon, 1965 * (MCZ paratype)
14. <i>Tenuipalpus spinosaurus</i> Castro, Feres and Ochoa, 2016 * (DZSJRP)
15. <i>Tenuipalpus tuttlei</i> Ochoa, 1988 * (NMNH holotype)
16. <i>Tenuipalpus victoriae</i> De Leon, 1967 * (MCZ holotype) <i>Tenuipalpus</i> Donnadieu, 1876 - sensu lato group
17. <i>Tenuipalpus annonae</i> De Leon, 1957 * (NMNH paratype)
18. <i>Tenuipalpus anoplus</i> Baker and Pritchard, 1953 * (NMNH paratype)
19. <i>Tenuipalpus apichai</i> Castro and Feres, 2013 * (DZSJRP holotype)
20. <i>Tenuipalpus ariauae</i> Feres and Hernandez, 2006 * (DZSJRP holotype)
21. <i>Tenuipalpus carlosflechtmanni</i> Feres and Hernandez, 2006 * (DZSJRP holotype)

Continued

Continued

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22. *Tenuipalpus cedrelae* De Leon, 1957 * (NMNH paratype)
23. *Tenuipalpus isabelae* Mesa, Moraes and Ochoa, 2006 * (DEES paratype)
24. *Tenuipalpus flechtmanni* Mesa, Moraes and Ochoa, 2006 * (DEES paratype)
25. *Tenuipalpus heveae* Baker, 1945 * (NMNH, DZSJRP holotype and paratypes)
26. *Tenuipalpus moraesi* Feres and Hernandez, 2006 * (DZSJRP holotype)
27. *Tenuipalpus orchidofilo* Moraes and Freire, 2001 * (DEES paratype)
28. *Tenuipalpus pagesae* Rimando, 1962 * (NMNH paratype)
29. *Tenuipalpus tapiae* Castro and Feres, 2013 * (DZSJRP holotype)
30. *Tenuipalpus* sp.
- Colopalpus* Pritchard and Baker, 1958
31. *Colopalpus mansonculus* Ghai and Shenhmar, 1985 ** (data taken from Xu and Zhang 2014)
32. *Colopalpus matthyssei* Pritchard and Baker, 1958 * (NMNH holotype)
33. *Colopalpus nambii* (Castro and Feres, 2013) * (DZSJRP holotype)
34. *Colopalpus pedrus* Manson, 1963 * (NMNH paratypes)
35. *Colopalpus zahirii* (Khanjani and Seeman, 1985) ** (data taken from Khanjani et al. 2013)
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Figures

