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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 Extrenatenuipalpus, indicating their origins are within Tenuipalpus. A list of Tenuipalpus sensu stricto species is presented.

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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 Extrenatenuipalpus as a monospecific genus and designated Tenuipalpus quadrirsetosus 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 – Ultratenatenuipalpus (h2 present; four segmented palp); Extrenatenuipalpus (f2 absent; three segmented palp); and five have setae h2 flagelliform – Tuttatenuipalpus (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); Deleonicus (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 Tuttatenuipalpus, Colopalpus and Extrenatenuipalpus.

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 quadridesetosus. Thus, the genera erected by Mitrofanov (1973) were synonymized with Tenuipalpus – with the exception of Ultratenatenuipalpus, 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 Ultratenatenuipalpus to be more significant than the form of h2, because Extrenatenuipalpus 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: anoplos (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: thesi (one pair 3a, one pair 4a), keiensis (one pair 3a, two pairs 4a) and xeroculus (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 Colopalus from Tenuipalpus based on differences of the body shape and position of the leg setae. These authors presented C. pedrus Manson and C. mansoni Collyer as valid species of Colopalus, and transferred C. rambii (Castro & Feres) and C. zahrii (Khanhani & Seeman) from Tenuipalpus to Colopalus.

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 gnathosomal and coxae I–II that is strongly forked medi-ally, 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 synap-omorphy, 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 Gahnianacarus (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 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 Trombididae [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. pal-matus, 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. pal-matus, again from the same specimens, and presented a drawing with good details of the dorsal view. These latter authors high-lighted 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 Acaurus 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 para- types 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 Apochromatic 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 opisthosaoma or elon-gate-ovale; 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)); opisthosaoma 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, 4A5 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 cryo-preserved 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.
DZSU'P – Collection of Acari, Departamento de Zoológica 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 palma tus Donnadieu, 1876
(= Tenuipalpus caudatus Dugès, 1834)

Diagnosis – Tenuipalpus sensu stricto

Female. Protopod sternum 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 setae 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. balbagensis 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 oblan caleolate to minute; setae h2 elongate, flagellate; semicircular cuticular crests on opist hosoma present or absent. Palp one to three segmented (palp one segmented only in T. chlorum 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 Cor pruz-Raros, T. mahoensis Collier and T. inophylli Gutierrez and Bolland). Femora, genua and tibiae with setae d inserted in lateral position on tubercles; tarsi I–II bearing an antiali cal 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 antiallial); tarsus III bearing zero to one solenidion. Setae ps1 modified as an accessory genital styel.

Im matures. 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 Acarici s, Colopal pus, Cyper acar us, Gahni acar us, Lisea palpus, Proli xis and Tenuil ush. 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 Ultraten uipalpus (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 Ultraten uipalpus.

As noted, Tenuipalpus sensu stricto and Ultraten uipalpus share several character states such as those mentioned above, as well as the semicircular, laterally extended pseudosoma that is wider than the opisthosoma (in some Ul tratenuipalpus), converging ridges running from near sc1 to the sejugal furrow (in a few Ultraten uipalpus), poorly developed genital plates, several large ovate to obovate dorsal and leg setae, and the laterally placed dorsal setae on the legs. However, no Ultraten uipalpus 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 palma tus Donnadieu, 1876: 112; Pritchard and Baker, 1958: 244 – synonymy.
Caligonus calyx Canestrini & Fanzago, 1876: 134; Canestrini, 1890: 457 – synonymy.

Redescription


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

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

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

Figure 7. Tenuipalpus caudatus (Dugès) (male): dorsum.
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 1–2–1–3–5, 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′–pζʺ; setae ftʺ on tarsi I–II lanceolate (ftʺ absent on tarsi III–IV); setae ftʹ on tarsi I–IV flagelliform.

Redescription – male


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 2–0–3–1–5–6(1), II 1–0–3–1–5–6(1), III 1–0–2–0–3–3, IV 0–0–1–0–3–3; setae ec on coxae il absent; setae 4b absent; trochanters I–IV bare; setae l′ on femora I–ll absent; setae l′′ on genua I–ll absent; seta d on genua III absent (genua III–IV nude); tectal pair of setae tc′–tc′′ on tarsi I–IV absent.

**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 idiosomal midline; 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.

**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 striae 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.

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

(Figures 11–27)

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

**Figure 10. Tenuipalpus caudatus (Dugès) (protonymph): dorsum, with details of legs.
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 sc2; 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, Sarapiqui, 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, Sarapiqui, 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 Viago, 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 DZSJRZ, located at the UNESP, São José do Rio Preto, State of São Paulo, Brazil (DZSJRZ n. 9549–9550); and one deutonymph collected on P. glabratum Kunth (Piperaceae), from La Selva, Heredia, Sarapiqui, 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 v2–h1 245 (240–260); width sc2–sc2 160 (150–165), c3–c3 190 (180–195), f2–f2 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. Opisthosa 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 \(pχ′−pχ″\). 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 16–20, c3 8–9, e1 5–6, e3 12–13, f1 14–17, f2 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 posteriorly 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

*Figure 18. Tenuipalpus erbei sp. nov. (female): (A) detail of tarsus II; (B) egg.*
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 setae 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 s...
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. podocarpi, 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 “semi-oval area extending anteriorly and posteriorly of dorsocentral hysterosomal seta 3”, and that the male hysterosoma is “without semi-oval area”. The reference to the crest as an asymmetrical “semi-oval 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.

Figure 20. Tenuipalpus erbei sp. nov. (male): (A) dorsum; (B) detail of tibia and tarsus II.
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.
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 bovani* De Leon, 1965a: 67; Bartica Nature Reserve, Guyana (= British Guiana), ex Pouteria sp. (Sapotaceae) – Type depository: MCZ.


9. *Tenuipalpus chilorum* 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.


12. *Tenuipalpus coyacus* De Leon, 1957: 83; San Blas, Nayarit, Mexico, ex oil palm (Arecaceae) – Type depository: MCZ.


15. *Tenuipalpus eugeniae* De Leon, 1965b: 521; Green Hills, Portland, Jamaica, ex Eugenia biflora (L.) DC. (Myrtaceae) – Type depository: MCZ.

16. *Tenuipalpus hastalini* De Leon, 1956: 57; Coral Gables, Florida, USA, ex Ocotea coriacea Britton (Lauraceae) – Type depository: USNM.


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.

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; Corumba, Mato Grosso, Brazil, ex *Celastrus* L. – 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.


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: Palisades 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 podocarpi 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
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.
**References**

André HM. 2011. *Dugès’ caudatus* is a Tenuipalpidae and not a Tydeidae (Acar.). Acarologia 51:69–85.


