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Brevipalpus phoenicis (Geijskes) species complex (Acari: Tenuipalpidae)—a closer look

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Abstract

Brevipalpus phoenicis sensu stricto (Geijskes) is redescribed and the species diagnosis established. Two former synonyms of *B. phoenicis* sensu lato, *B. yothersi* Baker and *B. papayensis* Baker, are resurrected and redescribed and their species diagnoses established. *Brevipalpus hondurani* Evans is also redescribed and diagnosed. Four new species, previously misidentified as *B. phoenicis* sensu lato or *B. obovatus* Donnadieu, are described—*B. azores* sp. nov., *B. feresi* sp. nov., *B. ferraguti* sp. nov., and *B. tucuman* sp. nov. Four new junior synonyms of *B. yothersi* are listed—*Brevipalpus amicus* Chaudhri and *B. recula* Chaudhri (new synonymies), and *B. mcbridei* Baker and *B. deleoni* Pritchard and Baker (misidentifications). A key is provided to separate these species. New morphological characters significant for species separation are presented and discussed.

Key words: *Brevipalpus* species groups, *Citrus*, citrus leprosis virus, differential interference contrast, flat mites, low temperature scanning electron microscopy, phase contrast, systematics

Introduction

Flat mites represent some of the most economically important plant feeding mite species in the world, especially those in the genus *Brevipalpus* Donnadieu (Jeppson *et al.* 1975; Childers & Rodrigues 2011). The importance of flat mites as agricultural pests has increased significantly over the past 40 years mainly because of their association with plant viruses and their increasingly obvious quarantine importance (Ochoa *et al.* 1994; Childers & Derrick 2003; Childers *et al.* 2003; Gerson 2008; Kitajima *et al.* 2010; Rodrigues & Childers 2013; Alberti & Kitajima 2014).

Plant viruses transmitted by species in the genus *Brevipalpus* have been described from more than 40 plant species (Kitajima *et al.* 2001, 2003; Rodrigues *et al.* 2008; Kitajima & Alberti 2014). Among these, the citrus leprosis virus complex is by far the most serious (Bastianel *et al.* 2010; Kitajima *et al.* 2011a; Roy *et al.* 2013, 2014; Alberti & Kitajima 2014; Kitajima & Alberti 2014). The citrus leprosis complex consists of two unrelated taxa of viruses, cytoplasmic and nuclear, found throughout South, Central and North America. The cytoplasmic viruses are citrus leprosis virus C (CiLV-C), citrus leprosis virus C2 (CiLV-C2) and Hibiscus green spot virus 2 (HGSV-s); and the nuclear viruses are citrus leprosis virus N (CiLV-N) and citrus necrotic spot virus (CiNSV) (Roy *et al.* 2015). The CiLV complex causes one of the most important invasive diseases in the Americas (Rodrigues & Childers 2013), and poses a major threat to citrus industries worldwide. This threat is exacerbated by the widespread distribution of the potential vectors. For example, over the past decade, CiLV has spread at an alarming rate throughout South and Central America and most recently within Mexico (Rodrigues & Childers 2013, Alberti

& Kitajima 2014; Kitajima & Alberti 2014)—these regions all had resident *Brevipalpus* mites prior to the disease emerging.

As with many mite groups, poor descriptions of flat mite taxa have caused substantial taxonomic challenges for several decades now. As indicated by McGregor (1949: 1) in this passage written over 65 years ago in USA "To the present time, only eight species in this family have been reported from this country. Due to the nature of the descriptions and illustrations of some of these species, as well as to the lack of critical study of their morphology, confusion has existed in the taxonomy of this group of mites." This statement still holds true today, especially so for species within *Brevipalpus*, as discussed later.

Three species of *Brevipalpus* are implicated in transmission of several viruses across the world, including CiLV—*B. phoenicis* (Geijskes), *B. californicus* (Banks) and *B. obovatus* Donnadieu (Knorr *et al.* 1968; Maeda *et al.* 1998; Kitajima *et al.* 2001, 2003; Rodrigues *et al.* 2008; Rodriguez & Childers 2013; Kitajima & Alberti 2014). Since the taxonomic status for these individual species is uncertain, the identification of which species is/are actually involved in the transmission of CiLV presents a challenge. As each of these three taxa are associated with hundreds of recorded host plants outside the genus *Citrus* (Rutaceae), there are growing concerns regarding the existence of host plants that may represent cryptic asymptomatic reservoirs of CiLV as well as other *Brevipalpus* transmitted viruses (Rodrigues & Childers 2013). Adding further complexity to this virus-vector-host interaction, previous research has indicated, firstly, that *B. phoenicis* and *B. californicus* actually comprise several cryptic species (Beard *et al.* 2013; Navia *et al.* 2013; Beard *et al.* 2014b), and secondly, that species in the *B. phoenicis* complex have historically been regularly misidentified as *B. obovatus* (Beard, Welbourn, Ochoa, pers. obs.). With these two factors in mind, most published virus-transmission data, host plant range and distributional data regarding these species are of little value without vouchered specimens being made available, as is so often the case.

Oomen (1982), Ochoa (1985), Al-Gboory (1987), Childers *et al.* (2003), Welbourn *et al.* (2003), and Mesa (2005) have all previously highlighted the importance of detailed morphological examinations of *Brevipalpus* species, due to the presence of species complexes (Beard *et al.* 2013; Beard *et al.* 2014b). Likewise, molecular studies of *Brevipalpus* mites affecting citrus, and other crops, also suggest the presence of species complexes (Rodrigues *et al.* 2004; Navia *et al.* 2013). The use of deutonymphal characters has proven to be of some value for separating close species, though apparent intraspecific variation often makes separation difficult (Baker 1949; Attiah 1956; Manson 1963; Knorr 1968; Prieto-Trueba 1984; Ochoa & Salas 1989; Welbourn *et al.* 2003). Until the extent of this variation is understood, and deutonymphs are accurately and reliably linked with adults through rearing and morphological and molecular taxonomic approaches, they will remain of limited use. Additionally, the frustrating occurrence of asymmetry in the expression of the solenidia on tarsus II of individual *Brevipalpus* mites in both the *phoenicis* and *obovatus* groups (De Leon 1967; Ochoa 1985; Ochoa & Salas 1989; Kitajima *et al.* 2011b) highlights the need for further morphological and molecular analysis to help us identify species limits and understand their implications. Here we present the results of meticulous comparisons of voucher specimens from various studies (Baker 1949; Pritchard & Baker 1952, 1958; DeLeon 1967; Knorr 1968; Chaudhri *et al.* 1974; Ochoa 1985; Welbourn *et al.* 2003), and local and intercepted material from across the world held in the USNM, with type specimens of the suspected synonyms and other species in the *phoenicis* complex, using several microscopy techniques.

Taxonomic history of *B. phoenicis*

The genus *Brevipalpus* was created in 1875 by Donnadieu with the description of *Brevipalpus obovatus*. This description represents the beginning of a long and complicated taxonomic history, which culminates in our collective inability to separate the more than 300 species that have been described since *B. obovatus* (Mesa *et al.* 2009; Beard *et al.* 2013). The early descriptions, (e.g. Donnadieu 1875; Canestrini & Fanzago 1876; Banks 1904, 1912; Oudemans 1938; Geijskes 1939; McGregor 1949), are plagued with misidentifications, inconsistencies, erroneous or incomplete drawings, ignored characters, and inadequate host plant identification. In his major review of the genus, Baker (1949: 350) seemed to be aware of the situation judging from the following passage "Although some of the early described species cannot yet be identified, reproductions of many of the figures and references to the early literature are given. Owing to the minute differences between some of the species, such as *donnadieui* and

its close relatives, final determinations can be made only when material from type hosts and localities can be studied. For this reason certain early names, such as *obovatus*, cannot now be applied to any species in available collections, and some recently described species may prove to be synonyms of these earlier described mites." In other words, at the time Baker wrote that statement the available diagnostics were in such a poor state that not even the type species for the genus, *B. obovatus*, could be reliably identified.

Brevipalpus phoenicis* versus *B. obovatus

Geijskes (1939) described *B. phoenicis* from specimens feeding on *Phoenix canariensis* Chabaud (Arecaceae) in a greenhouse at The Hague, The Netherlands (Dosse 1957b). In the original description, Geijskes (1939) indicated the presence of one solenidion on tarsus II but subsequent examination of the type material by Pritchard & Baker (1952) revealed that *B. phoenicis* bears two solenidia on tarsus II. Furthermore, Pritchard & Baker (1952:39) stated in the same study that "*phoenicis* is thus the only known species of *Brevipalpus* in which the female has two sensory rods on tarsus II together with five dorsolateral hysterosomals", and based on these two characters alone synonymised four *Brevipalpus* species (*B. yothersi* Baker, *B. mcbridei* Baker, *B. papayensis* Baker, *B. deleoni* Pritchard & Baker) with *B. phoenicis*. As a consequence of the characters presented by Pritchard & Baker, which were presented again by Dosse (1957a, b), for the past 62 years, any *Brevipalpus* mite that lacked setae *f2* and had two solenidia on tarsus II was identified as *B. phoenicis* with no further question or regard for any other characters (Beard *et al.* 2014b; pers. obs. Beard, Ochoa & Welbourn). Our recent evaluation of mite collections from across the world has revealed that many specimens identified as *B. phoenicis* were in fact *B. obovatus* and vice versa (pers. obs. Beard & Ochoa; Beard *et al.* in prep.). It is a major concern that two apparently well defined species are so consistently misidentified. With this in mind, decades of host association and distributional data could be erroneous. Such records continue to complicate species identification and the separation of closely related species. *Brevipalpus obovatus* currently has seven synonyms (*B. amicus* Chaudhri; *B. assamensis* Sadana & Gupta; *B. origanum* Baker, Tuttle & Abbatiello; *B. pereger* Donnadieu; *Tenuipalpus bioculatus* McGregor; *T. inornatus* Banks; *T. pseudocuneatus* Blanchard) and two more suspected synonyms (*B. quianniunis* Ma & Yuan and *B. tinsukiaensis* Sadana & Gupta). Meanwhile, *B. phoenicis* sensu lato has five synonyms (*B. deleoni* Prtichard & Baker; *B. mcbridei* Baker; *B. papayensis* Baker; *B. phoenicoides* Gonzalez; *B. yothersi* Baker) with eight more suspected (*B. adelos* Ahmad & Akbar; *B. colens* Li, Hasan & Ashfaq; *B. daqingis* Ma & Yuan; *B. hafizii* Chaudhri & Akbar; *B. hainanensis* Ma & Yuan; *B. jambhiri* Sadana & Balpreet; *B. nocivus* Siddiqui, Chaudhri & Akbar; *B. portheo* Chaudhri & Akbar; *B. recula* Chaudhri) (Mesa *et al.* 2009). Based on this alone, the interpretation of a significant number of articles regarding these two species (and their synonyms), in which voucher specimens are not lodged or made available or in which no comparison with any type specimens has been made, should be questioned and carefully considered.

Brevipalpus yothersi* and *B. papayensis

Brevipalpus yothersi was described from numerous females and nymphs collected on privet (*Ligustrum* sp., Oleaceae) in Orlando, Florida, USA (Baker 1949). *Brevipalpus papayensis* was described from numerous females and nymphs collected on papaya (*Carica papaya*, Caricaceae) in Oahu, Hawaii, USA (Baker 1949). Both *B. yothersi* and *B. papayensis* were subsequently synonymised with *B. phoenicis* by Pritchard and Baker (1952).

Brevipalpus phoenicis* sensu stricto versus *B. phoenicoides

Gonzalez (1975) studied the type specimen of *B. phoenicis* and addressed the findings of Pritchard and Baker (1952, 1958). Gonzalez (1975) indicated variation in the *B. phoenicis* complex and separated *B. phoenicoides* Gonzalez from *B. phoenicis*. Ochoa & Salas (1989) and Evans *et al.* (1993), based on studies of the variation in the setae on deutonymphs raised from a single female on *Phaseolus vulgaris* (Fabaceae), synonymised *B. phoenicoides* with *B. phoenicis*.

Materials and Methods

Mites were examined at 1000 X magnification using a DIC and Phase Contrast Zeiss Axioscope™ microscope. All measurements are presented in micrometers (µm) as a range (paratype specimens, and non-type material where available) followed by the measurements for the holotype in square brackets (both sides measured). Distances

between setae were measured as the distance from the inside edge of one setal base to the other (i.e., the minimum distance between two setal bases). Leg setal numbers are written as the total number of phaneres followed by the number of solenidia in parentheses. Chaetotaxy follows that of Lindquist (1985) and the names of leg segments are abbreviated to the first two letters of each name (e.g., fe = femur, ti = tibia).

Specimens in 70% ethanol were used for Low Temperature SEM (LT-SEM) studies, utilising the technique outlined by Bolton *et al.* (2014), which is described briefly here. Specimens were secured to 15 x 30 mm copper plates using ultra smooth, round (12 mm diameter) carbon adhesive tabs (Electron Microscopy Sciences, Inc., Hatfield, PA, USA). The specimens were frozen conductively, in a Styrofoam box, by placing the plates on the surface of a pre-cooled (-196°C) brass bar whose lower half was submerged in liquid nitrogen. After 20–30 seconds, the holders containing the frozen samples were transferred to the Quorum PP2000 cryo-prep chamber (Quorum Technologies, East Sussex, UK) attached to an S-4700 field emission scanning electron microscope (Hitachi High Technologies America, Inc., Dallas, TX, USA). The specimens were etched inside the cryotransfer system to remove any surface contamination (condensed water vapour) by raising the temperature of the stage to -90°C for 10–15 min. Following etching, the temperature inside the chamber was lowered below -130°C, and the specimens were coated with a 10 nm layer of platinum using a magnetron sputter head equipped with a platinum target. The specimens were transferred to a pre-cooled (-130°C) cryostage in the SEM for observation. An accelerating voltage of 5 kV was used to view the specimens. Images were captured using a 4pi Analysis System (Durham, NC, USA). Because the specimens were not tightly secured to the adhesive tabs, it was often possible to remove the specimens from the LT-SEM and turn them over to the view their ventral position for additional imaging; thus both dorsal and ventral images were taken of individual mites. Several specimens from the LT-SEM studies were recovered and stored for future DNA studies following the methods outlined in Dowling *et al.* (2010).

List of abbreviations

ANIC Australian National Insect Collection, CSIRO Entomology, G.P.O. Box 1700, Canberra, Australian Capital Territory, 2601, Australia.

AQIS Department of Agriculture, Australian Government (formerly Australian Quarantine and Inspection Service), Australia.

BRI Queensland Herbarium, Brisbane Botanic Gardens Mt Coot-tha, Toowong, Brisbane, Queensland, 4066, Australia.

MNCN Museo Nacional de Ciencias Naturales, Consejo Superior de Investigaciones Cientificas, José Gutierrez Abascal, 2. 28006, Madrid, Spain.

NCBN Netherlands Centre for Biodiversity Naturalis, P.O. Box 9517, 2300 Ra Leiden, The Netherlands.

NTDPIF Entomology Collection, Department of Resources (Dept Primary Industry & Fisheries), G.P.O. Box 3000, Darwin, Northern Territory, 0801, Australia.

QM Queensland Museum, P.O. Box 3300, South Brisbane, Queensland, 4101, Australia.

SAM South Australian Museum, G.P.O. Box 234, Adelaide, South Australia, 5001, Australia.

UNESP Laboratorio de Acarologia, Departmento de Zoologia e Botânica, Universidade Estadual Paulista, São José do Rio Preto, São Paulo, Brazil, 15054-000.

UPVLA Laboratorio de Acarologia, Instituto Agroforestal Mediterráneo, Universidad Politécnica de Valencia, Camino de Vera, s/n. 46022, Valencia, Spain.

UQIC The University of Queensland Insect Collection, now Queensland Museum (QM).

USNM United States National Insect & Mite Collection, US National Museum of Natural History (Smithsonian), held at Systematic Entomology Laboratory (SEL), Beltsville Agricultural Research Center West (BARC West), United States Department of Agriculture (USDA), Building 005, 10300 Baltimore Ave, Beltsville, Maryland, 20705, USA.

Key to select* species within the *Brevipalpus phoenicis* species complex (based on adult females)

1. Prodorsum with areolae medially (Figs 5a, 34a, 47a) 2
- Prodorsum with folds, or weak incomplete reticulation medially (Figs 15a, b) . . . . . *B. ferraguti* sp. nov. Ochoa & Beard
2. Dorsal seta on palp femorogenu narrow (Fig. 47b); spermatheca vesicle oval with a strong distal stipe (Fig. 48e); cuticle on dorsal opisthosoma between setae *e1*-*e1* to *h1*-*h1* usually with strong chevrons (V-shaped folds), becoming much weaker

towards *h1*-*h1* (Figs 47e–f, 49, 51) . . . . . *B. yothersi* Baker (1949)

- Dorsal seta on palp femorogenu broad (Figs 23b, 34b); spermatheca vesicle round without stipe (Figs 9e–f, 26e, 46e), or not developed (Fig. 35e); cuticle on dorsal opisthosoma between setae *e1*-*e1* to *h1*-*h1* without strong chevrons, usually with more or less transverse folds (Figs 5e, 8f, 25f, 34e) 3

3. Genital plate with "warts"/cells fused to form large cells (Figs 9d, 24b, 35c–d) 4

- Genital plate with mostly transversely aligned elements, with "warts"/cells fused to form transverse bands (Figs 6c–d, 26c–d, 46c–d) 6

4. Cuticle on posterior dorsal opisthosoma, laterad setae *e1*-*e1*, reticulate with large cells, not dome-shaped (Figs 23c–e); dorsal seta on palp femorogenu somewhat cuneate (Fig. 23b) . . . . . *B. hondurani* Evans

- Cuticle on posterior dorsal opisthosoma, laterad setae *e1*-*e1*, with a series of large, dome-shaped cells (Figs 8d–e, 34c–e); dorsal seta on palp femorogenu broad, lanceolate (Figs 8b, 34b) 5

5. Posterior opisthosomal setae *e3*, *f3*, *h1*, *h2* broad, 9–13 µm (Fig. 8f); spermatheca with a round vesicle (Figs 9e, f) . . . . . *B. feresi* sp. nov. Ochoa & Beard

- Posterior opisthosomal setae *e3*, *f3*, *h1*, *h2* moderately broad, 7–10 µm (Fig. 34f); vesicle of spermatheca not visible, spermathecal duct ends in a membranous bulb (Fig. 35e) . . . . . *B. phoenicis* sensu stricto (Geijskes)

6. Prodorsum with large smooth region anterolaterally (Figs 5a; 25a); dorsal opisthosoma smooth between *c1*-*c1* and *d1*-*d1* (Figs 5c, 25c–d) 7

- Prodorsum with short folds and reticulation anterolaterally (Figs 45a–b); dorsal opisthosoma with folds and wrinkles between *c1*-*c1* and *d1*-*d1* (Figs 45c–d) . . . . . *B. tucuman* sp. nov. Beard & Ochoa

7. Cuticle anterior to each seta *d1* with an obvious oblique fold (Figs 25c–d); cuticle between *d1*-*d1* and *e1*-*e1* with a few strong transverse folds (Figs 25c–e); ventral cuticle between setae *4a*-*4a* and ventral plate with distinct transverse bands (Figs 26a–b) . . . . . *B. papayensis* Baker

- Cuticle anterior to each seta *d1* smooth (Fig. 5c); cuticle between *d1*-*d1* and *e1*-*e1* smooth (Figs 5c–e); ventral cuticle between setae *4a*-*4a* and ventral plate mostly verrucose with separately formed "warts", with some "warts" fused into short transverse bands (Figs 6a–b) . . . . . *B. azores* sp. nov. Beard & Ochoa

* = species in the *B. phoenicis* species group that possess strong sculpturing on the cuticle of the central prodorsum were not included in this study. See Gonzalez (1975) for information regarding such species.

Family Tenuipalpidae Berlese

Type genus—*Tenuipalpus* Donnadieu, 1875

Brevipalpus Donnadieu

Diagnosis (adult female). Dorsal opisthosomal setae *c1*, *c3*, *d1*, *d3*, *e1*, *e3*, *f3*, *h1*, *h2* present (except *d1*, *e1* absent in *B. recki*); setae *f2* present or absent; setae *c2*, *d2*, *e2* absent; setae *h2* not elongate. Anterior margin of prodorsum with broad flat projection extending over coxae I–II and base of gnathosoma. Venter with ventral, genital and anal plates well developed and sclerotised; two pairs of pseudanal setae present (*ps1–2*). Palps four segmented. Tarsus II with one or two short rod-shaped solenidia present (antiaxial solenidion always present, paraxial solenidion present or absent) (except solenidia elongate in *B. recki*).

Brevipalpus phoenicis species group

Diagnosis (adult female). As per genus, in addition to the following characters. Dorsal opisthosomal setae *f2* absent. Tarsus II with two distal solenidia (one paraxial, one antiaxial). Palp four segmented, setal formula 0-1-2-3(1). Setal formula for legs I–IV (coxae to tarsi): 2-2-1-1, 1-1-2-1, 4-4-2-1, 3-3-1-1, 5-5-3-3, 9(1)-10(2)-5-5.

Brevipalpus azores sp. nov. Beard & Ochoa

(Figs 1a, 3a, 5–7)

Material examined. Holotype. Female, Azores (Portugal), ex. lemon (Rutaceae), intercepted in Boston, USA, 18.i.1975, J.M.W. (#75-8887 USNM; 2 females on slide). **Paratypes.** Female same data as holotype (same slide as holotype); female, same data as holotype; female, ex. banana fruit (Musaceae), Azores (Portugal), intercepted in Philadelphia, USA, 17.viii.1943, V.C. Durham (USNM).

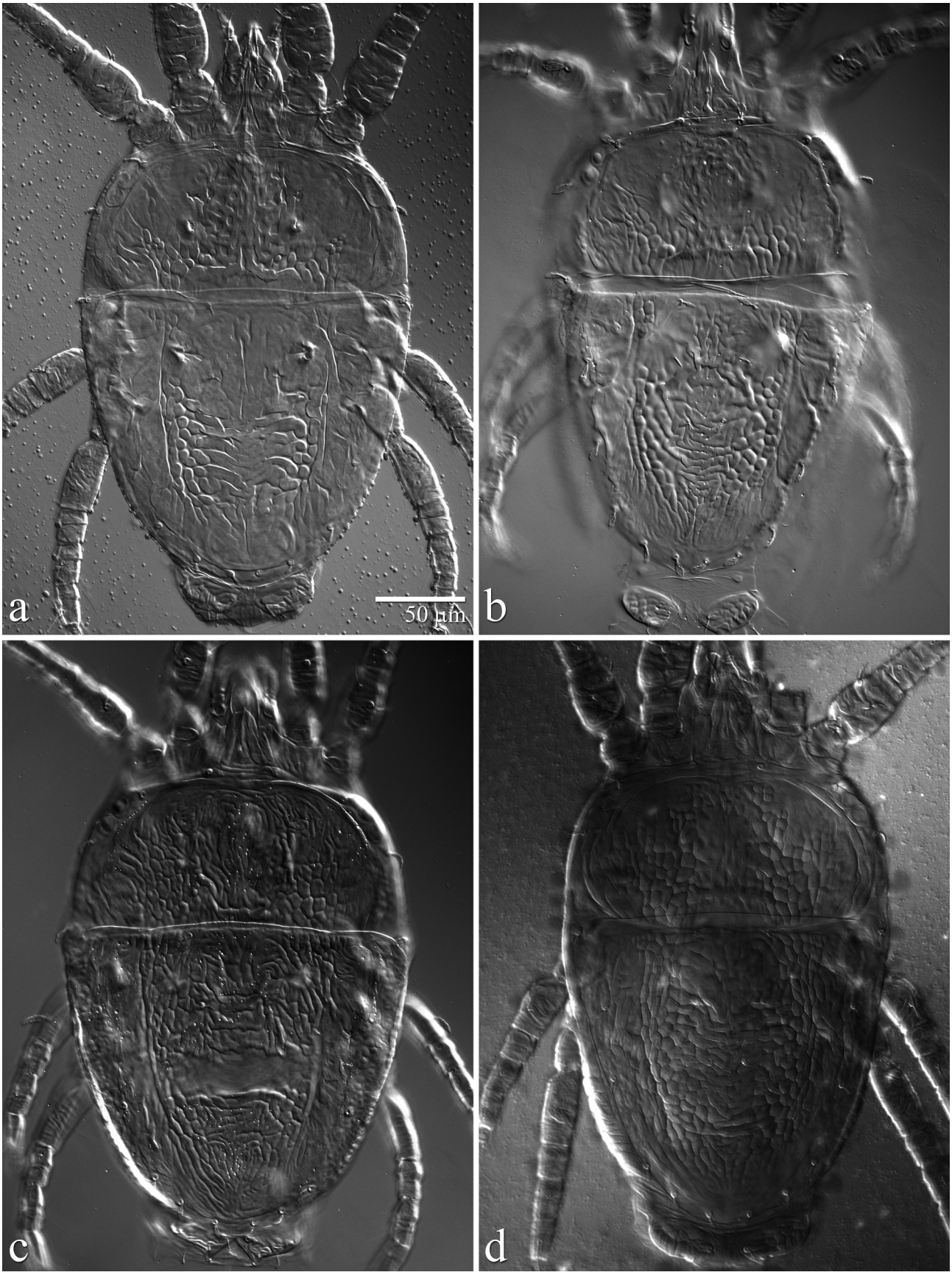

FIGURE 1. Female dorsal habitus, a. *Brevipalpus azores* sp. nov.; b. *B. feresi* sp. nov; c. *B. ferraguti* sp. nov.; d. *B. hondurani*.

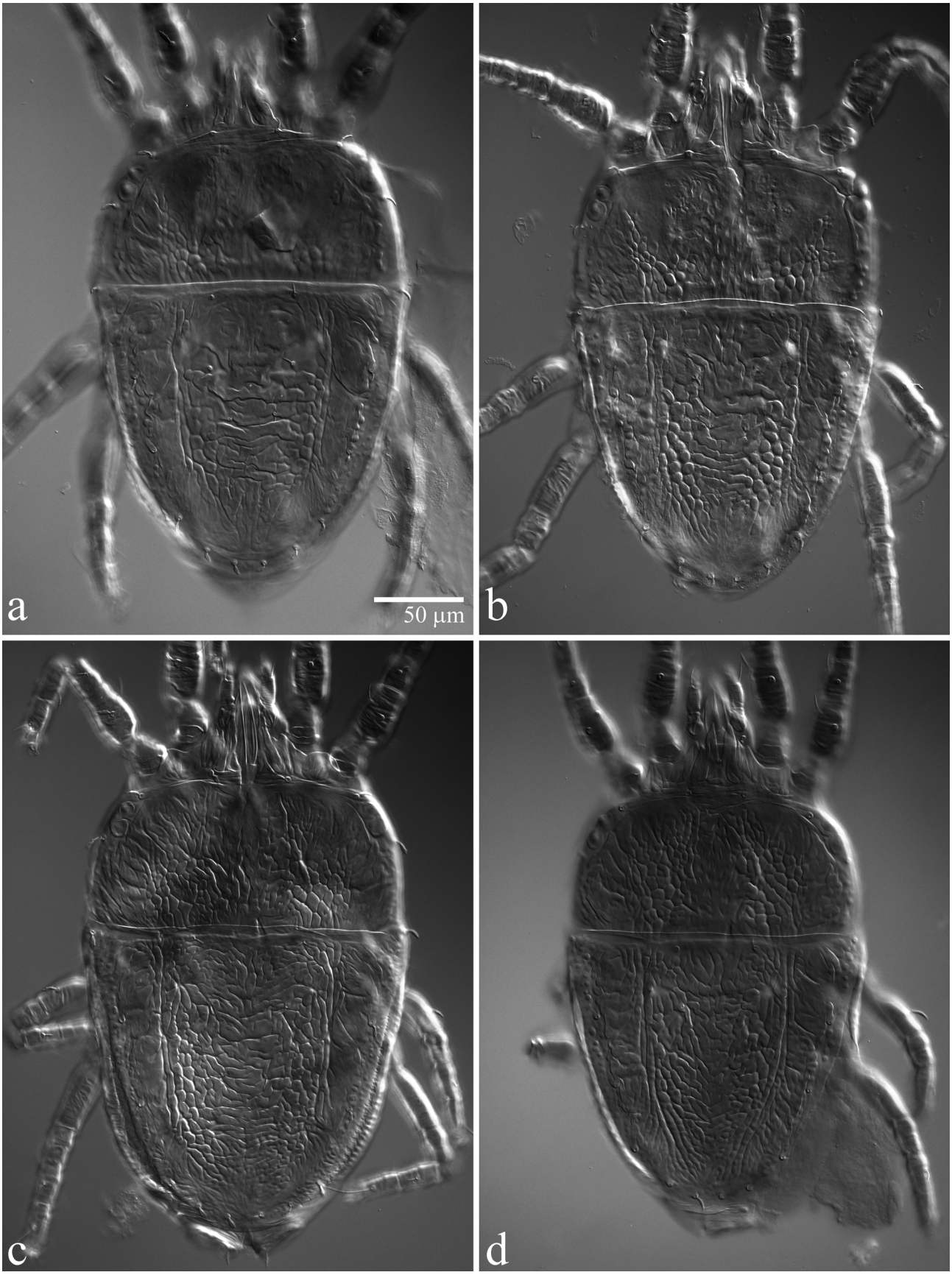

FIGURE 2. Female dorsal habitus, a. *Brevipalpus papayensis*; b. *B. phoenicis* sensu stricto; c. *B. tucuman* sp. nov.; d. *B. yothersi*.

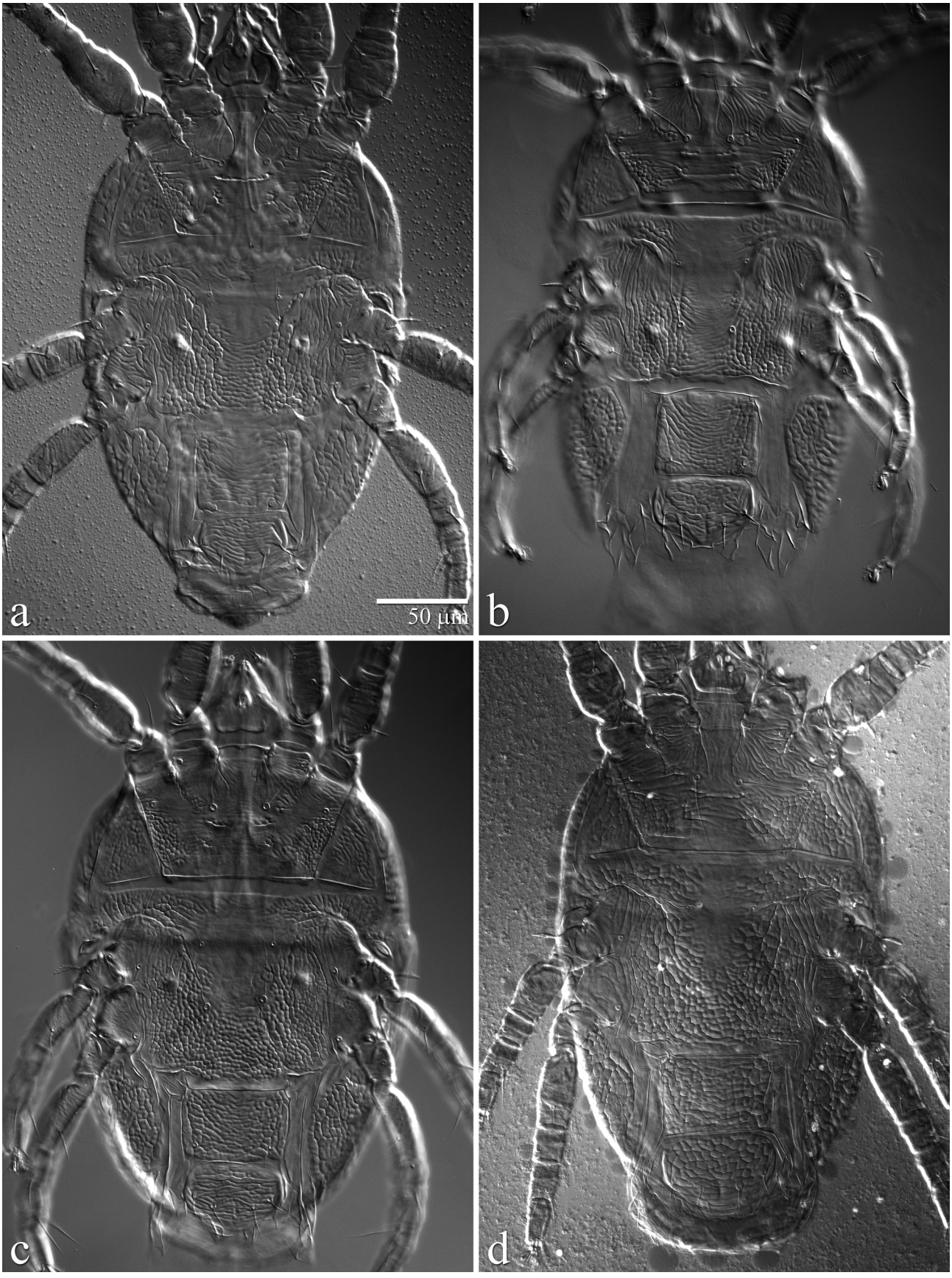

FIGURE 3. Female ventral habitus, a. *Brevipalpus azores* sp. nov.; b. *B. feresi* sp. nov; c. *B. ferraguti* sp. nov.; d. *B. hondurani*.

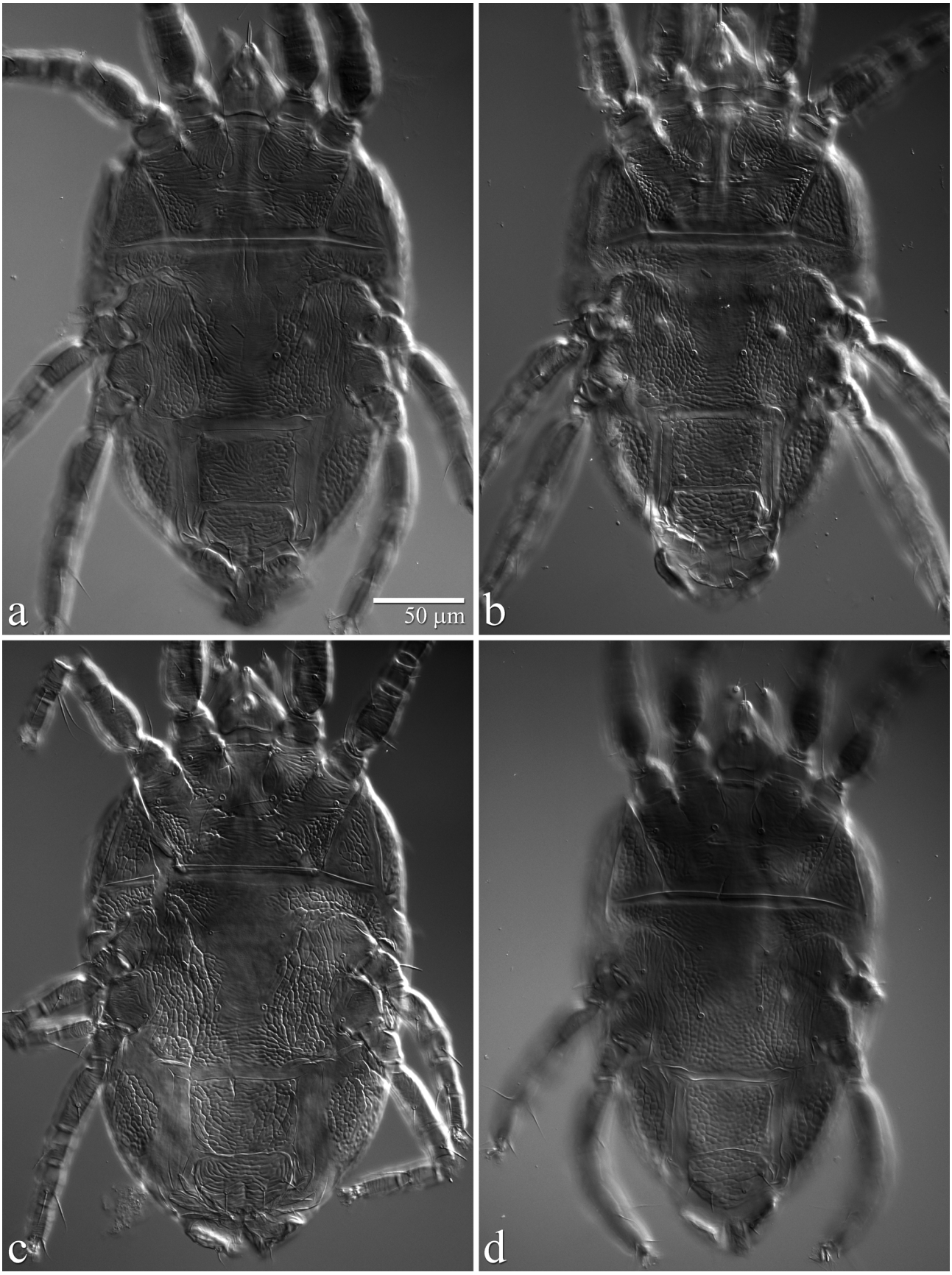

FIGURE 4. Female ventral habitus, a. *Brevipalpus papayensis*; b. *B. phoenicis* sensu stricto; c. *B. tucuman* sp. nov.; d. *B. yothersi*.

