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## 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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### 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.

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### 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 matthyseii*, 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<sup>1</sup>).

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 tristetosus* 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. chichlorum* 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).

*Priscapalpus 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. *Priscapalpus* 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*, *Gahnacarus*, *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**.

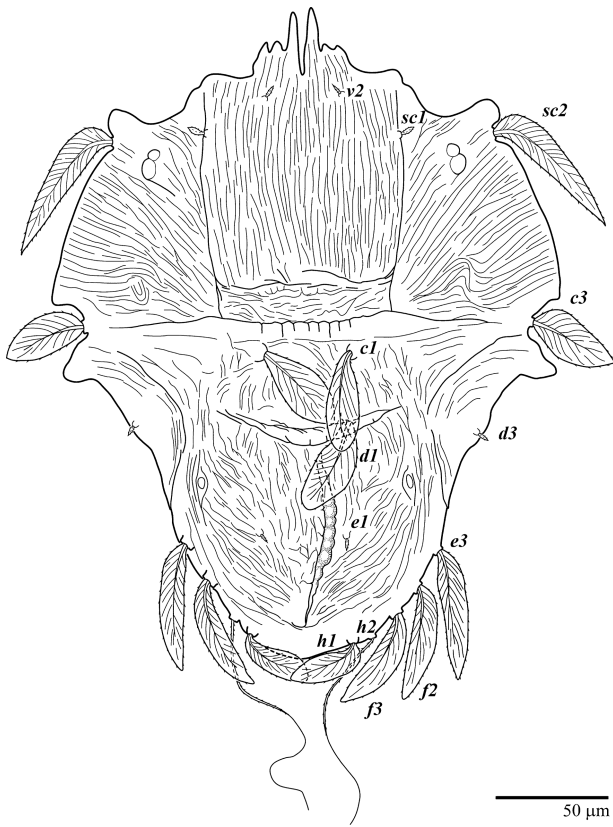
*Caligonus calyx* Canestrini & Fanzago, 1876: 134; Canestrini, 1890: 457 – **synonymy**.

## Redescription

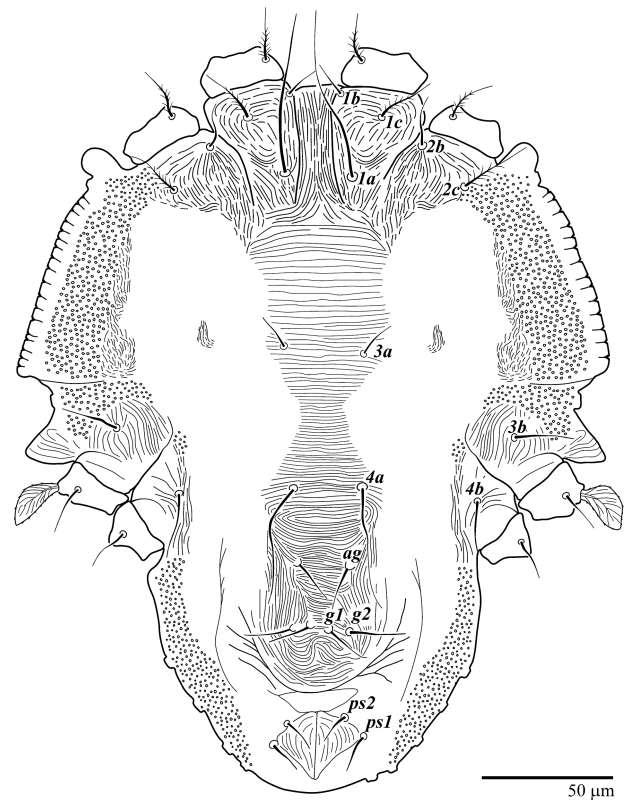
André (2011), Baker (1945), Baker and Pritchard (1953), Ehara and Masaki (2001), McGregor (1949).

## 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



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



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



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

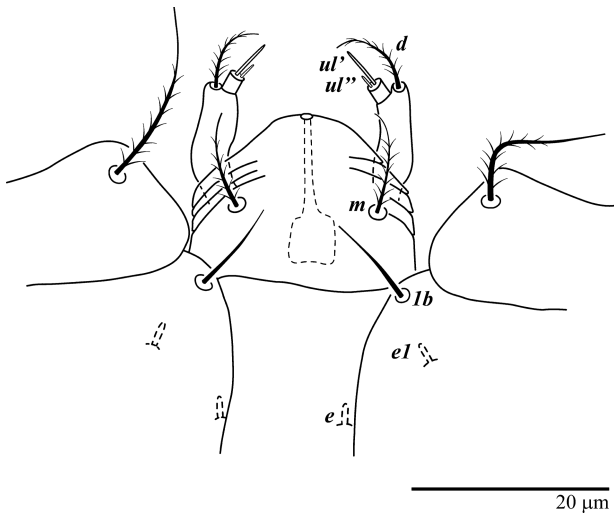


Figure 4. *Tenuipalpus caudatus* (Dugès) (female): hypostome.

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 ( $\omega'$  paraxial and ventrolateral;  $\omega''$  antiaxial); tarsus III with one solenidium  $\omega'$  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).

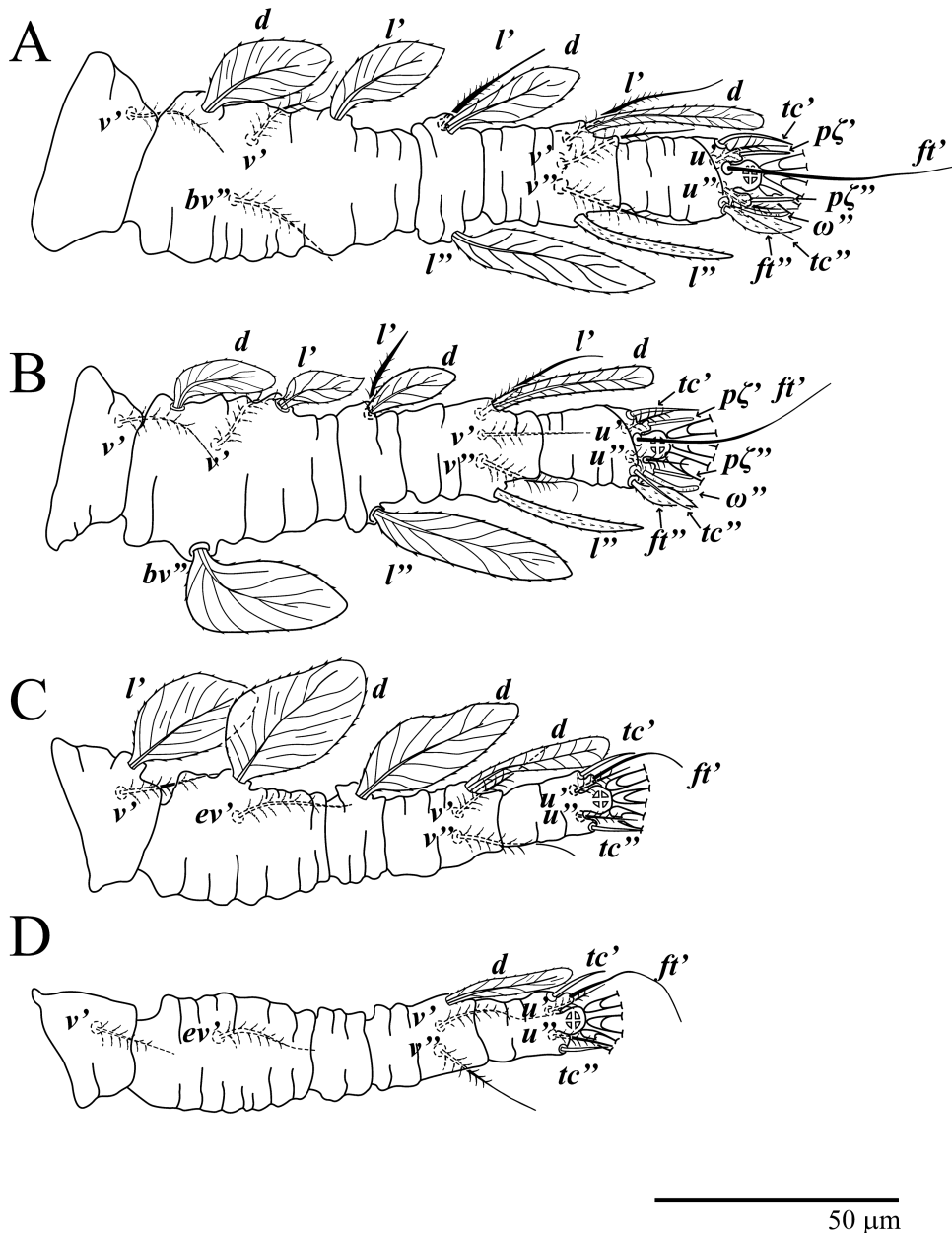


Figure 5. *Tenuipalpus caudatus* (Dugès) (female): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