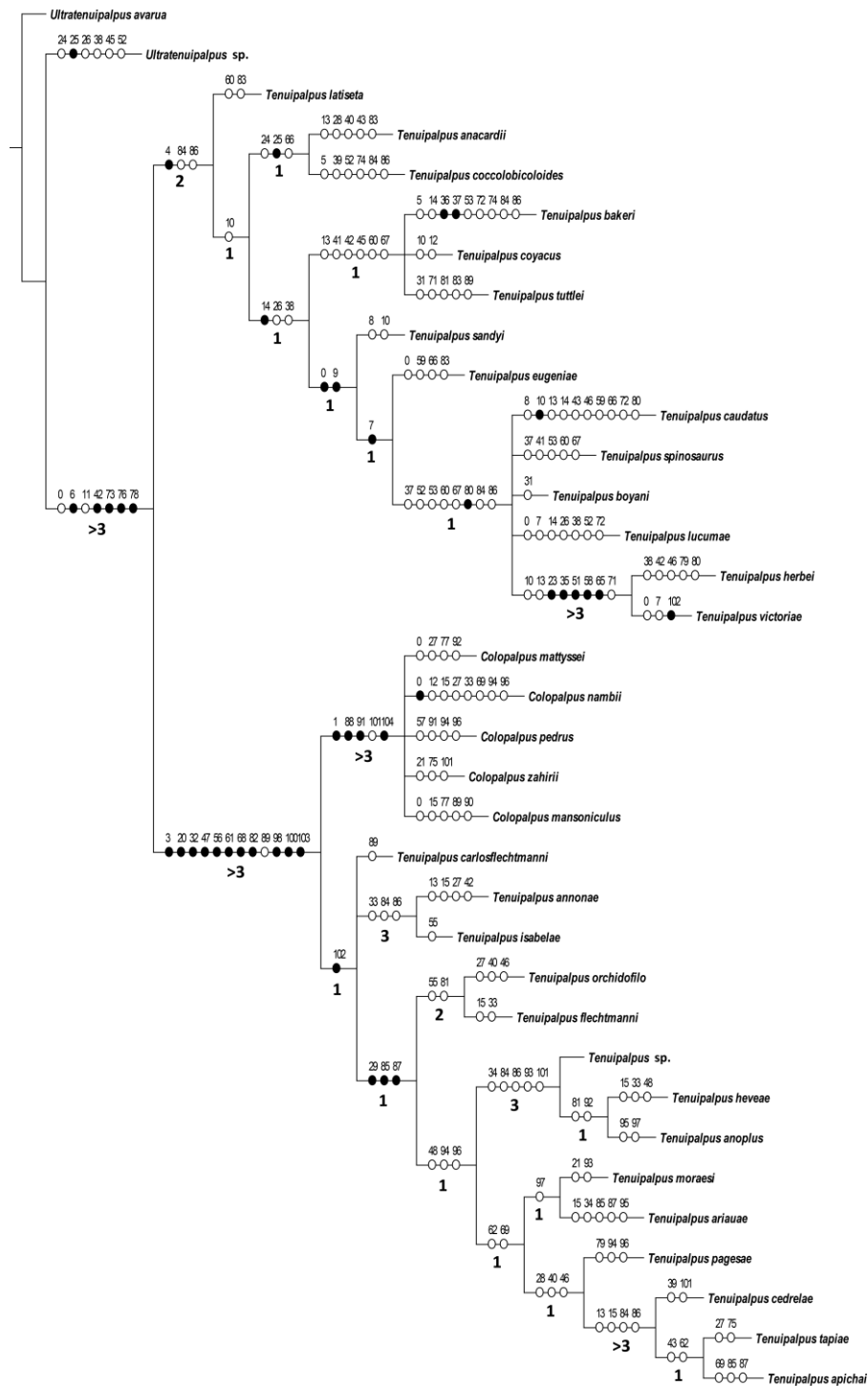


Figure 1. Hypothesis of phylogeny for the genera *Tenuipalpus* Donnadieu (sensu stricto e sensu lato groups) and *Colopalpus* Pritchard and Baker

(Acari, Tenuipalpidae) (L = 284, CI = 41, RI = 69). Numbers above circles are characters; below branches are Bremer branch support indexes; black circles are non homoplasious characters; white circles are characters with homoplasy.

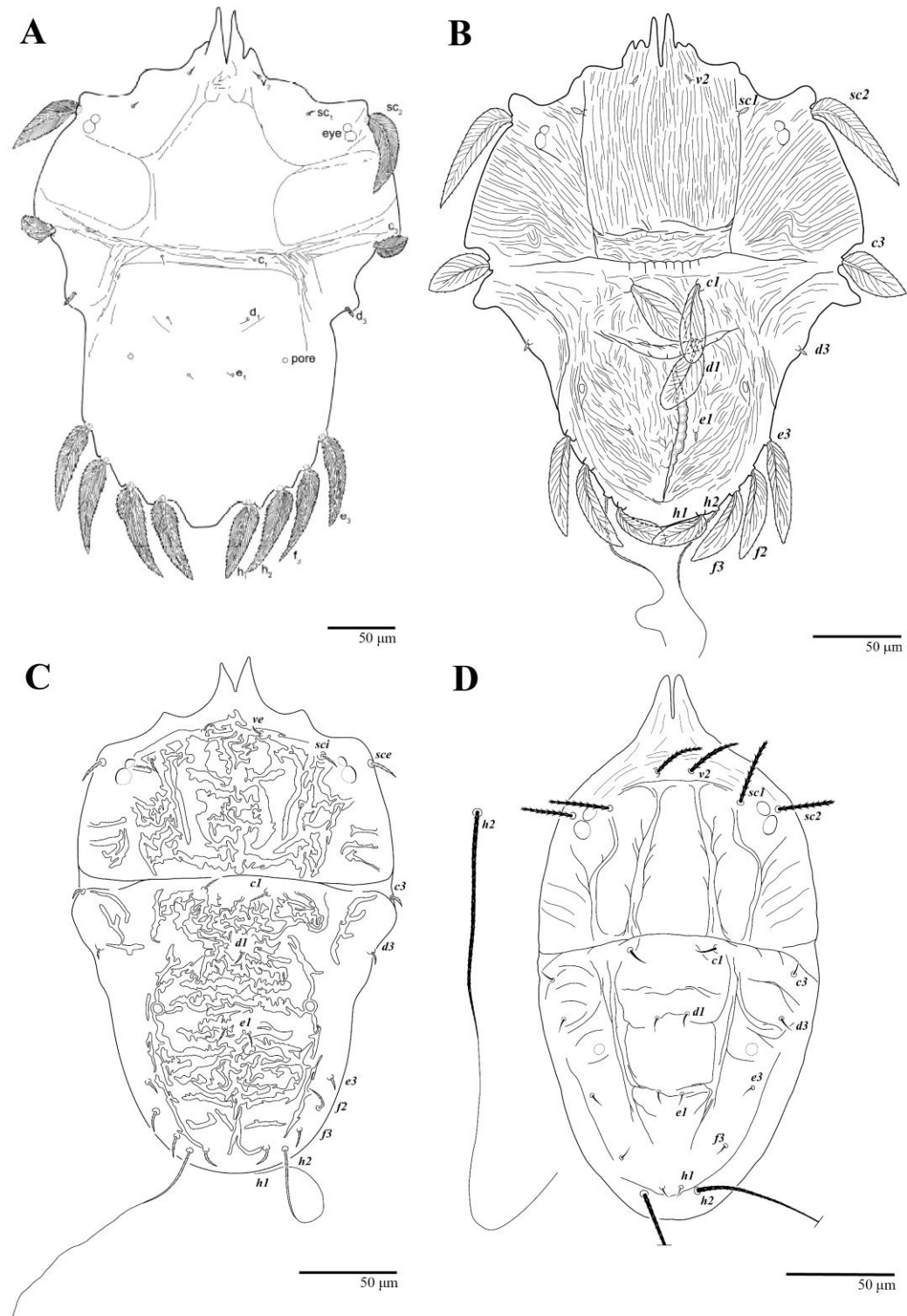


Figure 2. Outgroup: **A.** *Ultratenuipalpus avarua* Xu, Fan and Zhang (after Xu *et al.* 2013): note setae *h2* not flagelliform and body projection between setae *h1*. Ingroup: **B.** *Tenuipalpus caudatus* (Dugès), (after Castro *et al.*

2016a): species of *T. sensu stricto* group; note the presence of lateral body projections associated with setae *c3*. **C.** *Tenuipalpus apichai* Castro and Feres (after Castro and Feres 2013): species of *T. sensu lato* group; note the absence of lateral body projection associated with setae *c3*; **D.** *Colopalpus matthyssei* Pritchard and Baker (after Castro *et al.* 2015); note the elongate-ovate body shape.