Other material examined. **Canary Islands (Spain):** female, 3 protonymphs, larva, ex. lemon fruit (Rutaceae), intercepted in Philadelphia, USA, 18.ii.1948, R. Kennelty (USNM; 2 slides); 3 females, ex. lemons (Rutaceae), 4.ii.1959, J.M. del Rivero (USNM; 2 slides). **Democratic Republic of the Congo** (labelled as Belgian Congo)**:** female, ex. large leaf Quinine (possibly *Chinchona* sp. (Rubiaceae)), Mulunga, INEAC, 18.v.1955, E.W. Baker (#99 USNM); ex. tea leaf (Theaceae), Mulunga, INEAC, 18.v.1955, E.W. Baker (#104 USNM). **India:** 5 females, deutonymph, ex. *Citrus* sp. (Rutaceae), Pomora, Assam, 20.ii.1959, C.A. Fleschner (#59-17921 USNM, 2 slides); 18 females, deutonymph, protonymph, ex. *Citrus* sp. (Rutaceae), Kalimpong, 27.v.1959, C.A. Fleschner (USNM; 4 slides). **Portugal:** female, larva, ex. tangerine (Rutaceae), intercepted in Boston, USA, 11.ii.1975, J.M. VV (USNM, 2 slides); 2 females, larva, ex. *Citrus reticulata* (Rutaceae), intercepted in Boston, USA, 13.ii.1975, J.M. VV. (USNM); female, ex. *Citrus* fruit (Rutaceae), intercepted in New York, USA, 18.iii.1982, J. Wymond (USNM). **Rwanda and Burundi** (labelled as Ruanda-Urindi): 2 females, ex. *Citrus* sp. (Rutaceae), Butare (formerly Astrida), 22.v.1955, E.W. Baker (USNM; 2 slides); 2 females, 2 deutonymphs, "on ivy" (possibly *Hedera* sp. (Araliaceae)), Butare (formerly Astrida), 22.v.1955, E.W. Baker (#109 USNM; 3 slides). **South Africa**: female, ex. *Datura stramonium* var. *metal* (Solanaceae), Natal Herbarium, Durban, 28.ii.1940, no collector (USNM; identified as *Tenuipalpus australis*, with *B. obovatus* and *B. phoenicis* s.s.). **USA:** 2 females, ex. grape plants (Vitaceae), Glenn Dale, Maryland, 20.ix.1951, W.B. Wood (#51–86, with *B. yothersi*). **Spain:** 2 females, ex. *Citrus aurantium* (Rutaceae), Burjassot, Estacion Fitopatologica, Valencia, 2.ii.1944 (USNM; misidentified as *B. pseudocuneatus*); 2 females, ex. *Citrus aurantium* (Rutaceae), Cullera, Estacion Fitopatologica, Valencia, x.1949 (USNM; misidentified as *B. pseudocuneatus*).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with strong, broad areolae; sublateral cuticle with some rounded cells posteriorly, with distinct cluster of small rounded cells medially, smooth anteriorly. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle mostly smooth, with some weak wrinkles; *d1-d1* to *e1-e1* cuticle mostly smooth, with some weak wrinkles; *e1-e1* to *h1-h1* cuticle with series of strong transverse folds, abruptly becoming smooth towards *h1-h1*; sublateral cuticle laterad *e1-e1* with large rounded, distinctly domed cells. Ventral plate: cuticle with weak transverse bands; without separately formed individual warts. Genital plate: cuticle with uniform narrow transverse bands. Palp femorogenu with dorsal seta broad, flat, barbed. Spermatheca with thick major duct; vesicle not visible. Cuticular microplates not examined.

Female (n = 10). *Dorsum.* (Figs 1a, 5) Body measurements: length between setae *v2-h1* 220–238 [238], width between setae *sc2-sc2* 145–158 [156], *c3-c3* 154–168 [163]. Central prodorsum: cuticle with strong broad areolae (Fig. 1a, 5a). Sublateral prodorsum: posterior region with some reticulation forming a few rounded cells; with a distinct cluster of small rounded cells medially; anterior region with large area of smooth cuticle (Fig. 5a). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* almost entirely smooth, with some weak wrinkles medially (Fig. 5c); *d1-d1* to *e1-e1* almost entirely smooth, with some weak wrinkles medially (Figs 5c–e); *e1-e1* to *h1-h1* with series of strong transverse folds abruptly becoming smooth towards *h1-h1* with a distinct, single central longitudinal fold (Figs 5d–f). Sublateral opisthosoma: anterior cuticle smooth, with few longitudinal folds; posterior cuticle with large, rounded, distinctly domed cells (Figs 5d–f). Dorsal setae short, barbed: *v2* 6–9 [6], *sc1* 10–11 [10–11], *sc2* 9–12 [9–10], *c1* 6–8 [7–8], *c3* 8–10 [9], *e1* 6–8 [7], *e3* 7–8 [8], *f3* 7–10 [8–9], *h1* 7–9 [7–8], *h2* 7–9 [7–8].

Dorsal microplates. Not examined.

Gnathosoma. (Fig. 5b). Palp chaetotaxy as in species group (see species group Diagnosis). Palp femorogenu with barbed, broad flat dorsal seta.

Venter. (Figs 3a, 6a–e). Cuticle between *4a* and ventral plate entirely verrucose with separately formed individual rounded warts; central cuticle may have some weak raised transverse bands formed by fusion of smaller warts; warts and weak bands continue half way between *4a* and *3a* (Figs 6a–b). Ventral plate: with weak raised bands, mostly transverse in orientation; ventral plate without separately formed individual warts (Figs 6c–e). Genital plate: with uniform narrow transverse bands or folds (Figs 6c–e).

Spermathecal apparatus. Vesicle not visible; distal bulb not visible*; thick duct visible leading from ovipore.

Legs. Setal formula for legs I–IV as in species group (see species group Diagnosis). Tarsus II with two solenidia, paraxial 7–8 [7], antiaxial 7–8 [7] (Fig. 6f).

Male. Unknown.

Deutonymph. *Dorsum*. (Fig. 7) Prodorsal setae *v2* short to minute. Opisthosomal setae *c1*, *d1*, *d3*, *e1*, *e3* minute; setae *c3*, *f3*, *h1*, *h2* enlarged, broadly lanceolate, barbed (Fig. 7). Dorsal seta on palp femorogenu broad, as in adult.

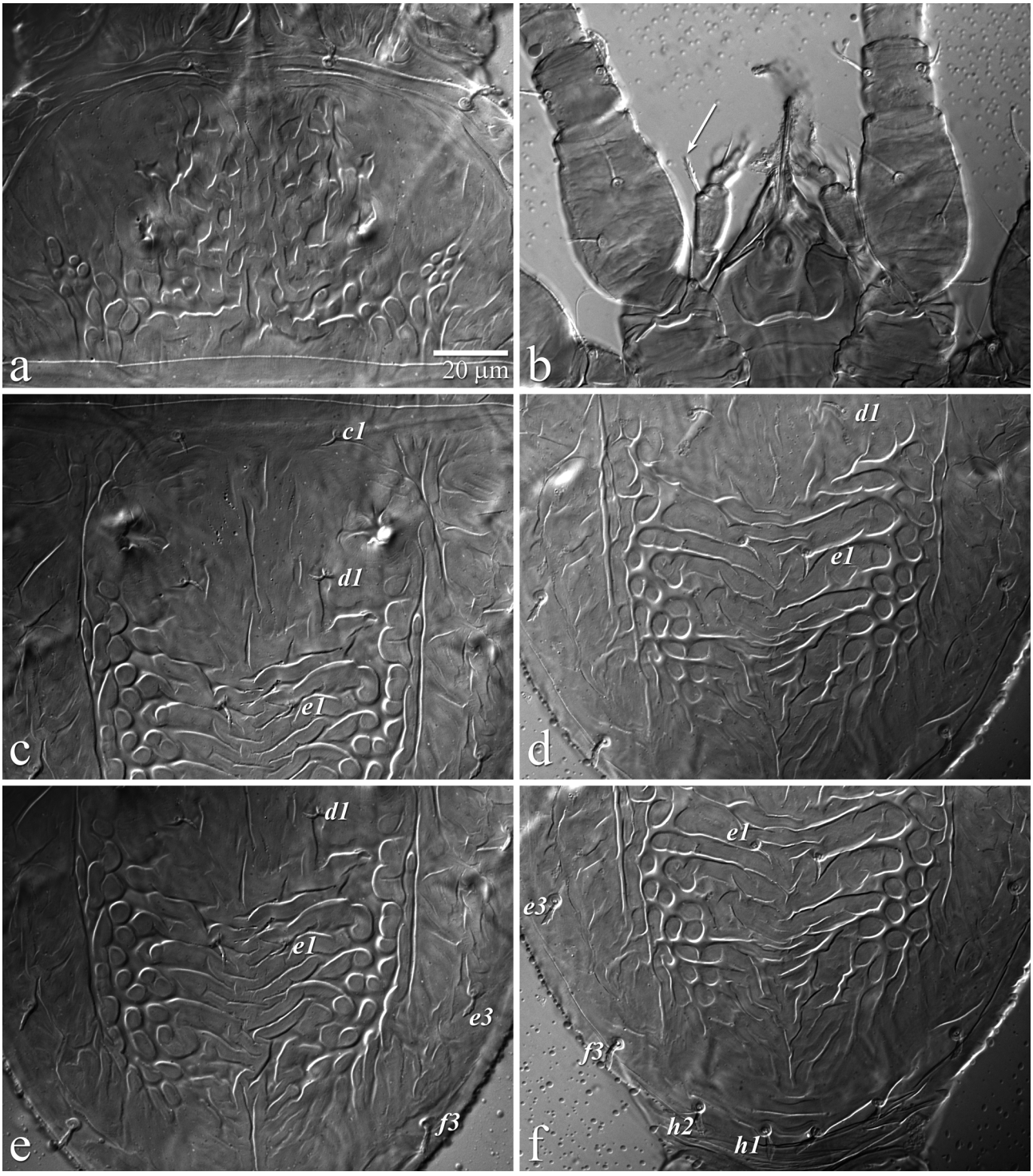

FIGURE 5. *Brevipalpus azores* sp. nov. female, a. prodorsum; b. gnathosoma (arrow indicates dorsal seta on palp femorogenu); c. anterior dorsal opisthosoma; d., e. central dorsal opisthosoma; f. posterior dorsal opisthosoma.

Hosts. Most commonly *Citrus* spp. (Rutaceae); but also collected from *Datura stramonium* (Solanaceae), *Musa* sp. (Musaceae), *Vitus* sp. (Vitaceae).

Distribution. Azores, Canary Islands, Democratic Republic of Congo, Guatemala, Honduras, India, Portugal, Rwanda Burundi, South Africa, Spain, USA (MD).

Etymology. This species is named for the type location, Azores.

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species D.

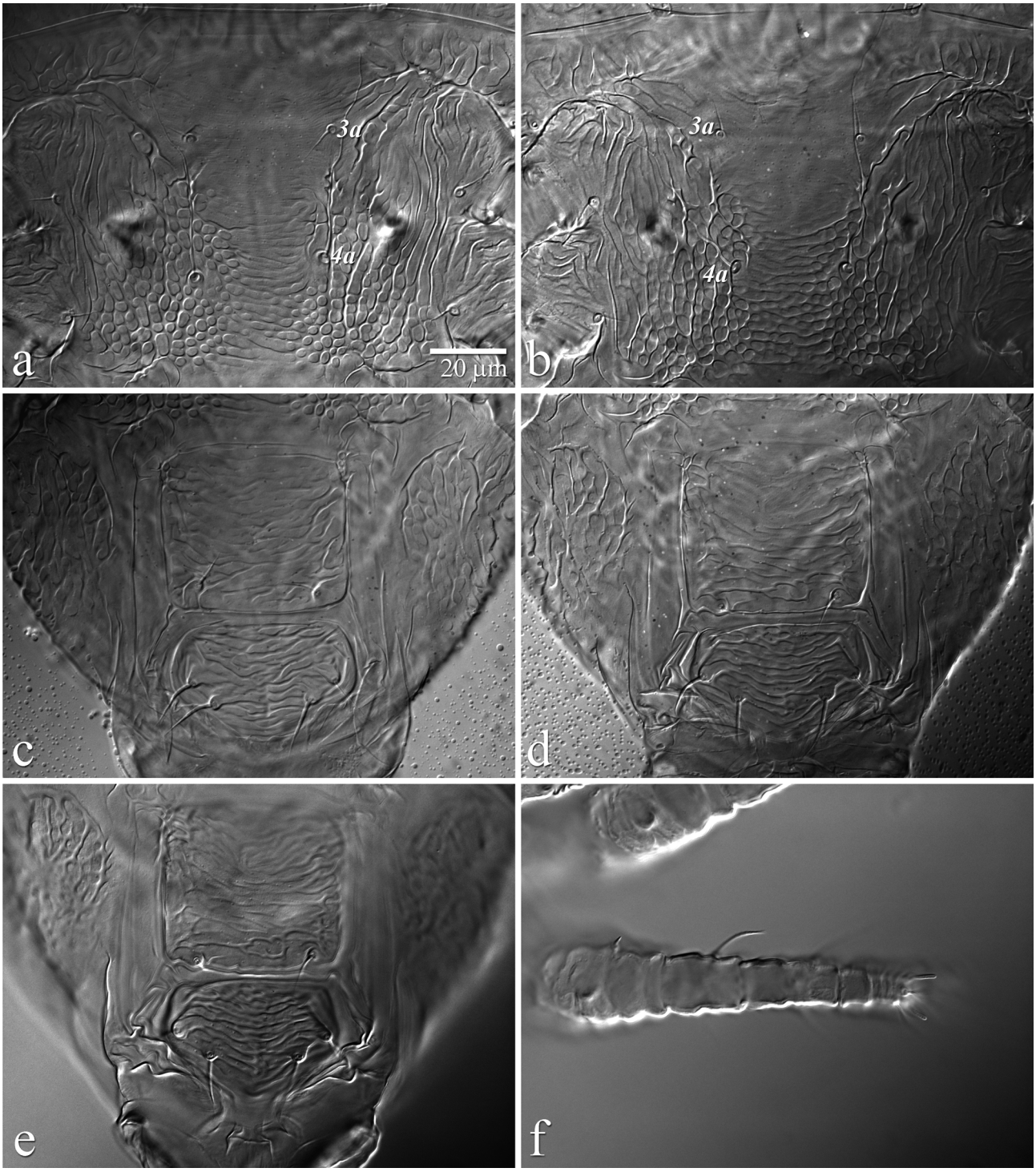

FIGURE 6. *Brevipalpus azores* sp. nov. female, a., b. ventral cuticle between coxae III–IV; c., d., e. posterior venter, indicating ventral and genital plates; f. leg II, indicating two solenidia on tarsus II.

*It is important to note here that the spermatheca as described here could represent an undeveloped receptacle. Within a single population of a given *Brevipalpus* species, there are often females with a fully developed spermathecal apparatus (which is usually a sclerotised vesicle of various morphology) mixed with females with an undeveloped spermathecal apparatus (which is usually a blindly ending duct with a distal membranous bulb of various morphology) (pers. obs. Beard & Ochoa; pers. obs. Oliveira & Navia; see also Alberti *et al.* 2014, Fig. 6.20). In this case, we need to collect and examine more females to find and describe the fully developed spermathecal apparatus.

FIGURE 7. *Brevipalpus azores* sp. nov. deutonymph dorsum.

***Brevipalpus feresi* sp. nov. Ochoa & Beard**
(Figs 1b, 3b, 8–14)

Material examined. Holotype. Female, Brazil, ex. *Croton floribundus*, (Euphorbiaceae), Rio Petro, São Paulo, 8.vi.2011, Daud, Ochoa, Feres, Demite (UNESP). **Paratypes.** 13 females, 1 deutonymph, same data as holotype (UNESP, USNM).

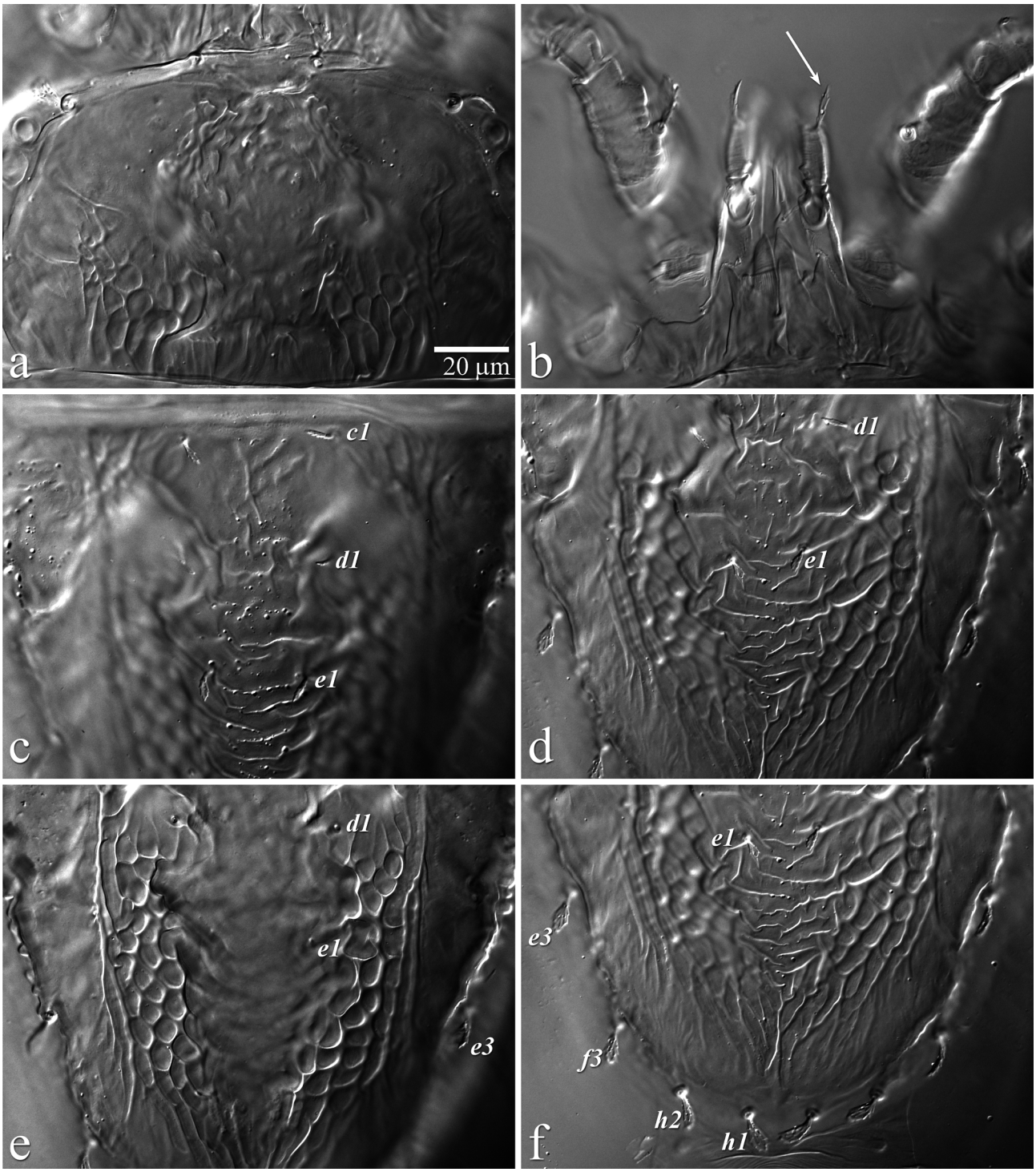

FIGURE 8. *Brevipalpus feresi* sp. nov. female, a. prodorsum; b. gnathosoma (arrow indicates dorsal seta on palp femorogenu); c. anterior dorsal opisthosoma; d., e. central dorsal opisthosoma (different focal planes); f. posterior dorsal opisthosoma.

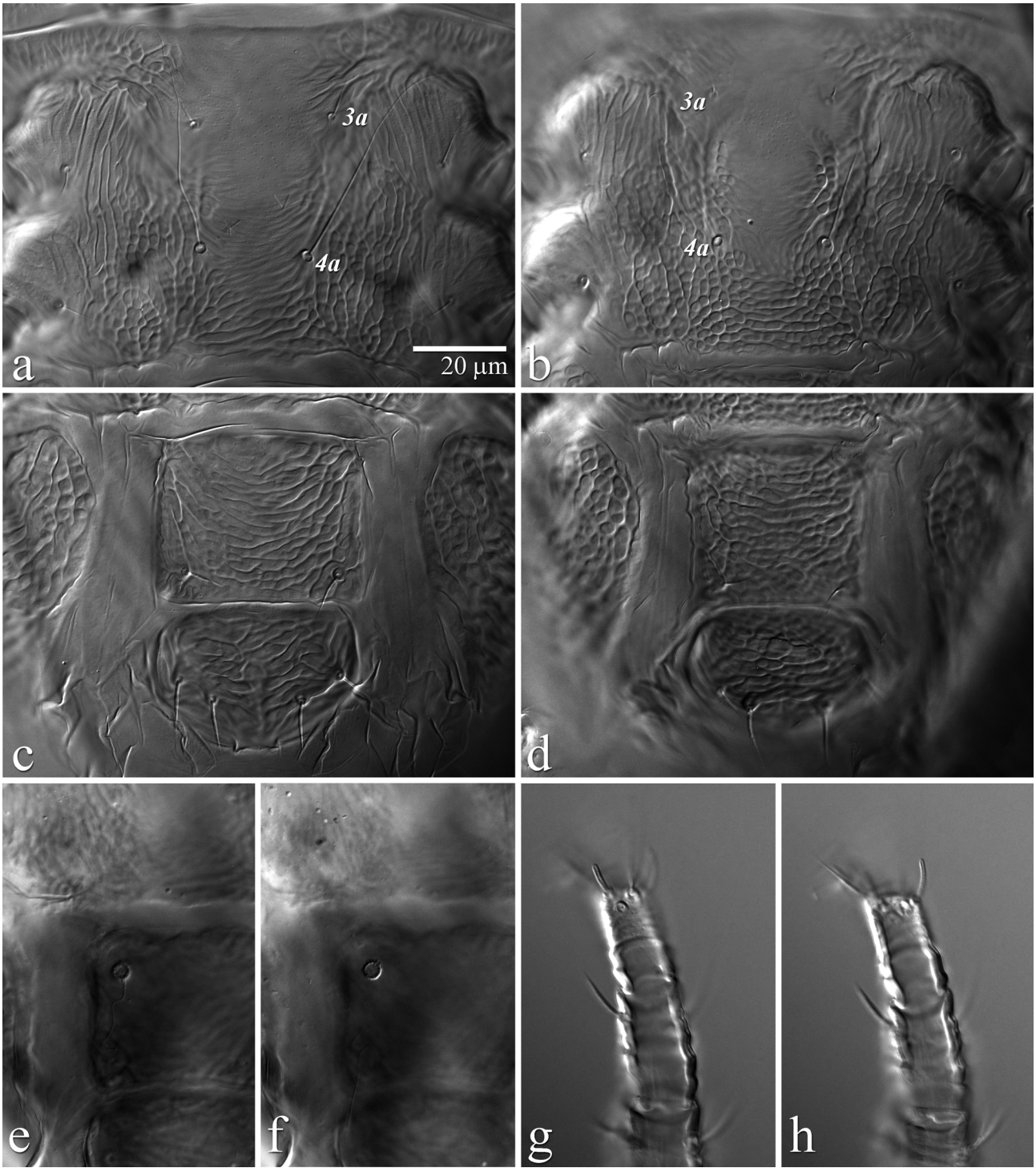

FIGURE 9. *Brevipalpus feresi* sp. nov. female, a., b. ventral cuticle between coxae III–IV; c., d. posterior venter, indicating ventral and genital plates; e., f. spermatheca (different focal planes) ; g., h. leg II, indicating two solenidia on tarsus II (different focal planes).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with strong, broad areolae; sublateral cuticle with reticulation forming broad rounded cells posteriorly, mostly smooth anteriorly. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle mostly smooth to wrinkled; *d1-d1* to *e1-e1* cuticle with irregular folds; *e1-e1* to *h1-h1* cuticle with series of short transverse folds, becoming longitudinal towards *h1-h1*; sublateral cuticle reticulate with large, uniform, distinctly rounded cells, cells becoming elongate towards *h1-h1*. Ventral plate: cuticle with few or no separately formed individual warts (i.e. weakly verrucose); warts are fused to form transverse bands. Genital plate: cuticle uniformly verrucose-reticulate, with large

transversely elongate cells formed by fused warts. Palp femorogenu with dorsal seta broad, flat, barbed. Spermatheca: a long narrow, convoluted duct terminating in a small rounded vesicle, with weakly formed crown of short projections. Cuticular microplates: separate individual, rounded to irregularly rounded plates, with multiple short irregular ridges over dorsal surface; ridges aligned in haphazard directions, no parallel ridges present.

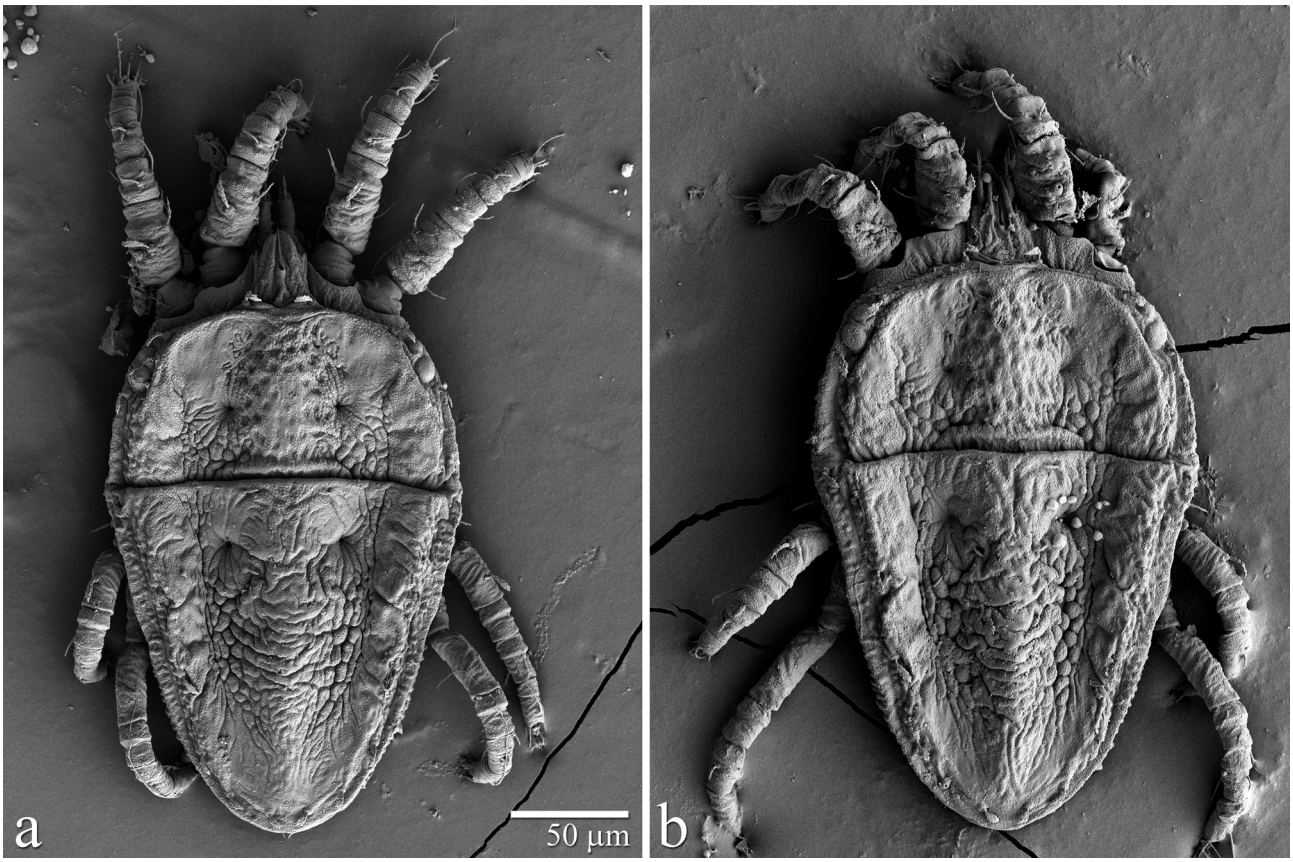

FIGURE 10. *Brevipalpus feresi* sp. nov. female dorsal habitus.

Female (n = 7). *Dorsum.* (Figs 1b, 8, 10, 11) Body measurements: length between setae *v2-h1* 222–240 [240], width between setae *sc2-sc2* 143–149 [149], *c3-c3* 157–166 [162]. Central prodorsum: cuticle with strong, broad areolae. Sublateral prodorsum: posterior region with reticulation forming a broad rounded cells; anterior region with broad smooth area (Figs 1a, 8a, 10, 11). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* smooth to wrinkled (Fig. 8c); *d1-d1* to *e1-e1* with irregular folds (Figs 8c–d); *e1-e1* to *h1-h1* with short series of short transverse folds, becoming longitudinal folds towards *h1-h1* (Figs 8d, f). Sublateral opisthosoma: cuticle reticulate with large, uniform, distinctly rounded cells laterad *d1-e1* (Fig. 8e), cells becoming less rounded posteriorly (Fig. 8f). Dorsal setae moderately broad, barbed: *v2* 10–13 [12–13], *sc1* 13–14 [13], *sc2* 13–15 [14], *c1* 7–11 [10–11], *c3* 10–14 [13–14], *e1* 7–9 [7], *e3* 10–13 [12], *f3* 9–13 [11–12], *h1* 10–13 [11–12], *h2* 9–12 [11].

Dorsal microplates. (Fig. 13). Separate rounded to irregularly shaped plates, of various sizes, with multiple short irregular ridges on dorsal surface, aligned in apparently random directions; no series of parallel ridges present.

Gnathosoma. (Fig. 8b). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed, moderately broad flat dorsal seta.

Venter. (Figs 3b, 9a–d, 12). Lateral cuticle between *4a* and ventral plate verrucose with separately formed rounded warts; central cuticle with weakly developed raised transverse bands, bands become weaker towards *4a-4a* and eventually disappear anterior to *4a-4a* becoming fine striae (may appear smooth); transverse bands maybe weakly formed or broken into transversely elongate warts; central cuticle without separately formed warts (Figs 9a–b, 12a). Ventral plate: with weak verrucose cuticle, with little or no separately formed warts; warts are fused together to form narrow transverse bands (transverse bands sometimes weak) (Figs 9c–d, 12b). Genital plate: uniformly verrucose or verrucose-reticulate, with moderate to large conglomerate warts which are often moderately transversely elongate (Figs 9c–d, 12b).

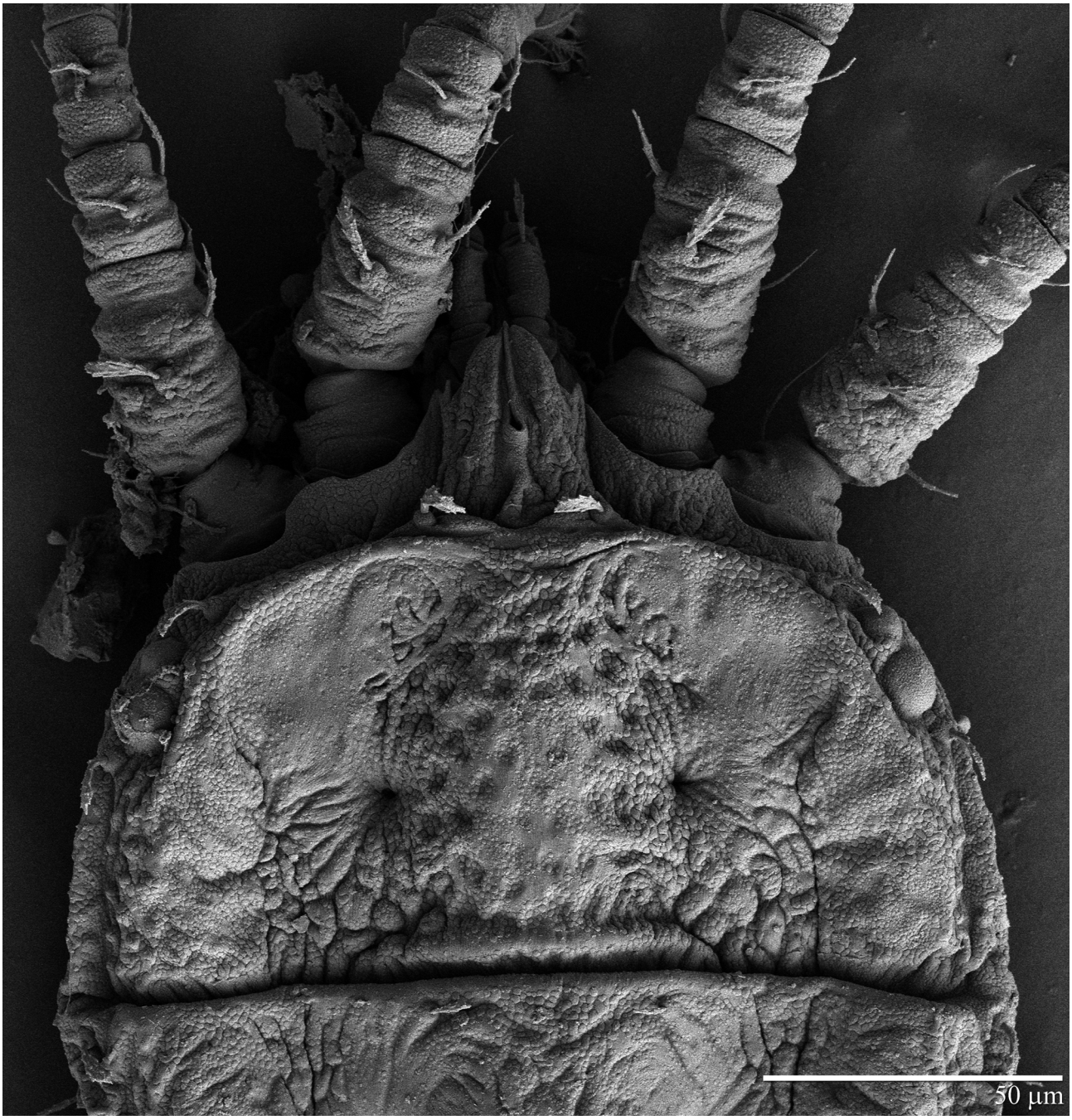

FIGURE 11. *Brevipalpus feresi* sp. nov. female, detail of prodorsum.