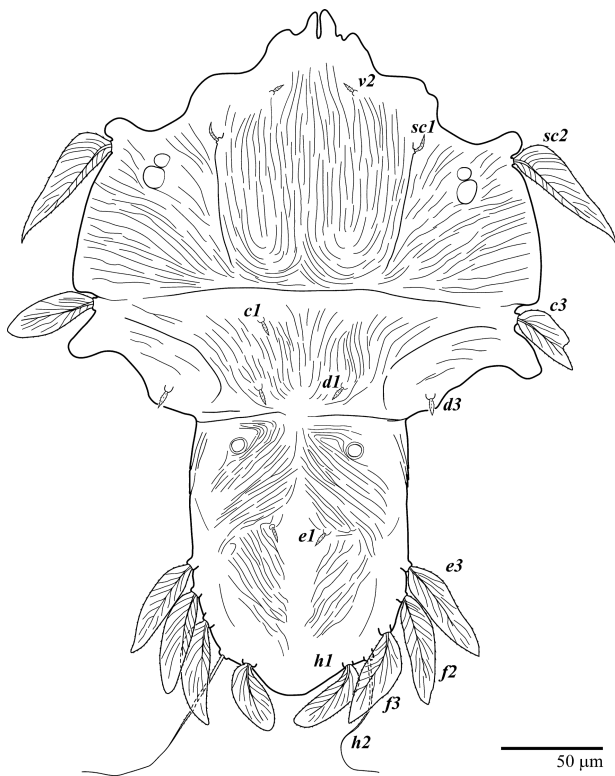


Figure 6. *Tenuipalpus caudatus* (Dugès) (male): dorsum.

#### 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.



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

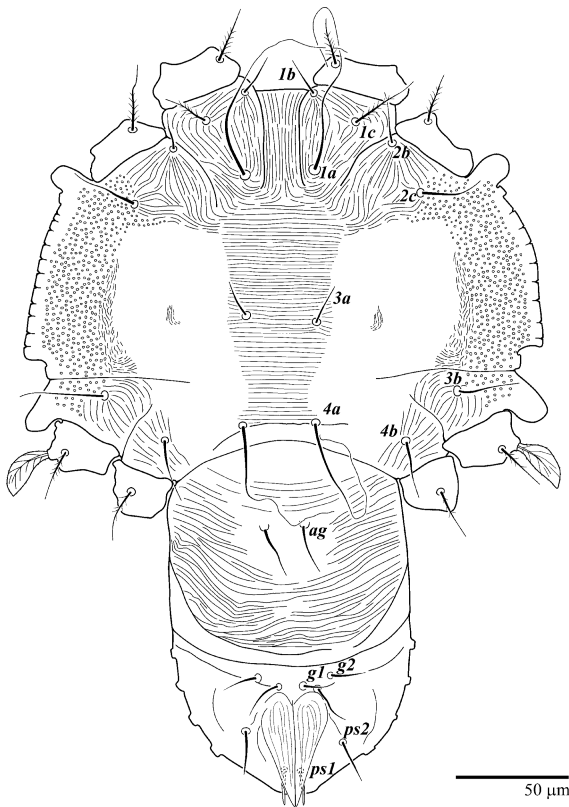


Figure 8. *Tenuipalpus caudatus* (Dugès) (male): venter. Note one aberrant additional seta *g* on right side of anal plate.

**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 ( $\omega''$ ) and two eupathidia  $p\zeta''-p\zeta'''$ ; 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

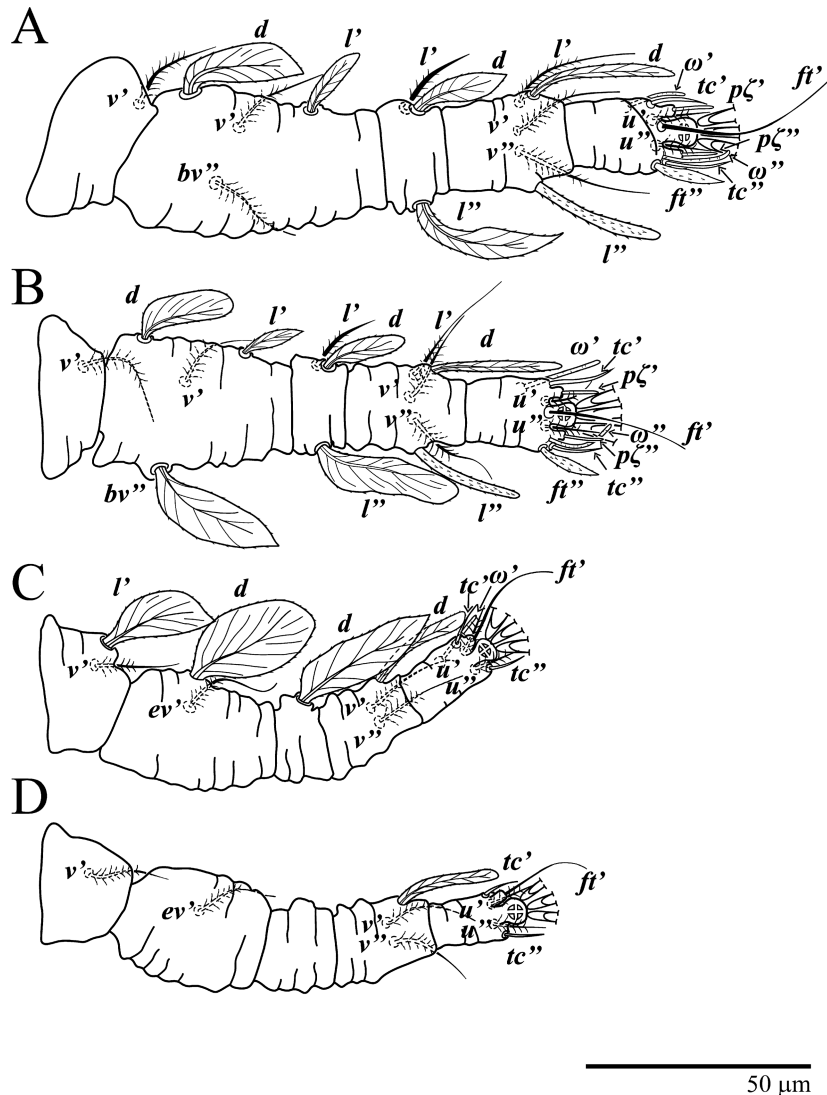


Figure 9. *Tenuipalpus caudatus* (Dugès) (male): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).



