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Morphological observations on *Brevipalpus phoenicis* (Acari: Tenuipalpidae) including comparisons with *B. californicus* and *B. obovatus*

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Abstract. The genus *Brevipalpus* has over 300 species worldwide. The three most important agricultural pest species in the genus, *Brevipalpus californicus* (Banks), *B. obovatus* Donnadieu, and *B. phoenicis* (Geijskes), have been consistently confused and misidentified for more than 50 years. The present study provides a discussion of the characters and character states used to separate these mites. Low-temperature scanning electron microscopy and traditional light microscopy techniques were used to illustrate the subtle morphological differences between these three species. Morphology of the dorsal propodosoma, opisthosoma, and leg chaetotaxy of all three species was examined and compared. The number of dorsal setae, the number of solenidia (*omega*) on tarsus II, and dorsal cuticular patterns were the most important characters in the identification of *Brevipalpus* species. *B. phoenicis* is similar to *B. californicus* in having two *omega* on tarsus leg II and different from *B. obovatus* which has only one *omega* on tarsus leg II and similar to *B. obovatus* in having only one pair of F setae (f_3), but differing from *B. californicus* which has two pairs of F setae (f_{2-3}). The dorsal opisthosomal and propodisomal cuticular patterns frequently used to distinguish between these three species are useful but one must be aware that age, feeding, and mounting techniques can affect the appearance of these characters.

Key words: false spider mites, flat mites, morphology, low-temperature scanning electron microscopy

Introduction

The family Tenuipalpidae Berlese includes more than 600 species in 30 genera (Smiley and Gerson, 1996; Smiley *et al*., 1996) and is placed in the

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Tetranychoidea along with the families Tetranychidae, Tuckerellidae, and Linotetranidae. *Brevipalpus* Donnadieu, 1875 is the largest genus in the Tenuipalpidae, with approximately 300 species worldwide. Their cryptic coloration and slow movement make these small (200–300 μm) mites difficult to detect (Baker, 1949; Ochoa and Salas, 1989; Ochoa *et al.*, 1994, 1996). However, their damage to tropical crops, ornamentals, and the recently discovered ability of some species to serve as virus vectors make them important for agriculture worldwide (Ochoa *et al.*, 1994; Kitajima *et al.*, 1996; Chagas *et al.*, 2001; Childers *et al.*, 2001). Three species, *B. californicus* (Banks), *B. obovatus* Donnadieu, and *B. phoenicis* (Geijskes), are important pests of a variety of plants, especially citrus (Pritchard and Baker, 1958; Childers *et al.*, 2003).

McGregor (1949) was the first to prepare a monograph of the Tenuipalpidae (=Pseudoleptidae), while Baker (1949) conducted the first major revision of the genus *Brevipalpus*. These early works were followed by Pritchard and Baker's (1951) monograph of the Tenuipalpidae (=Phytoptipalpidae) of California and in 1958 they published a revision of the world species. The revision of the Tenuipalpidae by Reck (1959) was largely ignored as most workers followed Pritchard and Baker (1958).

Variations in the dorsal setal pattern and number of solenidia (*omega*) on leg II have prompted some authors to split *Brevipalpus* into several genera *Cenopalpus* (Pritchard and Baker, 1958); *Hystripalpus* (Mitrofanov, 1973); *Pritchardipalpus* (Mitrofanov, 1973); *Brachypalpus* (Mitrofanov, 1973); and *Tauripalpus* (Mitrofanov, 1973). Smith Meyer (1979) synonomized these five genera with *Brevipalpus* arguing that the variability in diagnostic characters did not support creation of new genera. Subsequent authors have agreed with Smith Meyer in all but the synonomy of *Cenopalpus* (Baker and Tuttle, 1987; Smiley and Gerson, 1996). Baker *et al.* (1975) split *Brevipalpus* into seven species groups based on the number of dorsal opisthosomal setae, number of setae on the palpal tarsus, and number of *omega* on leg II. Smith Meyer (1979) added the *B. spinosus* group based on the proposed synonymy of *Cenopalpus* with *Brevipalpus*. Baker and Tuttle (1987) added the *B. portalis* and *B. frankensiae* species groups based on specimens from Mexico. Currently, there are nine recognized species groups in *Brevipalpus* (Smith Meyer, 1979; Baker and Tuttle, 1987) with *Cenopalpus* as a separate genus.