Spermathecal apparatus. (Figs 9e–f). A long narrow, convoluted duct is visible, ending in a rounded vesicle with weakly formed crown of short projections (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 8–10 [9–10], antiaxial 6–8 [7] (Figs 9g–h).

Male. Unknown.

Deutonymph. *Dorsum.* (Fig. 14) Prodorsal setae *v2* long, broadly lanceolate (Fig. 14a). Opisthosomal setae *c1*, *d1*, *e1* minute; setae *c3*, *d3*, *e3*, *f3*, *h1*, *h2* enlarged, broadly lanceolate, barbed (Fig. 14b). Dorsal seta on palp femorogenu broad, as in adult.

Hosts. *Croton floribundus* (Euphorbiaceae).

Distribution. São Paulo, Brazil.

Etymology. This species is named in honour of Brazilian acarologist, Dr Reinaldo J. F. Feres, for his dedication to the study of mites in South America.

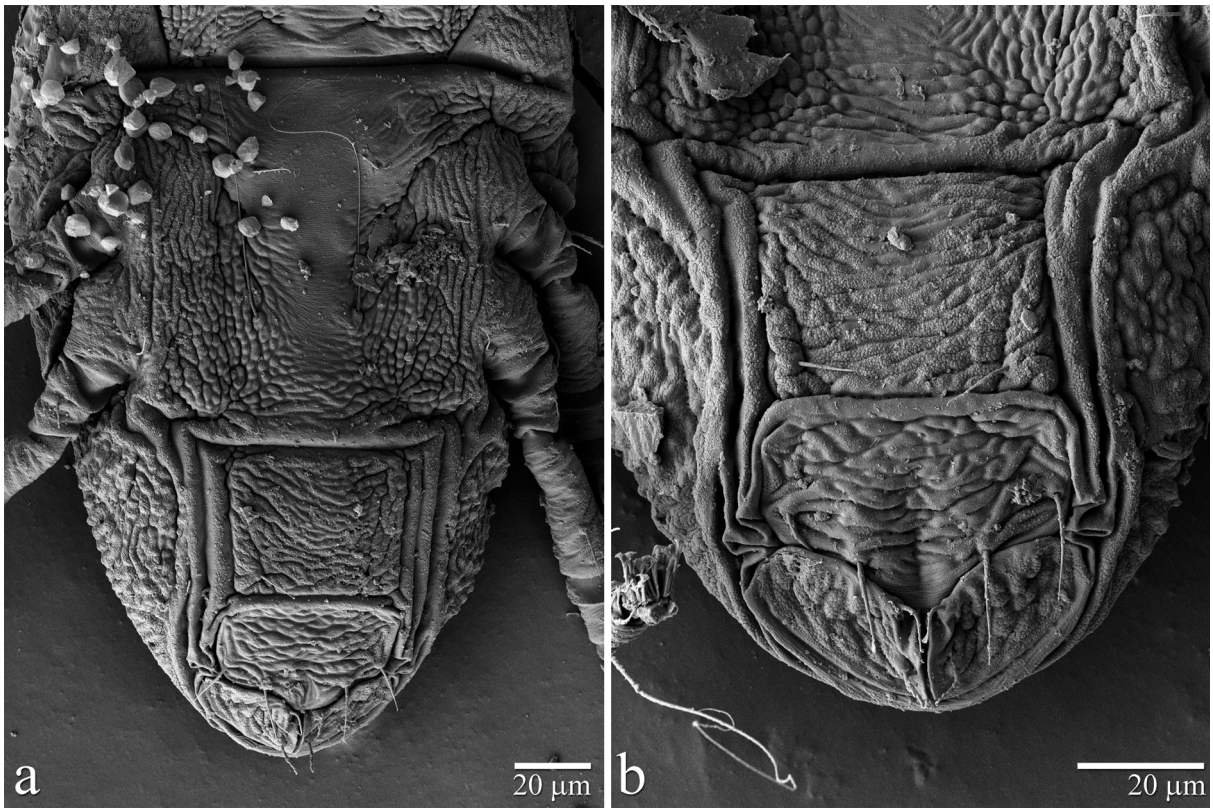

FIGURE 12. *Brevipalpus feresi* sp. nov. female, a. ventral habitus; b. detail of ventral and genital plates.

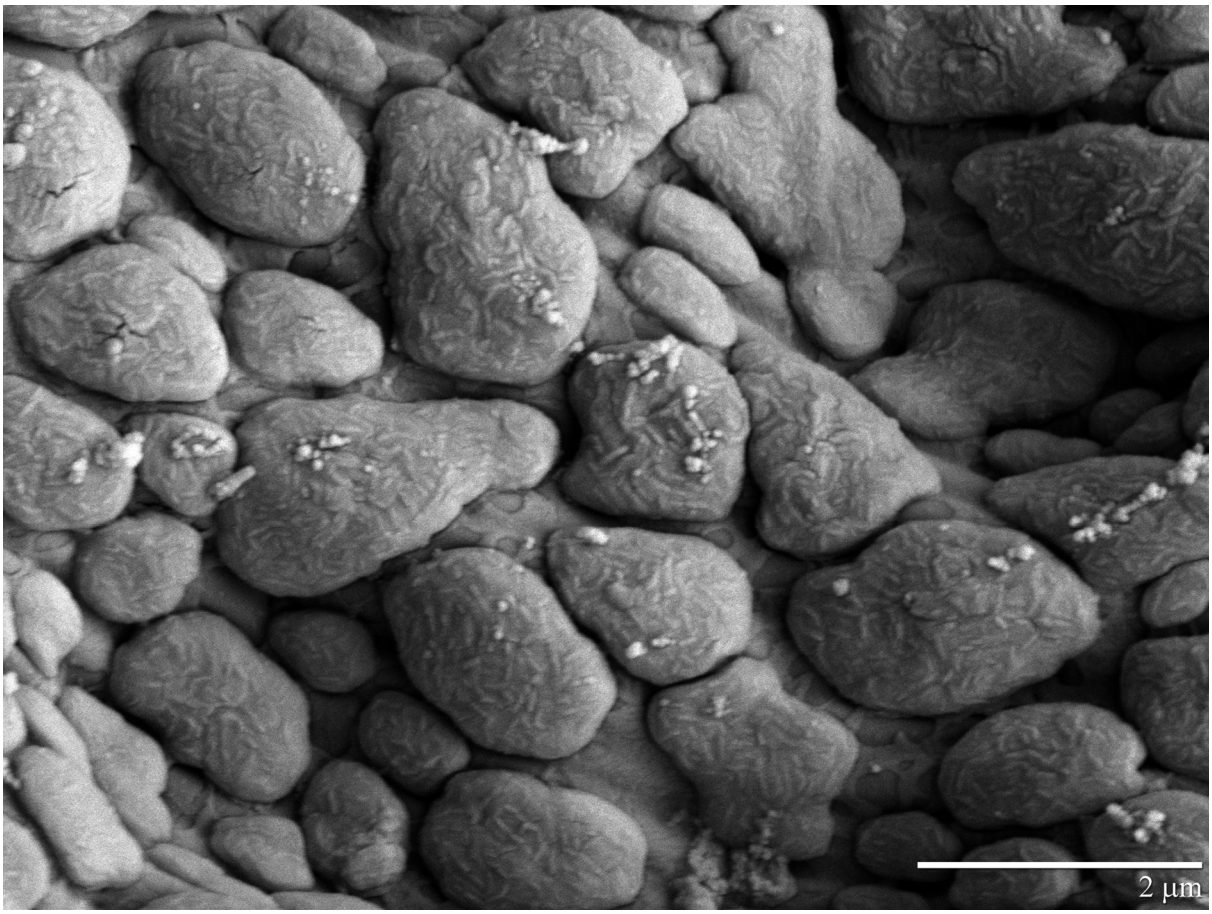

FIGURE 13. *Brevipalpus feresi* sp. nov. female, detail of microplates on dorsal cuticle (15,000X).

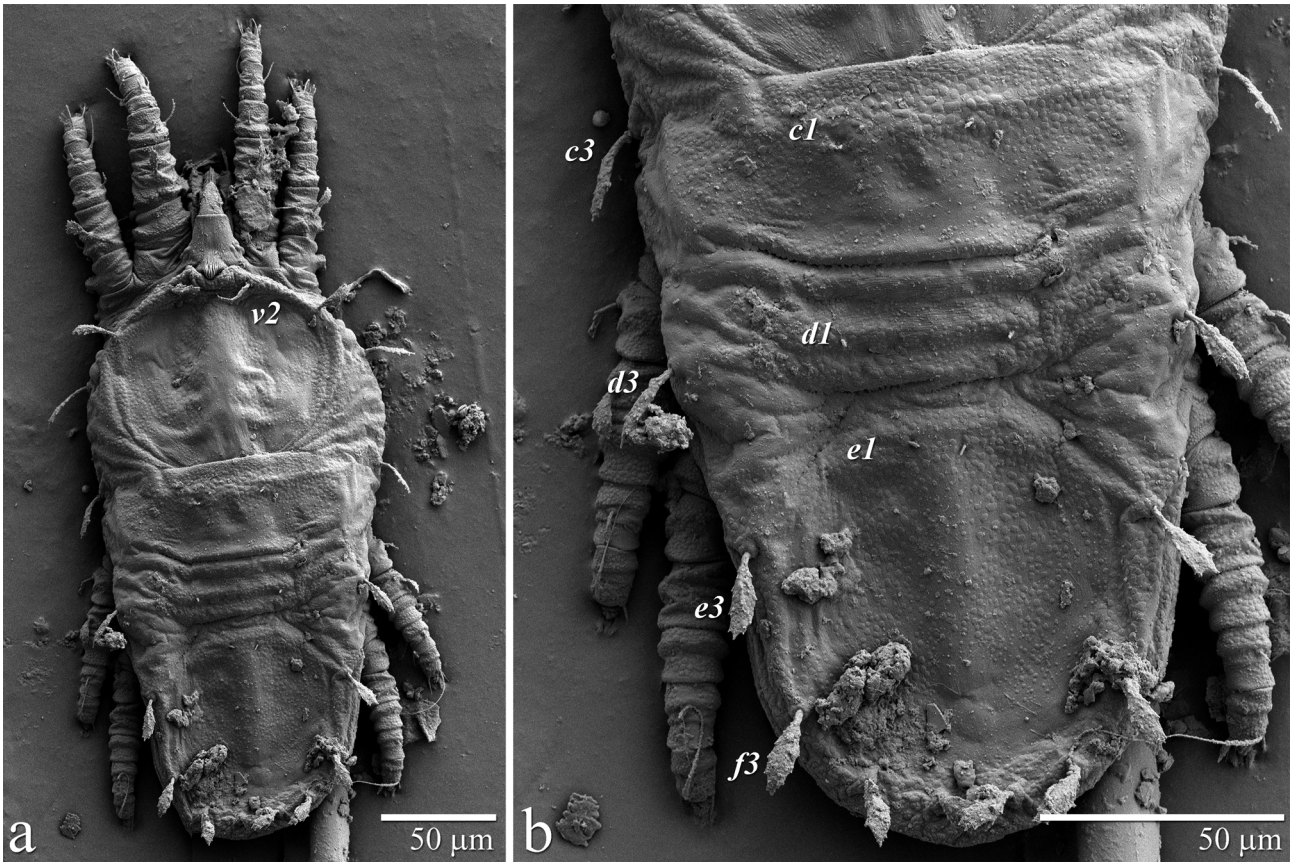

FIGURE 14. *Brevipalpus feresi* sp. nov. deutonymph dorsum (scale bar = a. 100 microns; b. 50 microns).

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species E. Large numbers of mites were observed in the field (pers. com. R. Feres).

Brevipalpus ferraguti sp. nov. Ochoa & Beard

(Figs 1c, 3c, 15–22)

Material examined. Holotype. Female, Spain, ex. "Ngaio", *Myoporum laetum* (Scrophulariaceae), Valencia, 2.viii.2011, F. Ferragut (MNCN). **Paratypes.** 3 females, 4 deutonymphs, protonymph same data as holotype (UPVLA; USNM).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with longitudinal wrinkles or fine folds; sublateral cuticle with reticulation forming large cells posteriorly, with weak reticulation and folds anteriorly; areolae absent. Dorsal opisthosoma: *c1*-*c1* to *d1*-*d1* cuticle with strong wrinkles and folds; *d1*-*d1* to *e1*-*e1* cuticle with strong wrinkles and folds becoming series of short narrow transverse folds; *e1*-*e1* to *h1*-*h1* cuticle with series of short narrow transverse folds, becoming weakly reticulate towards *h1*-*h1*; sublateral cuticle reticulate with large, regular cells anteriorly becoming elongate posteriorly. Ventral plate: cuticle weakly verrucose, with separately formed individual warts; central warts often fused to form weak transverse bands or elongate warts. Genital plate: cuticle with uniformly narrow transverse bands. Palp femorogenu with dorsal seta broad, flat, barbed. Spermatheca: a long narrow, ending in an elongate membranous bulb. Cuticular microplates: separate individual, rounded to oblong plates, with multiple series of distinct parallel ridges over dorsal surface, groups of ridges aligned in multiple directions; resultant surface pattern resembles a "ball of yarn".

Female (n = 4). *Dorsum.* (Figs 1c, 15, 17–19) Body measurements: length between setae *v2*-*h1* 237–246 [246], width between setae *sc2*-*sc2* 148–159 [159], *c3*-*c3* 170–182 [182]. Central prodorsum: cuticle with wrinkles, mostly longitudinally oriented, wrinkles may be weak; areolae absent (Figs 15a–b, 16). Sublateral prodorsum:

posterior region with reticulation forming large cells; anterior region with weak reticulation becoming folds (Figs 15a–b, 16). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* with wrinkles and folds, may appear weakly reticulate (Figs 15c, 17, 19); *d1-d1* to *e1-e1* wrinkles becoming series of short narrow transverse folds (Figs 15d, 17, 19); *e1-e1* to *h1-h1* with series of transverse folds, becoming weakly reticulate or wrinkled towards *h1-h1* (Figs 15e, 17, 19). Sublateral opisthosoma: cuticle reticulate, with regular to longitudinally elongate cells (Fig. 19). Dorsal setae short, narrow, barbed: *v2* 9–11 [9–10], *sc1* 12–15 [14–15], *sc2* 12–13 [12], *c1* 6–7 [broken], *c3* 10–14 [13–14], *e1* 8–9 [8], *e3* 10–14 [11–12], *f3* 11–13 [11–12], *h1* 9–11 [10], *h2* 11–12 [11].

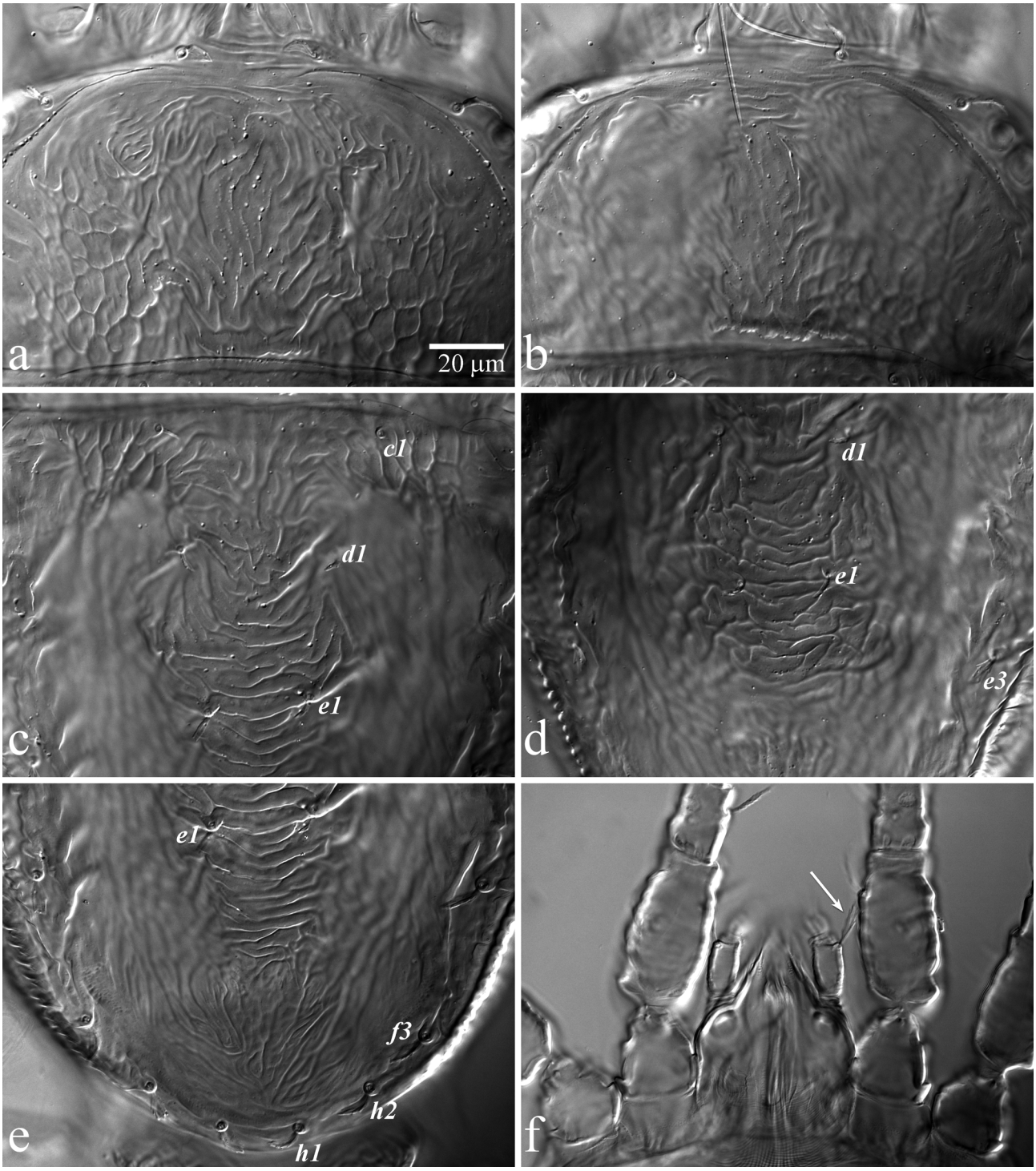

FIGURE 15. *Brevipalpus ferraguti* sp. nov. female, a., b. prodorsum; c. anterior dorsal opisthosoma; d. central dorsal opisthosoma; e. posterior dorsal opisthosoma; f. gnathosoma (arrow indicating dorsal seta on palp femorogenu).

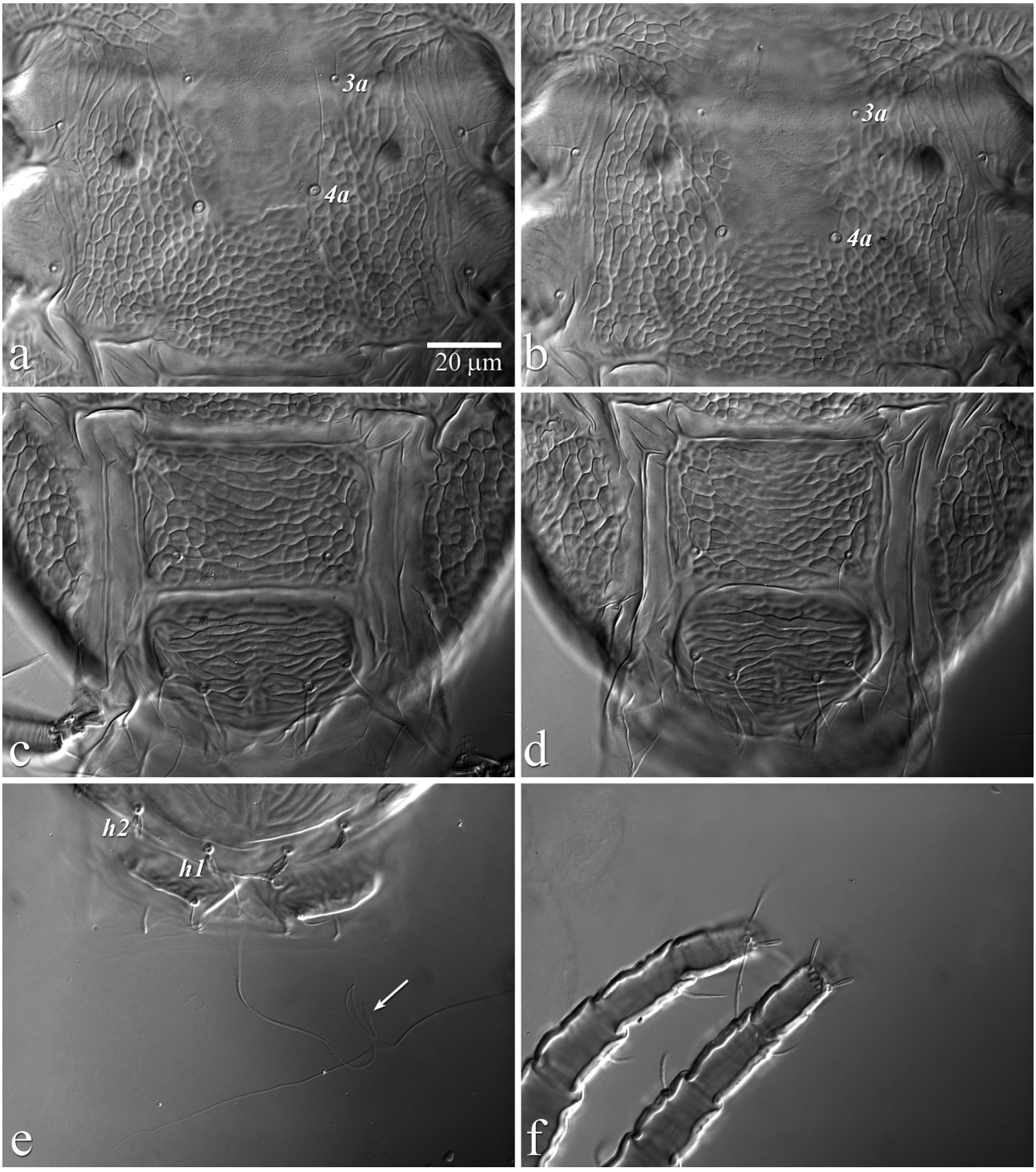

FIGURE 16. *Brevipalpus ferraguti* sp. nov. female, a., b. ventral cuticle between coxae III–IV; c., d. posterior venter, indicating ventral and genital plates; e. spermatheca (arrow indicates distal bulb); f. right legs I–II, indicating two solenidia on tarsus II.

Dorsal microplates. (Fig. 21). Separate individual, rounded to oblong plates, with multiple series of distinct parallel ridges on dorsal surface aligned in multiple directions. Dorsal ridges vary in length and alignment, and resultant surface pattern resembles a "ball of yarn".

Gnathosoma. (Fig. 15f). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed, broad flat dorsal seta.

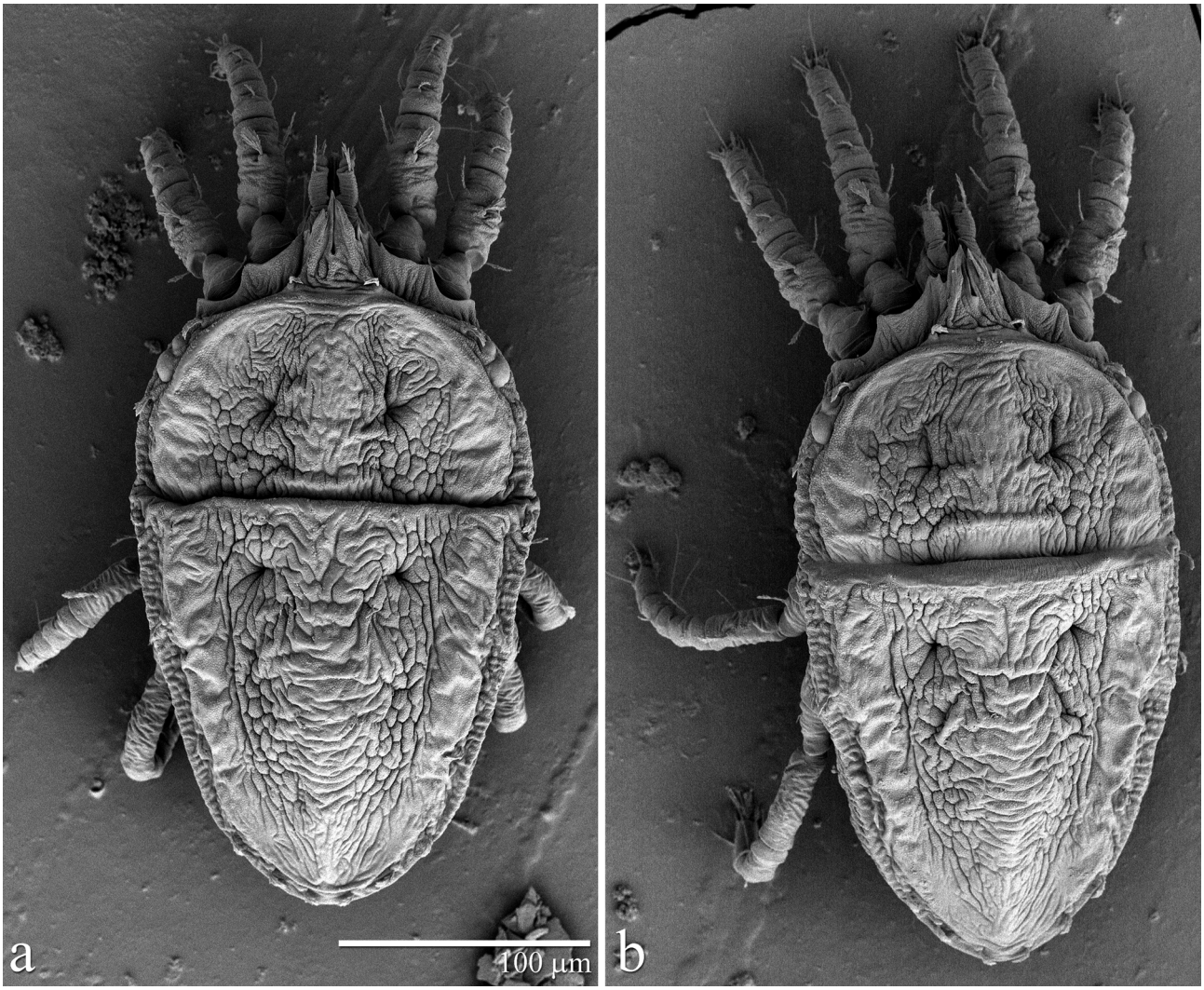

FIGURE 17. *Brevipalpus ferraguti* sp. nov. female dorsal habitus.

Venter. (Figs 3c, 16a–d, 20a–b). Cuticle between *4a* and ventral plate entirely verrucose with separately formed rounded warts; central cuticle may have some transversely elongate warts (formed by fusion of rounded warts) (Figs 16a–b, 20a–b). Ventral plate: with weak verrucose cuticle or weakly reticulate cuticle with rounded cells; cells in reticulation formed by fusion of smaller warts; sometimes with few weak transverse bands formed centrally (Figs 16c–d, 20b). Genital plate: with uniform narrow transverse bands or folds (Figs 16c–d, 20b).

Spermathecal apparatus. (Fig. 16e). Long narrow, duct often visible, ending blindly in small elongate, pointed, membranous bulb (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 8–9 [9], antiaxial 7–8 [7] (Fig. 16f).

Male. Unknown.

Deutonymph. *Dorsum.* (Fig. 22) Prodorsal setae *v2* short. Opisthosomal setae *c1*, *d1*, *e1* minute; setae *c3*, *d3*, *e3*, *f3*, *h1*, *h2* enlarged, broadly lanceolate, barbed (Fig. 22). Dorsal seta on palp femorogenu broad, as in adult.

Hosts. Ngaio or mousehole tree, *Myoporum laetum* (Scrophulariaceae).

Distribution. Spain.

Etymology. This species is named in honour of its collector, Spanish acarologist, Francisco Ferragut, for his dedication to the field of acarology.

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species F. The recorded host plant is a native to New Zealand that has been introduced to several other countries, including Spain.

FIGURE 18. *Brevipalpus ferraguti* sp. nov. female detail of prodorsum.

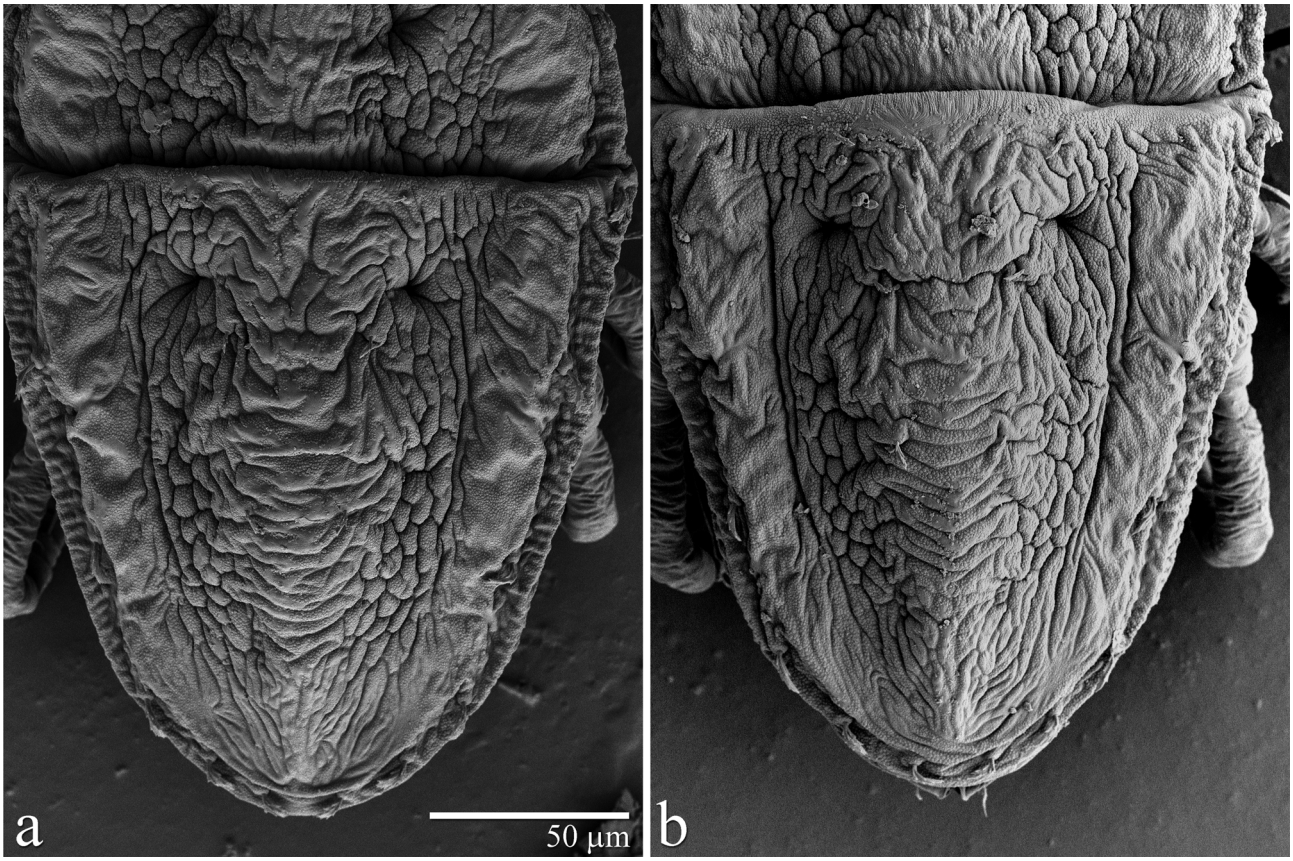

FIGURE 19. *Brevipalpus ferraguti* sp. nov. female detail of opisthosoma.

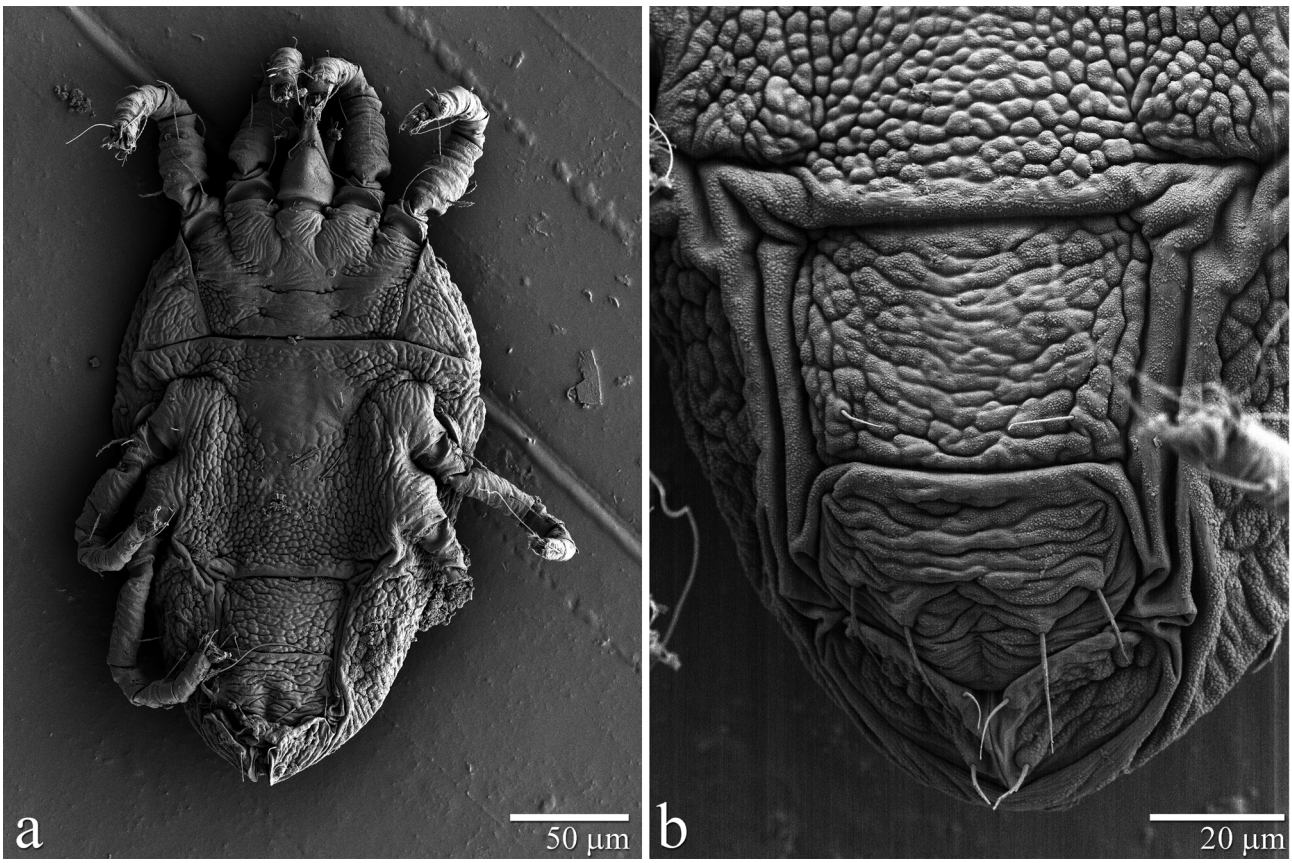

FIGURE 20. *Brevipalpus ferraguti* sp. nov. female, a. ventral habitus; b. detail of ventral and genital plates.