CONCLUSION

A considered advance about the taxonomic and systematic knowledge of the genera *Tenuipalpus* and *Colopalpus* was presented in this study. These results contribute for a more natural classification of this Tenuipalpidae group. Furthermore, the advances presented here also will allow the better comparison of potential new species with previously known taxa, and this decreasing the chance of creating synonyms.

The results supported the division of the genus *Tenuipalpus* into two groups: *T. sensu stricto*, which is well supported by presence of a pair of lateral projections associated with setae c3, considered a synapomorphy for this group; and a largest group, *T. sensu lato*, which comprises more than 250 known species, and still includes several morphologically dissimilar species. The identification of novel morphological characters will be useful for establishing a more natural classification for this last group.

The results also indicate that *Colopalpus* is a valid genus of Tenuipalpidae, and that characteristics present in females and males are important for the diagnosis of the species. Furthermore, it might be necessary the transference of species included in *Tenuipalpus sensu lato* group to *Colopalpus*. In this case, the study of type specimens is highly recommended, due to descriptions and illustrations with insufficient details (e.g. positions of leg setae).

Finally, studies about the ontogenetic development of leg setae in Tenuipalpidae are recent and limited just a few species. The knowledge of this characteristic for more taxa will allow a better understanding about possible ontogenetic patterns in the development of leg setae within of Tenuipalpidae. The identification of patterns of the development of leg setae may be useful in the separation of more robust groups in Tenuipalpidae (e.g. including these data in the phylogenetic analysis).

APPENDIX

Appendix A

Morphological characters used in the phylogenetic analysis

Gnathosoma

0. Palps: 5 segmented (trochanter, femur, genua, tibiae and tarsus separated) (0); 4 segmented (trochanter + (femora and genua fused) + tibiae + tarsus) (1); 3 segmented (trochanter + (femur, genua and tibiae fused) + tarsus) (2); 2 segmented (trochanter, femur, genua, and tibiae fused) + tarsus (3); 2 segmented (trochanter + (tarsus, femora, genua and tibiae fused)) (4); 1 segmented (all segments fused) (5).

Body shape (characters 1 to 11)

1. Shape of the body: prodorsum wider than opisthosoma (0); elongate-ovate (1).

2. Shape of the body (when prodorsum wider than opisthosoma): lateral margins of prodorsum extended beyond margins of opisthosoma (0); lateral margins of prodorsum not extended beyond margins of opisthosoma (1).

3. Pair of lateral body projections associated with setae *sc2*: present (0); absent (1).

4. Pair of lateral body projections associated with setae *c3*: present (0); absent (1).

5. Position of setae *c3* associated with lateral body projections: inserted anterior to the projections (0); inserted on the projections (1).

6. Body projection between setae *h1*: present (0); absent (1).

7. Longitudinal crest on opisthosoma: present (0); absent (1).

8. Transverse crest on opisthosoma posterior to setae *e1*: present (0); absent (1).

9. Prodorsum with ridges from setae *sc1* to sejugal furrow: present (0); absent (1).

10. Anterior margin of prodorsum: with one paired triangular projection forming a notch between them (0); with 2 paired triangular projections forming a notch between them (1); with three paired median projections forming notch between them (2).

11. Genito-ventral plate: developed (0); weakly developed (as in *Tenuipalpus*) (1); not developed (as in *Ultratenuipalpus* and Tetranychidae) (2).

Dorsal setae (characters 12 to 73)