Over the years numerous authors have noted intraspecific variation in *Brevipalpus* spp. especially *B. californicus*, *B. obovatus*, and *B. phoenicis* (De Leon, 1961a, 1965, 1967; Manson, 1967; Knorr, 1968; Gonzalez, 1975; Baker *et al.*, 1975; Baker and Tuttle, 1987) resulting in numerous synonymous species (Table 1). Manson (1967) observed a lack of consistency in

Table 1. B. californicus, *B. obovatus*, and *B. phoenicis* with synonymized species names and generic combinations[a]

B. californicus (Banks)
Tenuipalpus californicus Banks (1904)
Brevipalpus californicus (Banks): McGregor (1949)
Tenuipalpus australis Tucker (1926)
Brevipalpus australis (Tucker): Baker (1949)
Synonymy: Pritchard and Baker (1958)
Tenuipalpus vitis Womersley (1940)
Synonymy: Pritchard and Baker (1958)
Brevipalpus woglumi McGregor (1949)
Synonymy: Pritchard and Baker (1951)
Brevipalpus confusus Baker (1949)
Synonymy: Pritchard and Baker (1958)
Brevipalpus browningi Baker (1949)
Synonymy: Pritchard and Baker (1958)
B. obovatus Donnadieu
Brevipalpus obovatus Donnadieu (1875)
Brevipalpus pereger Donnadieu (1875)
Synonymy: Pritchard and Baker (1958)
Tenuipalpus inornatus Banks (1912)
Brevipalpus inornatus (Banks): McGregor (1949)
Synonymy: Pritchard and Baker (1958)
Brevipalpus bioculatus McGregor (1914)
Synonymy: McGregor (1949)
Brevipalpus pseudocuneatus Blanchard (1940)
Synonymy: Pritchard and Baker (1951)
Brevipalpus origanum Baker *et al*. (1975) New synonymy[b]
B. phoenicis (Geijskes)
Tenuipalpus phoenicis Geijskes (1939)
Brevipalpus phoenicis (Geijskes): Sayed (1946)
Brevipalpus yothersi Baker (1949)
Synonymy: Pritchard and Baker (1951)
Brevipalpus mcbridei Baker (1949)
Synonymy: Pritchard and Baker (1951)
Brevipalpus papayensis Baker (1949)
Synonymy: Pritchard and Baker (1951)

Table 1. (*continued*)

Brevipalpus deleoni Pritchard and Baker (1958)
Synonymy: De Leon (1961b)
Brevipalpus phoenicoides Gonzalez (1975)
Synonymy: Evans *et al*. (1993)

[a] The author and year following an author in parenthesis was the first proposed generic change and the author and year following 'synonymy' was the first to propose that synonymy. For complete synonymies of each species refer to the references listed below.
[b] Baker *et al*. (1975) was originally proposed as a synonym on an Addenda sheet placed in Baker and Tuttle (1987).

the reticulation pattern of the female prodorsum and variation in the size and shape of the dorsal setae for all three species. He suggested these variations were associated with differences in host plants. Gonzalez (1975) stated the same variation could be found within populations of mites collected from a single host plant species. There has been concern that *B. phoenicis*, *B. californicus*, and *B. obovatus* represent a complex group including a number of species (Knorr, 1968; Baker and Tuttle, 1987). There is need for a detailed study of these species, involving both molecular analysis and a comprehensive morphological review. The present study begins to address the latter objective through the use of low-temperature scanning electron microscopy (LTSEM). Currently, the only species shown to vector citrus leprosis is *B. phoenicis* (Rodrigues *et al.*, 2000). We have chosen to focus this study primarily on the morphology of *B. phoenicis*, making comparisons to *B. obovatus* and *B. californicus*.