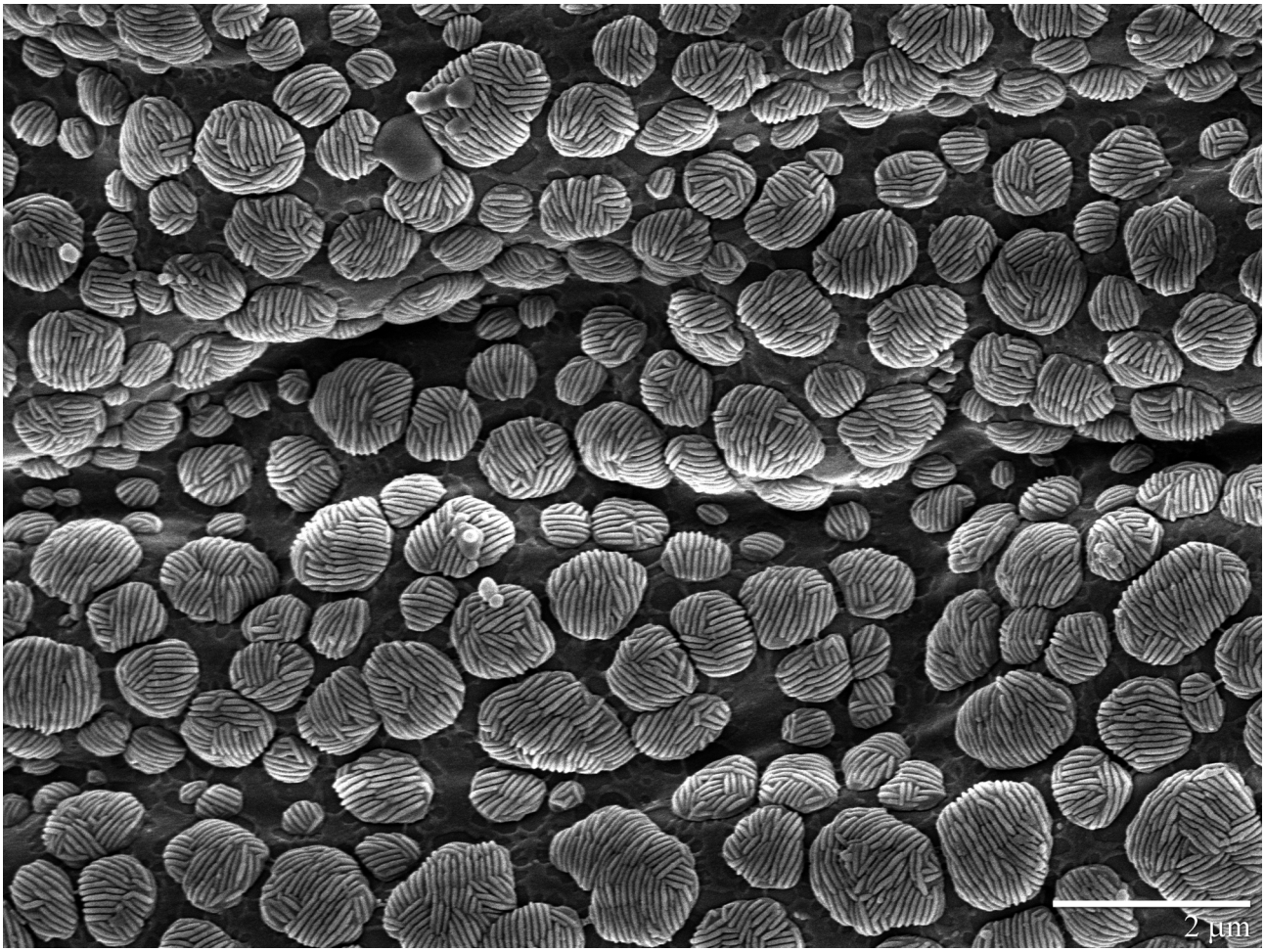

FIGURE 21. *Brevipalpus ferraguti* sp. nov. female detail of microplates on dorsal cuticle (15,000X).

Brevipalpus hondurani **Evans**
(Figs 1d, 3d, 23–24)

Brevipalpus hondurani Evans 1993: 141, Fig. 5. Original designation.

Material examined. Types. Holotype. Female, Honduras, ex. *Heterocentron subtriplinervium* (Melastomataceae), Parque La Tigra, FCO, Morazan, 16.xii.1987, G.A. Evans (USNM). **Paratype.** Same data as holotype except, ex. *Passiflora biflora* (Passifloraceae) (USNM).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with weak areolae; sublateral cuticle with reticulation forming large cells posteriorly, with large cells anteriorly, and with large smooth region anterolaterally. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle mostly smooth or weakly wrinkled; *d1-d1* to *e1-e1* cuticle with short transverse folds; *e1-e1* to *h1-h1* cuticle with few weak chevron shaped folds (V-shaped), cuticle becoming smooth towards *h1-h1*; sublateral cuticle reticulate with large, uniform, broad cells. Ventral plate: cuticle with irregularly shaped warts; central warts more elongate than lateral warts. Genital plate: cuticle with large warts. Palp femorogenu with dorsal seta broad, flat, barbed. Spermatheca: a moderately thick duct is visible leading from ovipore; no vesicle visible. Cuticular microplates: not examined.

Female (n = 2). *Dorsum.* (Figs 1d, 23) Body measurements: length between setae *v2-h1* 246–252 [246], width between setae *sc2-sc2* 145–162 [162], *c3-c3* 165–169 [169]. Central prodorsum: cuticle with weak areolae, usually longitudinally elongate (Fig. 23a). Sublateral prodorsum: posterior region reticulate with large cells; anterior region with narrow band large cells to setae *v2*, and large smooth area laterally (Fig. 23a). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* smooth or weakly wrinkled (Figs 23c–d); *d1-d1* to *e1-e1* with transverse folds, becoming

FIGURE 22. *Brevipalpus ferraguti* sp. nov. deutonymph dorsum.

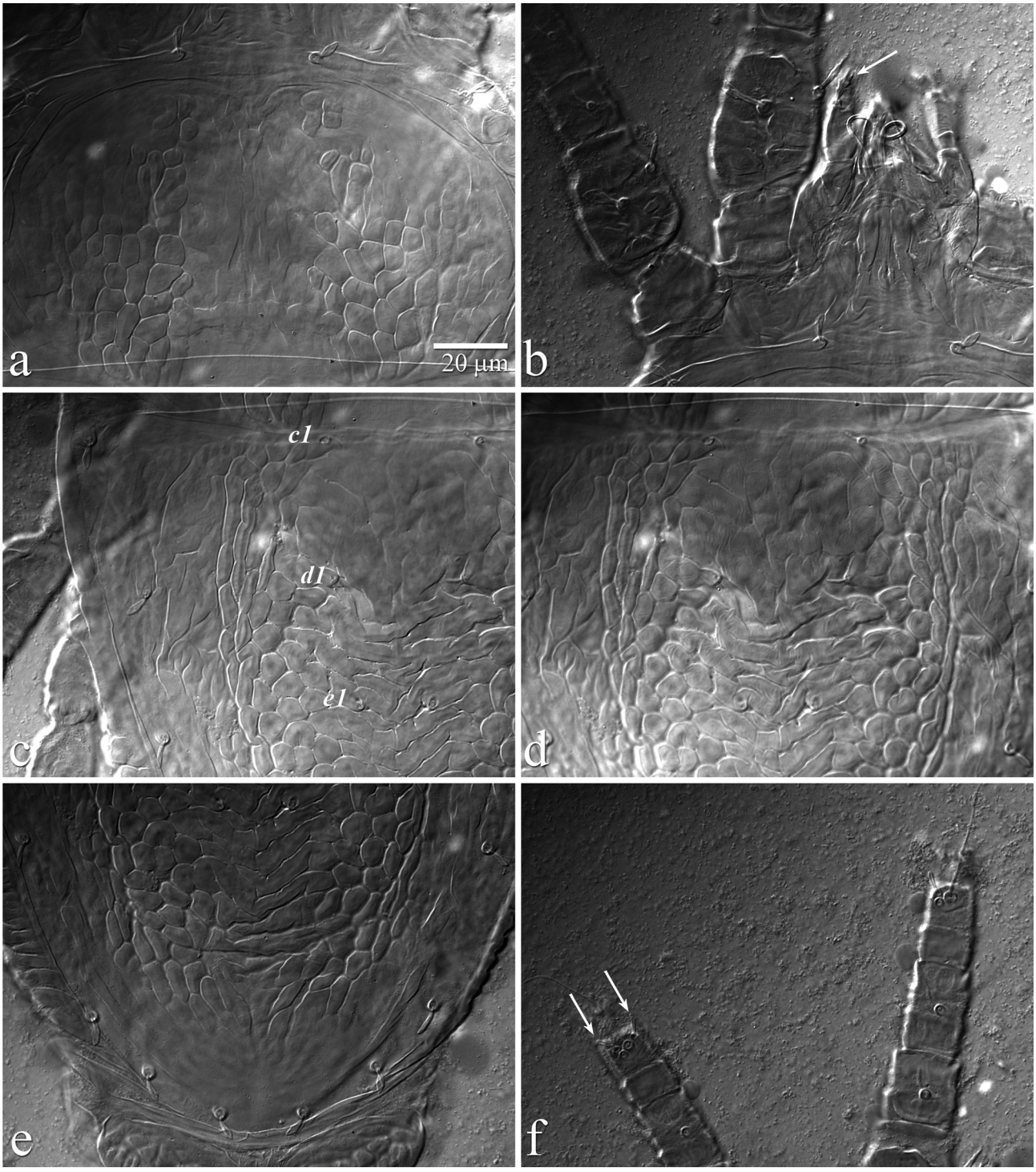

FIGURE 23. *Brevipalpus hondurani* female (holotype), a., prodorsum; b. gnathosoma (arrow indicating dorsal seta on palp femorogenu); c. anterolateral dorsal opisthosoma; d. anterior dorsal opisthosoma; e. posterior dorsal opisthosoma; f. left legs I–II with arrows indicating two solenidia on tarsus II.

chevrons (V-shaped) towards *e1-e1* (Figs 23c–d); *e1-e1* to *h1-h1* with strong chevrons becoming weak reticulation towards *h1-h1* (Fig. 23e). Sublateral opisthosoma: cuticle reticulate with large uniform cells often distinctly rounded, lateral and posterior cells becoming longitudinally elongate (Figs 23c, e). Dorsal setae short, apparently smooth: *v2* 7–8 [8], *sc1* 8–9 [8–9], *sc2* 9 [9], *c1* 6–7 [6–7], *c3* 8 [8], d1 6 [6], d3 8 [8], *e1* 6 [–], *e3* 7–8 [7–8], *f3* 9–10 [9–10], *h1* 7–8 [7–8], *h2* 8 [8].

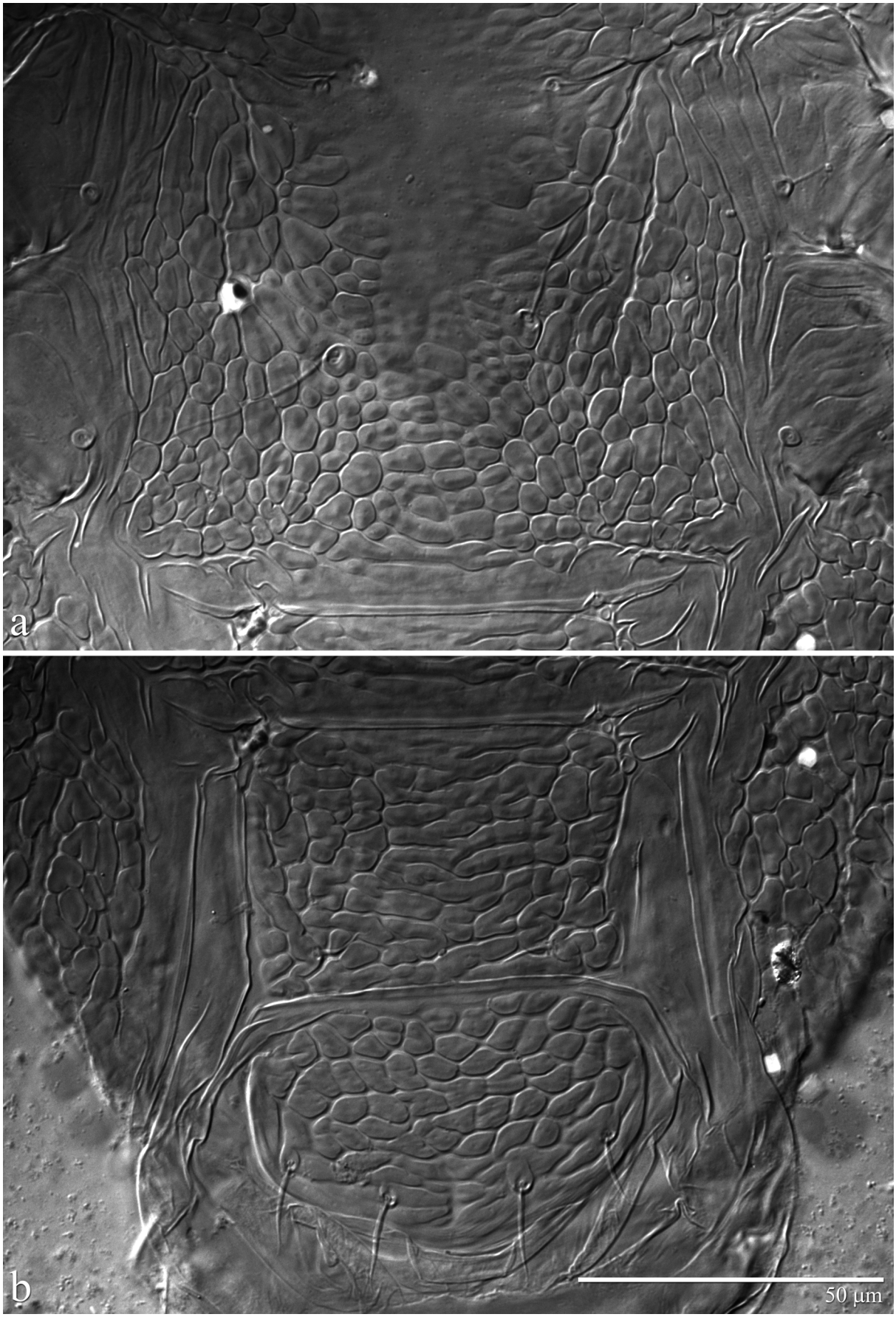

FIGURE 24. *Brevipalpus hondurani* female (holotype), a. ventral cuticle between coxae I–II; b. posterior venter with detail of ventral and genital plates.

Dorsal microplates. Not examined.

Gnathosoma. (Fig. 23b). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed, broadly cuneate dorsal seta.

Venter. (Figs 3d, 24a–b). Cuticle between *4a* and ventral plate reticulate with quite large cells, becoming weak and disappearing towards *4a-4a* (Fig. 24a). Ventral plate: with irregularly shaped cells; central cells fused to form some weak transverse bands (Fig. 24b). Genital plate: with uniform large cells (Fig. 24b).

Spermathecal apparatus. Not visible (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 5–6 [5], antiaxial 5–6 [5–6] (Fig. 23f).

Male. Unknown.

Deutonymph. Unknown.

Hosts. *Chamaedorea* sp. (Arecaeae); *Heterocentron subtriplinervium* (Melastomataceae); *Hydrocotyle mexicana* (Apiaceae); *Passiflora biflora* (Passifloraceae).

Distribution. Honduras.

Remarks. This species has not been recollected and is only known from the type material.

***Brevipalpus papayensis* Baker**

(Figs 2a, 4a, 25–33)

Brevipalpus papayensis Baker 1949: 375, Figs 84–86. Original designation.

Material examined. Types. Holotype. Female, USA, Hawaii, ex. papaya *Carica papaya* (Caricaceae), Kailua, Oahu, 26.iii.1941, W.C. Look. (USNM). **Paratypes.** 28 females, 15 nymphs, same data as holotype (USNM).

Other material examined. **Australia:** 3 females, ex. pale knotweed *Polygonum lapathifolium* (Polygonaceae), Long Pocket, Brisbane, Queensland, 27°31'S 153°00'E, 19.x.2000, J.J. Beard (QM); 5 females, 1 deutonymph, ex. coffee leaves *Coffea arabica* (Rubiaceae), Maroochy Research Station, Maroochy, Queensland, 26°38'40"S 152°56'23"E, 25.i.2001, J.J. Beard (QM); 26 females, ex. ornamental street tree, Taringa, Brisbane, Queensland, 27°29'48"S 152°58'46"E, 26.ix.2001, J.J. Beard (QM); 4 females, ex. *Lenwebbia* sp. (Myrtaceae), The Gap, Brisbane, Queensland, 27°26'S 152°57'E, 31.v.2004, J.J. Beard (QM); 3 females, ex. lemon fruit, *Citrus* sp. (Rutaceae), Anstead, Queensland, 05.ix.2014, J.J. Beard (QM); 15 females, ex. lemon fruit, *Citrus* sp. (Rutaceae), near Tolga, Far North Queensland, 03.ix.2014, D.F. Papacek (QM). **Costa Rica:** 6 females, ex. *Citrus latifolia* (Rutaceae), University de Costa Rica Campus, San Pedro, 29.viii.2012, William Villalobos (USNM); 6 females, ex. oranges, *Citrus sinensis* (Rutaceae), *C. latifolia*, University de Costa Rica Campus, San Pedro, 29.viii.2012, William Villalobos (USNM). **Indonesia:** 5 females, tea *Camellia sinensis* (Theaceae), Tijiater, Bogor, 26.vii.1956, W. P. van der Knapp (USNM; with *B. yothersi* on same slides); tea *Camellia sinensis* (Theaceae), Java, Dec. 1956, W.E. van der Knapp (USNM). **Norfolk Island:** 6 females, 2 deutonymphs, ex. orange fruit, 29.0016°S 167.92874°E, 12.vi.2013, M. Gorton (AQIS, North Queensland; MJG098a). **USA:** 6 females, ex. papaya leaves *Carica papaya* (Caricaceae), University of Hawaii Manoa Campus, Honolulu, Hawaii, 01.iv.2013, M. Melzer (USNM); 4 females, ex. coffee leaves *Coffea arabica* (Rubiaceae), University of Hawaii Manoa Campus, Honolulu, Hawaii, 01.iv.2013, M. Melzer (USNM).

Diagnosis. Female. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with strong areolae; sublateral cuticle with reticulation forming few large cells posteriorly, with large smooth region anteriorly, with narrow band of weak reticulation. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle mostly smooth to weakly wrinkled; *d1-d1* to *e1-e1* cuticle smooth with weak irregular folds; *e1-e1* to *h1-h1* cuticle with several transverse folds abruptly becoming longitudinal folds towards *h1-h1*; sublateral cuticle reticulate with large, uniform cells, some rounded cells, cells becoming elongate towards *h1-h1*. Ventral plate: cuticle with bands in mixed orientation; lateral and posterior bands mostly transverse; central bands mostly oblique. Genital plate: cuticle with irregular narrow transverse bands. Palp femorogenu with dorsal seta broad, setiform, barbed. Spermatheca: moderately thick duct, ending in sclerotised spherical vesicle with crown of minute projections. Cuticular microplates: not examined.

FIGURE 25. *Brevipalpus papayensis* female (paratype), a. prodorsum; b. gnathosoma (arrow indicates dorsal seta on palp femorogenu); c., d. anterior dorsal opisthosoma; e. central dorsal opisthosoma; f. posterior dorsal opisthosoma.

Female (n = 12). *Dorsum.* (Figs 2a, 25, 27–29) Body measurements: length between setae *v2-h1* 232–244 [240], width between setae *sc2-sc2* 146–152 [152], *c3-c3* 166–174 [166]. Central prodorsum: cuticle with strong areolae, usually longitudinally elongate (Figs 25a, 28). Sublateral prodorsum: posterior region with some reticulation forming a few large cells; anterior region with large smooth area, and narrow band of weak reticulation with small cells (Figs 25a, 28). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* smooth or weakly wrinkled, with pair of strong oblique folds adjacent to setae *d1* (Figs 25c–d, 29); *d1-d1* to *e1-e1* smooth or with weak

irregular folds with a few strong transverse folds (Figs 25c–e, 29); *e1*-*e1* to *h1*-*h1* with several transverse folds abruptly becoming longitudinal folds towards *h1*-*h1* (Figs 25e–f, 29). Sublateral opisthosoma: cuticle reticulate with large uniform cells often distinctly rounded, lateral cells becoming longitudinally elongate. Dorsal setae short, barbed; setae *f3*, *h1*, *h2* moderately broad: *v2* 7–9 [7–8], *sc1* 10–12 [11–12], *sc2* 10–12 [10–11], *c1* 5–9 [5], *c3* 8–10 [9–10], *e1* 6–8 [6–7], *e3* 7–8 [8], *f3* 8–10 [9–10], *h1* 8–9 [8], *h2* 7–9 [8–9].

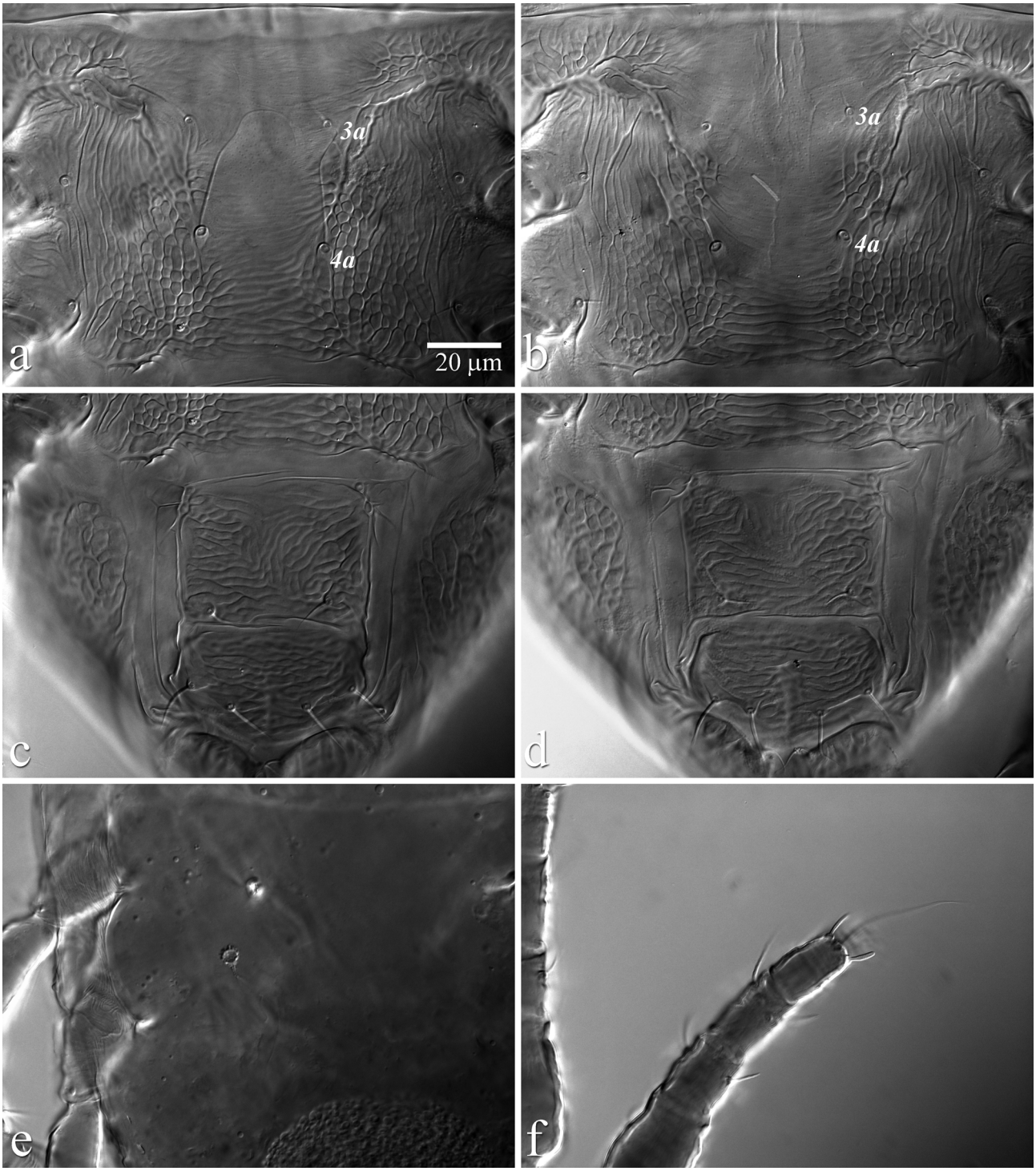

FIGURE 26. *Brevipalpus papayensis* female (paratype), a., b. ventral cuticle between coxae III–IV; c., d. posterior venter, indicating ventral and genital plates; e. spermatheca; f. right legs I–II, indicating two solenidia on tarsus II.

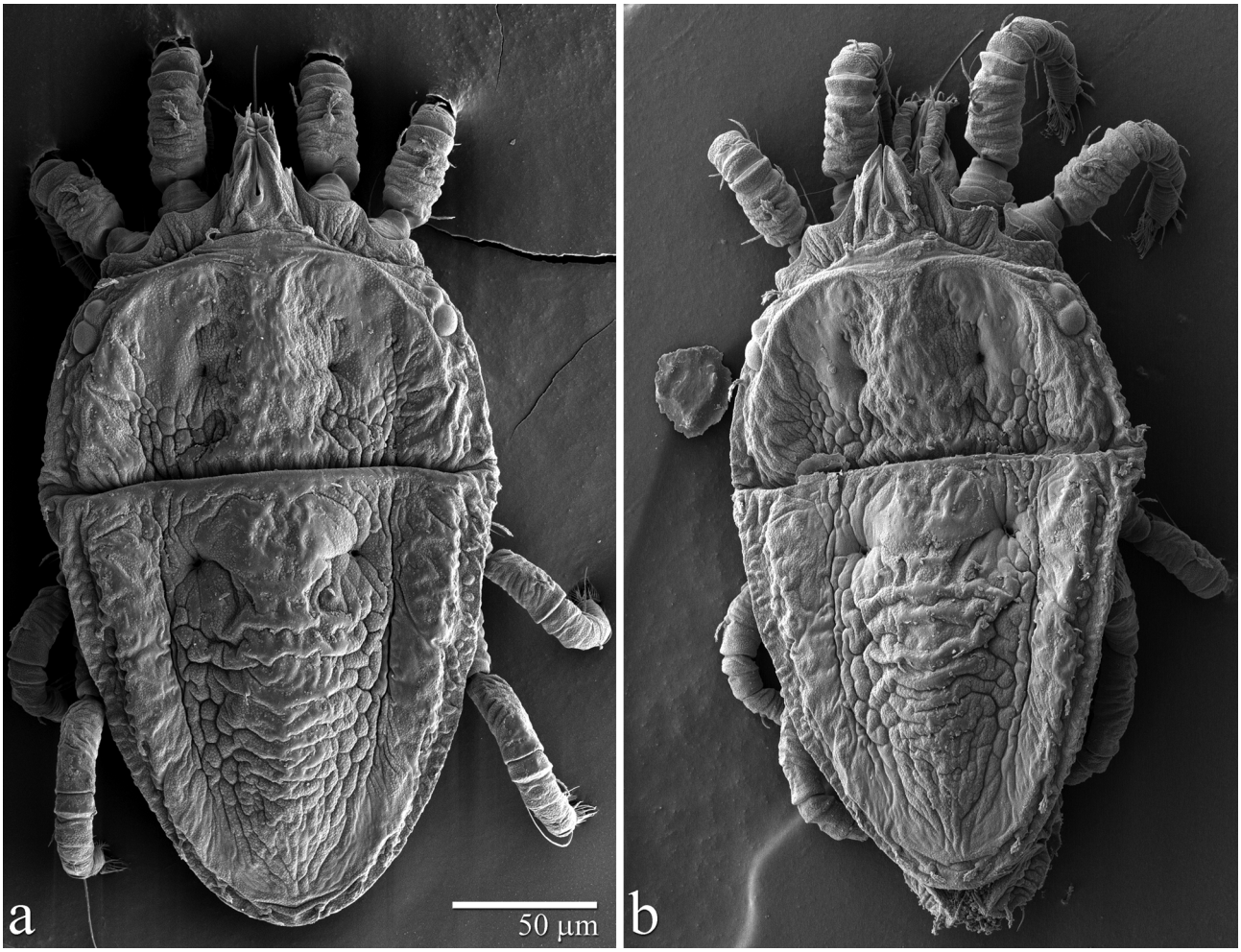

FIGURE 27. *Brevipalpus papayensis* dorsal female habitus, a. from papaya leaves (Hawaii); b. from coffee leaves (Hawaii).

Dorsal microplates. (Fig. 32) Separate individual, irregularly rounded plates, with irregular multi-directional ridges on dorsal surface; no series of parallel ridges present.

Gnathosoma. (Fig. 25b). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed, broadly setiform dorsal seta.

Venter. (Figs 4a, 26a–d, 30). Cuticle between *4a* and ventral plate verrucose laterally with separately formed rounded warts; central cuticle with raised transverse bands, bands weaker towards *4a-4a* and eventually disappearing; central cuticle without separately formed warts (Figs 26a–b, 30a). Ventral plate: with raised bands of mixed orientation; lateral and posterior bands usually transverse, and central bands (sometimes anterior bands) usually distinctly longitudinal to oblique (Figs 26c–d, 30b); ventral plate usually without separately formed warts (Figs 26c–d, 30b). Genital plate: non-uniform verrucose, with "warts" aligned transversely, and/or forming weak transverse bands (Figs 26c–d, 30b).

Spermathecal apparatus. (Fig. 26e). Long moderately thick, convoluted duct, ending in small, sclerotised, spherical vesicle, with crown of minute projections. Vesicle may be undeveloped, with duct ending blindly or in small, membranous bulb (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 7–9 [7–8], antiaxial 8–9 [9] (Fig. 26f).

Male. Unknown.

Deutonymph. Dorsum. (Fig. 33) Opisthosomal setae *c1*, *c3*, *d1*, *d3*, *e1*, *e3* minute; setae *f3*, *h1*, *h2* enlarged, broadly lanceolate, barbed (Figs 33 b–d). Dorsal seta on palp femorogenu broad, as in adult (Fig. 33a).

Hosts. *Camellia sinensis* (Theaceae); *Carica papaya* (Caricaceae); *Citrus sinensis*, *C. latifolia* (Rutaceae).

Distribution. Australia, Costa Rica, Indonesia, USA (Hawaii).

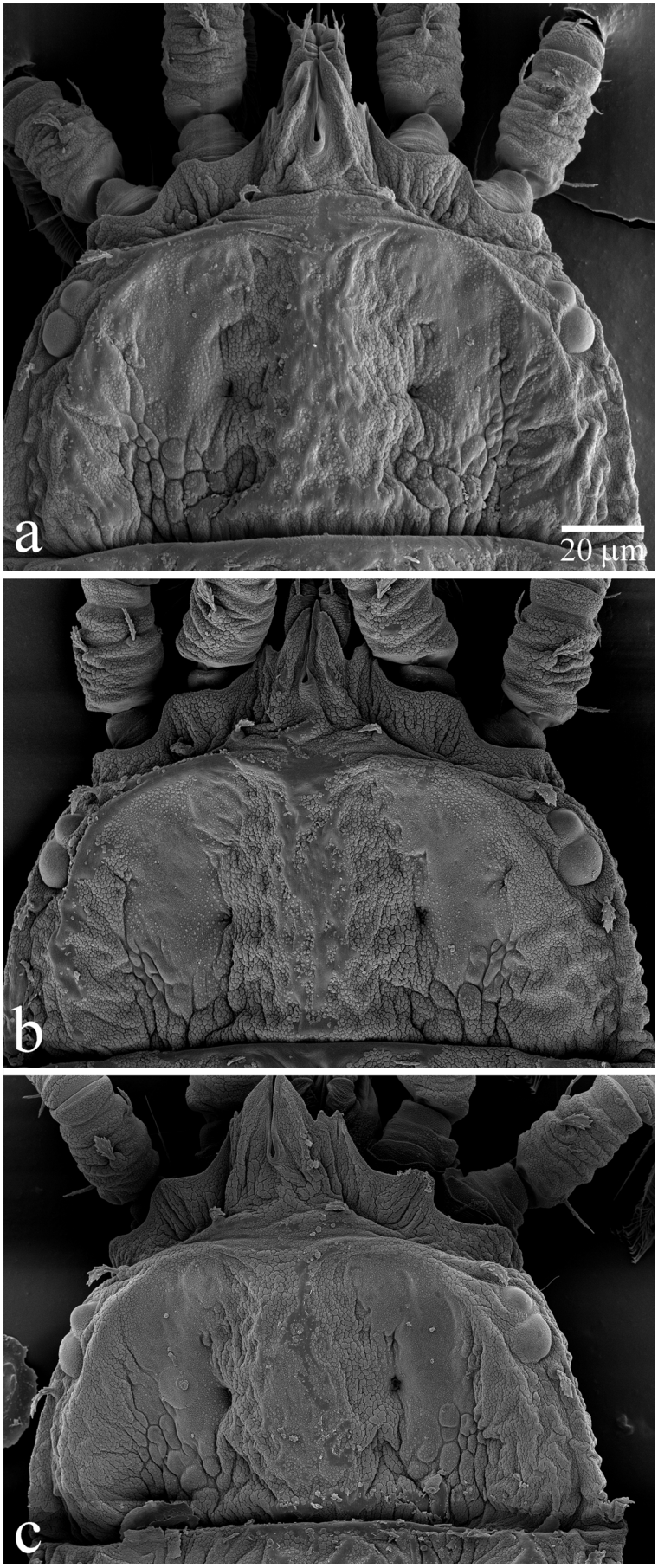

FIGURE 28. *Brevipalpus papayensis* female prodorsum, a., b. from papaya leaves (Hawaii); c. from coffee leaves (Hawaii).