12. Length of setae v2 (when not strongly barbed): minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).

13. Shape of setae v2 setiform (when minute): smooth (0); barbed (1).

14. Setae sc1 setiforme: present (0); absent (1).

15. Length of setae sc1 (when not strongly barbed): minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).

16. Shape of setae sc1 setiform (when minute): smooth (0); barbed (1).

17. Shape of setae sc1 setiform (when short): smooth (0); barbed (1).

18. Base of setae sc1 (when not setiform): cuneate or attenuate (0); obtuse (1); rounded (2).

19. Tip of setae sc1 (when not setiform): acute (0); obtuse (1); rounded (2).

20. Setae sc2 setiform: present (0); absent (1).

21. Length of setae sc2 (when not long and strongly barbed): minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).

22. Shape of setae sc2 setiform (when short): smooth (0); barbed (1).

23. Shape of setae sc2 (when not setiform): broadly falcate (0); narrowly falcate (1).

24. Tip of setae sc2 (when broadly falcate): acute (0); obtuse (1); rounded (2).

25. Internal region of setae sc2 (when broadly falcate): concave (0); convex (1); linear (2).

26. **Setae c1 setiform:** present (0); absent (1).
27. **Length of setae c1 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
28. **Shape of setae c1 setiform (when minute):** smooth (0); barbed (1).
29. **Shape of setae c1 setiform (when short):** smooth (0); barbed (1).
30. **Base of setae c1 (when not setiform):** cuneate or attenuate (0); obtuse (1); rounded (2).
31. **Tip of setae c1 (when not setiform):** acute (0); obtuse (1); rounded (2).
32. **Setae c3 setiforme:** present (0); absent (1).
33. **Length of setae c3 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
34. **Shape of setae c3 setiform (when minute):** smooth (0); barbed (1).
35. **Shape of setae c3 (when not setiform):** broad (0); narrow (1).
36. **Base of setae c3 (when broad):** cuneate or attenuate (0); obtuse (1); rounded (2).
37. **Tip of setae c3 (when broad):** acute (0); obtuse (1); rounded (2); truncate (3).
38. **Setae d1 setiform:** present (0); absent (1).
39. **Length of setae d1 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
40. **Shape of setae d1 setiform (when minute):** smooth (0); barbed (1).
41. **Base of setae d1 (when broad):** cuneate or attenuate (0); obtuse (1); rounded (2).
42. **Length of setae d3 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
43. **Shape of setae d3 setiform (when minute):** smooth (0); barbed (1).
44. **Shape of setae d3 setiform (when short):** smooth (0); barbed (1).
45. **Setae e1 setiform:** present (0); absent (1).
46. **Shape of setae e1 setiform (when minute):** smooth (0); barbed (1).
47. **Setae e3 setiform:** (0) present; (1) absent.
48. **Length of setae e3 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
49. **Shape of setae e3 setiform (when minute):** smooth (0); barbed (1).
50. **Shape of setae e3 setiform (when short):** smooth (0); barbed (1).
51. **Shape of setae e3 (when not setiform):** broad (0); narrow (1).

- 52. Base of setae e3 (when broad):** cuneate or attenuate (0); obtuse (1); rounded (2).
- 53. Tip of setae e3 (when broad):** acute (0); obtuse (1); rounded (2).
- 54. Position of setae e3:** inserted on lateral position (0); inserted mesad lateral margin (1).
- 55. Setae f2:** (0) present; (1) absent;
- 56. Setae f2 setiform:** (0) present; (1) absent.
- 57. Length of setae f2 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
- 58. Shape of setae f2 (when not setiform):** broad (0); narrow (1).
- 59. Base of setae f2 (when broad):** cuneate or attenuate (0); obtuse (1); rounded (2).
- 60. Tip of setae f2 (when broad):** acute (0); obtuse (1); rounded (2).
- 61. Setae f3 setiform:** present (0); absent (1).
- 62. Length of setae f3 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
- 63. Shape of setae f3 setiform (when minute):** smooth (0); barbed (1).
- 64. Shape of setae f3 setiform (when short):** smooth (0); barbed (1).
- 65. Shape of setae f3 (when not setiform):** broad (0); narrow (1).
- 66. Base of setae f3 (when broad):** cuneate or attenuate (0); obtuse (1); rounded (2).
- 67. Tip of setae f3 (when broad):** acute (0); obtuse (1); rounded (2).
- 68. Setae h1 setiform:** present (0); absent (1).
- 69. Length of setae h1 setiform:** minute ($<10\ \mu\text{m}$) (0); short ($\geq 10\ \mu\text{m}$) (1).
- 70. Shape of setae h1 setiform (when minute):** smooth (0); barbed (1).
- 71. Shape of setae h1 (when not setiform):** broad (0); narrow (1).
- 72. Tip of setae h1 (when broad):** acute (0); obtuse (1); rounded (2).
- 73. Setae h2 setiform:** present (0); absent (1).

Ventral setae (character 74 to 79)

- 74. Pair of setae 3a2:** present (0); absent (1).
- 75. Pair of setae 4a2:** present (0); absent (1).
- 76. Pair of setae ps3:** present (0); absent (1).

77. Length of setae **4a1**: short (0); elongate and flagelliform (1).
78. Position of setae **g1**: same level to setae **g2** (0); posterior to setae **g2** (1).
79. Setae **ag**, **g1** and **g2**: smooth (0); barbed (1).

Leg chaetotaxy (characters 80 to 97)

80. Position of setae **4b**: usual (0); unusual, closer to setae **4a** (1).
81. Setae **l'** on trochanter III: present (0); absent (1).
82. Position of setae **d** on femora I and II: lateral (0); dorsal (1).
83. Setae **ev'** on femora IV: present (0); absent (1).
84. Setae **l'** on genua I: present (0); absent (1).
85. Setae **l''** on genua I: present (0); absent (1).
86. Setae **l'** on genua II: present (0); absent (1).
87. Setae **l''** on genua II: present (0); absent (1).
88. Position of setae **d** on genua I and II: (0) lateral; (1) dorsal.
89. Setae **d** on genua III: present (0); absent (1).
90. Setae **d** on genua IV: present (0); absent (1).
91. Position of setae **d** on tibia I and II: lateral (0); dorsal (1).
92. Setae **d** on tibia III: present (0); absent (1).
93. Setae **d** on tibia IV: present (0); absent (1).
94. Setae **tc'** on tarso III: present (0); absent (1).
95. Setae **tc''** on tarso III: present (0); absent (1).
96. Setae **tc'** on tarso IV: present (0); absent (1).
97. Setae **tc''** on tarso IV: present (0); absent (1).

Others

98. Most leg setae inserted on tubercles: present (0); absent (1).
99. Lateral ventral region of prodorsum and opisthosoma: ornamented (0); smooth (1).
100. Lateral ventral region of prodorsum and opisthosoma (when ornamented): colliculate (0); striate (1).

- 101. Region between 3a and 4a:** ornamented (0); smooth (1).
- 102. Region between 3a and 4a (when ornamented):** with transverse striae (0); with longitudinal striae (1); with small punctuations (2).
- 103. Immatures with projections anterior to the sc2 setae:** present (0); absent (1).
- 104. Male with opisthosoma strongly narrowed after the level of setae d3:** present (0); absent (1).