Material and Methods

Citrus leaf tissue with *B. phoenicis* was dissected and affixed to copper sample plates ($15 \times 29 \times 1.5$ mm) using a thin layer of methyl cellulose solution (Tissue Tek, OCT Compound, Ted Pella, Inc., Redding, CA, USA). The samples were then placed on a square brass tube ($13 \times 13 \times 20$ cm) that had been pre-cooled in liquid nitrogen where the specimens were rapidly frozen to -196°C. Samples were inserted into square brass holding tubes ($13 \times 13 \times 20$ cm) for temporary storage in liquid nitrogen. Selected samples were then transferred to the pre-chamber of a CT-1500 HF Oxford Cryotrans System (Oxford Instruments, Inc., Concord, MA, USA) where they were etched, sputter coated, and then transferred to the microscope's pre-cooled cryostage (-120°C) for imaging in the frozen state. No chemical fixation or

removal of water is needed for this technique. The mites were photographed at 4–10 kV accelerating voltage on a Hitachi S4100 field emission scanning electron microscope (Wergin *et al.*, 2000; Erbe *et al.*, 2001). The advantages of LTSEM in investigating mite morphology were discussed by Achor *et al.* (2001).

Specimens for light microscopy (phase contrast and differential interference contrast (DIC)) were removed from citrus and other plant material and preserved in 75–80% ethanol. Mites were cleared in Nesbitt's fluid and mounted on glass slides in Hoyer's mounting medium (Jeppson *et al.*, 1975; Krantz, 1978). Slides were cured 1–2 weeks at approximately 45°C in an incubator and sealed with Glyptal (1201 red enamel insulating paint, Glyptal Inc., Chelsea, MA, USA) prior to observation with a compound microscope. Light microscopy photographs were taken with a Zeiss Axioskop 2 with DIC using a Nikon DXM 1200 digital camera.

Brevipalpus phoenicis nymphs examined for variation were obtained from a colony established from a single female collected on citrus in lowland Costa Rica and reared on *Phaseolus vulgaris* L. (Leguminosae). At the end of 75 days the colony was preserved in alcohol and 200 nymphs were prepared for light microscopy.

Terminology for naming setae generally follows Grandjean (1939, 1958) as applied to the Tetranychidae by Lindquist (1985), Tuckerellidae by Quiros and Baker (1984), Linotetranidae by Smith Meyer and Ueckermann (1997) as well as other Prostigmata (Kethley, 1990). Descriptive terminology for the dorsal opisthosomal patterns follows Harris (1979).

Morphology

The body of acariform mites is divided into two parts, the gnathosoma and idiosoma (Krantz, 1978; Alberti and Coons, 1999). The idiosoma is divided into the propodosoma and hysterosoma. The propodosoma is defined as the area of the idiosoma anterior to the dorsal disjugal furrow anteriorly to the ventral sejugal furrow including legs I and II; the hysterosoma is the area posterior to the dorsal disjugal furrow to the ventral sejugal furrow including legs III (larvae) and IV (post-larval instars) (Alberti and Coons, 1999). We consider the number of dorsal setae, the number of solenidia (*omega*) on tarsus of leg II, and dorsal cuticular patterns to be the most important characters in the identification of *Brevipalpus* species.

The dorsum of *Brevipalpus* can be divided into the prodorsum (anterodorsal part of propodosoma, also called the aspidosoma) and the opisthosoma (the hysterosoma excluding legs III and IV) (Alberti and Coons, 1999). The prodorsum has three pairs of setae including one pair of verticals (v_2) and two pairs of scapular (sc_1 and sc_2), a pair of eyes, and variable ornamentation. The