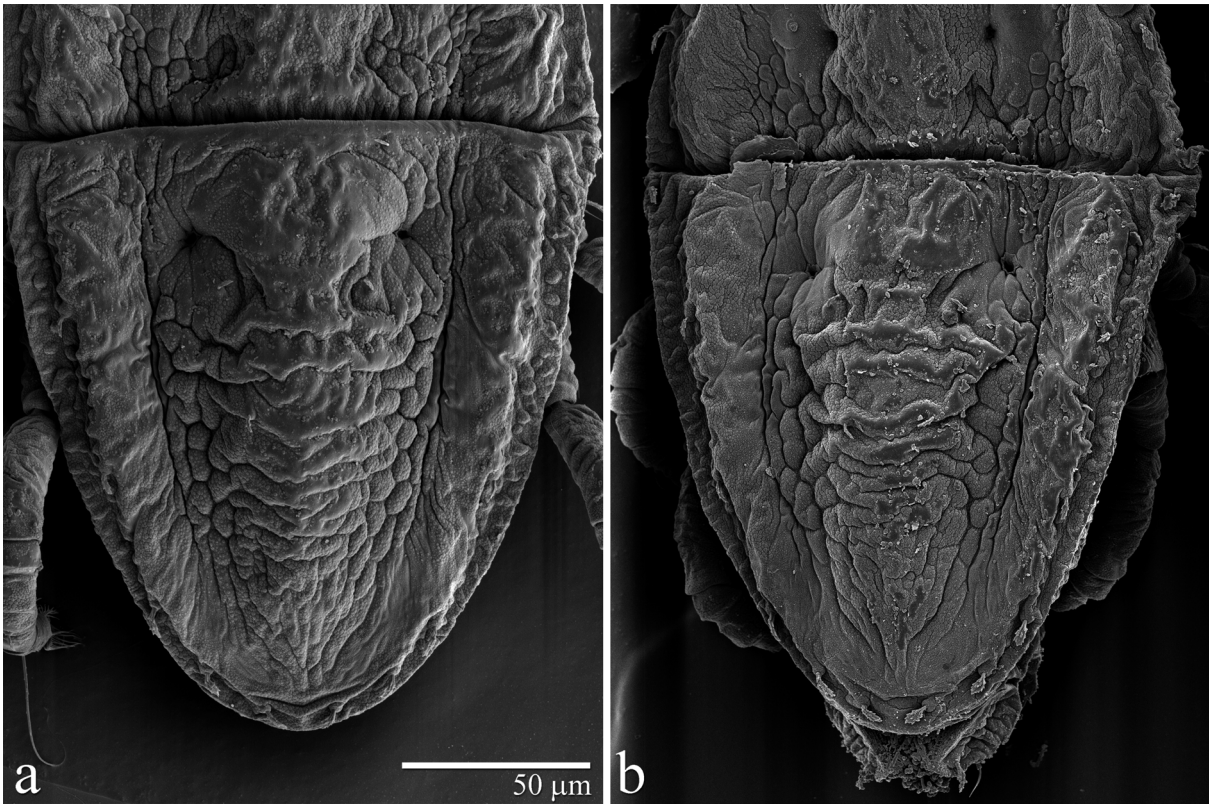

FIGURE 29. *Brevipalpus papayensis* female opisthosoma, a. from papaya leaves (Hawaii); b. from coffee leaves (Hawaii).

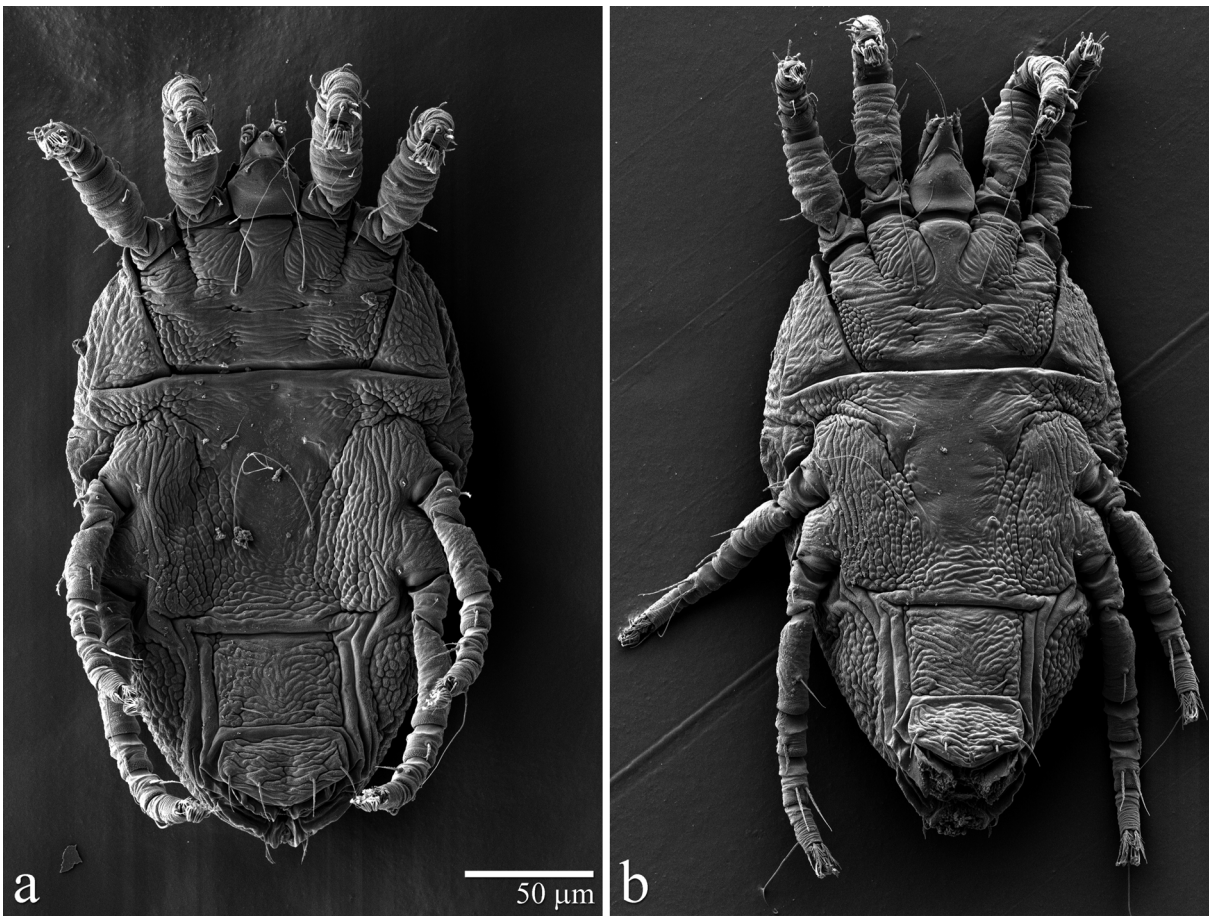

FIGURE 30. *Brevipalpus papayensis* female venter, a. from papaya leaves (Hawaii); b. coffee leaves (Hawaii).

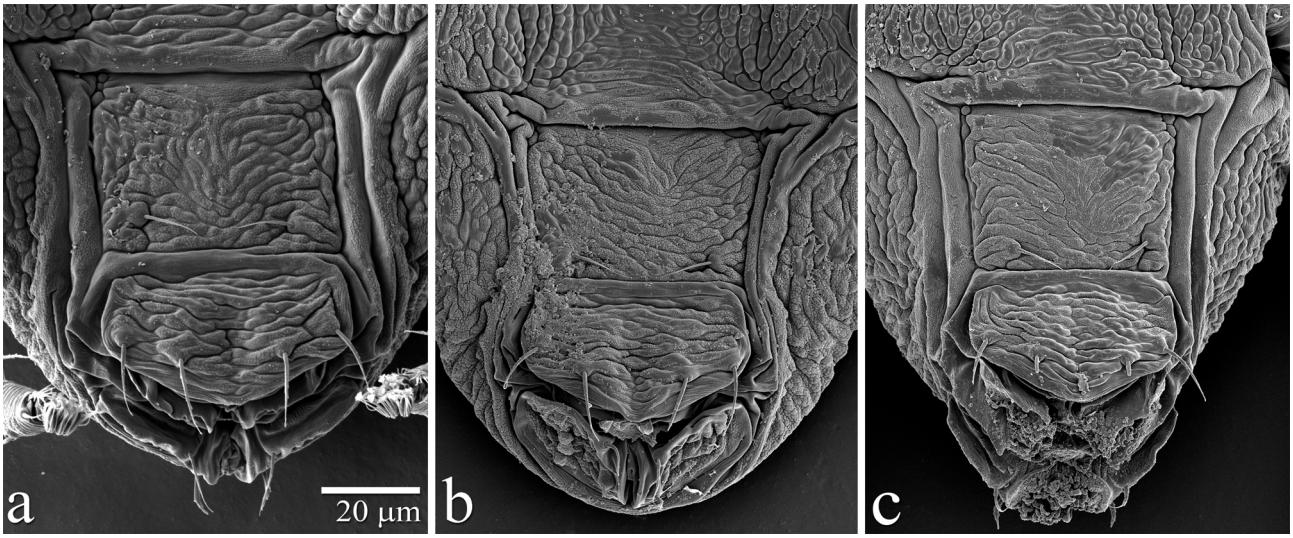

FIGURE 31. *Brevipalpus papayensis* female posterior ventral opisthosoma, a., b. from papaya leaves (Hawaii); c. coffee leaves (Hawaii).

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species C.

In order to establish the morphology of the microplates for *B. papayensis*, we were able to remove a paratype specimen from its slide preparation (mounted in Hoyer's media, 1941) and examine it using LT-SEM (Fig. 32a). This allowed us to compare the paratype microplates with those of the specimens we collected from papaya in Hawaii (type locality) (Fig. 32b), to confirm a match.

Brevipalpus phoenicis **(Geijskes) sensu stricto**
(Figs 2b, 4b, 34–44)

Tenuipalpus phoenicis Geijskes 1939: 23, Fig. 8. Original designation.
Brevipalpus phoenicis (Geijskes) Baker 1949: 360, Figs 16–17.
Brevipalpus phoenicis (Geijskes) Gonzalez 1975: 82, Fig. 1, part.

Material examined. Neotype (new designation). Female, The Netherlands, ex. *Phoenix canariensis* (Arecaceae), Botanical Gardens Science Park, Amsterdam, 22.vi.2012, F. Faraji (NCBN).

Other material examined. **Costa Rica:** 4 females, ex. orange leaves *Citrus sinensis* (Rutaceae), near Juan Viñas, Cartago, 3.iv.1959, E.W. Baker (collection #35; USNM). **The Netherlands:** 7 females, 6 deutonymphs, 6 protonymphs, 9 larvae, same data as neotype (NCBN, USNM, QM). **USA:** 6 females, ex. camphor leaf *Cinnamomum camphora* (Lauraceae), U.S. Botanic Garden, Washington D.C., 15.iii.1924 (USNM; remounted 1946 and 2013).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with strong, broad areolae; sublateral cuticle with reticulation forming broad rounded cells posteriorly, with distinct cluster of small rounded cells medially, mostly smooth anteriorly. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle strongly wrinkled; *d1-d1* to *e1-e1* cuticle wrinkled with few strong transverse folds; *e1-e1* to *h1-h1* cuticle with series of transverse folds, becoming weakly reticulate towards *h1-h1*; sublateral cuticle reticulate with band of large, uniform, distinctly rounded cells laterad *e1*. Ventral plate: cuticle weakly verrucose (some separate individual warts laterally), warts fused to form transverse bands, no separately formed individual warts centrally. Genital plate: cuticle uniformly verrucose to verrucose-reticulate, with large cells formed by fused warts. Palp femorogenu with dorsal seta broad, flat, barbed. Spermatheca: moderately thick duct terminating in membranous bulb. Cuticular microplates: separate individual, rounded to irregularly rounded plates, with irregular multidirectional ridges over dorsal surface; no series of parallel ridges present.

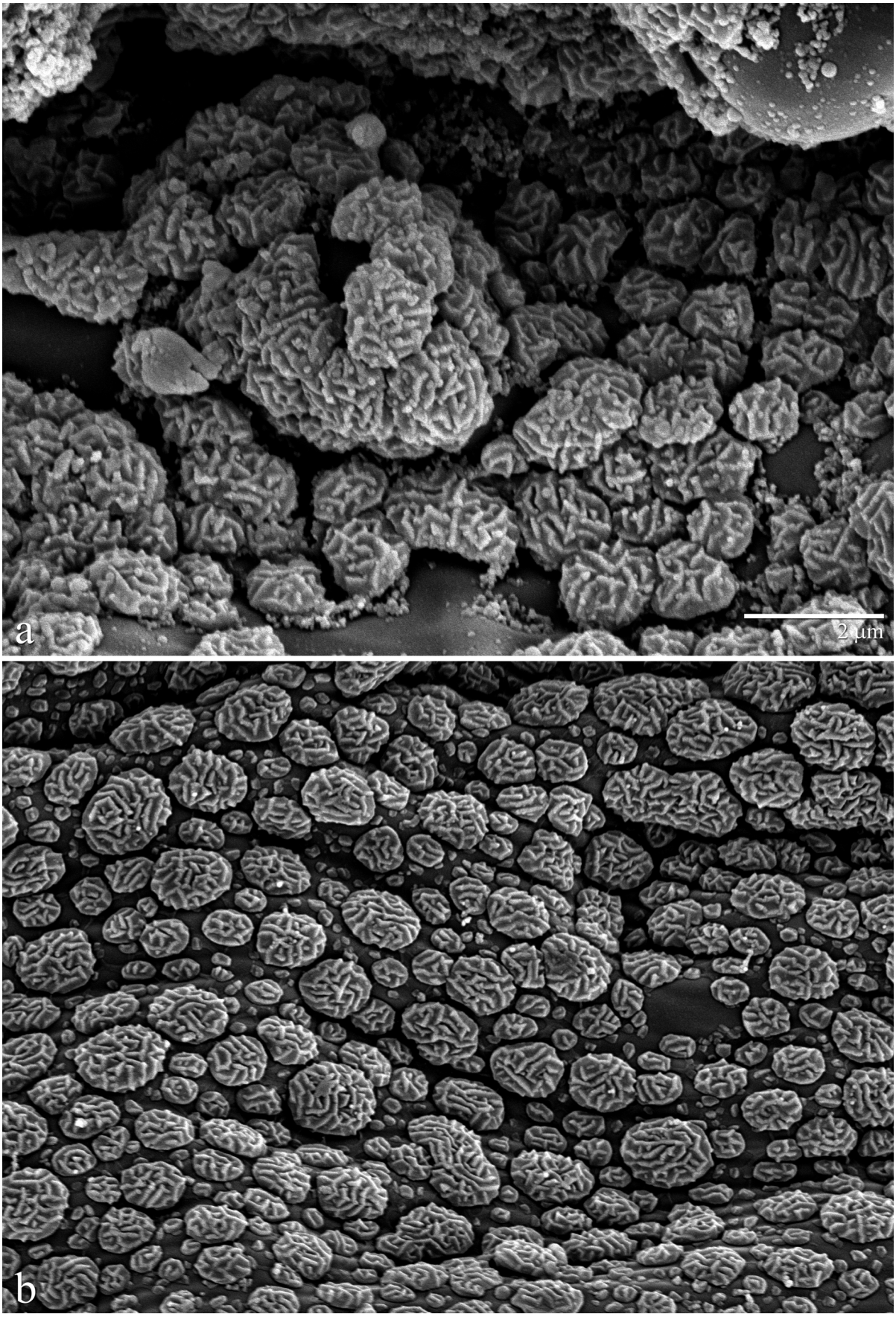

FIGURE 32. *Brevipalpus papayensis* female, detail of microplates on dorsal cuticle of, a. paratype specimen; b. specimen from type locality (15,000X).

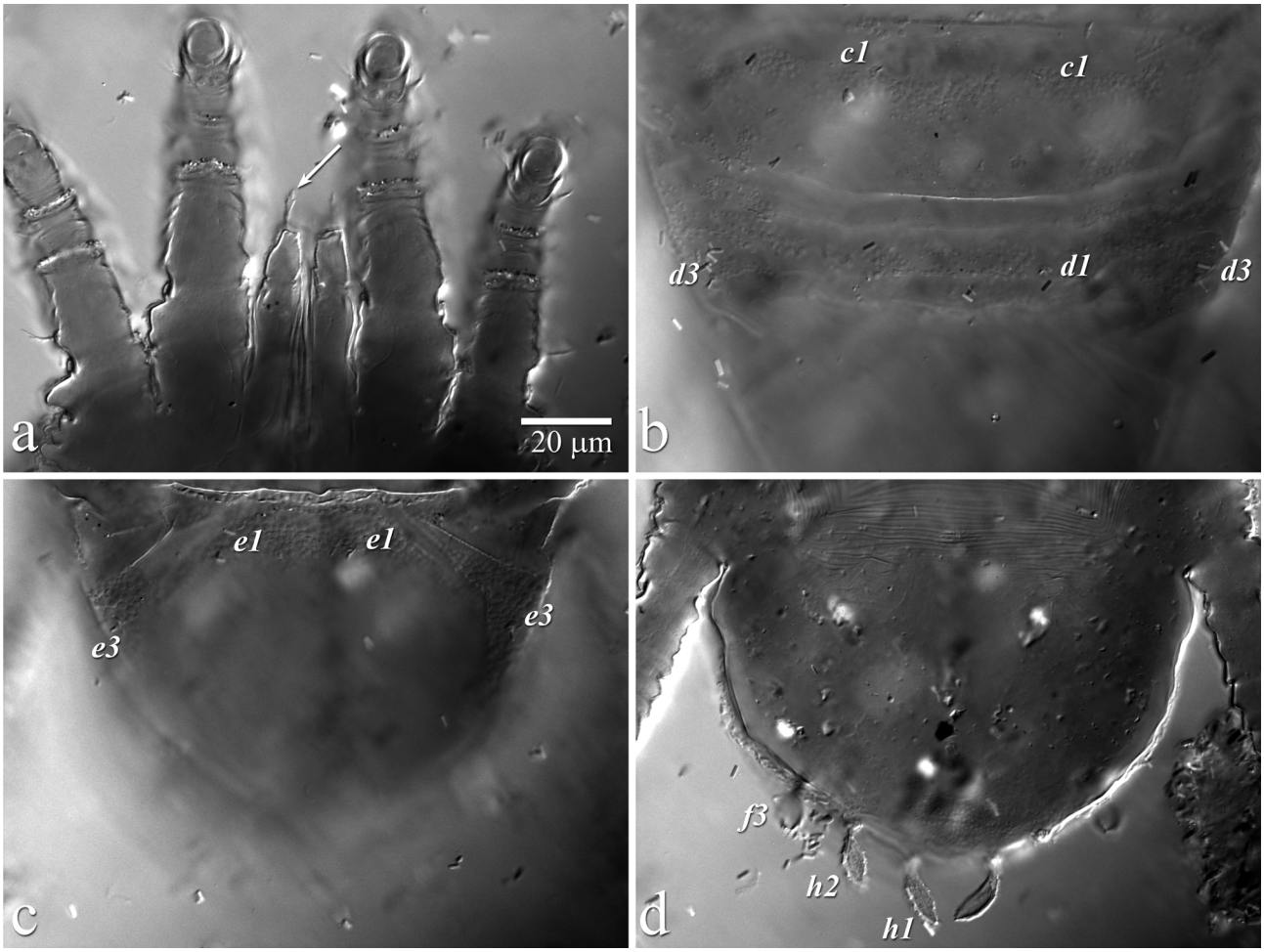

FIGURE 33. *Brevipalpus papayensis* deutonymph (paratype) with detail of, a. dorsal seta on palp femorogenu; b. minute dorsal setae on anterior opisthosoma; c. minute dorsal setae on opisthosoma; d. dorsal setae on posterior margin of opisthosoma.

Female (n = 12). *Dorsum.* (Figs 2b, 34, 36–39) Body measurements: length between setae *v2-h1* 217–238 [229], width between setae *sc2-sc2* 146–157 [147], *c3-c3* 152–163 [158]. Central prodorsum: cuticle with strong, broad areolae (Figs 34a, 37–38). Sublateral prodorsum: posterior region with reticulation forming large rounded cells; anterior region with broad smooth area, and narrow band of reticulation forming small cells (Figs 34a, 38). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* strongly wrinkled, can appear to be areolate (Figs 34c, 39); *d1-d1* to *e1-e1* wrinkled with a few strong transverse folds (Figs 34c–e, 37, 39); *e1-e1* to *h1-h1* with series of transverse folds, becoming weakly reticulate towards *h1-h1* (Figs 34e–f, 39). Sublateral opisthosoma: cuticle reticulate with large, uniform, distinctly rounded, dome-shaped cells, with narrow band of longitudinally elongate cells laterally (Figs 34e, 39). Dorsal setae short, moderately broad, barbed: *v2* 7–9 [8], *sc1* 9–12 [11], *sc2* 8–11 [10], *c1* 5–7 [5–6], *c3* 7–9 [7], *e1* 5–6 [6], *e3* 7–9 [7], *f3* 7–10 [9–10], *h1* 6–8 [7], *h2* 6–8 [7].

Dorsal microplates. (Fig. 42). Separate individual, rounded to irregularly rounded plates, with irregular multi-directional ridges on dorsal surface; no series of parallel ridges present.

Gnathosoma. (Fig. 34b). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed, broad flat dorsal seta.

Venter. (Figs 4b, 35a–d, 36, 40–41). Cuticle between *4a* and ventral plate verrucose laterally with separately formed rounded warts; central cuticle with raised transverse bands (formed by fused warts), bands become weaker towards *4a-4a* and eventually disappear; central cuticle without separately formed warts (Figs 35a–b, 40a). Ventral plate: cuticle usually without separately formed warts; warts are fused together to form transverse bands (transverse bands often weak); ventral plate with some separately formed warts laterally (Figs 35c–d, 41). Genital plate: uniformly verrucose or verrucose-reticulate, with large cells formed by fused or conglomerate warts (Figs 35c–d, 41).

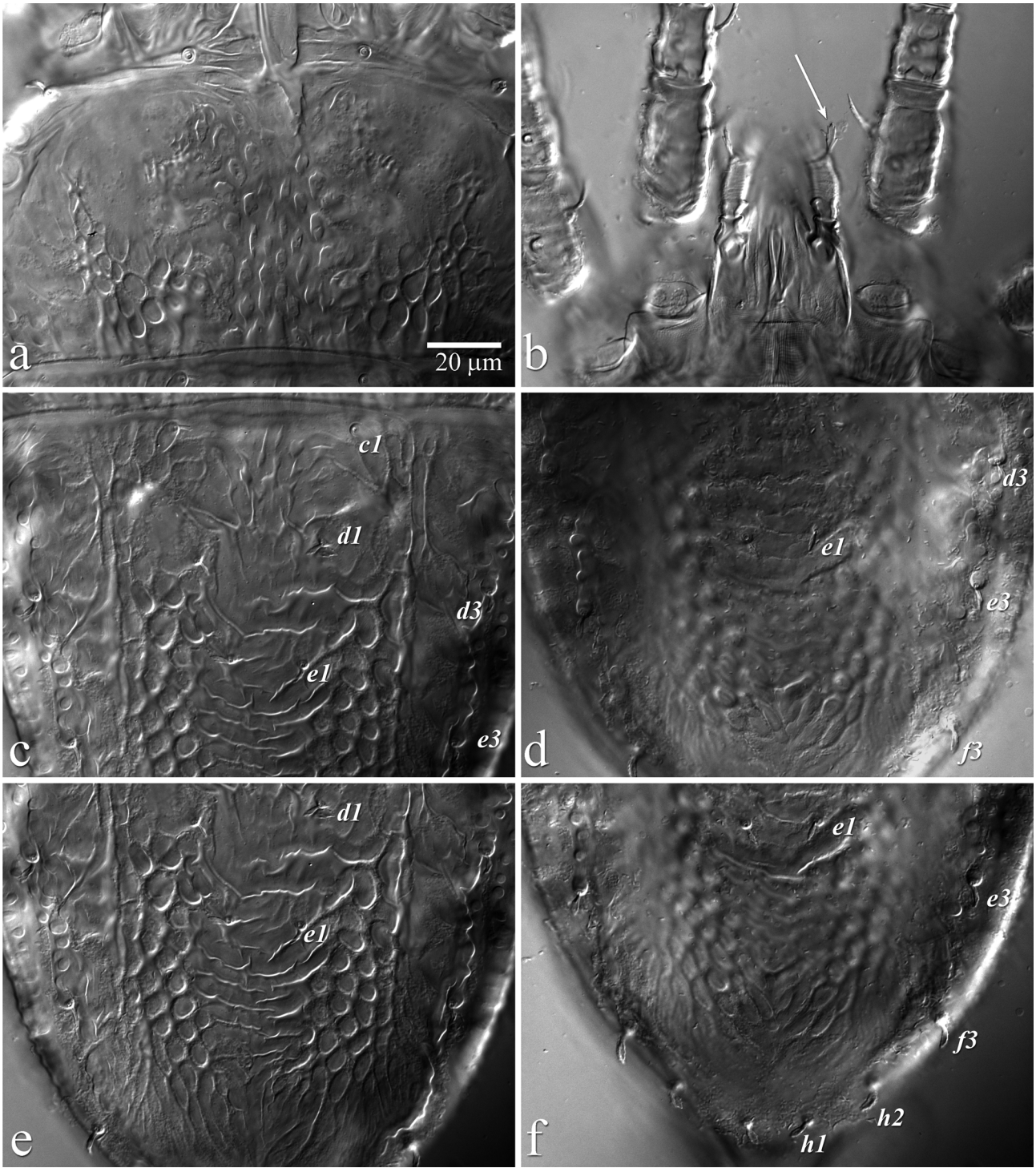

FIGURE 34. *Brevipalpus phoenicis* s.s. female (The Netherlands, type location and host), a. prodorsum; b. gnathosoma (arrow indicating dorsal seta on palp femorogenu); c. anterior dorsal opisthosoma; d., e. central dorsal opisthosoma; f. posterior dorsal opisthosoma.

Spermathecal apparatus. (Fig. 35e). Long moderately thick, convoluted duct ending blindly in small membranous bulb (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 7–8 [8], antiaxial 6–7 [7] (Fig. 35f).

Male. Unknown.

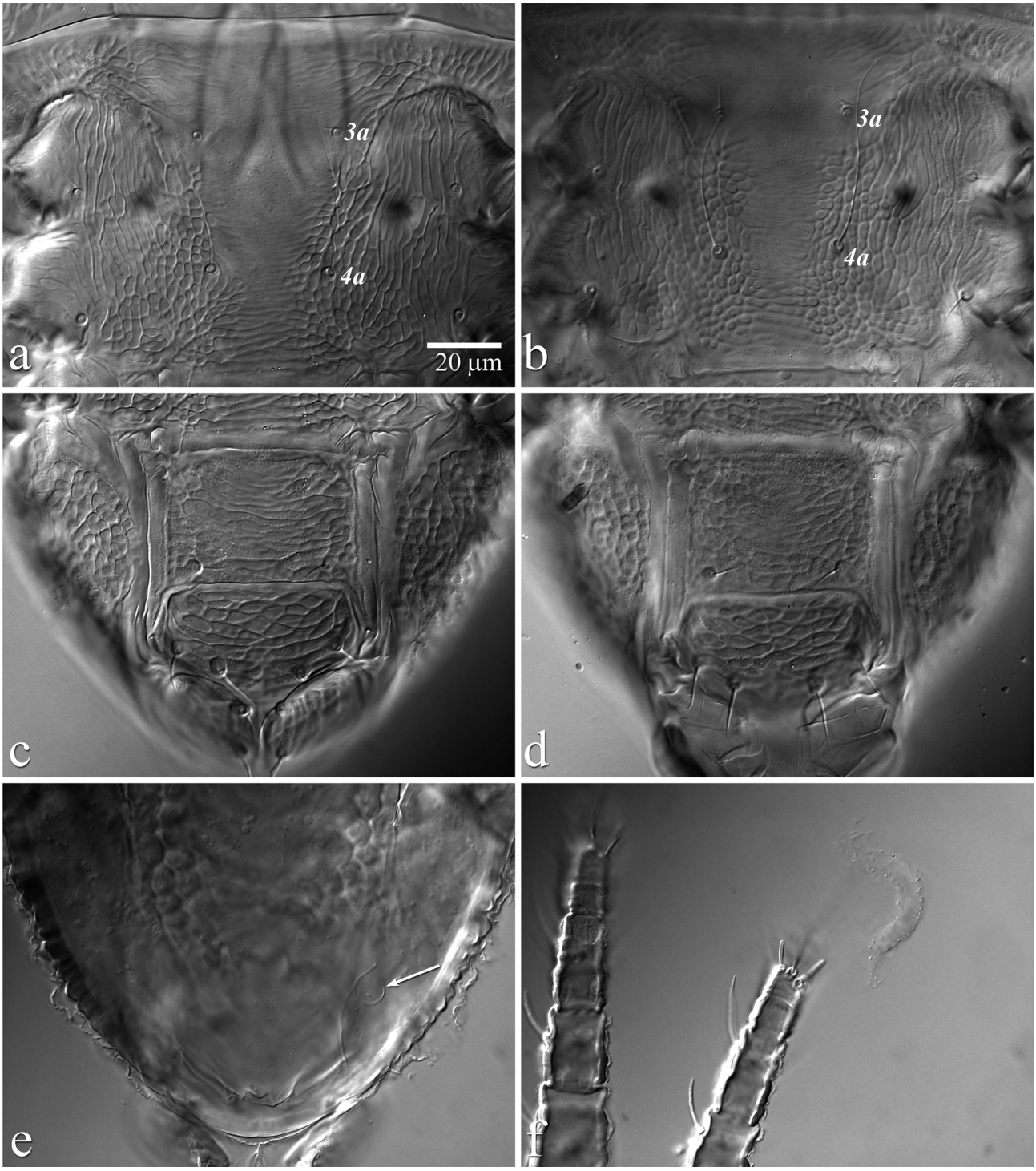

FIGURE 35. *Brevipalpus phoenicis* s.s. female (type location and host), a., b. ventral cuticle between coxae III–IV; c., d. posterior venter, indicating ventral and genital plates; e. spermatheca (arrow indicates distal bulb); f. right legs I–II, indicating two solenidia on tarsus II.

Deutonymph. *Dorsum.* (Figs 43–44) Prodorsum with setae *v2* short (Fig. 44a). Opisthosomal setae *c1*, *d1*, *d3*, *e1*, *e3* minute; setae *c3*, *f3*, *h1*, *h2* enlarged, broadly lanceolate, barbed (Figs 43, 44 b–d). Dorsal seta on palp femorogenu broad, as in adult (Fig. 44a).

Hosts. *Cinnamomum camphora* (Lauraceae); *Citrus sinensis* (Rutaceae), *Phoenix canariensis* (Arecaceae).

Distribution. Costa Rica, The Netherlands, USA** (Washington D.C.).

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species A.

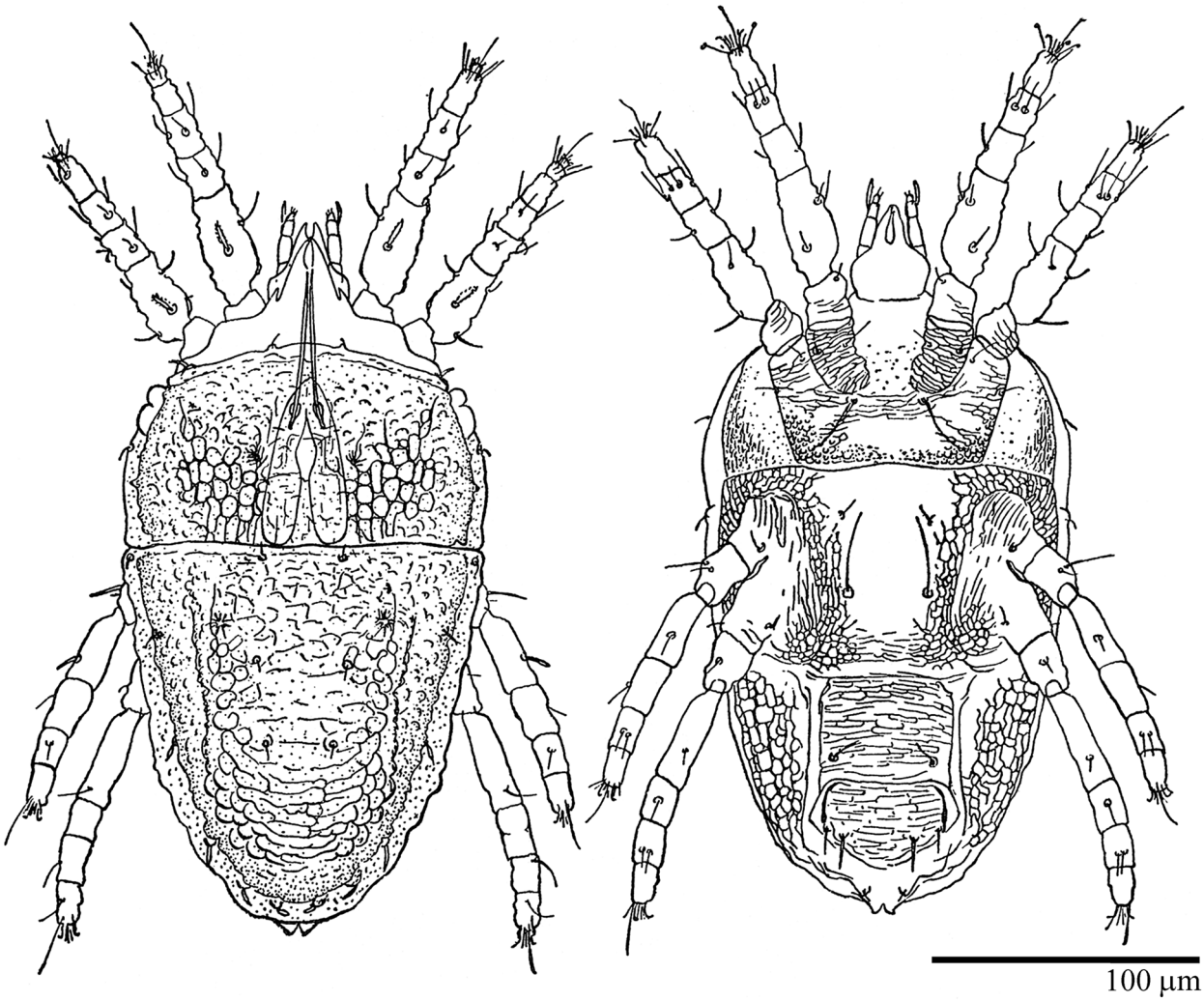

FIGURE 36. *Brevipalpus phoenicis* s.s. original illustrations after Geijskes 1939, Figure 8.

Baker (1949: 360) stated that until nymphal forms of *phoenicis* are studied, the exact identity of the species will remain unknown, and that he did not examine specimens of this species. The figures he provided (Baker 1949: 389, Figs 16 and 17), are reproductions of those from the original Geijskes description (here presented in Fig. 36). The type specimen of *B. phoenicis* was examined and referred to by Dosse (1957b), Pritchard & Baker (1952; via transmission from Dr R. Roepke) and Gonzalez (1975). Since the last recorded sighting of the type in 1975, it has apparently disappeared and its current location remains unknown. With the help of Drs. F. Faraji, T. Buys, K. van Dorp and S. van de Klundert, we were able to obtain specimens of *Brevipalpus phoenicis* sensu stricto from the same host plant and locality of the original Geijskes (1939) collection. Based on this material and a detailed comparison of drawings and descriptions of Geijskes (1939), Baker (1949), Dosse (1957b) and Gonzalez (1975) we provide a new diagnosis and description for this species, and designate a neotype to represent the species in the future.

**After discussion with staff members at the US Botanical Gardens in Washington D.C., it was noted that the type host plant species, *Phoenix canariensis*, once grew in the gardens; however the gardens underwent construction during the early 1930s and the palms were removed (Solit 1993). Prompted by this information, on two occasions Ochoa, and separately Ochoa and Beard, collected *Brevipalpus* specimens on palms and other plants at the US Botanical Gardens in a search for *B. phoenicis* s.s. On all three occasions they were unable to recover *B. phoenicis* s.s.; however, *B. yothersi* was found on each occasion. As a result, we are unable to confirm if *B. phoenicis* s.s. is currently present in USA.