Appendix B

Character matrix for the *Tenuipalpus* and *Colopalpus* species (Acari: Tenuipalpidae).

Taxon	Char0	Char1	Char2	Char3	Char4	Char5	Char6	Char7	Char8	Char9	Char10	Char11	Char12	Char13	Char14	Char15	Char16	Char17	Char18	Char19	Char20
<i>U. sp. nov.</i>	1	0	0	0	1	-	0	1	1	1	0	2	0	0	0	0	0	-	-	-	1
<i>U. avarua</i>	1	0	0	0	1	-	0	1	1	1	1	2	0	0	0	0	0	-	-	-	1
<i>T. anacardii</i>	2	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	1	-	-	-	1
<i>T. bakeri</i>	2	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	1	-	-	-	1
<i>T. boyani</i>	-	0	0	0	0	0	1	0	1	0	1	1	0	0	1	-	-	-	1	1	1
<i>T. caudatus</i>	3	0	0	0	0	0	1	0	0	0	2	1	0	1	0	0	1	-	-	-	1
<i>T. coccolobicoloides</i>	2	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	-	-	-	1
<i>T. coyacus</i>	2	0	0	0	0	0	1	1	1	1	0	1	1	-	1	-	-	-	0	0	1
<i>T. eugeniae</i>	4	0	0	0	0	0	1	0	1	0	1	1	0	0	1	-	-	-	1	1	1
<i>T. herbei</i>	3	0	0	0	0	0	1	0	1	0	0	1	0	1	1	-	-	-	1	1	1
<i>T. latiseta</i>	2	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	0	-	-	-	1
<i>T. lucumae</i>	4	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	1	-	-	-	1
<i>T. sandyi</i>	3	0	0	0	0	0	1	1	0	0	0	1	0	0	1	-	-	-	1	1	1
<i>T. spinosaurus</i>	3	0	0	0	0	0	1	0	1	0	1	1	0	0	1	-	-	-	1	1	1
<i>T. tuttlei</i>	2	0	0	0	0	0	1	1	1	1	1	1	0	1	1	-	-	-	0	0	1
<i>T. victoriae</i>	2	0	0	0	0	0	1	1	1	0	0	1	0	1	1	-	-	-	1	1	1
<i>T. annonae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	1	0	1	-	1	-	-	0
<i>T. anoplus</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0
<i>T. apichai</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	1	0	1	-	1	-	-	0
<i>T. arianae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	1	-	1	-	-	0
<i>T. carlosflehtmanni</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0
<i>T. cedrelae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	1	0	1	-	1	-	-	0
<i>T. flehtmanni</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	1	-	1	-	-	0
<i>T. heveae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	1	-	1	-	-	0
<i>T. isabelae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0
<i>T. moraesii</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0
<i>T. orchidofilo</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0
<i>T. pagesae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	1	-	-	-	0
<i>T. tapiae</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	1	0	1	-	1	-	-	0
<i>T. sp. nov.</i>	2	0	1	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0
<i>C. mansoniculus</i>	4	1	-	1	1	-	1	1	1	1	0	1	0	0	0	1	-	0	-	-	0
<i>C. mattyssei</i>	4	1	-	1	1	-	1	1	1	1	0	0	-	-	0	-	-	-	-	-	0
<i>C. nambii</i>	5	1	-	1	1	-	1	1	1	1	0	0	1	-	0	1	-	0	-	-	0
<i>C. pedrus</i>	2	1	-	1	1	-	1	1	1	1	0	0	0	0	0	0	0	-	-	-	0
<i>C. zahirii</i>	2	1	-	1	1	-	1	1	1	1	0	1	0	0	0	0	0	-	-	-	0