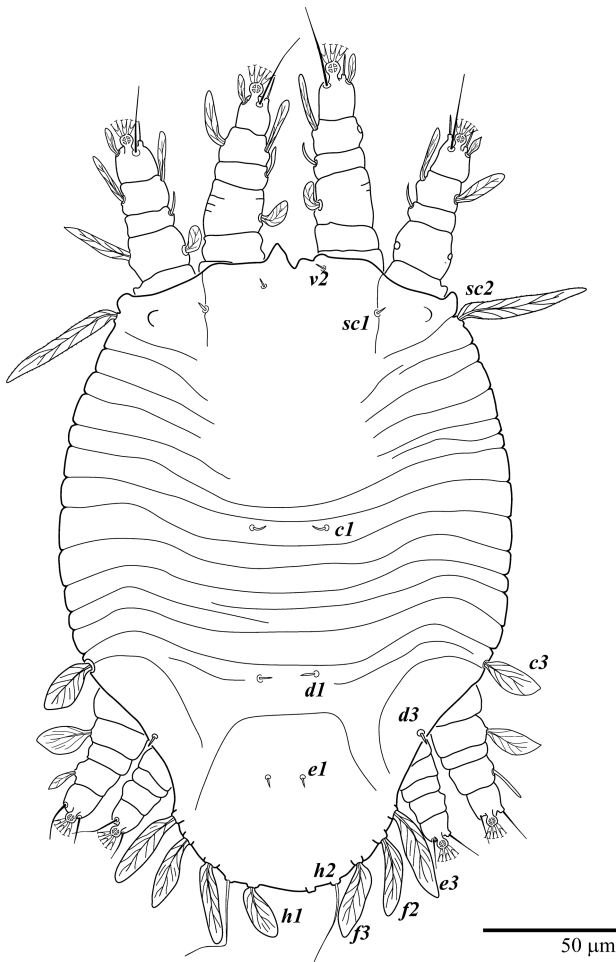


Figure 10. *Tenuipalpus caudatus* (Dugès) (protonymph): dorsum, with details of legs.

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 ( $\omega'$  paraxial, inserted ventrolaterally;  $\omega''$  antiaxial); other setae, and eupathidia, similar to those of female. Tarsus III with one antiaxial solenidium  $\omega'$ , 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

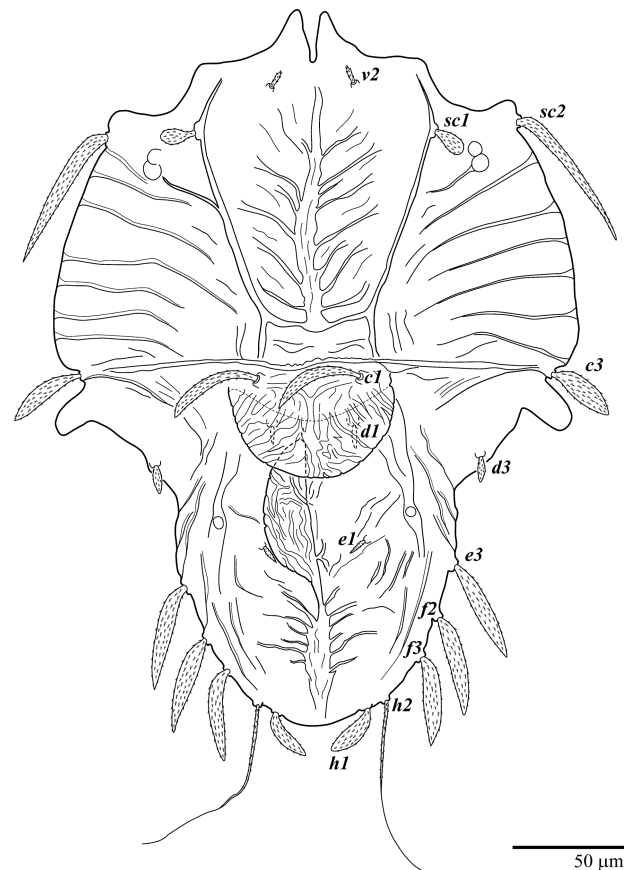
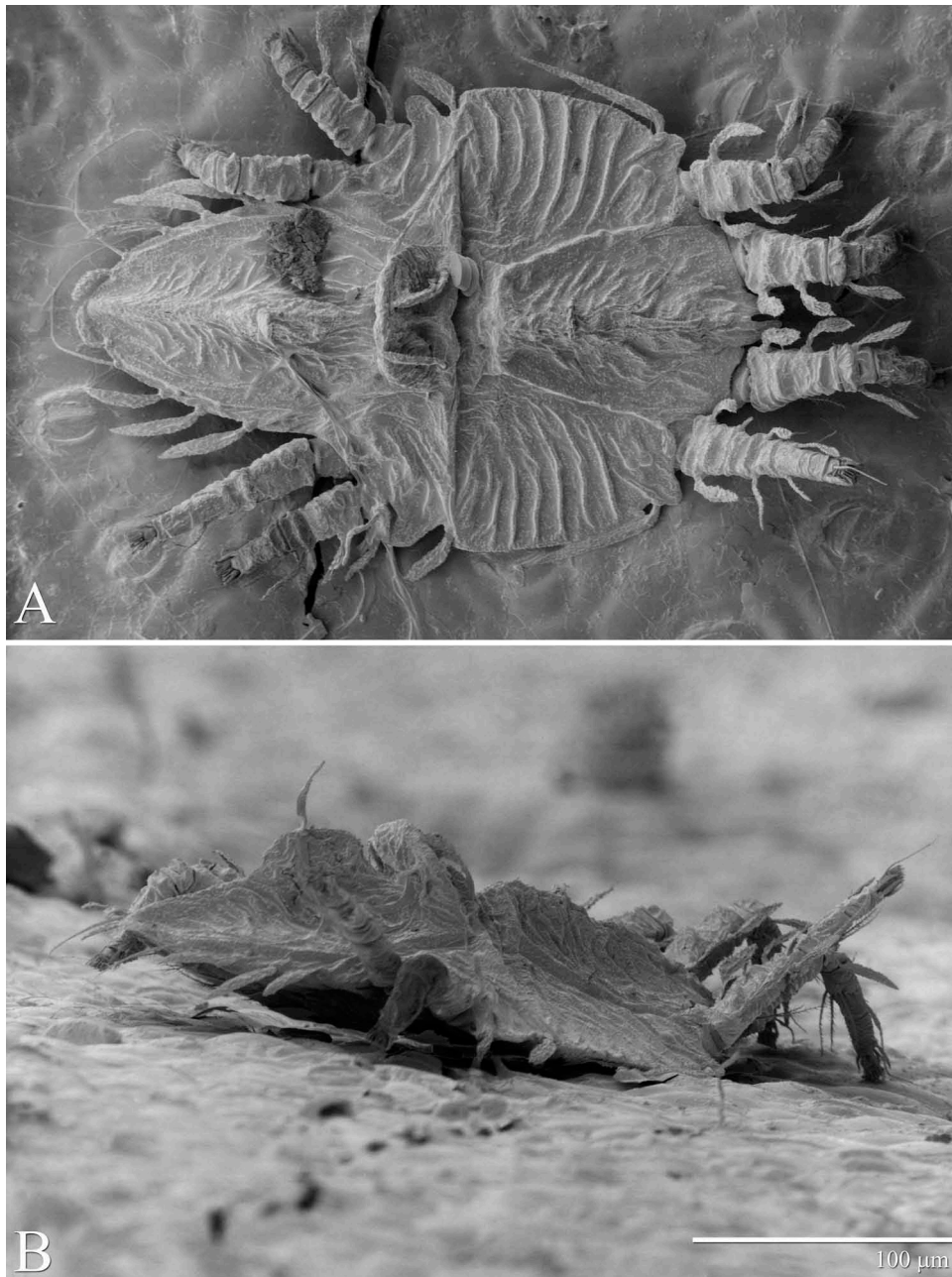


Figure 11. *Tenuipalpus erbei* sp. nov. (female): dorsum.