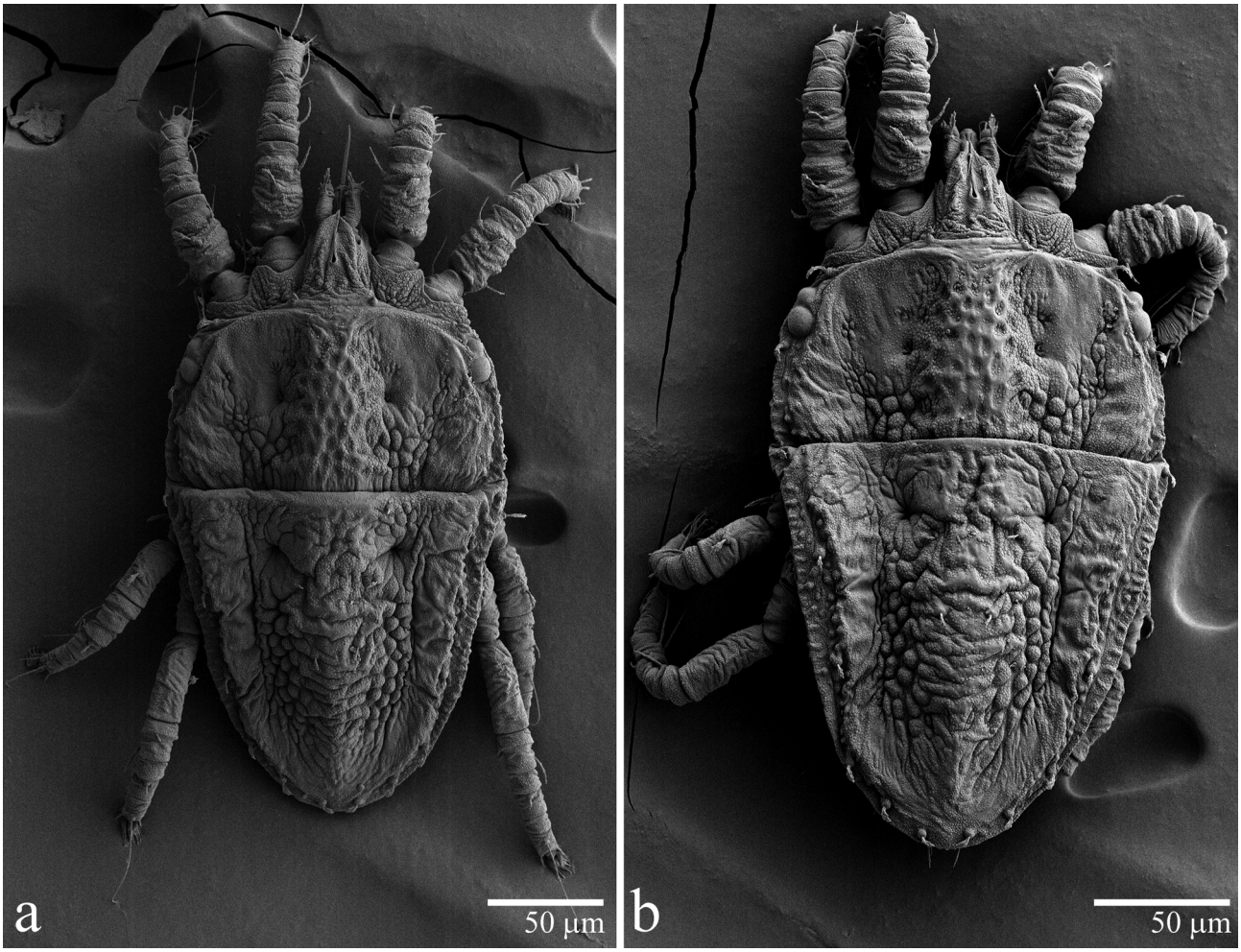

FIGURE 37. *Brevipalpus phoenicis* s.s. female dorsal habitus (type location and host).

Based on the figure provided in Düzgüneş (1965: 142, Fig. 16), it would appear that *B. phoenicis* s.s. could be present in Turkey. Based on the details discernible in Figure 1B in Berry and Fan (2012), we strongly suspect that *Brevipalpus phoenicis* sensu stricto is also present in New Zealand on *Citrus*. Specimens with similar microplate formation to *B. phoenicis* s.s. have been observed from Brazil on *Citrus* spp. (Mineiro *et al.* 2014) and are currently being examined further. Additionally, based on the work of Navia *et al.* (2013), we suspect that the lineage B5, collected from Brazil (HAP 17, 22, 42) and The Netherlands (HAP 23, from Genbank; Groot & Breewer 2006), could represent *B. phoenicis* s.s.

Brevipalpus tucuman **sp. nov. Beard & Ochoa**
(Figs 2c, 4c, 45–46)

Brevipalpus pseudocuneatus (Blanchard)—Baker 1949: 376, Figs 87–89. Misidentification.

Material examined. Holotype. Female, Argentina, ex. oranges and lemons [assumed to be *Citrus sinensis* and *C. latifolia* (Rutaceae)], Estacion Experimental Agricola, Tucuman, 27.xi.1916, E.W. Rust (USNM). **Paratypes.** 5 females, same data as holotype (USNM).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with strong, broad areolae; sublateral cuticle with reticulation forming large cells posteriorly, with short folds and wrinkles anteriorly. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle with some folds and wrinkles (can appear weakly reticulate); *d1-d1* to *e1-e1* cuticle with wrinkled with a few transverse folds; *e1-e1* to *h1-h1* cuticle with series of short transverse folds, becoming reticulate towards *h1-h1*; sublateral cuticle reticulate with large,

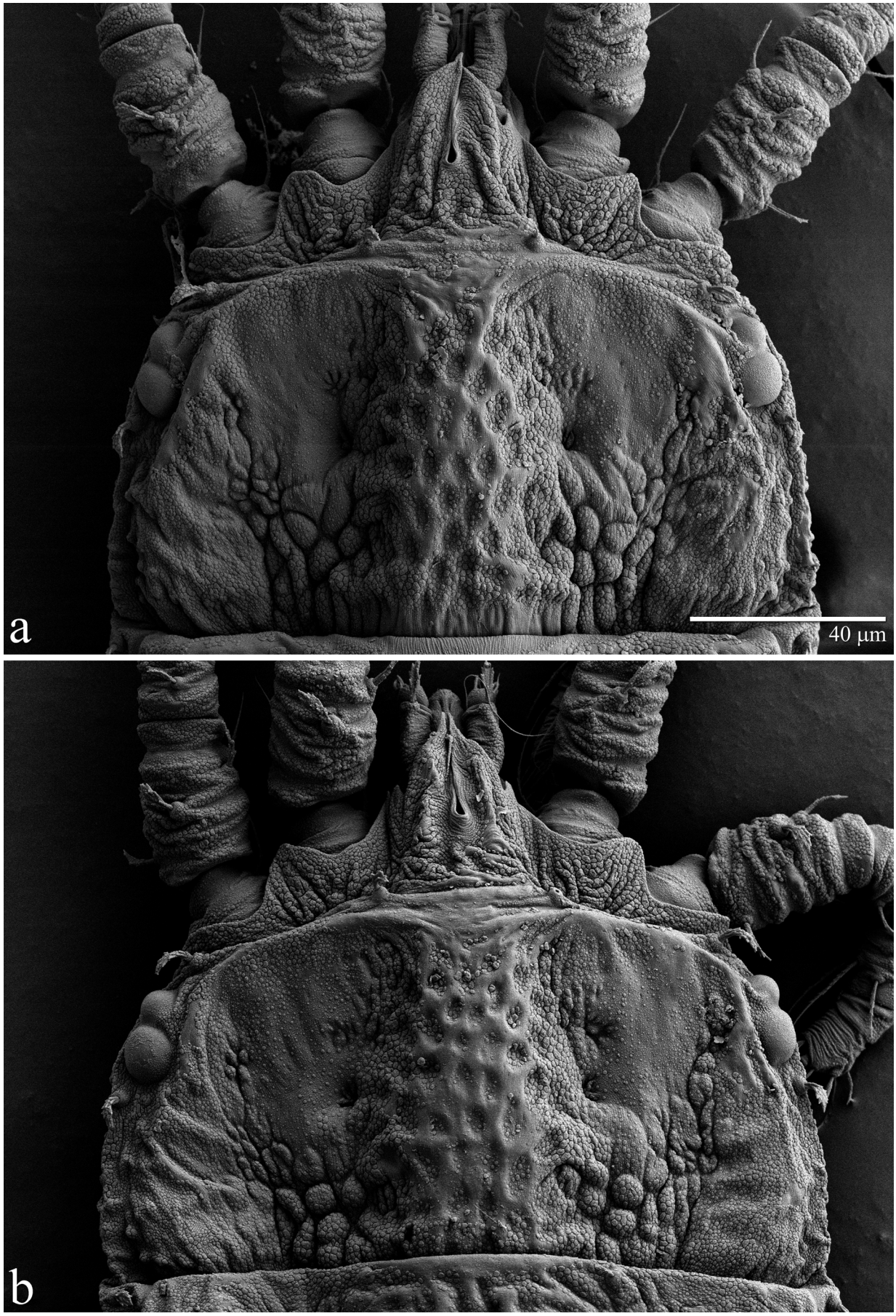

FIGURE 38. *Brevipalpus phoenicis* s.s. female, detail of prodorsum (type location and host).

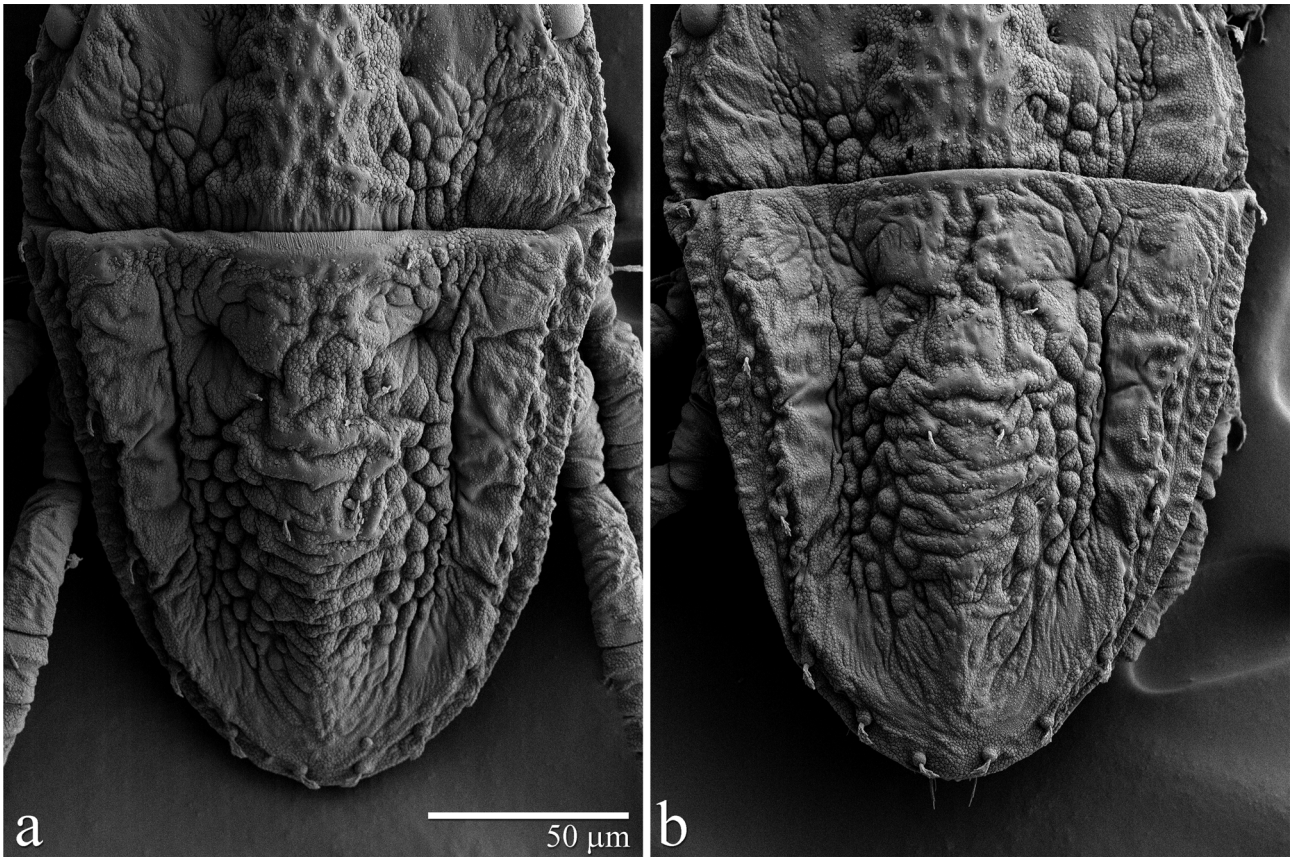

FIGURE 39. *Brevipalpus phoenicis* s.s. female, detail of dorsal opisthosoma (type location and host).

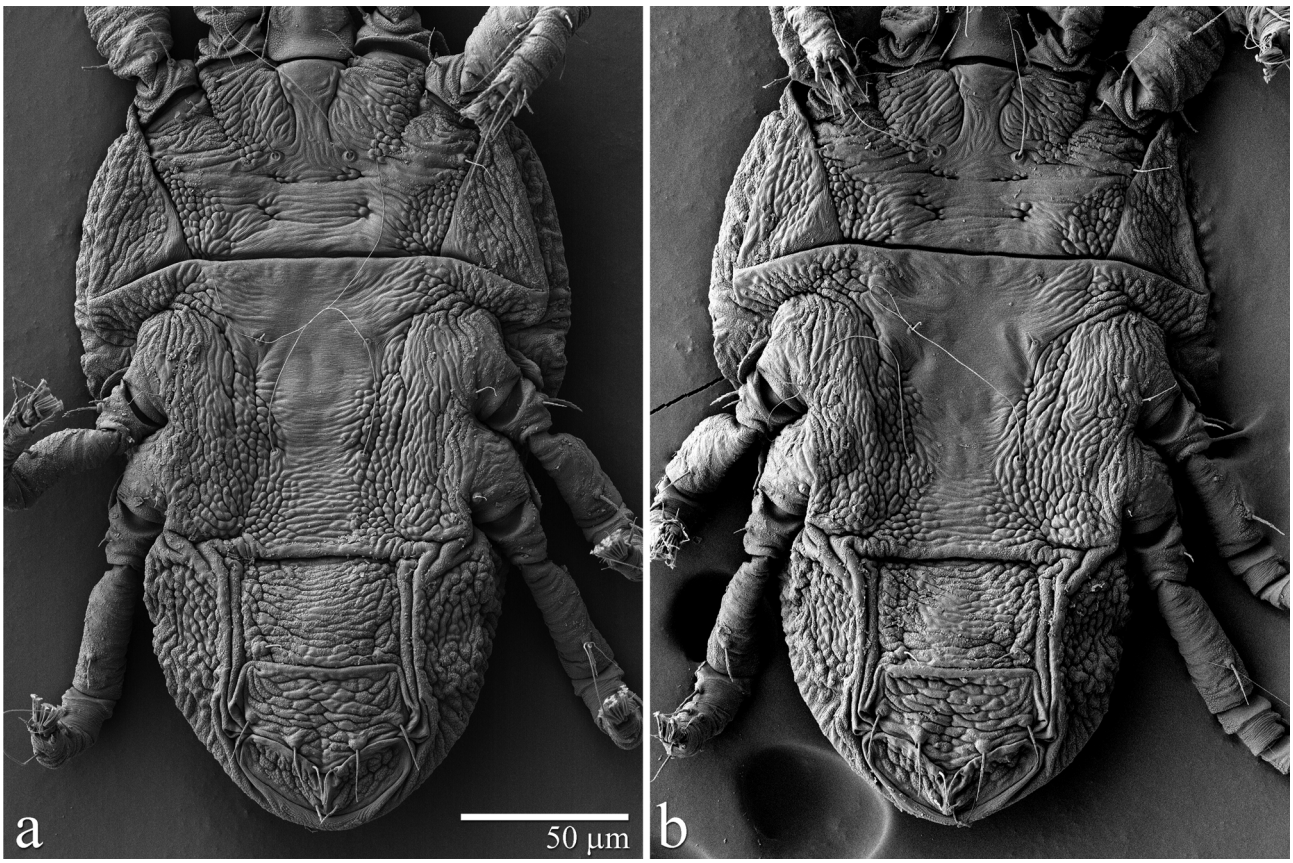

FIGURE 40. *Brevipalpus phoenicis* s.s. female venter (type location and host).

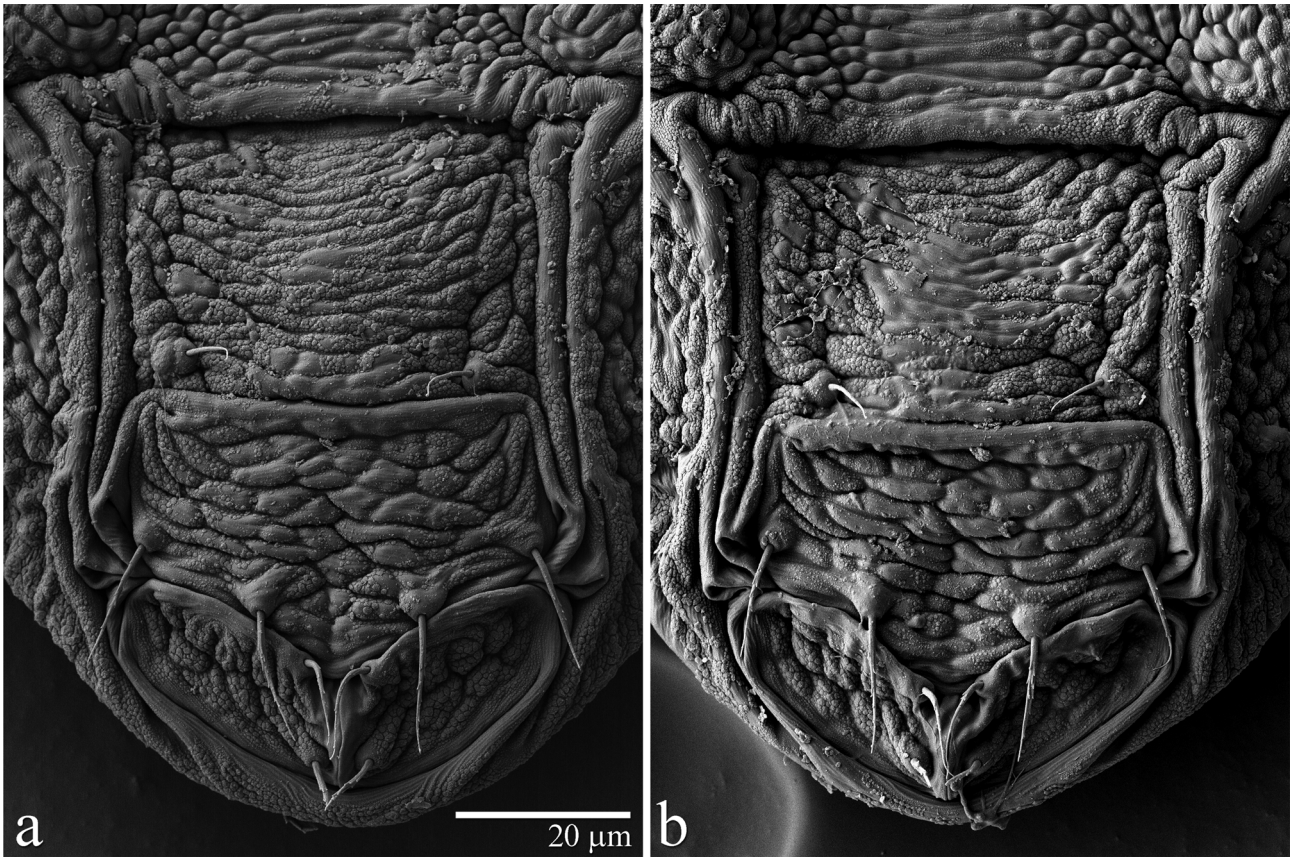

FIGURE 41. *Brevipalpus phoenicis* s.s. female, detail of ventral and genital plates (type location and host).

cells, cells slightly elongate towards *h1-h1*. Ventral plate: cuticle with irregularly shaped warts; central warts more elongate than lateral warts. Genital plate: cuticle with irregular transversely elongate cells, forming weak irregular bands. Palp femorogenu with dorsal seta broad, flat, barbed. Spermatheca: long fine duct terminating in small rounded vesicle; outer margin of vesicle with tiny projections. Cuticular microplates: not examined.

Female (n = 6). *Dorsum.* (Figs 2c, 45) Body measurements: length between setae *v2-h1* 229–244 [229], width between setae *sc2-sc2* 145–158 [145], *c3-c3* 160–174 [160]. Central prodorsum: cuticle with strong, broad areolae (Figs 45a–b). Sublateral prodorsum: posterior region with reticulation forming large cells; anterior region with short folds and wrinkles to setae *v2* (Figs 45a–b). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* with some folds or wrinkles, can appear weakly reticulate (Fig. 45c); *d1-d1* to *e1-e1* wrinkled with a few transverse folds (Figs 45c–d); *e1-e1* to *h1-h1* with series of transverse folds, becoming weakly reticulate towards *h1-h1* (Fig. 45e). Sublateral opisthosoma: cuticle reticulate with large irregularly shaped cells, often slightly longitudinally elongate (Fig. 45e). Dorsal setae short, moderately broad, barbed: *v2* 8–10 [10], *sc1* 8–11 [10], *sc2* 10–13 [10], *c1* 6–10 [8], *c3* 9–11 [9], *e1* 8–10 [–], *e3* 7–11 [10], *f3* 10–11 [10–11], *h1* 8–10 [9–10], *h2* 9–10 [9–10].

Dorsal microplates. Not examined.

Gnathosoma. (Fig. 45f). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed, broad flat dorsal seta.

Venter. (Figs 4c, 46a–d). Cuticle between *4a* and ventral plate verrucose laterally with separately formed rounded warts; central cuticle with transversely elongate warts often fused to form short transverse bands; become weaker towards *4a-4a* and eventually disappear; central cuticle with few separately formed warts (Figs 46a–b). Ventral plate: cuticle with irregularly shaped cells or warts; central cells or warts more elongate than lateral cells (Figs 46c–d). Genital plate: cuticle with irregular transversely elongate cells, forming irregular transverse bands (Figs 46c–d).

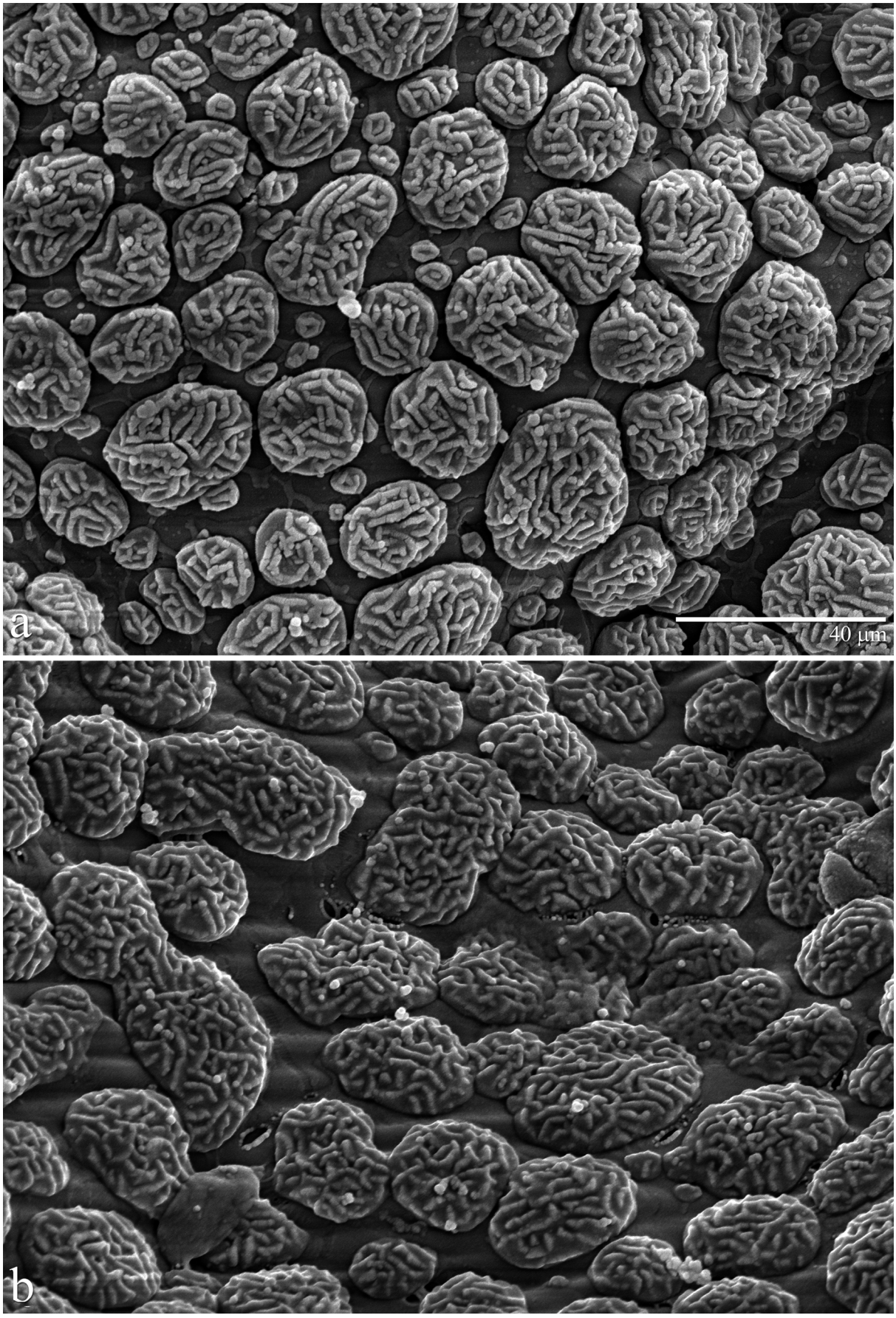

FIGURE 42. *Brevipalpus phoenicis* s.s. female detail of microplates on dorsal cuticle, a. The Netherlands (type location and host); b. Costa Rica (15,000X).

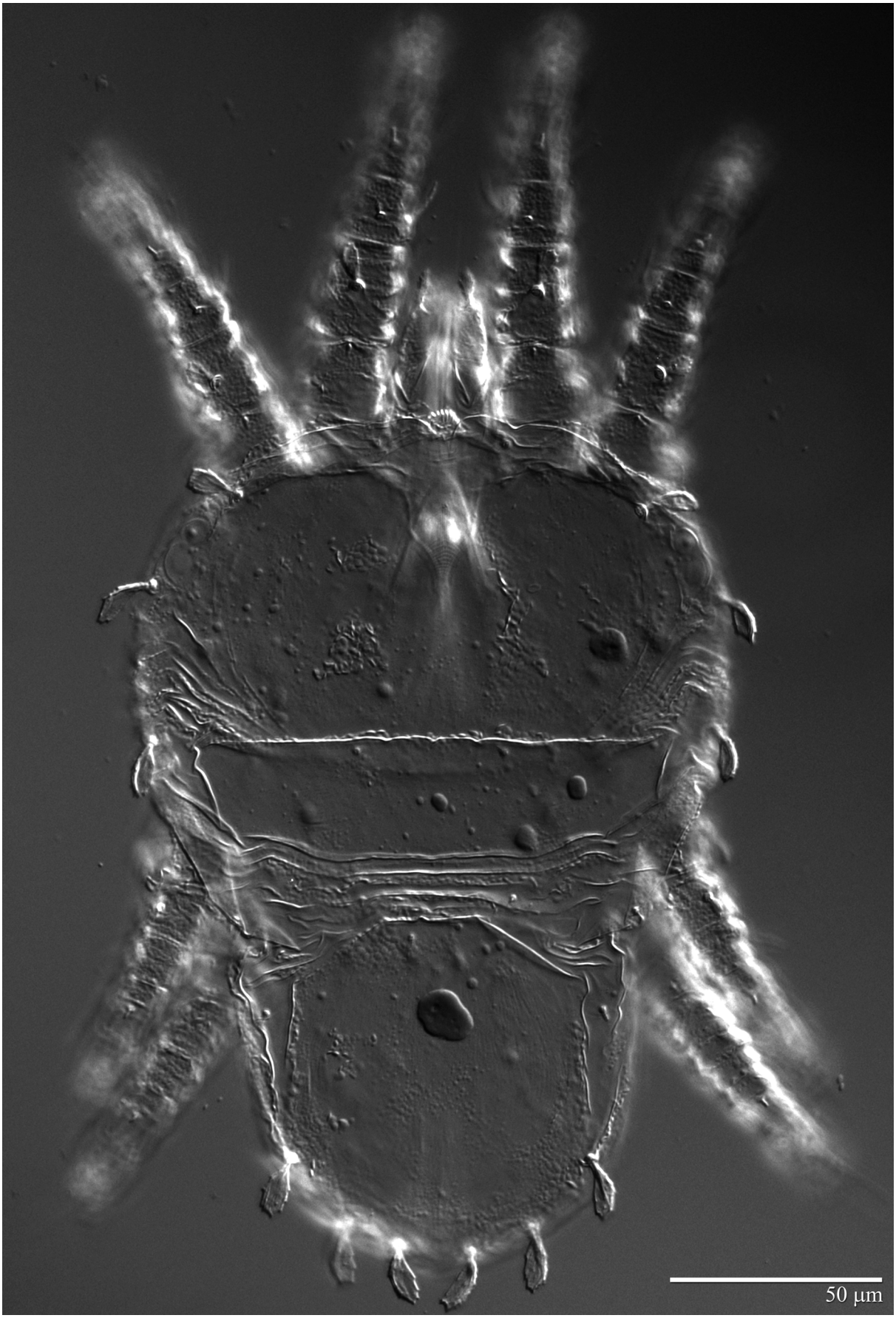

FIGURE 43. *Brevipalpus phoenicis* s.s. deutonymph dorsum (type location and host).

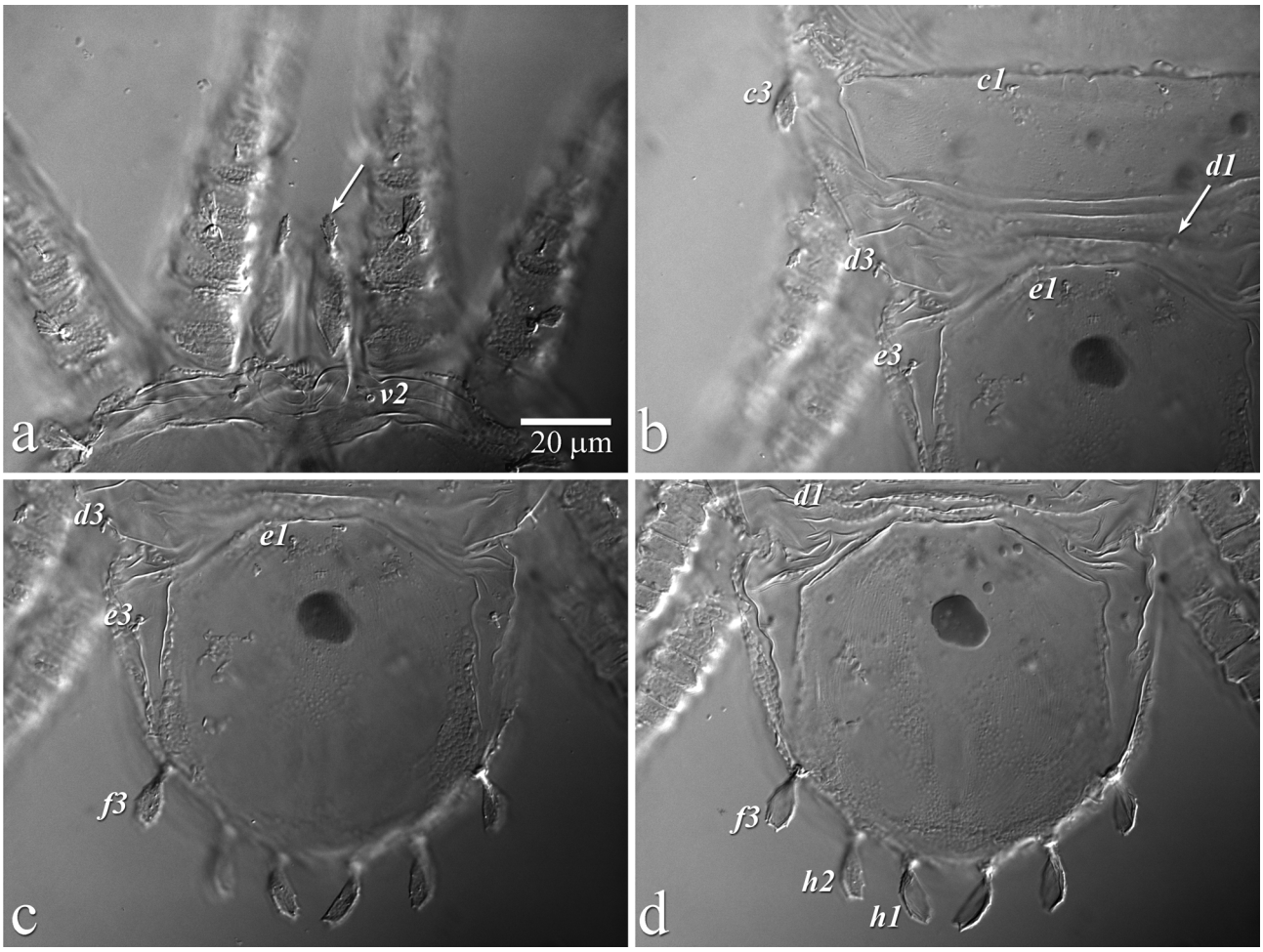

FIGURE 44. *Brevipalpus phoenicis* s.s. deutonymph (type location and host) detail of a. dorsal seta on palp femorogenu; b. dorsal setae on anterolateral opisthosoma; c. dorsal setae on opisthosoma; d. dorsal setae on posterior margin of opisthosoma.

Spermathecal apparatus. (Fig. 46e). Long fine duct terminating in rounded vesicle; outer perimeter of vesicle with series of tiny projections. Some females may have an undeveloped vesicle, in which duct terminates in membranous bulb (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 6–7 [7], antiaxial 6–7 [6] (Fig. 46f).

Male. Unknown.

Deutonymph. Unknown.

Hosts. *Citrus latifolia* (= *C.limon* (Grayum *et al.* 2012)), *C. sinensis* (Rutaceae).

Distribution. Tucuman, Argentina.

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species G. The specimens used in the type series for *B. tucuman* were originally identified as *B. pseudocuneatus* by Baker 1949: 376, with Figs 87–89. These slides were remounted in 1940 (written on slide) and then again by USNM staff in 2012. The original Blanchard types for *B. pseudocuneatus* were, until recently, considered lost. A slide box containing many specimens of Blanchard has recently been discovered in Argentina (pers. comm. M. Regonat) and may shed further light on the situation. For now, based on the original description of *B. pseudocuneatus* (Blanchard 1940), there are differences in the reticulation between true *B. pseudocuneatus* and *B. tucuman*. This, combined with the fact that *B. pseudocuneatus* has only one solenidion on tarsus II, separates these two species.