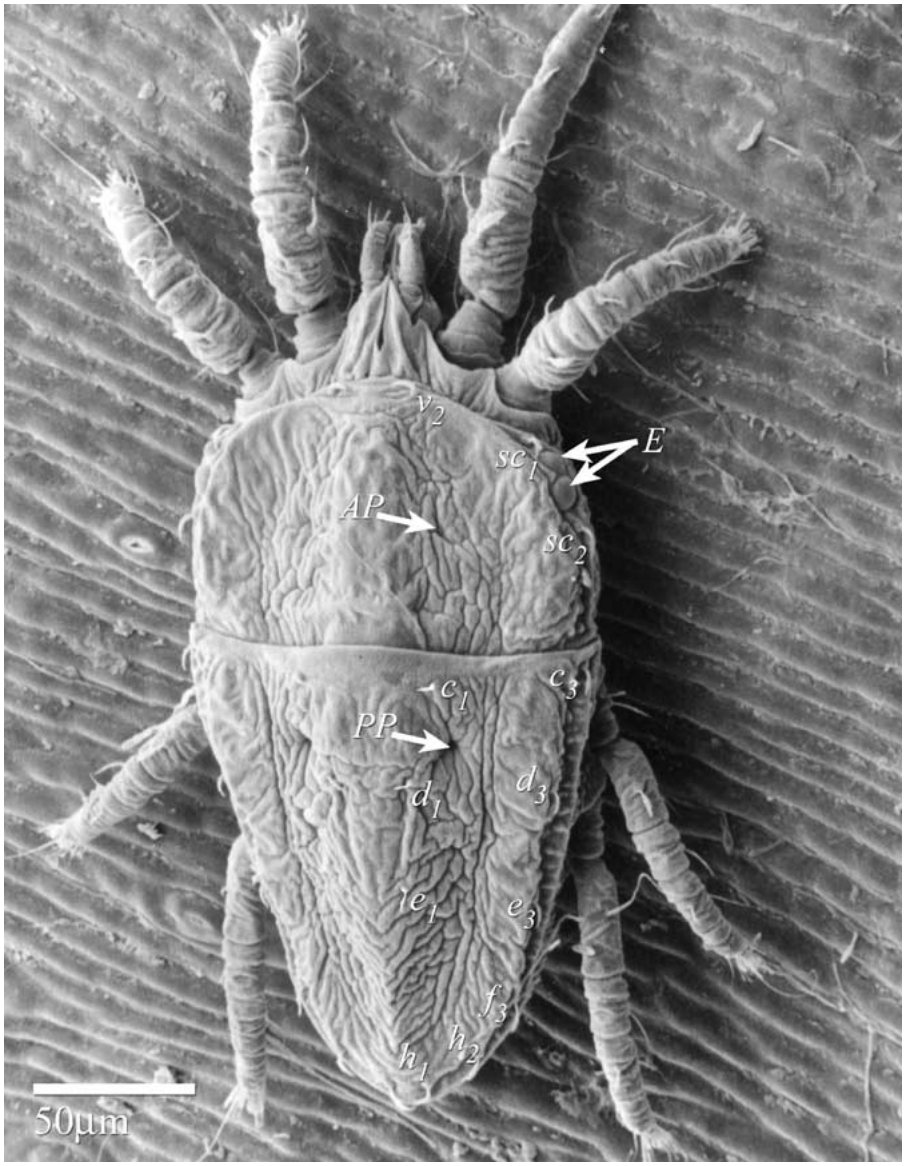

Figure 1. Dorsal view of *B. phoenicis*. Eyes: E; prodorsal pore: AP; opisthosomal pore: PP; prodorsal setae: v_2, sc_1 and sc_2; dorsal opisthosomal setae: c_1, c_3, d_1, d_3, e_1, e_3, f_3, h_1, h_2.

ornamentation ranges from smooth to reticulate. In addition, there is a single pair of pores (Figures 1, 2a and 10).

Larval acariform mites have six segments in the opisthosoma corresponding to segments VII through XIII in the primitive acarine segmentation