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

entire idiosomal midline; lateral body projections similar to that of female; tarsi I–II each with two solenidia ( $\omega'$  paraxial and ventrolateral;  $\omega''$  antiaxial). *Deutonymph*: With small lateral body projections anterior to setae *sc*<sub>2</sub>; leg chaetotaxy similar to that of female, except trochanter IV without seta *v'* and tarsus IV without setae *tc'* and *tc''*.

#### Material examined

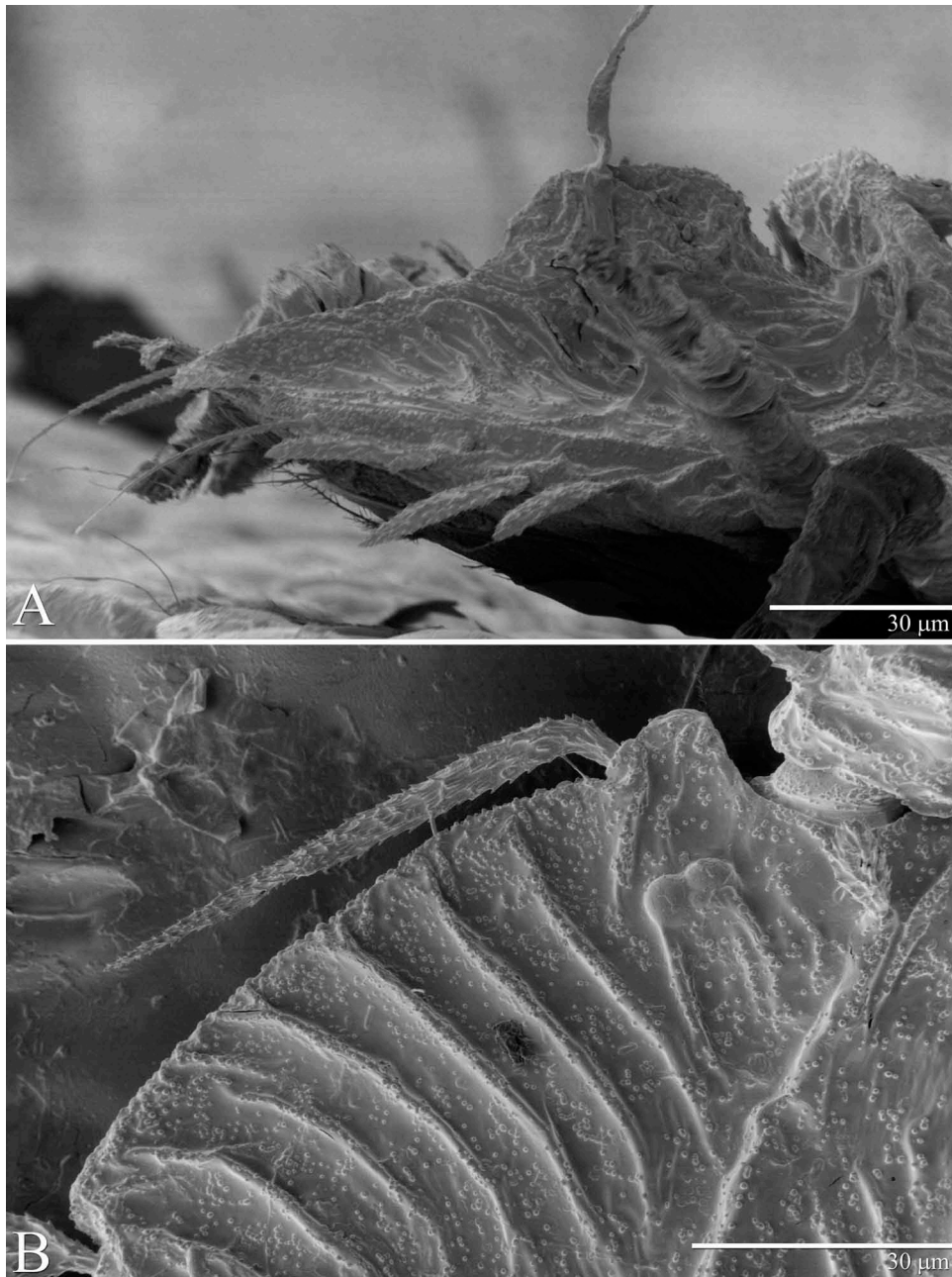
Holotype: female collected on *Piper glabratum* Kunth (Piperaceae), from La Selva, Heredia, Sarapiquí, Costa Rica, 10° 26'0"N, 84°1'0"W, 7 September 2005, coll. H. Aguilar, deposited in NMNH, located at the SEL-USDA, Beltsville, Maryland, USA. Paratypes: two females and one male, same slide as holotype; 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, ARS-USDA, 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*<sub>2</sub>–*h*<sub>1</sub> 245 (240–260); width *sc*<sub>2</sub>–*sc*<sub>2</sub> 160 (150–165), *c*<sub>3</sub>–*c*<sub>3</sub> 190 (180–195), *f*<sub>2</sub>–*f*<sub>2</sub> 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 *sc*<sub>2</sub> and another pair of obtuse lateral projections associated with setae *c*<sub>3</sub>; prodorsum with pair of strong, converging ridges from *sc*<sub>1</sub> to sejugal furrow. Opisthosoma with two large cuticular crests, one transverse immediately posterior to setae *c*<sub>1</sub> and another longitudinal between setae *d*<sub>1</sub> and *e*<sub>1</sub> (Figures 12B and 13A). On slides,



**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*.

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  $\omega''$  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.



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

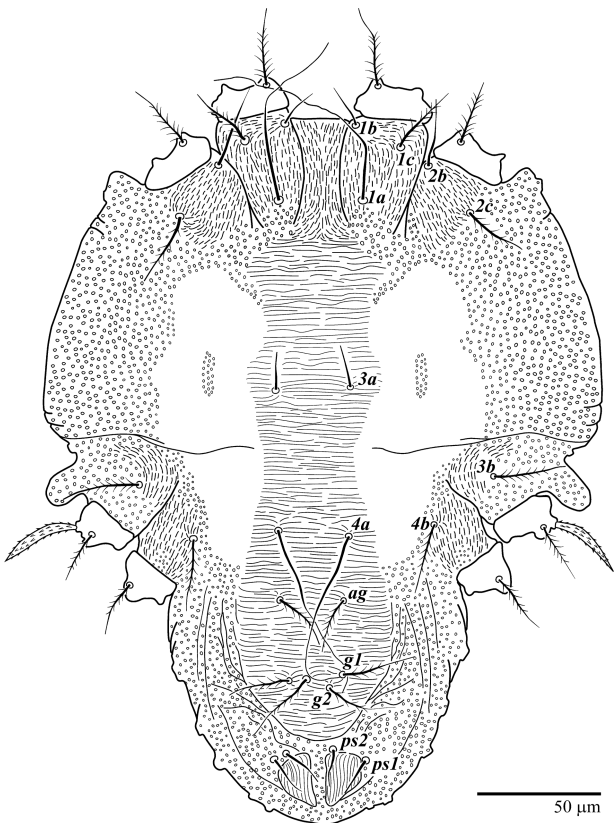


Figure 15. *Tenuipalpus erbei* sp. nov. (female): venter.

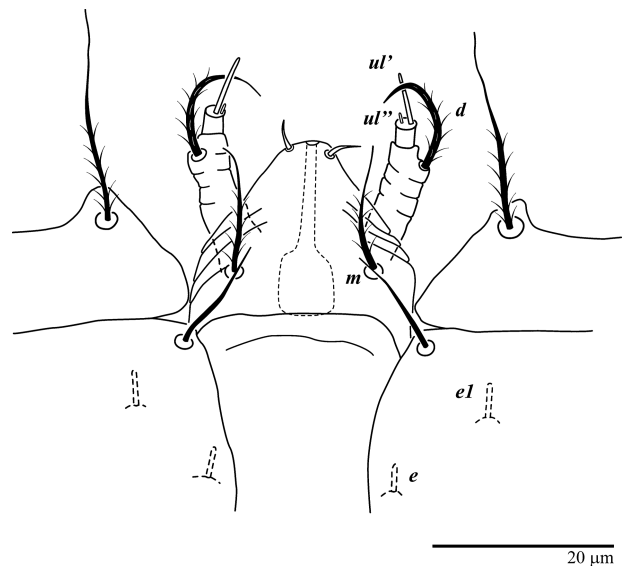


Figure 16. *Tenuipalpus erbei* sp. nov. (female): hypostome.