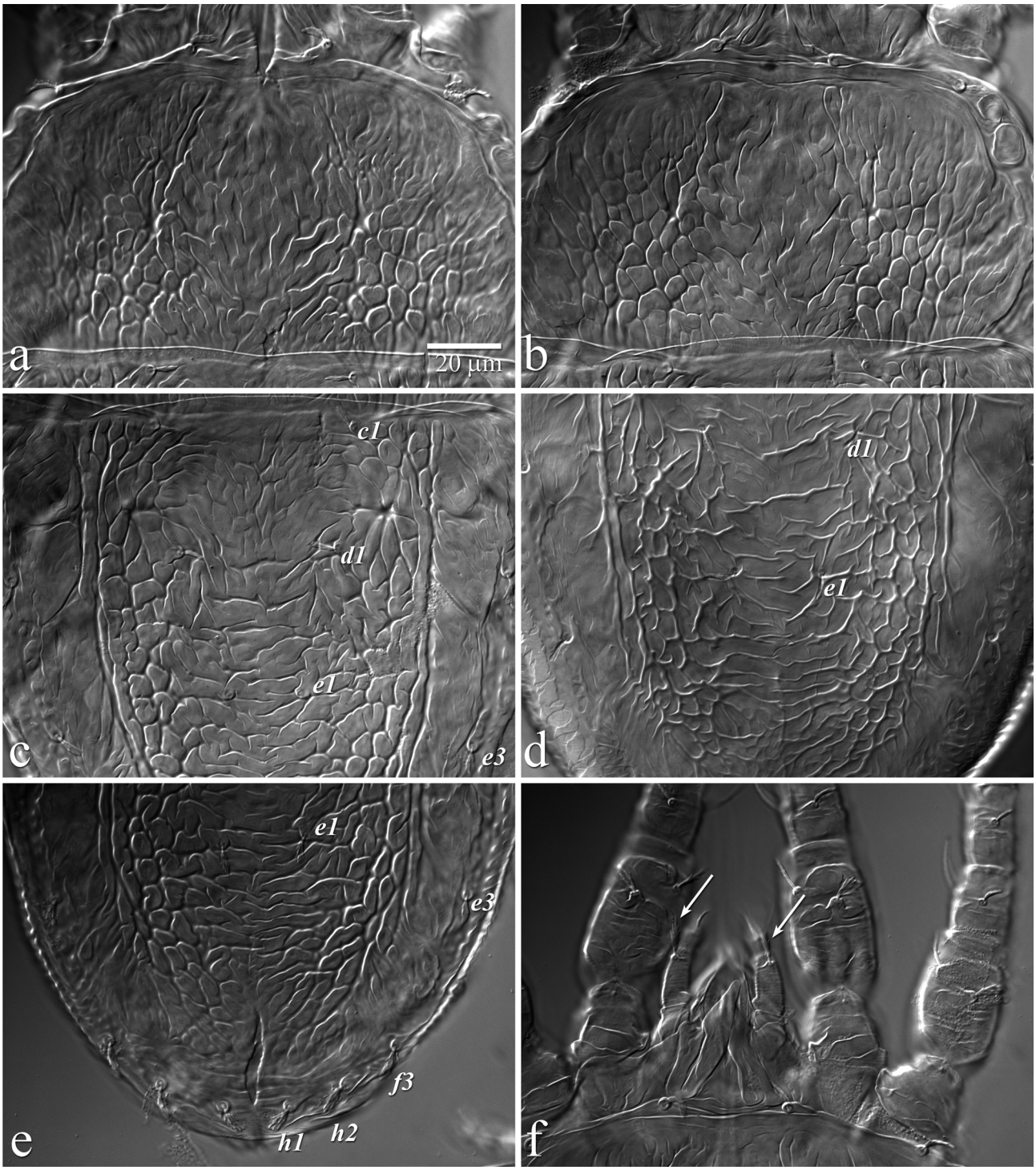

FIGURE 45. *Brevipalpus tucuman* sp. nov. female, a., b. prodorsum; c. anterior dorsal opisthosoma; d. central dorsal opisthosoma; e. posterior dorsal opisthosoma; f. gnathosoma (arrow indicates dorsal seta on palp femorogenu).

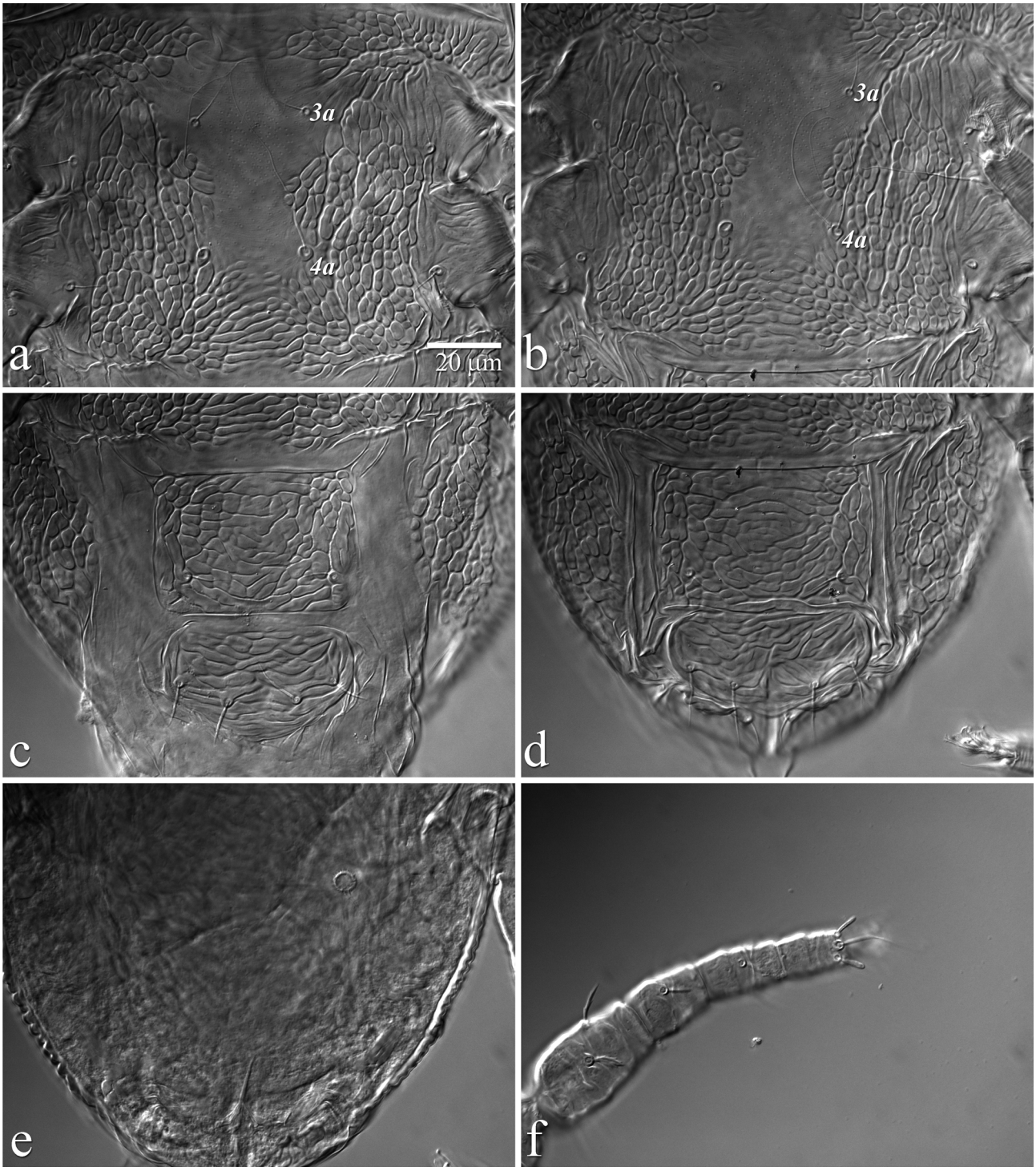

FIGURE 46. *Brevipalpus tucuman* sp. nov. female, a., b. ventral cuticle between coxae III–IV; c., d. posterior venter, indicating ventral and genital plates; e. spermatheca; f. right leg II, indicating two solenidia on tarsus II.

Brevipalpus yothersi **Baker**
(Figs 2d, 4d, 47–56)

Brevipalpus yothersi Baker 1949: 373, Figs 78–80. Original designation.
Brevipalpus mcbridei Baker 1949: 374, Figs 81–83. New synonymy.
Brevipalpus deleoni Pritchard and Baker 1958: 234, Fig. 33. New synonymy.
Brevipalpus phoenicoides Gonzalez 1975: 86, Figs 6–7. New synonymy.

Brevipalpus amicus Chaudhri 1972: 65. New synonymy.
Brevipalpus recula Chaudhri 1972: 63. New synonymy.

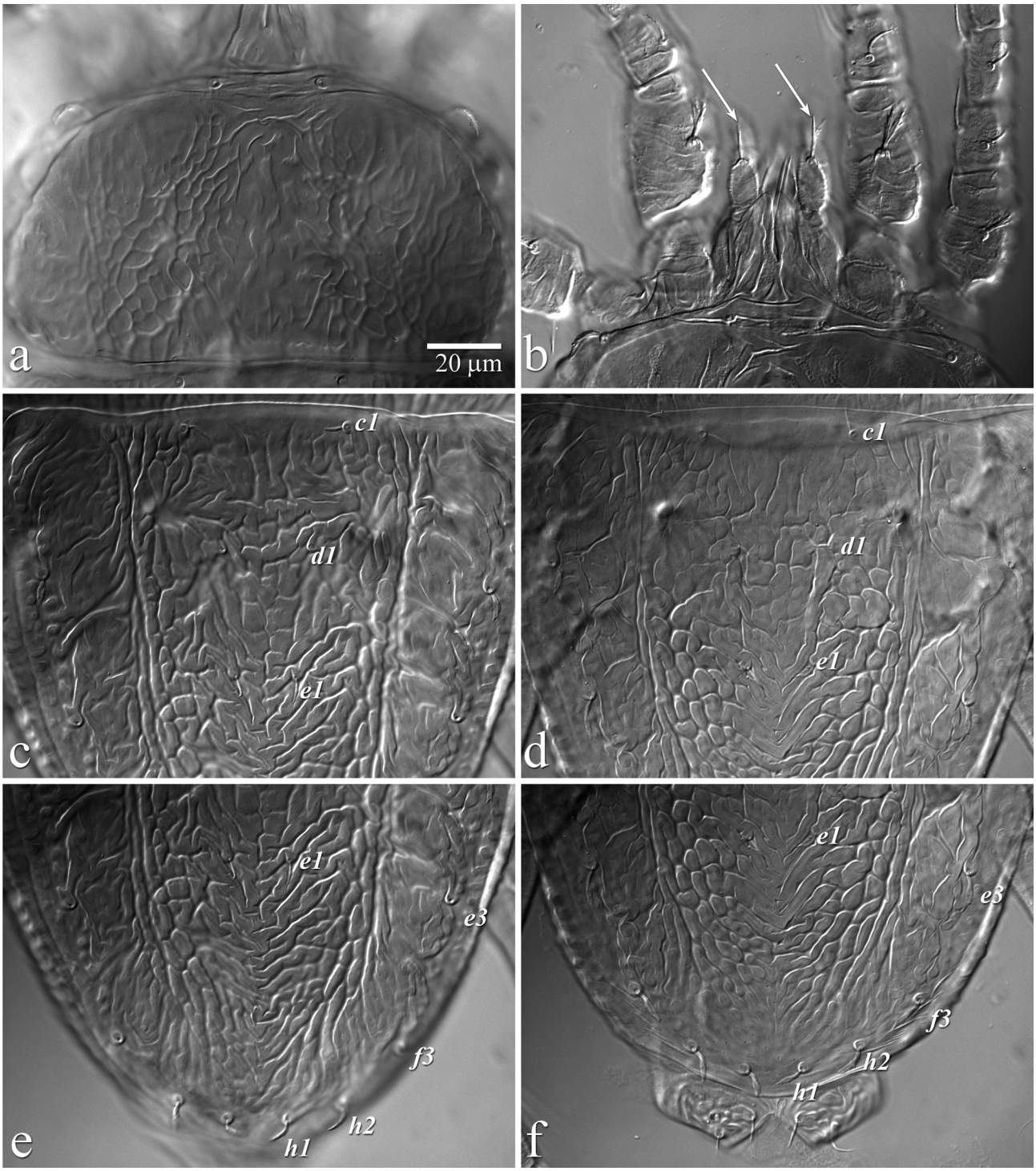

FIGURE 47. *Brevipalpus yothersi* female (paratype), a. prodorsum; b. gnathosoma (arrow indicates dorsal seta on palp femorogenu); c., d. anterior dorsal opisthosoma; e., f. posterior dorsal opisthosoma.

Material examined. Holotype. Female, USA, Florida, Orlando, ex. privet (Oleaceae), 2.xi.1913, M.A. Yothers (USNM; #1823; 3 females on slide). **Paratypes.** 30 females, many nymphs, same data as holotype (USNM; 15 slides; 8 remounted vii.1946, 12 remounted v.2011).

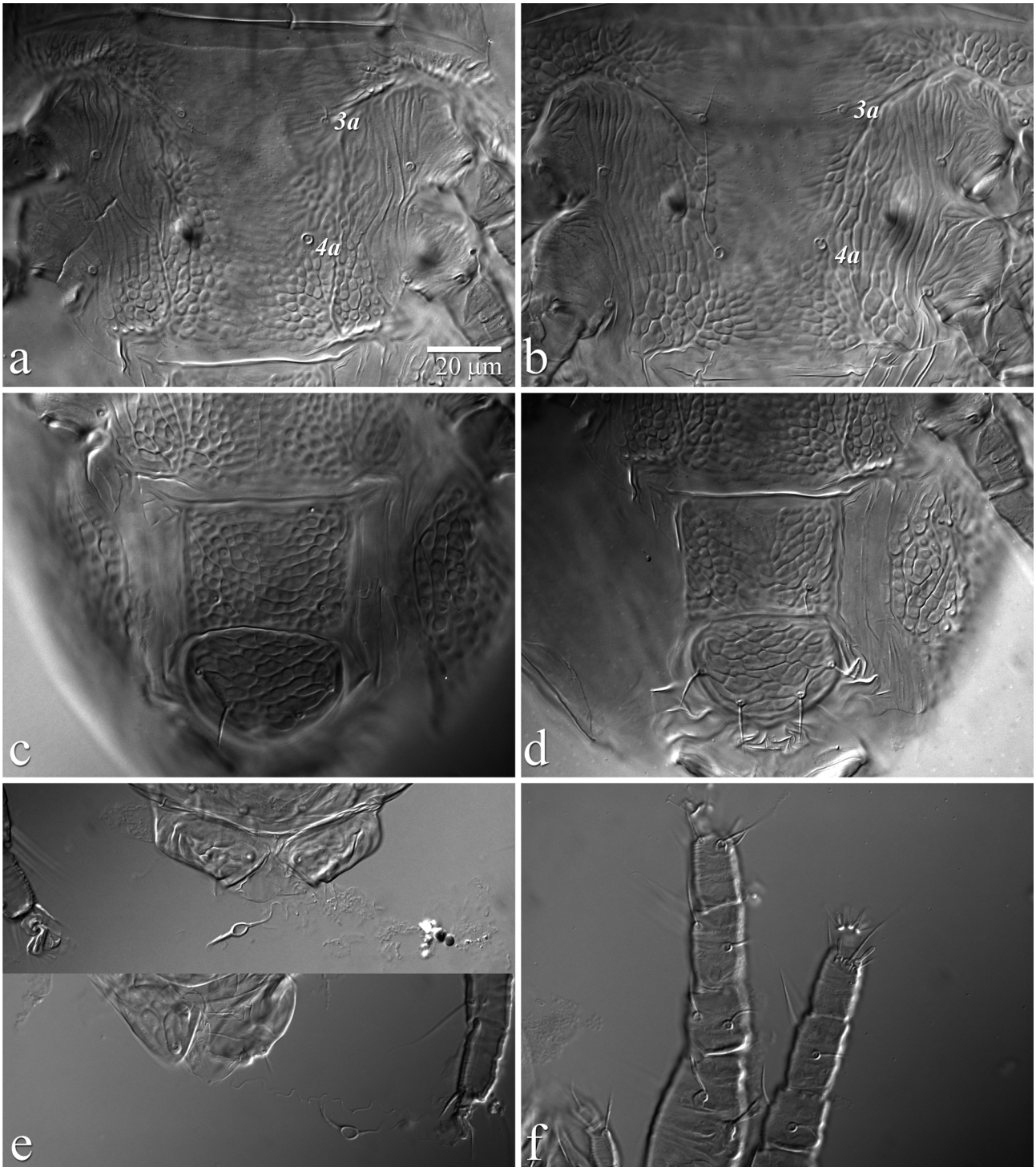

FIGURE 48. *Brevipalpus yothersi* female (paratype), a., b. ventral cuticle between coxae III–IV; c., d. posterior venter, indicating ventral and genital plates; e. spermatheca; f. right legs I–II, indicating two solenidia on tarsus II.

Other material examined. **Argentina:** female, ex. sweet orange (Rutaceae), Pindapoy Misiones, 22.viii.1950, L.C. Knorr (USNM); 2 females, ex. *Citrus sinensis* (Rutaceae), Saladas, Corrientes Province, 20.ii.1952, L.C. Knorr (USNM; 1 slide, with *B. obovatus*; *B. inornatus*; and *B. pseudocuneatus* topotype written on slide); female, ex. fruit of trifoliate orange *Poncirus trifoliata* (Rutaceae), Concordia Province, Entre Rios Province, 10.iii.1952, L.C. Knorr (USNM); 3 females, 3 deutonymphs, ex. Valencia oranges (Rutaceae), Santa Rosa, Corrientes Province, 31.iii.2005, C.C. Childers and J.C. Rodriguez (USNM; 3 slides); 2 females, 3 deutonymphs, protonymph, same data except Bella Vista, Corrientes Province (USNM); 2 females, ex. Valencia oranges (Rutaceae), Bella Vista, Corrientes Province, 1.iv.2005, C.C. Childers and J.C. Rodriguez (USNM). **Australia:** 4

females, ex. native shrub , Galvan's Gorge, Derby-Gibb River Road, Kimberley Region, Western Australia, 16º47'55"S, 125º50'39"E, 30.x.2000, J.J. Beard (QM); 2 females, ex. native shrub, Plain Creek, Kimberley Region, Western Australia, 16º15'06"S, 126º29'28"E, 30.x.2000, J.J. Beard (QM); 2 females, ex. native shrub, Bell Creek, Kimberley Region, Western Australia, 17º10'10"S, 125º21'32"E, 3.xi.2000, J.J. Beard (QM); 2 females, ex. various ornamental shrubs, Kalumburu Mission grounds, Kalumburu, Kimberley Region, Western Australia, 14º18'00"S, 126º38'00"E, 31.x.2000, J.J. Beard (QM; with *B. californicus* sensu lato); 3 females, deutonymph, ex. tuckeroo *Cupaniopsis anacardioides* (Sapindaceae), corner Frederick and Carnavon Streets, Broome, Kimberley Region, Western Australia, 18º00'11"S, 122º12'40"E, 7.xi.2000, J.J. Beard (QM); female, ex. fishtail palm *Caryota* sp. (Arecaceae), Humpty Doo, 32 km SE Darwin, Northern Territory, 12º35'S, 131º07'E, 15.xi.2000, J.J. Beard (QM); 11 females, ex. *Dendrobium conothum* (Orchidaceae), Winnellie, Darwin, Northern Territory, 12°26'S 130°54'E, 15.xi.2000, J.J. Beard (QM); 4 females, deutonymph, ex. *Macroptilium atropurpureum* (Fabaceae), Kununurra, Western Australia, 15º39'52"S, 128º44'09"E, 9.ix.2003, J.J. Beard (QM; 2 slides; with *B. californicus*); 3 females, ex. *Citrus* sp. (Rutaceae), Kununurra, Western Australia, 15º43'45"S, 128º41'31"E, 10.ix.2003, J.J. Beard (QM); 3 females, ex. lime *Citrus* sp. (Rutaceae), Kununurra, Western Australia, 15º43'45"S, 128º41'31"E, 10.ix.2003, J.J. Beard (QM); 10 females, 2 deutonymphs, ex. lemon fruit and leaves (Rutaceae), Carnarvon, Western Australia, 13.ix.2003, C.C. Childers (USNM); 13 females, ex. *Lenwebbia* sp. (Myrtaceae), The Gap, Brisbane, Queensland, 27°26'S 152°57'E, 28.iii.2004, J.J. Beard (QM); 5 females, ex. *Tecomaria capensis* (Bignoniaceae), Dingo Motel, Dingo, approx. 70km W Rockhampton, Queensland, 23°38'51"S 149°19'50"E, 20.iii.2005, J.J. Beard & P.I. Forster (QM); 5 females, deutonymph, ex. *Tabebua* sp. (Bignoniaceae), Smith Street, Darwin, Northern Territory, 12º27'24"S, 130º50'03"E, 17.v.2008, J.J. Beard and R Ochoa (QM); 2 females, ex. cape milkwood *Alstonia actinophylla* (Apocynaceae), Berry Springs National Park, Northern Territory, 12º42'21"S, 130º59'59"E, 18.v.2008, J.J. Beard and R. Ochoa (QM); 4 females, deutonymph, ex. beach spider lily *Hymenocallis littoralis* (Amaryllidaceae), Airport Resort Hotel, Darwin, Northern Territory, 31.xii.2009, M. Neal and T. Smith (NTDPIF; #59647); 6 females, 2 deutonymphs , ex. leaves of *Hibiscus* sp. (Malvaceae), Ironstone Lagoon Nursery, Knuckeys Lagoon, 7.i.2009, H. Wallace (NTDPIF; #59651); 3 females, same data except ex. leaves of native passion fruit vine *Passiflora* sp. (Passifloraceae) (NTDPIF; #59649); 6 females, same data except ex. leaves of ground cover *Gardenia* sp. (Rubiaceae) (NTDPIF; #59652); 26 females, 9 deutonymphs, 7 protonymphs, larva, ex. *Citrus* sp. (Rutaceae), Joey Citrus Orchard, via Mundubbera, Queensland, 25º37'58"S, 151º17'06"E, 12.v.2010, E. Carlton (QM, USNM); 12 females, 3 deutonymphs, 2 protonymphs, 2 larvae, ex. passionfruit vine *Passiflora edulis* Sims (Passifloraceae), Bundaberg, Queensland, 13.ii.2012, D.F. Papacek (QM, USNM); female, ex. pomegranate *Punica granatum* (Lythraceae), Broome, Kimberley Region, Western Australia, 17°59'00"S 122°12'00"E, 21.iv.2013, L. Halling (AQIS, Broome; LH1114); 5 females, ex. passionfruit *P. edulis* (Passifloraceae), Kununurra, Kimberley Region, Western Australia, 13.vi.2013, L. Halling (AQIS, Broome; LH1137); 6 females, 3 deutonymphs, ex. passionfruit *P. edulis* (Passifloraceae), Gibb River Community, Mt Barnett School, Kimberley Region, Western Australia, 16°32'13"S 126°07'41"E, 18.vi.2013, L. Halling (AQIS, Broome; LH1153). **Bangladesh:** female, ex. guava fruit (Myrtaceae), intercepted in Chicago, USA, 14.i.1985, J. Rennhack (USNM). **Belgian Congo:** 10 females, ex. papaya, Carica papaya (Caricaceae), Kinshasa (formerly Leopoldville), 12.iv.1955, E.W. Baker (USNM; 2 slides); female, larva, ex. *Citrus* leaf (Rutaceae), Mulunga, INEAC (Institut National pour L'Etude Agronomique de Congo Belge), 18.v.1955, E.W. Baker (#101 USNM). **Brazil:** 9 females, ex. coffee leaves (Rubiaceae), Pirajui, Sao Paulo, 19.iii.1950, coll. Newcomer (USNM, 1 slide); 4 females, ex. swingle fruits *Citrus aurantiifolia* (Rutaceae), intercepted in New York, 18.viii.1980, D. Kepik (USNM; 4 slides). **Burma:** 4 females, ex. *Citrus* sp. (Rutaceae), Rangoon, 18.vi.1959, C.A. Fleschner (USNM; 2 slides). **China:** female, ex. luggage, intercepted in New York, USA, 15.vi.1980, Fink and Blackhurst (USNM); 3 females, ex. *Citrus* sp. (Rutaceae), Fujian Province, 04.iv.2013, X. Yun and Q.-H. Fan (USNM). **Colombia:** female, ex. *Citrus aurantiifolia* (Rutaceae), intercepted in New York, USA, 22.iii.1980, E. Fink (USNM); female, ex. tangerines (Rutaceae), intercepted in Charleston, South Carolina, USA, 23.x.1991, S. Friedman (USNM, misidentified as *B. obovatus*). **Costa Rica:** female, ex. *Hibiscus* sp. flower (Malvaceae), intercepted in Texas, USA, 4.vi.1978, D. Johnston (USNM); 11 females, male, several immatures, ex. orange (Rutaceae), Atenas, 21.i.2009, H. Blanco (USNM; 3 slides). **Cuba:** female, ex. orange fruit (Rutaceae), intercepted in Houston Texas, USA, 22.xii.1949, O.E. Hunt (USNM, labelled as *B. mcbridei*). **Dominican Republic:** female, ex. citrus leaf (Rutaceae), San Juan, 1.iii.1975, J. Thaw (USNM); female, ex. mixed plants, intercepted in New York, USA, 17.iii.1980, E. Fink and P. Thomas (USNM, misidentified as *B. obovatus*); female,

ex. guava fruit (Myrtaceae), intercepted in New York, USA, 21.iv.1982, A. O'Connell (USNM); female, ex. *Citrus* sp. (Rutaceae), intercepted in USA, 5.v.1982, A. O'Connell (USNM). **Ecuador:** female, ex. *Citrus latifolia* (Rutaceae), intercepted in New York, USA, 20.iii.1980, B. Isakson (USNM, misidentified as *B. obovatus*). **El Salvador:** 3 females, ex. paradise tree *Simarouba glauca* (Simaroubaceae), San Salvador, 8.xi.1956, P.A. Berry (USNM); 7 females, ex. *Fernaldia* sp. (Apocynaceae), intercepted in Texas, USA, 30.x.1992, A. Nicola (USNM). **Ethiopia:** 3 females, deutonymph, ex. *Citrus reticulata* (Rutaceae), 2.xi.1966, L.C. Knorr (#8447 USNM; 2 slides); 5 females, same data except Tibila, 4.xi.1966 (#8448 USNM; 2 slides). **France:** 2f#, ex. *Alocasia cucullata* leaf (Araceae), intercepted in Washington DC, USA, 29.viii.1957, J.E. Mabry (USNM; with *B. obovatus*). **Guatemala:** 3, ex. *Fernaldia* sp. (Apocynaceae), intercepted in Texas, USA, 14.ix.1992, A. Nicola (USNM, 1 slide); 2, same data, except 19.x.1992 (1 slide). **Honduras:** 5 females, 5 deutonymphs, ex. chenille plant *Acalypha hispida* (Euphorbiaceae), Lancetilla, 21.xii.1958, coll. Matthysse (USNM, 2 slides; with 4 females *B. californicus*); female, ex. *Acalypha wilkesiana* (Euphorbiaceae), La Lima, 15.iii.1959, coll. Matthysse (USNM); female, ex. giant Cavendish banana *Musa* sp. (Musaceae), Coyoles, 1.vi.1982, J.T. Mirenda (USNM). **India:** female, *Citrus* sp. (Rutaceae), Nagpur, Maharashtra State, 12.ii.1959, C.A. Fleschner (USNM); female, ex. *Citrus* sp. (Rutaceae), New Delhi, 9.iv.1959, C.A. Fleschner (#59-17921 USNM); female, 2 males, ex. *Citrus sinensis* (Rutaceae), Chattroli, Himachal Pradesh State, 16.vii.1969, collector not indicated (USNM; 2 slides); 2 females, pharate female, deutonymph, ex. *Citrus medica* (Rutaceae), Ludhiana, Punjab State, 28.viii.1969, Knorr (USNM; 2 slides); female, ex. tangerine *Citrus reticulata* (Rutaceae), intercepted in Texas, USA, 3.ii.1983, C. Chapman (USNM, misidentified as *B. obovatus*); female, ex. Rutaceae, intercepted in New York, USA, 5.xii.1991, L. Schroeder (USNM, misidentified as *B. obovatus*). **Indonesia:** female, ex. tea *Camellia sinensis* (Theaceae), Tjiater, Jawa Barat, Bogor, 26.vii.1956, W.P. van der Knapp (USNM, on same slide with *B. papayensis*). **Israel:** female, ex. guava fruit *Psidium guajava* (Myrtaceae), intercepted in Washington DC, USA, 15.x.1985, C. Jushno (USNM); female, ex. guava fruit (Myrtaceae), intercepted in Chicago, no date, no collector (USNM). **Malaysia:** female, ex. rubber seedlings *Hevea* sp. (Euphorbiaceae), Selangor State, 1.iii.1950, A. Newsam (USNM); female, same data except June 1950 (*B. californicus* sensu lato on same slide). **Mexico:** female, ex. avocado *Persea americana* Mill. (Lauraeae), intercepted in California, USA, 4.x.1976, W. Manning (#77-3695 USNM); female, ex. *Hibiscus* sp. leaf (Malvaceae), intercepted in Texas, USA, 19.vi.1977, D. Johnston (USNM); 2 females, same data, except 4.viii.1979 (2 slides); female, ex. *Fraxinus* sp. leaf (Oleaceae), intercepted in Texas, USA, 18.vii.1979, D. Johnston (USNM); female, ex. coconut *Cocos nucifera* (Arecaceae), San Antonio, 10.viii.1981, D. Johnston (USNM); female, ex. coconut fruit *Cocos nucifera* (Arecaceae), intercepted in Brownsville, USA, 10.iv.1986, J. Cano (USNM). **Nigeria:** female, ex. banana (Musaceae), Ibadan, Oyo State, 28.ii.1975, JGM (USNM); female, ex. *Citrus sinensis* (Rutaceae), intercepted in New York, USA, 26.ii.1980, E. Fink and J. Nemazi (USNM). **Pakistan:** 2 females, ex. loquat *Eriobotrya japonica* (Rosaceae), Siakot, Punjab Province, 14.x.1964, M.A. Ghani (USNM, with *Tenuipalpus* sp.); female, ex. *Peganum harmala* (Nitrariaceae), 1 mile east of Hafizabad, 19.v.1969, Chaudhri (USNM; paratype slide *Brevipalpus amicus* Chaudhri); 2 females, ex. sunflower *Helianthus annuus* (Asteraceae), 1 mile north of Kotri, Sindh Province, 13.xii.1972, Chaudhri (USNM; paratype slide *Brevipalpus recula* Chaudhri); female, ex. *Citrus* sp., 2 miles south of Lyallpur, 27.x.1976, Chaudhri (USNM; misidentified as *Brevipalpus creber*); female, ex. guava fruit (Myrtaceae), intercepted in New York, USA, 18.vii.1980, B. Isakson (USNM). **The Philippines:** female, ex. orchid leaf, intercepted in Chicago, USA, 13.ix.1985, Keith and Taylor (USNM); female, ex. guava *Psidium guajava* (Myrtaceae), intercepted in California, USA, 11.xii.1995, C. Knakorm (USNM, misidentified as *B. obovatus*). **Puerto Rico:** 2 females, ex. fig leaf (Moraceae), Hato Rey, 13.i.1977, S. Medina Gaudo (USNM; 2 slides). **Spain:** female, ex. *Citrus sinensis* (Rutaceae), intercepted in New York, USA, 25.viii.1980, E. Fink (USNM). **Sri Lanka:** 10 females, ex. tea (Theaceae), 1951, G.O. Evans (USNM). **Thailand:** 4 females, deutonymph, 2 protonymphs, larva, ex. *Pandanus* sp. (Pandanaceae), Bangkapi, Bangkok, 1.i.1974, L.C. Knorr (Acari collection -University De Chile; 2 paratype slides of *Brevipalpus phoenicoides* Gonzalez); female, ex. okra *Hibiscus esculentus* (Malvaceae), Bangkhen, 18.x.1976, L.C. Knorr (USNM); 2 females, ex. *Cannabis sativa* (Cannabaceae), Bangkhen, 28.vi.1977, L.C. Knorr (USNM; 2 slides); female, ex. guava (Myrtaceae), intercepted in New York, USA, 21.ii.1991, M. Garcia (USNM). **Trinidad:** female, ex. Cucurbitaceae, intercepted in New York, USA, 28.iii.1980, E. Fink and T. Gary (#80-5894 USNM). **USA:** 2 females, ex *Citrus* sp. (Rutaceae), "at Dr Person's place", Orlando, Florida, 30.v.1922, J.R. Springer (USNM); 4 females, 1 deutonymph, ex English walnut *Juglans regia* (Juglandaceae), Orlando, Florida, 26.xi.1926, O.C. McBride (USNM; paratype slides of *B. mcbridei*: 5 slides—2 remounted vii.1946, 5 remounted v.2011); 9 females, 3 deutonymphs,

protonymph, ex. grape plants (Vitaceae), 20.ix.1951, W.B. Wood (USNM; 4 slides, with *B. azores* sp. nov.); 5 females, 2 males, ex. coconut leaf (Arecaceae), Fort Lauderdale, 8.x.1953, O.D. Link (USNM; one slide); 4 females, ex. guava fruit (Myrtaceae), University of Maryland Farm, Maryland, 17.ix.1954, F.G.B. (USNM); 2 females, several immatures, ex. *Maranta* sp. (Marantaceae), Bradenton, 7.x.1954, G.W. Dekle (USNM); 4 females, ex. *Petrea* sp. (Verbenaceae), southern Miami, Florida, 30.ix.1954 (USNM; holotype slide of *B. deleoni*); female, ex. king palm (Arecaceae), Gainesville, Florida, 27.xii.1954, L.C. Kuitert (USNM); 2 females, 2 nymphs, ex. *Citrus* (with leprosis) (Rutaceae), Lake Alfred, Florida, 16.i.1958, L.C. Knorr (USNM); female, ex. *Haya* sp. (Caryophyllaceae), Guadulcanal, 9.xii.1963, J. Fine (USNM). **Venezuela:** female, ex. guava *Psidium guajava* (Myrtaceae), intercepted in New York, USA, 20.iii.1980, B. Isakson (USNM); 8 females, 8 immatures, ex. lemon fruit (Rutaceae), 22.v.1997, C.C. Childers (USNM; 2 slides).

Diagnosis. As per *Brevipalpus phoenicis* species group, in addition to the following. Prodorsum: central cuticle with strong areolae; sublateral cuticle with reticulation forming large cells posteriorly, weakly reticulate anteriorly. Dorsal opisthosoma: *c1-c1* to *d1-d1* cuticle smooth to weakly reticulate; *d1-d1* to *e1-e1* cuticle weakly reticulate or wrinkled; *e1-e1* to *h1-h1* cuticle with series chevron shaped folds (V-shaped), becoming weaker towards *h1-h1*; sublateral cuticle reticulate with regular cells, cells becoming longitudinally elongate towards *h1-h1*. Ventral plate: cuticle uniformly verrucose with separately formed individual small warts. Genital plate: cuticle uniformly verrucose to verrucose-reticulate, with large cells formed by fused warts. Palp femorogenu with dorsal seta setiform, barbed. Spermatheca: long narrow, convoluted duct terminating in sclerotised oval vesicle with thick distal stipe. Cuticular microplates: separate individual, oval plates, with series of distinct parallel ridges over dorsal surface.