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Taxon	Char21	Char22	Char23	Char24	Char25	Char26	Char27	Char28	Char29	Char30	Char31	Char32	Char33	Char34	Char35	Char36	Char37	Char38	Char39	Char40
<i>U. sp. nov.</i>	-	-	0	1	2	1	-	-	-	0	2	1	-	-	0	2	2	1	-	-
<i>U. avarua</i>	-	-	0	0	1	0	0	0	-	-	-	1	-	-	0	1	0	0	0	0
<i>T. anacardii</i>	-	-	0	1	0	0	0	1	-	-	-	1	-	-	0	1	1	0	0	1
<i>T. bakeri</i>	-	-	0	0	1	1	-	-	-	1	1	1	-	-	0	0	3	1	-	-
<i>T. boyani</i>	-	-	0	0	1	1	-	-	-	0	0	1	-	-	0	1	0	1	-	-
<i>T. caudatus</i>	-	-	0	0	1	1	-	-	-	0	1	1	-	-	0	1	0	1	-	-
<i>T. coccolobicoloides</i>	-	-	0	1	0	0	0	0	-	-	-	1	-	-	0	1	1	0	1	0
<i>T. coyacus</i>	-	-	0	0	1	1	-	-	-	1	1	1	-	-	0	1	1	1	-	-
<i>T. eugeniae</i>	-	-	0	0	1	1	-	-	-	0	1	1	-	-	0	1	1	1	-	-
<i>T. herbei</i>	-	-	1	-	-	1	-	-	-	-	-	1	-	-	1	-	-	0	1	-
<i>T. latifolia</i>	-	-	0	0	1	0	0	0	-	-	-	1	-	-	0	2	1	0	0	0
<i>T. lucumae</i>	-	-	0	0	1	0	0	0	-	-	-	1	-	-	0	1	0	0	0	0
<i>T. sandyi</i>	-	-	0	0	1	1	-	-	-	0	1	1	-	-	0	1	1	1	-	-
<i>T. spinosaurus</i>	-	-	0	0	1	1	-	-	-	0	1	1	-	-	0	1	1	1	-	-
<i>T. tuttlei</i>	-	-	0	0	1	1	-	-	-	0	0	1	-	-	0	1	1	1	-	-
<i>T. victoriae</i>	-	-	1	-	1	1	-	-	-	0	1	1	-	-	1	-	-	1	-	-
<i>T. annonae</i>	1	1	-	-	-	0	1	-	0	-	-	0	1	-	-	-	-	-	-	-
<i>T. anoplus</i>	1	1	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0
<i>T. apichai</i>	1	1	-	-	-	0	0	1	-	-	-	0	0	1	-	-	-	0	0	1
<i>T. ariauae</i>	1	1	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0
<i>T. carlosflehtmanni</i>	1	1	-	-	-	0	0	0	-	-	-	0	0	1	-	-	-	0	0	0
<i>T. cedrelae</i>	1	1	-	-	-	0	0	1	-	-	-	0	0	1	-	-	-	0	1	-
<i>T. flehtmanni</i>	1	1	-	-	-	0	0	0	-	-	-	0	1	-	-	-	-	0	0	0
<i>T. heveae</i>	1	1	-	-	-	0	0	0	-	-	-	0	1	-	-	-	-	0	0	0
<i>T. isabelae</i>	1	1	-	-	-	0	0	0	-	-	-	0	1	-	-	-	-	-	-	-
<i>T. moraei</i>	0	-	-	-	-	0	0	0	-	-	-	0	0	1	-	-	-	0	0	0
<i>T. orchidifilo</i>	1	1	-	-	-	0	1	-	1	-	-	0	0	1	-	-	-	0	0	1
<i>T. pagesae</i>	1	1	-	-	-	0	0	1	-	-	-	0	0	1	-	-	-	0	0	1
<i>T. tapiae</i>	1	1	-	-	-	0	1	-	1	-	-	0	0	1	-	-	-	0	0	1
<i>T. sp. nov.</i>	1	1	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0
<i>C. mansoniculus</i>	1	0	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0
<i>C. mattyssei</i>	-	-	-	-	-	0	1	-	0	-	-	0	0	0	-	-	-	0	0	0
<i>C. nambii</i>	1	0	-	-	-	0	1	-	0	-	-	0	1	-	-	-	-	0	0	0
<i>C. pedrus</i>	1	1	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0
<i>C. zahirii</i>	0	-	-	-	-	0	0	0	-	-	-	0	0	0	-	-	-	0	0	0

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Taxon	Char41	Char42	Char43	Char44	Char45	Char46	Char47	Char48	Char49	Char50	Char51	Char52	Char53	Char54	Char55	Char56	Char57	Char58	Char59	Char60
<i>U. sp. nov.</i>	0	1	-	0	1	-	1	-	-	-	0	0	1	0	0	1	-	0	1	1
<i>U. avarua</i>	-	1	-	1	0	0	1	-	-	-	0	1	0	0	1	-	-	-	-	-
<i>T. anacardii</i>	-	0	1	-	0	0	1	-	-	-	0	1	1	0	0	1	-	0	1	1
<i>T. bakeri</i>	1	1	-	1	1	-	1	-	-	-	0	1	0	0	0	1	-	0	1	0
<i>T. boyani</i>	0	0	0	-	0	0	1	-	-	-	0	0	0	0	0	1	-	0	1	0
<i>T. caudatus</i>	0	0	1	-	0	1	1	-	-	-	0	0	0	0	0	1	-	0	0	0
<i>T. coccolobicoloides</i>	-	0	0	-	0	0	1	-	-	-	0	0	1	0	0	1	-	0	1	1
<i>T. coyacus</i>	1	1	-	1	1	-	1	-	-	-	0	1	1	1	0	1	-	0	1	0
<i>T. eugeniae</i>	0	0	0	-	0	0	1	-	-	-	0	1	1	0	0	1	-	0	0	1
<i>T. herbei</i>	-	1	-	1	0	1	1	-	-	-	1	-	-	0	0	1	-	1	-	-
<i>T. latisetia</i>	-	0	0	-	0	0	1	-	-	-	0	1	0	0	0	1	-	0	1	0
<i>T. lucumae</i>	-	0	0	-	0	0	1	-	-	-	0	1	0	0	0	1	-	0	1	0
<i>T. sandyi</i>	0	0	0	-	0	0	1	-	-	-	0	1	1	0	0	1	-	0	1	1
<i>T. spinosaurus</i>	1	0	0	-	0	0	1	-	-	-	0	0	1	0	0	1	-	0	1	1
<i>T. tuttlei</i>	1	1	-	1	1	-	1	-	-	-	0	1	1	1	0	1	-	0	1	0
<i>T. victoriae</i>	1	0	1	-	0	0	1	-	-	-	1	-	-	0	0	1	-	1	-	-
<i>T. annonae</i>	-	1	-	0	0	-	0	1	-	1	-	-	-	0	0	0	1	-	-	-
<i>T. anoplus</i>	-	0	0	-	0	0	0	0	0	-	-	-	-	0	0	0	1	-	-	-
<i>T. apichai</i>	-	0	1	-	0	1	0	0	1	-	-	-	-	0	0	0	1	-	-	-
<i>T. ariauae</i>	-	0	0	-	0	0	0	0	1	-	-	-	-	0	0	0	0	-	-	-
<i>T. carlosflehtmanni</i>	-	0	0	-	0	0	0	1	-	1	-	-	-	0	0	0	1	-	-	-
<i>T. cedrelae</i>	-	0	0	-	0	1	0	0	1	-	-	-	-	0	0	0	1	-	-	-
<i>T. flehtmanni</i>	-	0	0	-	0	0	0	1	-	1	-	-	-	0	1	-	-	-	-	-
<i>T. heveae</i>	-	0	0	-	0	0	0	1	-	1	-	-	-	0	0	0	1	-	-	-
<i>T. isabelae</i>	-	0	0	-	-	-	0	1	-	1	-	-	-	0	1	-	-	-	-	-
<i>T. moraesi</i>	-	0	0	-	0	0	0	0	1	-	-	-	-	0	0	0	0	-	-	-
<i>T. orchidofilo</i>	-	0	0	-	0	1	0	1	-	1	-	-	-	0	1	-	-	-	-	-
<i>T. pagesae</i>	-	0	0	-	0	1	0	0	1	-	-	-	-	0	0	0	0	-	-	-
<i>T. tapiae</i>	-	0	1	-	0	1	0	0	1	-	-	-	-	0	0	0	0	-	-	-
<i>T. sp. nov.</i>	-	0	0	-	0	0	0	0	1	-	-	-	-	0	0	0	1	-	-	-
<i>C. mansonculus</i>	-	0	0	-	0	0	0	1	-	0	-	-	-	0	1	-	-	-	-	-
<i>C. mattyssei</i>	-	0	0	-	0	0	0	0	0	-	-	-	-	0	1	-	-	-	-	-
<i>C. nambii</i>	-	0	0	-	0	0	0	1	-	0	-	-	-	0	0	0	1	-	-	-
<i>C. pedrus</i>	-	0	0	-	0	0	0	0	0	-	-	-	-	0	0	0	0	-	-	-
<i>C. zahirii</i>	-	0	0	-	0	0	0	0	0	-	-	-	-	0	1	-	-	-	-	-