**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

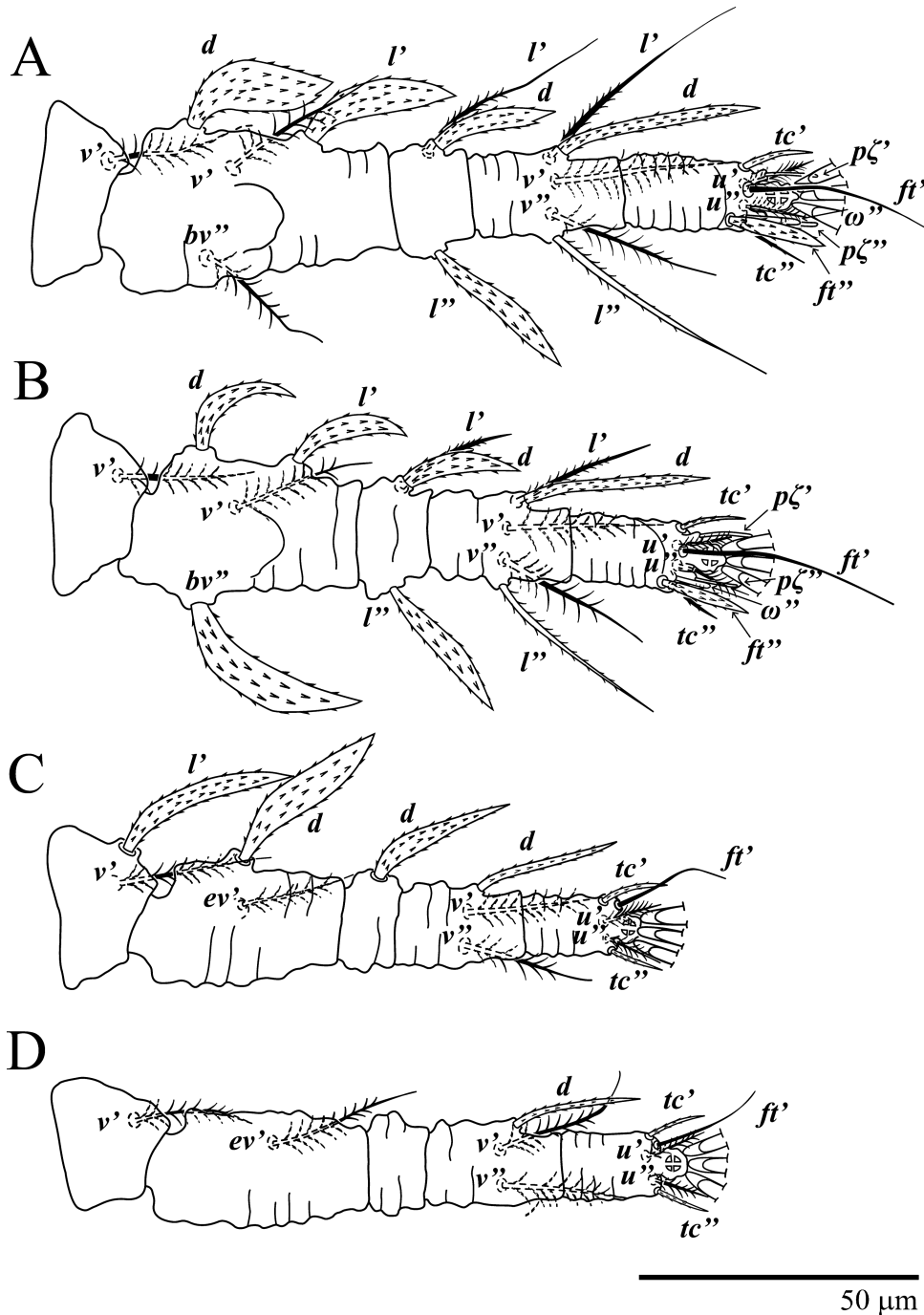


Figure 17. *Tenuipalpus erbei* sp. nov. (female): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

with one pair of small lateral projections anterior to setae *sc1* 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 ( $\omega'$  paraxial, inserted ventrolaterally;  $\omega''$  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

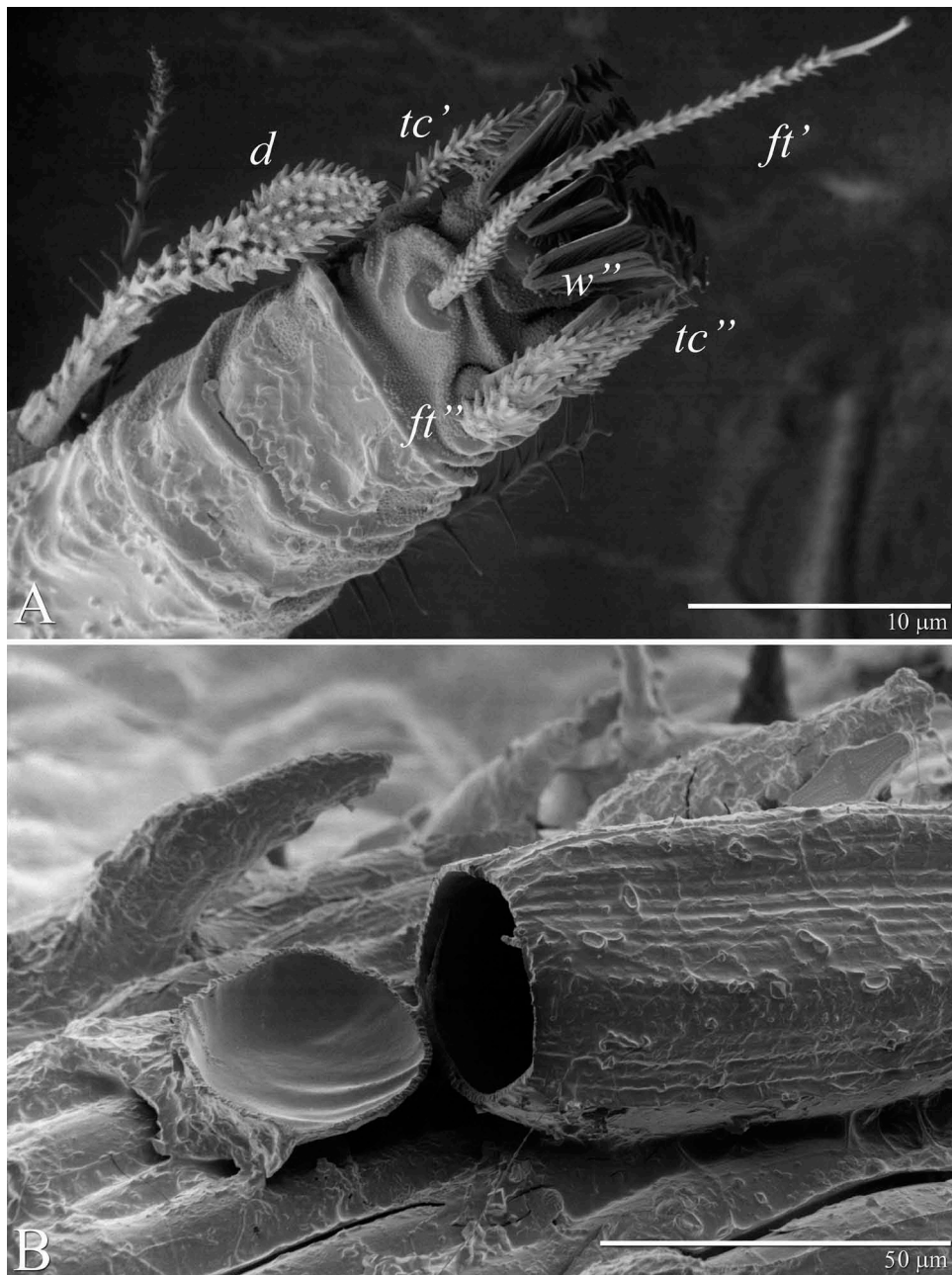


Figure 18. *Tenuipalpus erbei* sp. nov. (female): (A) detail of tarsus II; (B) egg.