Female (n = 12). *Dorsum.* (Figs 2d, 47, 49–51) Body measurements: length between setae *v2-h1* 200–226 [216], width between setae *sc2-sc2* 131–146 [143], *c3-c3* 140–158 [152]. Central prodorsum: cuticle with strong areolae, usually longitudinally elongate (Figs 47a, 49–50). Sublateral prodorsum: posterior region with reticulation forming large cells; anterior region weakly reticulate to setae *v2*, becoming broadly wrinkled to smooth (Figs 47a, 50). Central opisthosoma: cuticle between *c1-c1* and *d1-d1* smooth to weakly reticulate (Figs 47c–d, 49, 51); *d1-d1* to *e1-e1* weakly reticulate and/or wrinkled (Figs 47c–d, 49, 51); *e1-e1* to *h1-h1* usually with strong chevrons (V-shaped folds), becoming much weaker towards *h1-h1* (Figs 47e–f, 49, 51). Sublateral opisthosoma: cuticle reticulate with regular-uniform cells, lateral cells becoming longitudinally elongate (Figs 47e–f). Dorsal setae lanceolate, barbed: *v2* 11–17 [15], *sc1* 11–18 [17], *sc2* 12–19 [17], *c1* 8–12 [lost], *c3* 8–17 [14], *e1* 6–9 [8], *e3* 8–16 [13], *f3* 10–14 [12–13], *h1* 8–12 [11], *h2* 8–13 [12].

Dorsal microplates. (Fig. 53). Separate individual, rounded to oblong plates, with a series of distinct (mostly) parallel ridges on dorsal surface.

Gnathosoma. (Fig. 47b). Palp as in species group (see group Diagnosis). Palp femorogenu with barbed setiform dorsal seta.

Venter. (Figs 4d, 48a–d, 52). Cuticle between *4a* and ventral plate uniformly verrucose with separately formed rounded "warts", often weaker centrally (Figs 48a–b, 52a). Ventral plate: uniformly verrucose, with separately formed small, rounded "warts"; may be weaker centrally (Figs 48c–d, 52b). Genital plate: uniformly verrucose or verrucose-reticulate, with large cells formed by fused or conglomerate "warts" (Figs 48c–d, 52b).

Spermathecal apparatus. (Fig. 48e). A long narrow, convoluted duct, ending in a sclerotised, oval vesicle, with a thick distal stipe. Vesicle sometimes not visible (see * in Remarks for *B. azores*).

Legs. Setal formula for legs I–IV as in species group (see group Diagnosis). Tarsus II with two solenidia, paraxial 4–6 [4–5], antiaxial 6–8 [6–7] (Figs 48f).

Deutonymph. *Dorsum.* (Figs 54–56) Prodorsal setae v2 broadly lanceolate, barbed (Figs 54a, 55a). Opisthosomal setae *c1*, *d1*, *e1* usually minute to short; setae *f3*, *h1*, *h2* enlarged, broadly lanceolate, barbed; setae *c3*, *d3*, *e3* variable, short (like *c1*, *d1*, *e1*) (*e3* short Fig. 56) to enlarged (like *f3*, *h1*, *h2*) (*e3* enlarged Figs 54c, 55c), within a single population (Figs 54–56). Dorsal seta on palp femorogenu setiform, as in adult (Fig. 55a). Broadly lanceolate setae *c1*, *d1*, *e1* have sometimes been observed for this species (Gonzalez 1975; Ochoa 1985; Evans *et al.* 1993).

Hosts. A very broad host range, with a strong association with *Citrus* spp. (Rutaceae)—see *Other material examined*.

Distribution. Suspected world-wide distribution—see *Other material examined*.

Remarks. This species is listed by Beard *et al.* (2013) as *Brevipalpus phoenicis* group species B.

FIGURE 49. *Brevipalpus yothersi* female dorsal habitus (Australia).

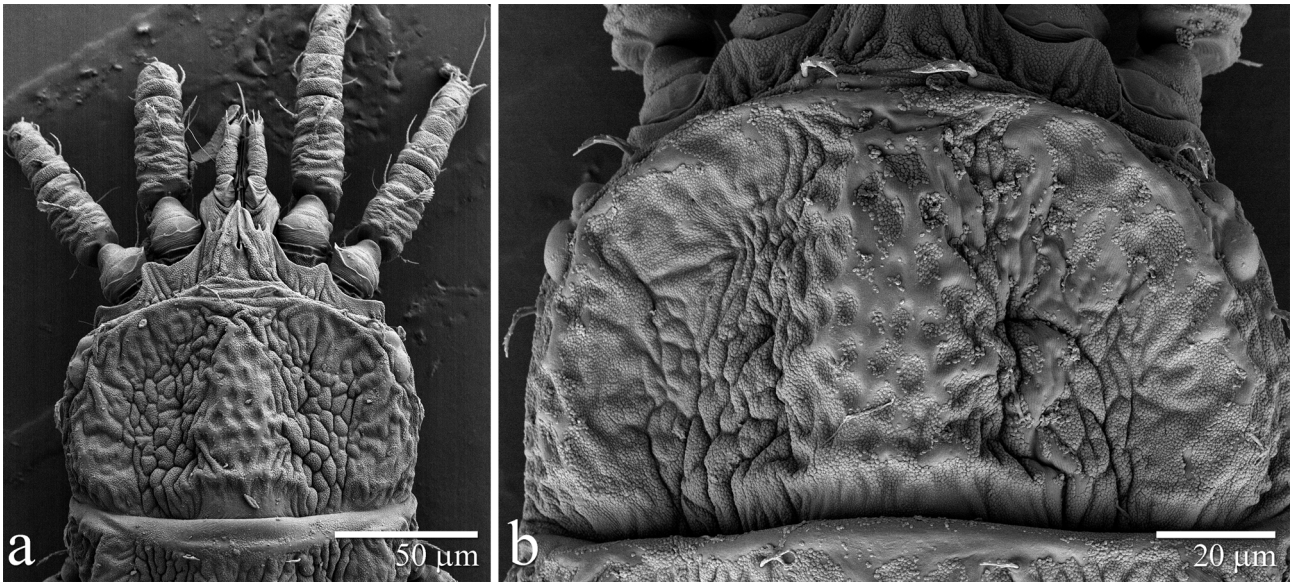

FIGURE 50. *Brevipalpus yothersi* female, detail of prodorsum, a. Australia; b. Colombia.

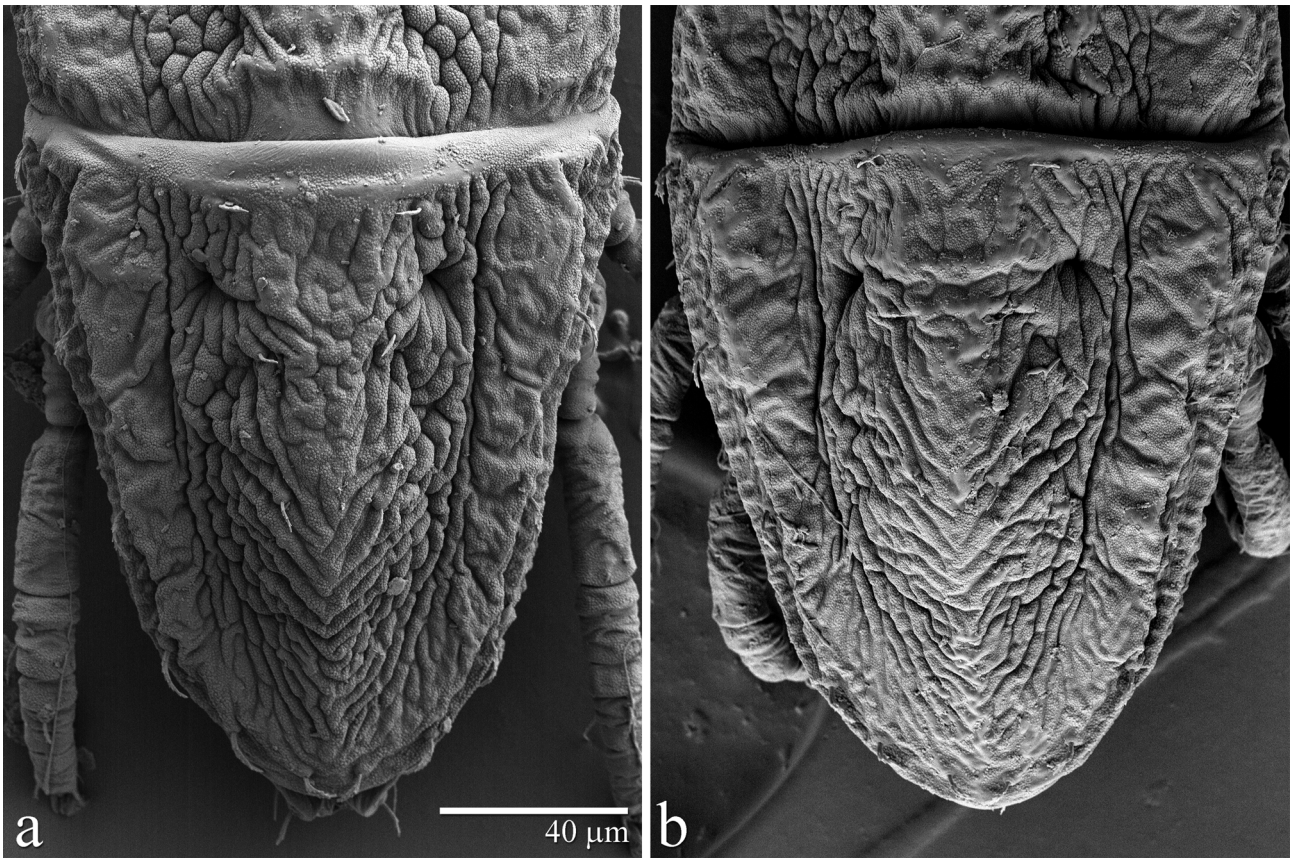

FIGURE 51. *Brevipalpus yothersi* female, detail of opisthosoma, a. Australia; b. Colombia.

Baker (1949) originally described *B. yothersi* and *B. mcbridei* as separate species based on differences in the setae of the nymphs; however, Pritchard and Baker (1952) later synonymised them both under the name *B. phoenicis* as rearing experiments performed by Knorr revealed that the nymphal setae variation that was used to separate them was actually intraspecific and not interspecific (see Pritchard & Baker 1952:38, and Knorr 1968:336). As we have raised *B. yothersi* to species level again, *B. mcbridei* becomes a junior synonym of *B. yothersi*, rather than of *B. phoenicis* sensu stricto. In addition, De Leon (1961: 178) made *B. deleoni* a synonym of *B. phoenicis* sensu lato. Here we confirm that *B. deleoni* is actually a junior synonym of *B. yothersi*.

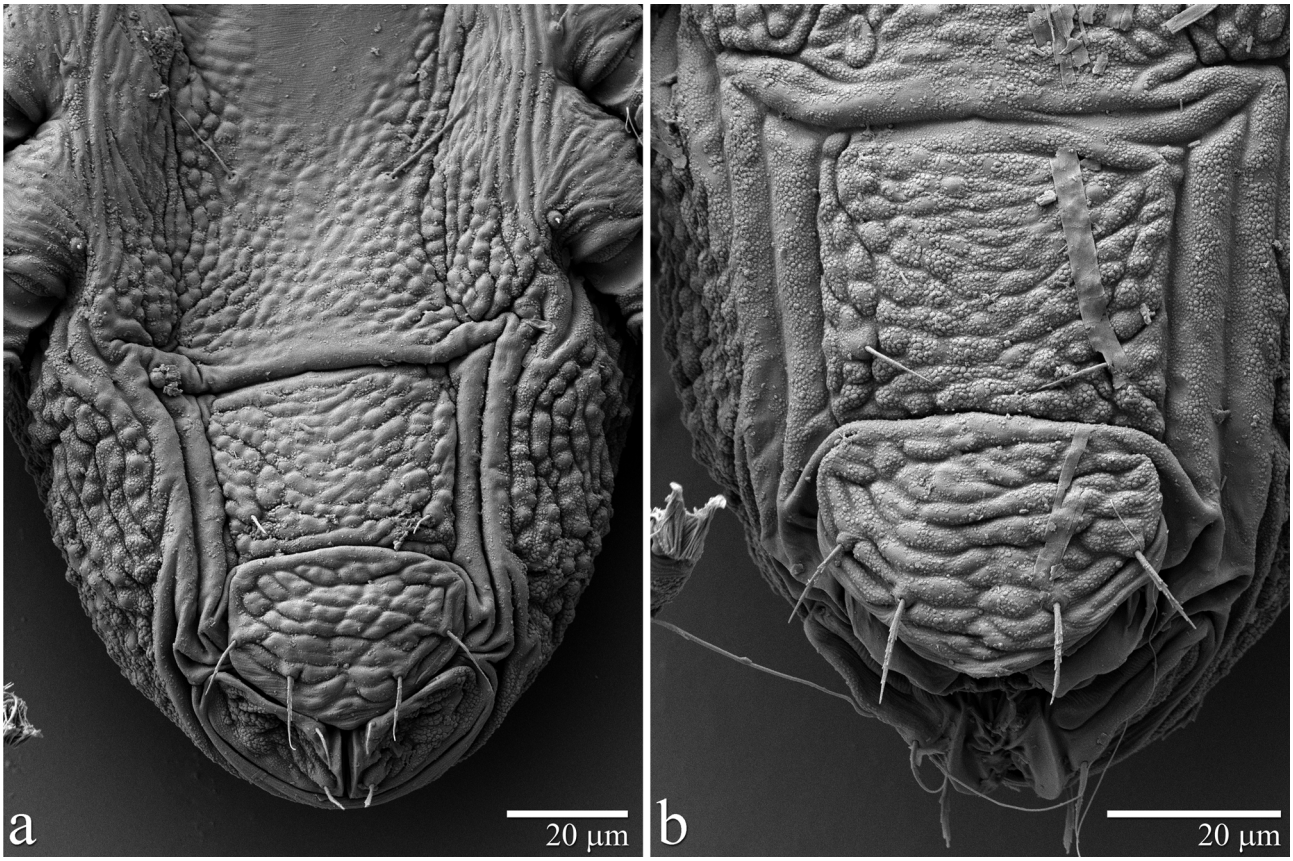

FIGURE 52. *Brevipalpus yothersi* female, a. ventral habitus (Australia); b. detail of ventral and genital plates (Australia).

After examining the external morphology and spermatheca of *B. phoenicoides* paratypes, we believe that *Brevipalpus phoenicoides* is not *B. phoenicis* s.s. but is in fact a junior synonym of *B. yothersi*.

Chaudhri (1972, 1974) described and re-described *B. amicus* and *B. recula* placing them in the *B. obovatus* group, though the paratypes clearly have two solenidia on tarsus II (pers. obs. Beard & Ochoa). After examining type material of both these species, they are here considered to be junior synonyms of *B. yothersi*. The measurements provided in our description include those taken from the types of *B. yothersi* synonyms: *B. mcbridei*, *B. recula*, *B. phoenicoides* and *B. deleoni*.

Based on the description and associated figures, we cannot separate *B. incognitus* Ferragut & Navia 2013 from *B. yothersi* morphologically. Further, molecular data does not exist for the morphologically analysed specimens and thus we cannot conclusively use signatures of molecular divergence to indicate species divergence for *B. incognitus*. Unfortunately, we have so far been unable to access specimens of *B. incognitus* for examination with DIC or LT-SEM (for microplate structure).

It has recently been shown that *Brevipalpus yothersi* has a strong association with the citrus leprosis virus complex and it is suggested to be a vector of the cytoplasmic leprosis viruses (Roy *et al.* 2015). Due to this association, we strongly suggest that for all future collections of this species from *Citrus* hosts, it is important to provide much greater details regarding the species, variety and root stock of the host plant.

Discussion

This study highlights the level of morphological detail necessary for reliable species separation in this group. The results reveal a diversity that is consistent with cryptic species present within the genus *Brevipalpus*. More critically, it indicates that traditional characters are no longer sufficient for species descriptions and separation. The presence of cryptic species has far reaching implications for the study of the genus *Brevipalpus*. Inconsistent or confusing results could be due to the fact that research has been dedicated to what was thought to be one species of

mite, whereas in fact several species were present, each with their own ecology and biology. As the mites are vectors of numerous plant viruses, our ability to recognise species is critical for determining host plant specificity, vector-pathogen specificity and the potential for disease spread. This example highlights the need for sound systematics and the critical nature of accurate identification, as the detection of cryptic species can often be the difference between success and failure in research programs and should not be considered an "academic luxury".

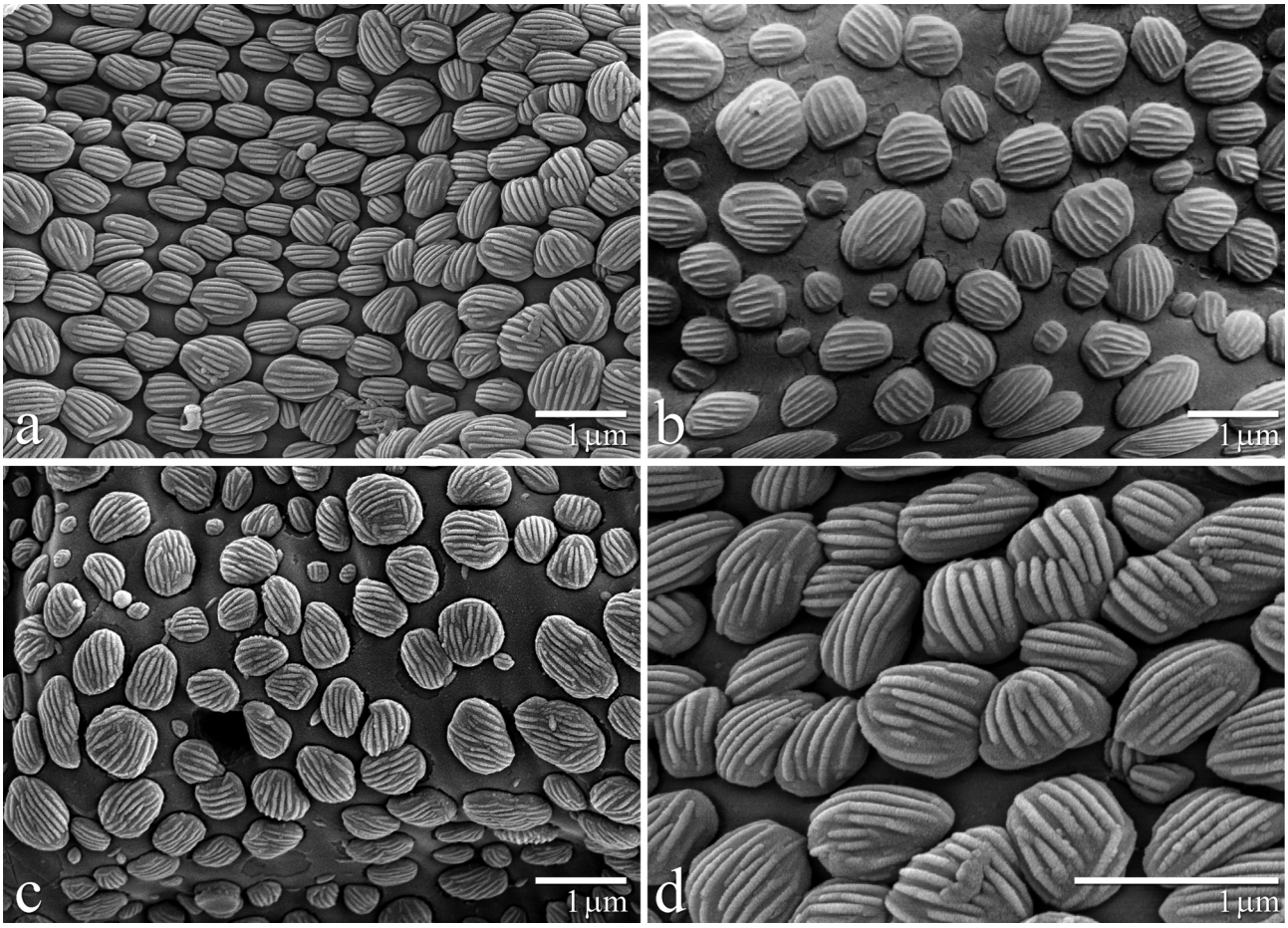

FIGURE 53. *Brevipalpus yothersi* female detail of microplates on dorsal cuticle, a. Australia; b. USA; c. Brazil (a., b., c. 15,000X); d. detail of dorsal cuticle (Brazil) (40,000X).

The discovery of the presence of specific patterns in the microplates (sensu Welbourn *et al.* 2003) on the cuticle of tenuipalpid mites has proven to be a critical addition to the set of characters available for both species separation and confirmation. Based on our observations, the structure of the microplates does not vary significantly over the surface of the mites. Most of our images are taken from the central prodorsum or dorsal opisthosoma. Due to their nature, observation of the microplates can only be made using low temperature scanning electron microscopy (LT-SEM). The microplates appear to be composed of a wax-like substance and standard SEM preparation techniques remove this wax-like surface or significantly alter it. Attempts to observe the microplates using an environmental or variable pressure SEM have so far been unsuccessful. Here, detailed studies of the cuticular microplates have provided unique taxonomic characters to distinguish species within this *Brevipalpus* species complex, but they have also been used diagnostically within other genera of the Tenuipalpidae (e.g. Beard *et al.* 2014a). As LT-SEM equipment is simply not available to most researchers and identifiers, the diagnostics provided here are based on characters observable using Differential Interference Contrast (DIC) microscopy. Phase contrast microscopy is inadequate to observe several critical characters (Beard *et al.* 2013), and thus DIC is recommended as a minimum requirement for identifying these mite species, as discussed further below.

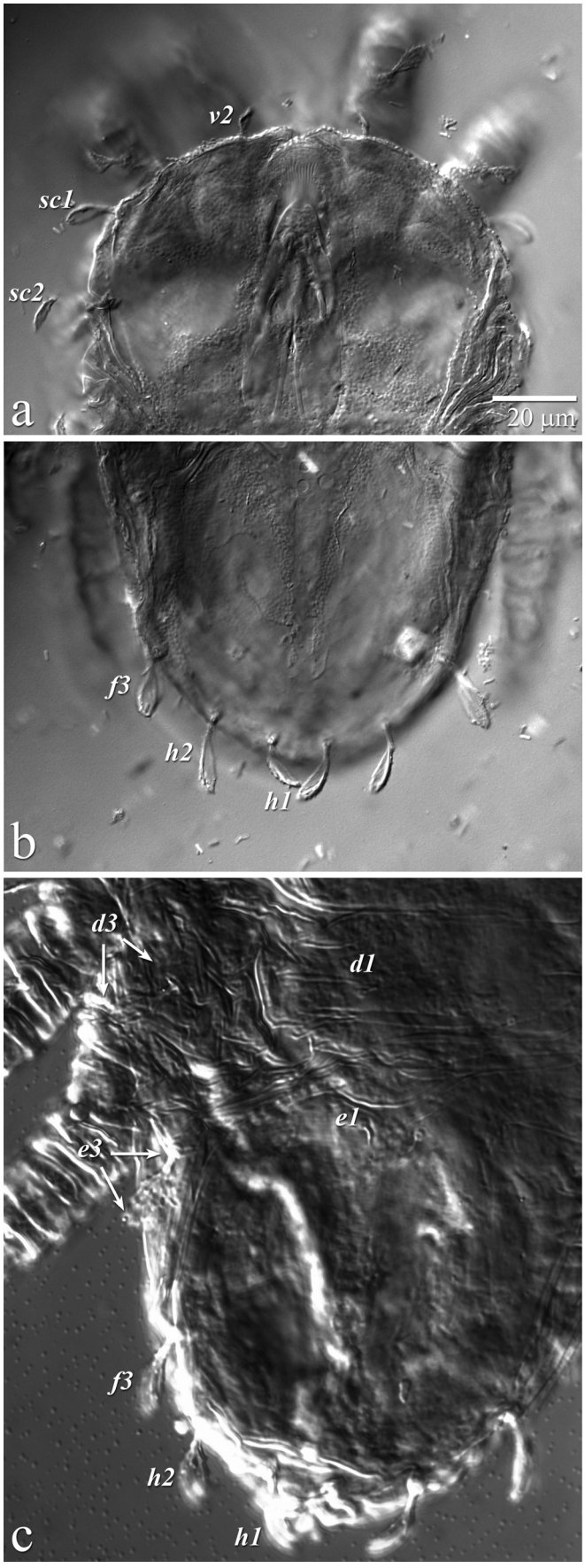

FIGURE 54. *Brevipalpus yothersi* deutonymph (paratype) with detail of a. setae on prodorsum; b. dorsal setae on posterior margin of opisthosoma; c. dorsal setae on opisthosoma (arrows indicate setae *d3*, *e3* length).

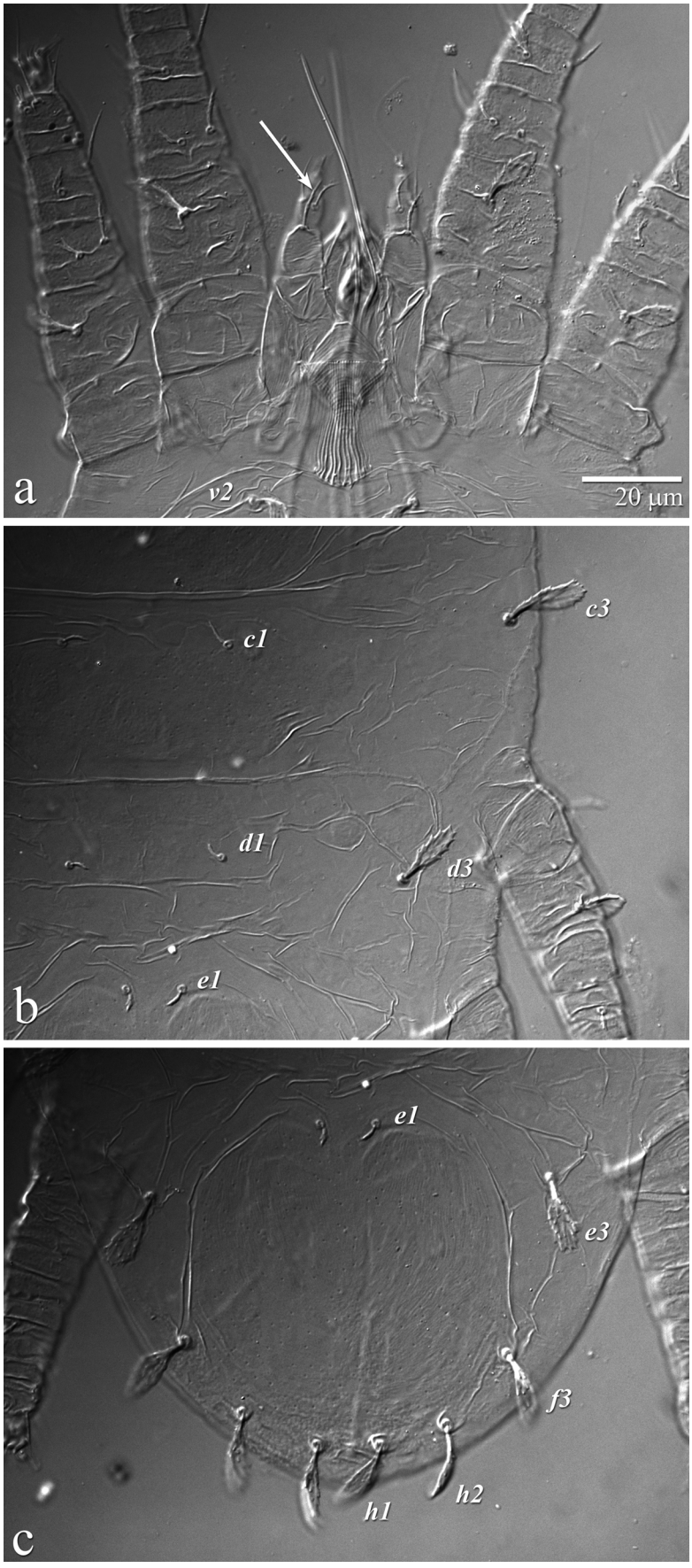

FIGURE 55. *Brevipalpus yothersi* deutonymph (*Citrus*, Australia) with details of a. dorsal seta on palp femorogenu; b. dorsal setae on anterior opisthosoma; dorsal setae on posterior margin of opisthosoma.

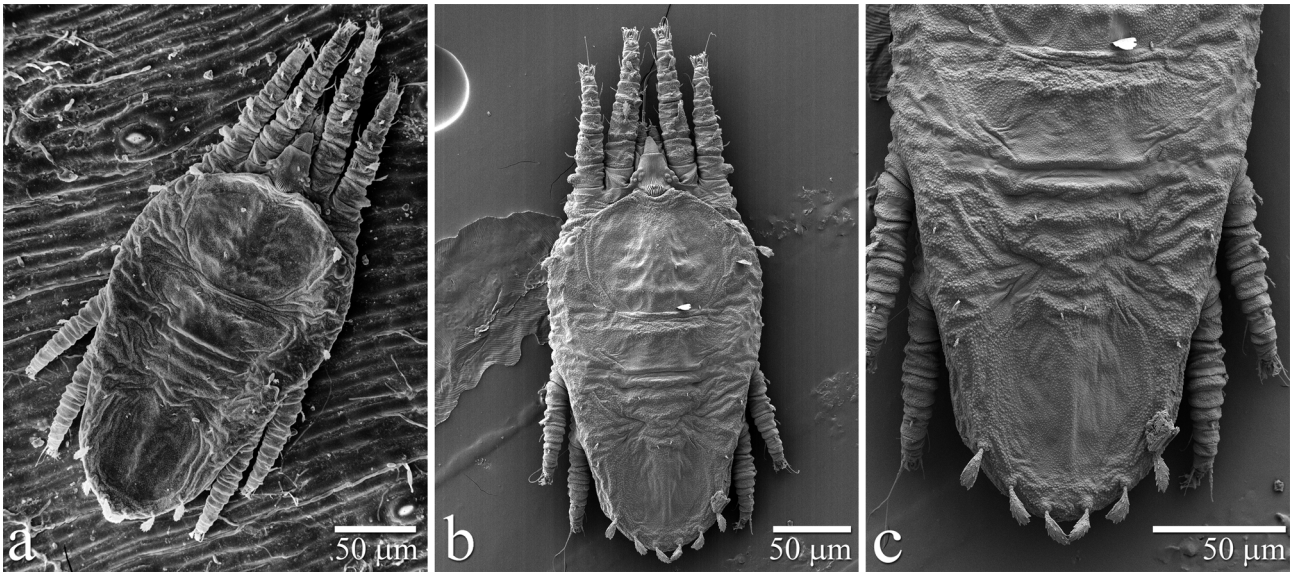

FIGURE 56. *Brevipalpus yothersi* deutonymph, dorsal habitus from a. *Citrus*, Florida, USA; b. *Passiflora*, Australia; c. detail of specimen in b.

The existence of multiple species within the *B. phoenicis* species complex generates many questions regarding the virus-vector-host associations. In regions where citrus leprosis virus is present, a study of any mite voucher specimens collected both before and after the arrival of the virus could prove revealing. Based solely on the material studied here (dating from as early as 1916) and without any additional dedicated collecting effort, the most common species associated with *Citrus* spp. (with or without citrus leprosis virus) is *B. yothersi*. This, and the other *Brevipalpus* species mentioned in this paper and their possible associations with viruses, are in need of critical and meticulous evaluation.

The virus-vector-host associations for citrus leprosis are becoming increasingly complicated. For example, all three species of citrus leprosis virus are now known to occur in Colombia (citrus leprosis virus cytoplasmic type (CiLV-C), cytoplasmic type 2 (CiLV-C2), and citrus leprosis virus nuclear type (CiLV-N)) (Roy *et al.* 2014) and individual host plants with mixed infections of nuclear and cytoplasmic viruses are being discovered (Roy *et al.* 2013, 2014). Based on what we now know regarding the complexity of the *Brevipalpus phoenicis* species group, it is absolutely critical that all future virus-vector work be conducted on identified individuals. Given the co-occurrence of multiple species, we can no longer use unsorted field-collected populations in viral transmission work. To obtain the sample sizes necessary for such work, we recommend using individuals that have been raised from single females with a voucher made of the original female (after producing progeny) and vouchers made of a subsample of her progeny. Further, we recommend, where possible, identification be made using a modification of the technique developed by Dowling *et al.* (2010) whereby an individual specimen can be imaged using low temperature scanning electron microscopy, followed by nondestructive nucleic acid extraction (modified for joint DNA and RNA extraction using ZR Tissue and Insect RNA Microprep kit (Zymo Research, Orange, CA, USA) to facilitate detection of viral RNA) and then mounted and preserved on a slide for vouchering in a museum collection, and traditional examination of the morphology. This method maximises the diagnostic data collected from each individual specimen, with four sets of data being collected for each individual—imaging of morphological characters using LT-SEM, DNA for sequence-based identification, RNA for viral detection, and morphological examination using DIC microscopy, with the specimen ultimately being vouchered in a museum collection.

The use of microscopes with both Differential Interference Contrast (DIC) and Phase Contrast optics to identify *Brevipalpus* species could prove critical in establishing reliable integrated pest management and quarantine programs (Beard *et al.* 2013). There are several characters critical for species separation that are not discernible using Phase Contrast optics (Beard *et al.* 2013). We recommend that DIC be used whenever possible for *Brevipalpus* diagnostics. In addition, the use of Low Temperature Scanning Electron Microscopy (LT-SEM) has proven invaluable for the identification of *Brevipalpus* species. The large number of specimens misidentified as *B.*

phoenicis, B. obovatus and *B. californicus* is, in part, related to the quality and optic systems used to identify these mites and the lack of comparison made with type specimens or vouchers. Further complicating our ability to correctly identify species in this group are the many poorly curated collections, the many types that are held in inaccessible collections, and the lack of voucher specimens for numerous studies conducted on *Brevipalpus* species.

It is highly likely that the practice of growing ornamentals and shade trees close to fruit crops such as coffee, citrus, passionfruit, mango, and other fruit trees, facilitates the movement of *Brevipalpus* mites between unrelated plant species. It is common to collect more than one species of *Brevipalpus* from the same individual host tree, and often from the same individual leaf (Ochoa 1985; Ochoa *et al.* 1994; pers. obs. Beard & Ochoa). True host plant specificity and/or strong host plant associations can be clouded and confused when mite species mix together on border/fence plants and shade trees, or when dispersing females are collected from incidental hosts. The presence of actively growing colonies, with eggs and immatures, is a strong indicator that the plant is a true host. True host associations can be complicated by poor knowledge of, and changing, host taxonomy. For example, the most commonly grown *Citrus* within the Americas, variously known as Persian or Tahitian lime, has recently been validated as a single species, *Citrus latifolia* (Grayum *et al.* 2012). Such shifts in taxonomy could impact on our understanding of the *Citrus*-associated *Brevipalpus* species complexes and their interactions with citrus leprosis virus. Future collectors should place greater emphasis on attaining the correct host plant identification, including variety and root stock information, as this could prove vital for our future understanding of the biology of these mites.

In addition, we encourage researchers to contribute to the expansion of our understanding of setal homologies within the family Tenuipalpidae (Tetranychoidea) by including details of all stages and ontogenetic changes in leg chaetotaxy in all future descriptions and redescriptions of tetranychoid taxa.

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