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Taxon	Char61	Char62	Char63	Char64	Char65	Char66	Char67	Char68	Char69	Char70	Char71	Char72	Char73	Char74	Char75	Char76	Char77	Char78	Char79	Char80
<i>U. sp. nov.</i>	1	-	-	-	0	1	1	1	-	-	0	2	1	1	1	0	1	1	0	0
<i>U. avarua</i>	1	-	-	-	0	1	0	1	-	-	0	0	1	1	1	0	1	1	0	0
<i>T. anacardii</i>	1	-	-	-	0	0	1	1	-	-	0	1	0	1	1	1	1	0	0	0
<i>T. bakeri</i>	1	-	-	-	0	1	0	1	-	-	0	0	0	0	1	1	1	0	0	0
<i>T. boyani</i>	1	-	-	-	0	1	0	1	-	-	0	1	0	1	1	1	1	0	0	1
<i>T. caudatus</i>	1	-	-	-	0	0	0	1	-	-	0	0	0	1	1	1	1	0	0	0
<i>T. coccolobicoloides</i>	1	-	-	-	0	0	1	1	-	-	0	1	0	0	1	1	1	0	0	0
<i>T. coyacus</i>	1	-	-	-	0	1	0	1	-	-	0	1	0	1	1	1	1	0	0	0
<i>T. eugeniae</i>	1	-	-	-	0	0	1	1	-	-	0	1	0	1	1	1	1	0	0	0
<i>T. herbei</i>	1	-	-	-	1	-	-	1	-	-	1	-	0	1	1	1	1	0	1	0
<i>T. latiseta</i>	1	-	-	-	0	1	1	1	-	-	0	1	0	1	1	1	1	0	0	0
<i>T. lucumae</i>	1	-	-	-	0	1	0	1	-	-	0	0	0	1	1	1	1	0	0	1
<i>T. sandyi</i>	1	-	-	-	0	1	1	1	-	-	0	1	0	1	1	1	1	0	0	0
<i>T. spinosaurus</i>	1	-	-	-	0	1	1	1	-	-	0	1	0	1	1	1	1	0	0	1
<i>T. tuttlei</i>	1	-	-	-	0	1	0	1	-	-	1	1	0	1	1	1	1	0	0	0
<i>T. victoriae</i>	1	-	-	-	1	-	-	1	-	-	1	-	0	1	1	1	1	0	0	1
<i>T. annonae</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	0	1	1	0	0	0
<i>T. anoplus</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	1	1	1	0	0	0
<i>T. apichai</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	1	1	1	0	0	0
<i>T. ariauae</i>	0	0	1	-	-	-	-	0	0	1	-	-	0	1	1	1	1	0	0	0
<i>T. carlosflehtmanni</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	0	1	1	0	0	0
<i>T. cedrelae</i>	0	0	1	-	-	-	-	0	0	1	-	-	0	1	1	1	1	0	0	0
<i>T. flehtmanni</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	1	1	1	0	0	0
<i>T. heveae</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	1	1	1	0	1	0
<i>T. isabelae</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	0	1	1	0	0	0
<i>T. moraesii</i>	0	0	1	-	-	-	-	0	0	1	-	-	0	1	1	1	1	0	0	0
<i>T. orchidofilo</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	1	1	1	0	0	0
<i>T. pagesae</i>	0	0	1	-	-	-	-	0	0	1	-	-	0	1	1	1	1	0	1	0
<i>T. tapiae</i>	0	1	-	1	-	-	-	0	0	1	-	-	0	1	0	1	1	0	0	0
<i>T. sp. nov.</i>	0	1	-	1	-	-	-	0	1	-	-	-	0	1	1	1	1	0	1	0
<i>C. mansonculus</i>	0	1	-	0	-	-	-	0	0	0	-	-	0	1	1	1	0	0	0	0
<i>C. mattyssei</i>	0	0	0	-	-	-	-	0	0	0	-	-	0	1	1	1	0	0	0	0
<i>C. nambii</i>	0	1	-	0	-	-	-	0	1	-	-	-	0	1	1	1	1	0	0	0
<i>C. pedrus</i>	0	0	0	-	-	-	-	0	0	0	-	-	0	1	1	1	1	0	0	0
<i>C. zahirii</i>	0	0	0	-	-	-	-	0	0	0	-	-	0	1	0	1	1	0	0	0