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

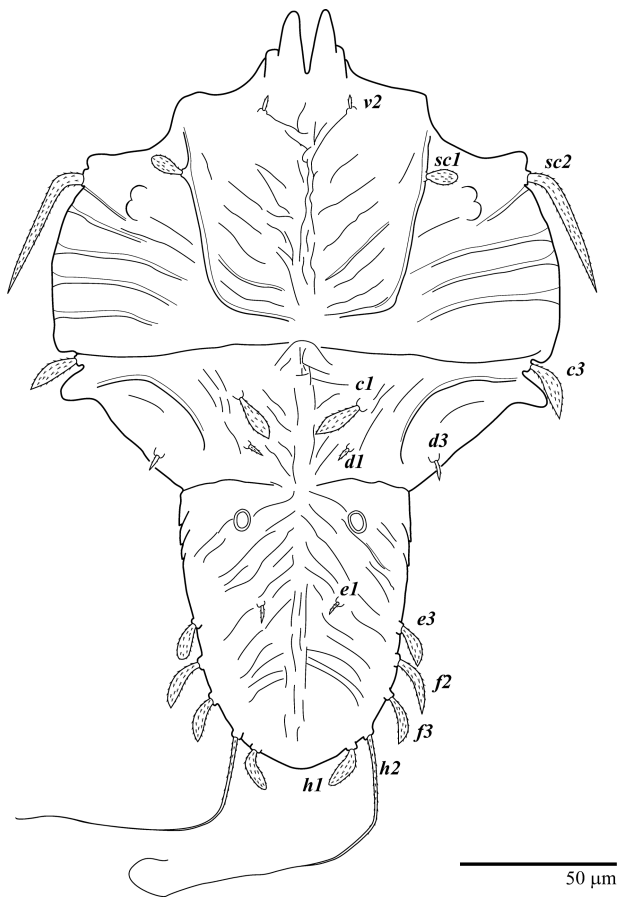


Figure 19. *Tenuipalpus erbei* sp. nov. (male): dorsum.

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,  $\omega'$ , 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. chichlorum*, *T. coccolobicolus* De Leon and *T. rhyusus* 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.

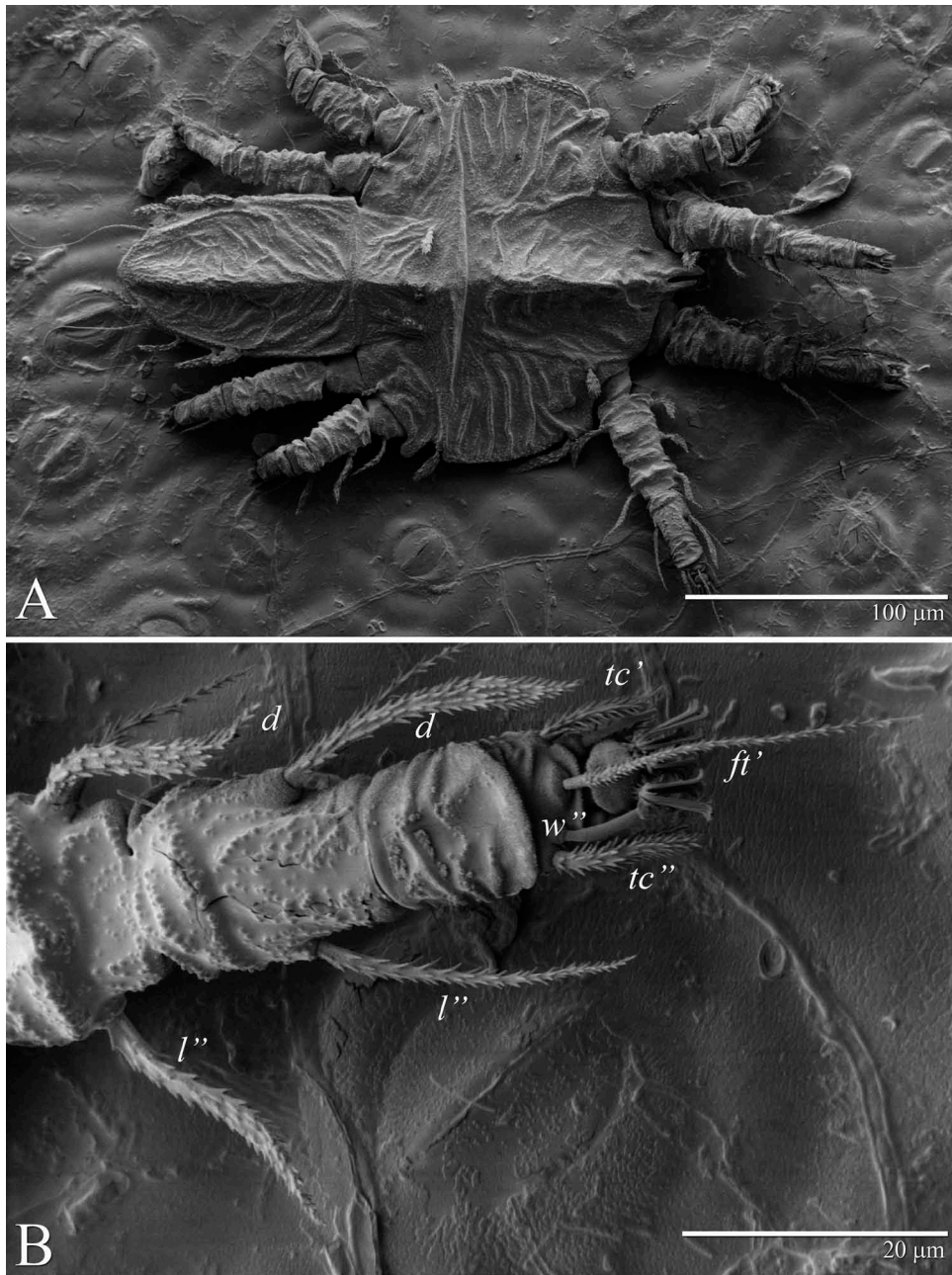
Regarding setae *4a*, the duplication of this seta was also considered homoplasious under Meyer's (1993) species groupings. We note that this seta is not duplicated within *Tenuipalpus* sensu stricto, and may therefore be a synapomorphy. However, the duplication or not of setae *4a* is present in several 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



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

projections as being associated with setae c3. Their shape can be broad (as in *T. micheli*) to narrow (as in *T. podocarp*), 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*, 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.



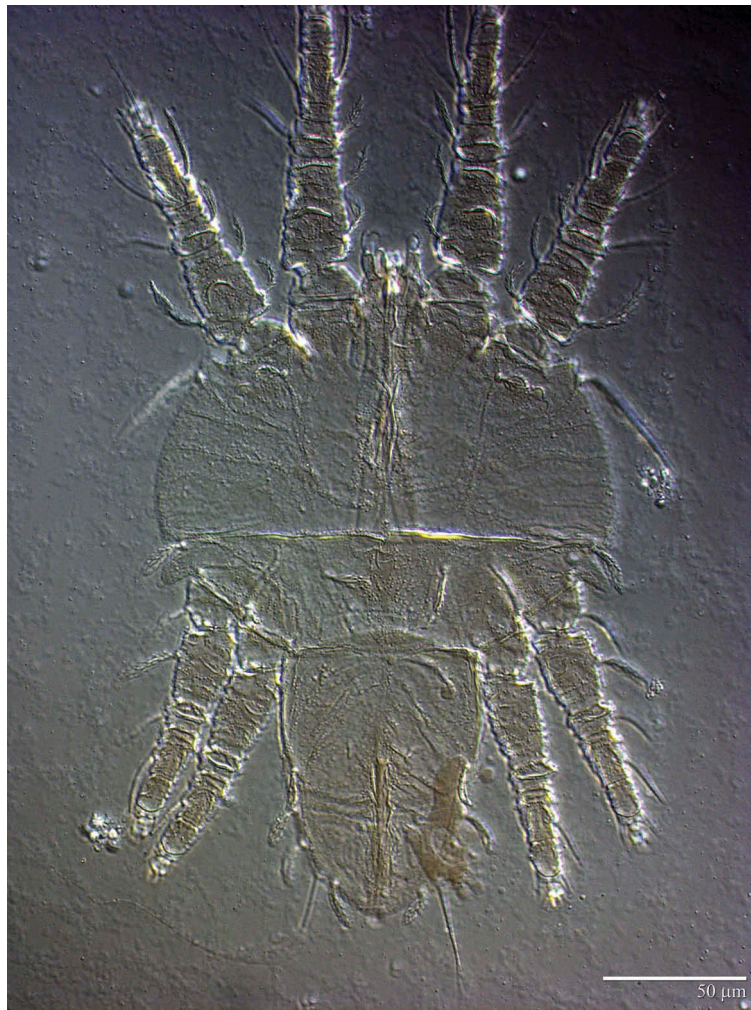


Figure 21. *Tenuipalpus erbei* sp. nov. (male): dorsum.

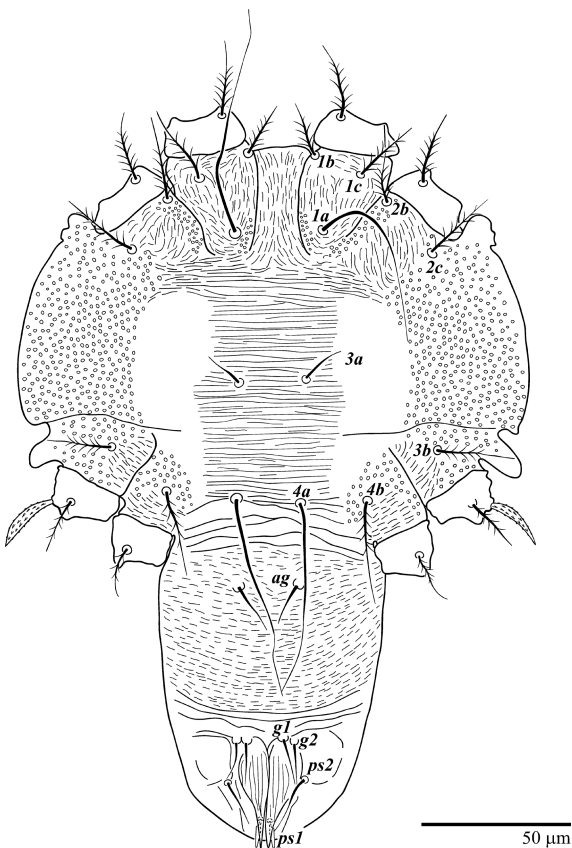


Figure 22. *Tenuipalpus erbei* sp. nov. (male): venter.

#### 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.

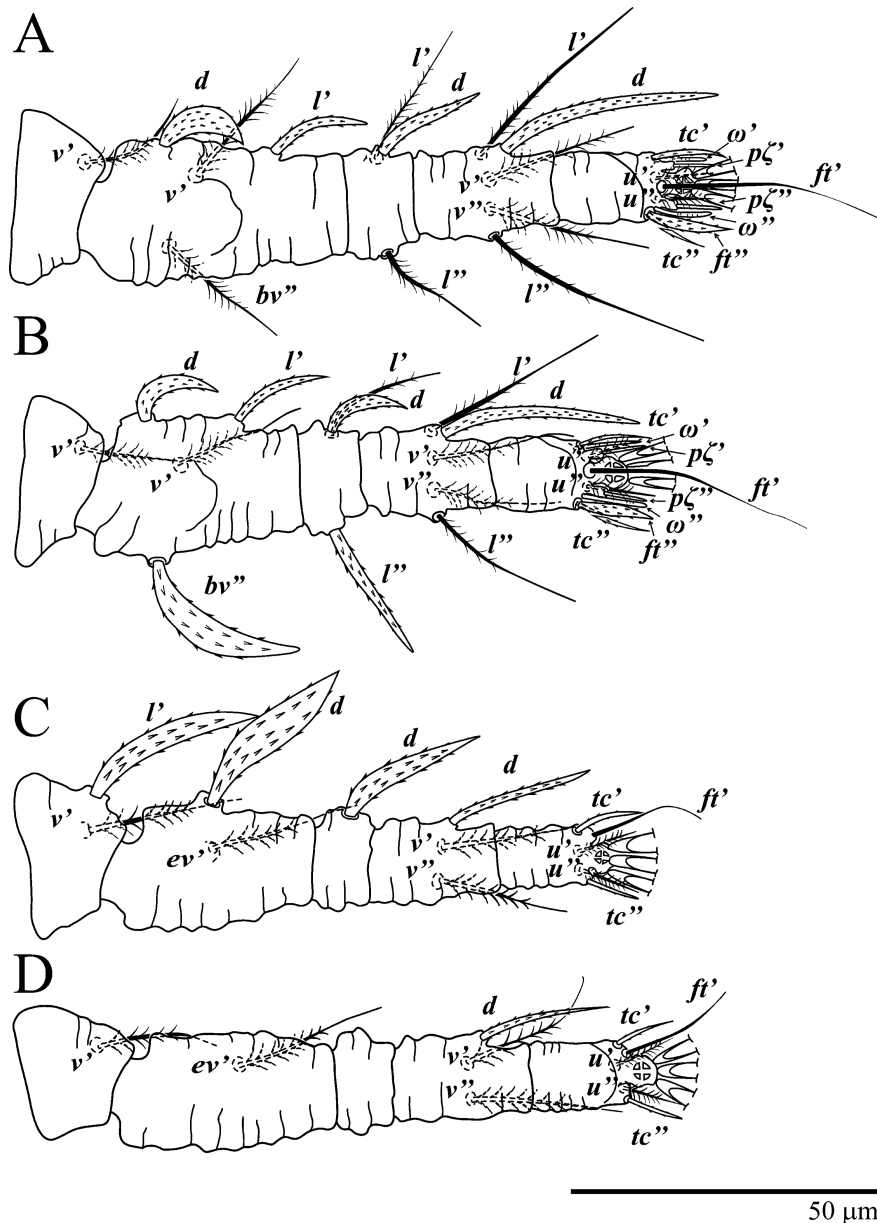


Figure 23. *Tenuipalpus erbei* sp. nov. (male): (A) leg I; (B) leg II; (C) leg III; (D) leg IV. (Right legs).

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 chicolorum* 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 *Cocotea coriacea* Britton (Lauraceae) – Type depository: USNM.

17. *Tenuipalpus imias* Cao, 1982: 14; Imias, Guantanamo, Cuba, ex *Hippomane mancinella* L. (Euphorbiaceae) – Type depository: Colección de la Estación Biológica Docente (EBD) de la Facultad de Biología, 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'Historie Naturelle de Paris, France.