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Taxon	Char81	Char82	Char83	Char84	Char85	Char86	Char87	Char88	Char89	Char90	Char91	Char92	Char93	Char94	Char95	Char96	Char97	Char98	Char99	Char100
<i>U. sp. nov.</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>U. avarua</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>T. anacardii</i>	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. bakeri</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. boyani</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. caudatus</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. coccolobicoloides</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. coyacus</i>	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. eugeniae</i>	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. herbei</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. latisetia</i>	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. lucumae</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. sandyi</i>	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. spinosaurus</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. tuttlei</i>	1	0	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
<i>T. victoriae</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>T. ammonae</i>	0	1	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1
<i>T. anoplus</i>	1	1	0	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1
<i>T. apichai</i>	0	1	0	1	0	1	0	0	1	1	0	0	0	1	0	1	0	1	0	1
<i>T. ariauae</i>	0	1	0	0	0	0	0	0	1	1	0	0	0	1	1	1	1	1	0	1
<i>T. carlosflehtmanni</i>	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1
<i>T. cedrelae</i>	0	1	0	1	1	1	1	0	1	1	0	0	0	1	0	1	0	1	0	1
<i>T. flehtmanni</i>	1	1	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1
<i>T. heveae</i>	1	1	0	1	1	1	1	0	1	1	0	1	1	1	0	1	0	1	0	1
<i>T. isabelae</i>	0	1	0	1	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1
<i>T. moraesii</i>	0	1	0	0	1	0	1	0	1	1	0	0	1	1	0	1	1	1	0	1
<i>T. orchidofilo</i>	1	1	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1
<i>T. pagesae</i>	0	1	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	1	0	1
<i>T. tapiae</i>	0	1	0	1	1	1	1	0	1	1	0	0	0	1	0	1	0	1	0	1
<i>T. sp. nov.</i>	0	1	0	1	1	1	1	0	1	1	0	0	1	1	0	1	0	1	0	1
<i>C. mansonculus</i>	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	1
<i>C. mattyssei</i>	0	1	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	1	1	-
<i>C. nambii</i>	0	1	0	0	0	0	0	1	1	1	1	0	0	1	0	1	0	1	1	-
<i>C. pedrus</i>	0	1	0	0	0	0	0	1	1	1	0	0	1	1	0	1	0	1	1	-
<i>C. zahirii</i>	0	1	0	0	0	0	0	1	1	1	1	0	1	0	0	0	0	1	0	1

Continued

Continued

Taxon	Char101	Char102	Char103	Char104
<i>U. sp. nov.</i>	0	0	0	0
<i>U. avarua</i>	0	0	?	0
<i>T. anacardii</i>	0	0	0	0
<i>T. bakeri</i>	0	0	?	0
<i>T. boyani</i>	0	0	0	0
<i>T. caudatus</i>	0	0	0	0
<i>T. coccolobicoloides</i>	0	0	0	0
<i>T. coyacus</i>	0	0	0	0
<i>T. eugeniae</i>	0	0	?	0
<i>T. herbei</i>	0	0	0	0
<i>T. latisetia</i>	0	0	0	0
<i>T. lucumae</i>	0	0	0	0
<i>T. sandyi</i>	0	0	0	0
<i>T. spinosaurus</i>	0	0	0	0
<i>T. tuttlei</i>	0	0	?	0
<i>T. victoriae</i>	0	2	0	0
<i>T. annonae</i>	0	1	?	0
<i>T. anoplus</i>	1	-	1	0
<i>T. apichai</i>	0	1	?	0
<i>T. ariauae</i>	0	1	1	0
<i>T. carlosflehtmanni</i>	0	1	?	0
<i>T. cedrelae</i>	1	-	1	0
<i>T. flehtmanni</i>	0	1	1	0
<i>T. heveae</i>	1	-	1	0
<i>T. isabelae</i>	0	1	1	0
<i>T. moraesi</i>	0	1	1	0
<i>T. orchidofilo</i>	0	1	1	0
<i>T. pagesae</i>	0	1	1	0
<i>T. tapiae</i>	0	1	1	0
<i>T. sp. nov.</i>	1	-	1	0
<i>C. mansonculus</i>	1	-	?	1
<i>C. mattyssei</i>	1	-	1	1
<i>C. nambii</i>	1	-	1	1
<i>C. pedrus</i>	1	-	-	1
<i>C. zahirii</i>	0	0	1	1

TERMO DE REPRODUÇÃO XEROGRÁFICA

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