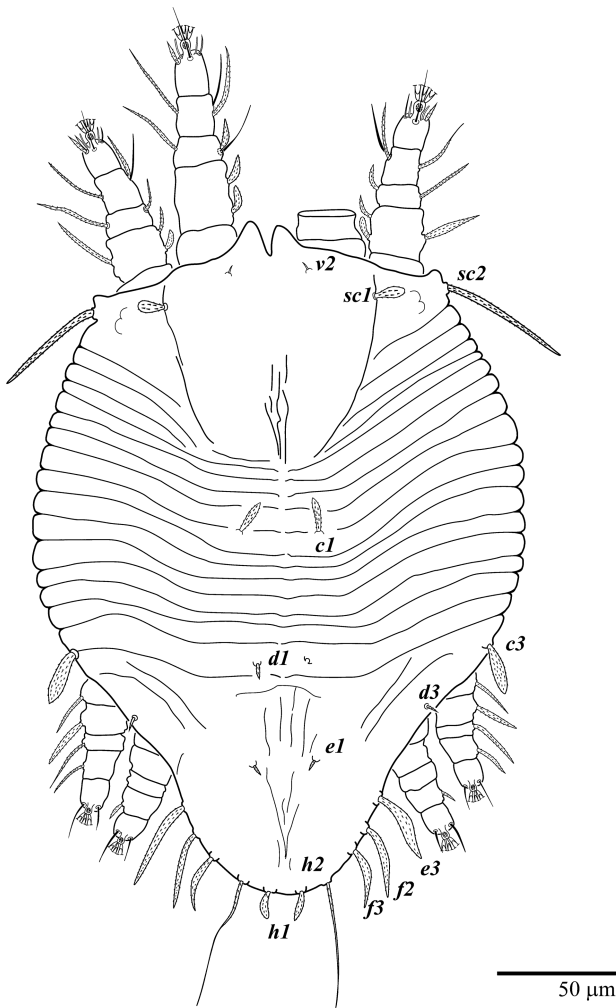


Figure 24. *Tenuipalpus erbei* sp. nov. (deutonymph): dorsum, with detail of legs.

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 mansoni* 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 podocarpus* 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 rhyusus* 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 chamaedoreae* (Salas & Ochoa, 1985). (Article

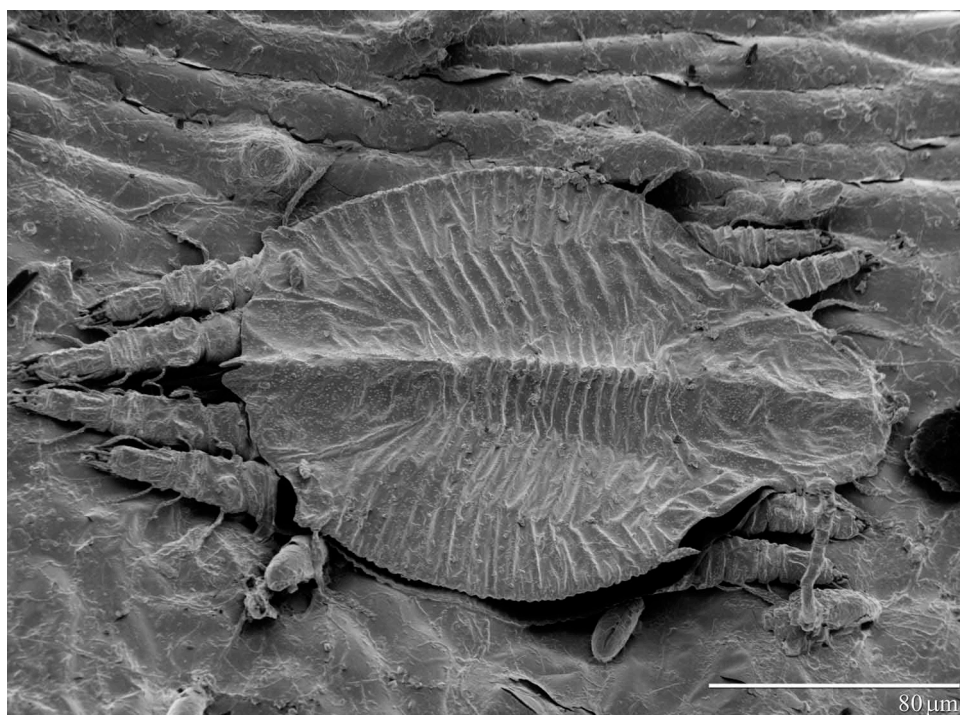


Figure 25. *Tenuipalpus erbei* sp. nov. (deutonymph): dorsum of caste skin.



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

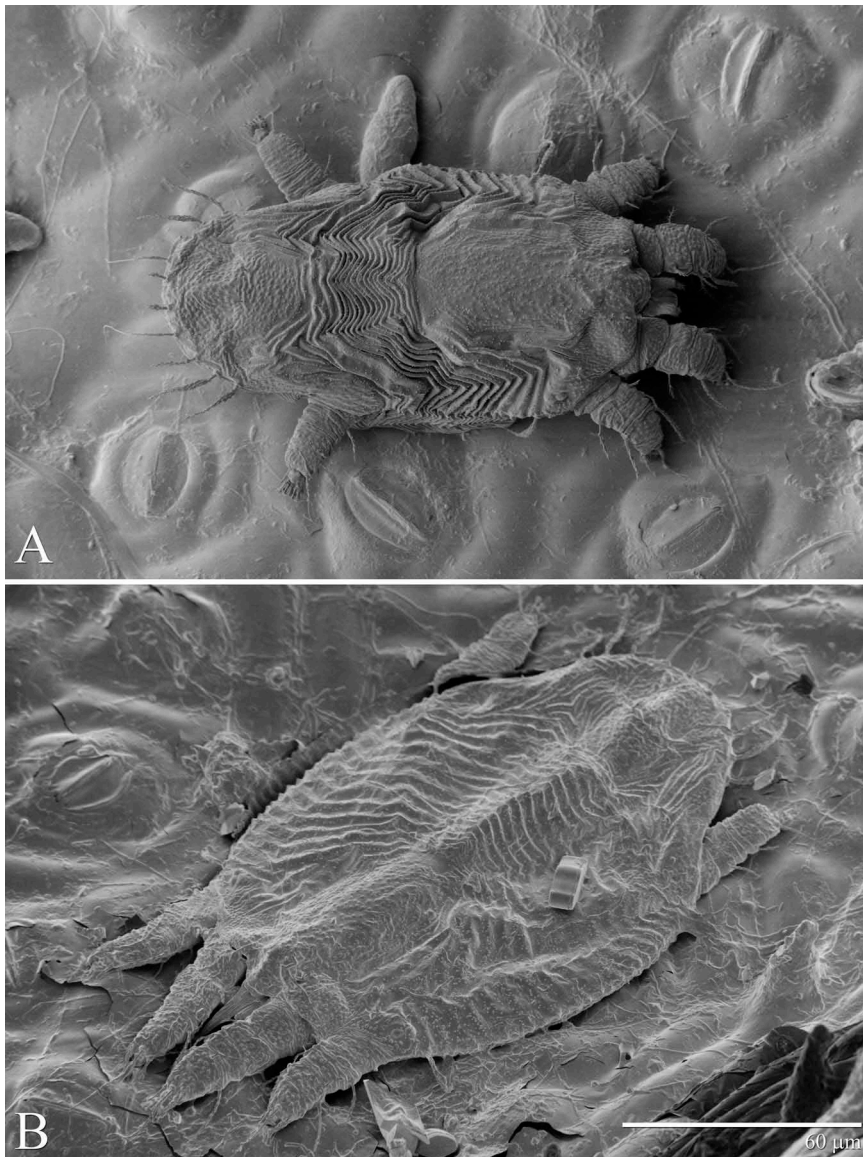


Figure 27. *Tenuipalpus erbei* sp. nov. (larva): (A) soon after out of the egg; (B) dorsum of caste skin.

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 guattertioides* (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.).

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