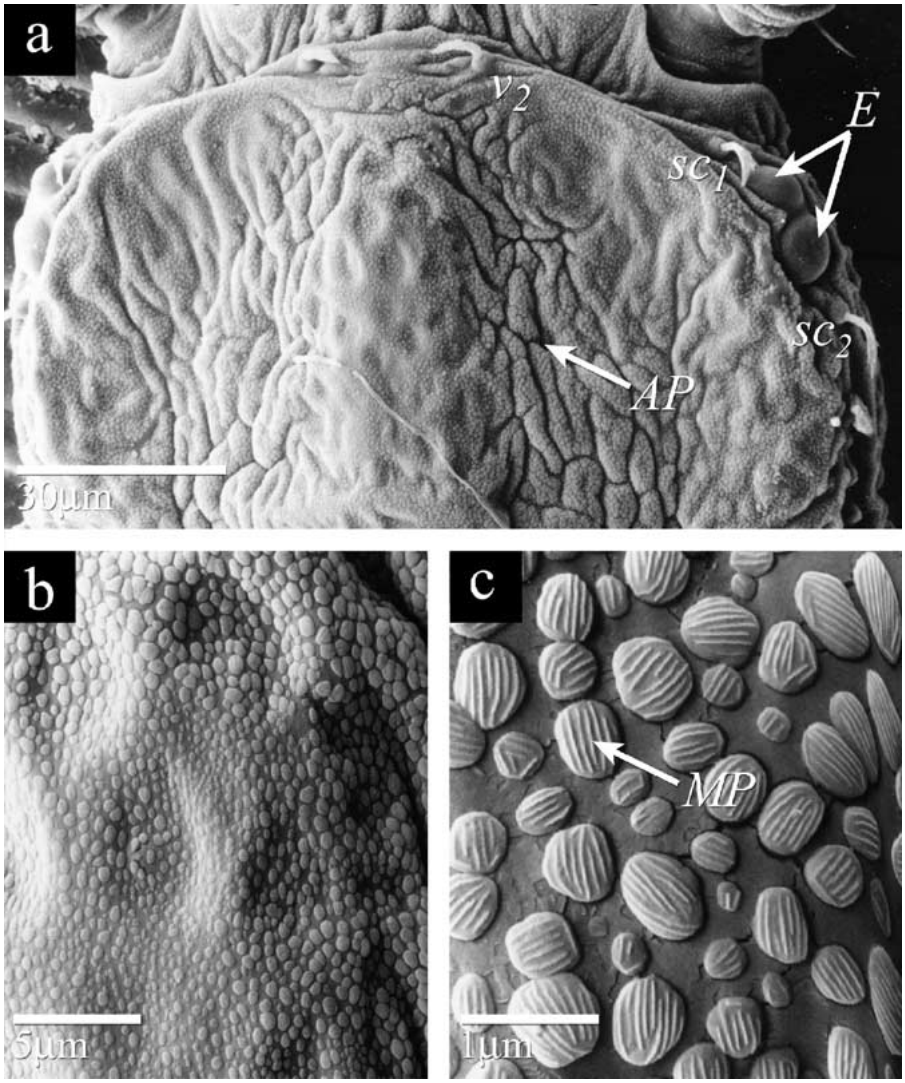

Figure 2. Prodorsum of *B. phoenicis*. (a) Prodorsum. Eyes: E; prodorsal pore: AP; prodorsal setae: v_2, sc_1 and sc_2. (b) View of microplates on prodorsum. (c) Close-up view of microplates; microplate: MP.

(Alberti and Coons, 1999). All instars of the Tetranychoidea retain setal elements of the six acariform opisthosomal segments of a larval acariform mite (Lindquist, 1985). The naming of the dorsal opisthosomal setae has traditionally relied on their relative positions (Pritchard and Baker, 1951, 1958; Baker and Tuttle, 1987) (Table 2) without regard to opisthosomal segmentation. Pritchard and Baker (1951) used a modified notation for the Tetra-

Table 2. Comparison of notation systems for opisthosomal setae in the Tenuipalpidae[a]

Grandjean (1939)	Baker and Tuttle (1987)	Pritchard and Baker (1958)
C		
c_1	DC_1	1st Dorsocentral
c_2	DL_1	1st Sublateral
c_3	L_1	Humeral
D		
d_1	DC_2	2nd Dorsocentral
d_2	DL_2	2nd Sublateral
d_3	L_2	1st Dorsolateral
E		
e_1	DC_3	3rd Dorsocentral
e_2	DL_3	3rd Sublateral
e_3	L_3	2nd Dorsolateral
F		
f_2	DL_4^*	4th Sublateral*
f_3	L_4	3rd Dorsolateral
H		
h_2	L_5	4th Dorsolateral
h_1	L_6	5th Dorsolateral
PS		
ps_1	Anal setae	Anal setae
ps_2	Anal setae	Anal setae
g_1 (DN)	Genital setae	Genital setae
g_2 (AD)	Genital setae	Genital setae
ag (PN)	Pregenitals	Medioventral setae

[a] Note the genital (*g*) and aggenital (*ag*) setae are post-larval. The f_2 (DL4 or 4th sublateral) setae may be on the opisthosoma margin in some species. DC – dorsocentral, DL – dorsolateral, L – lateral.

nychidae and erroneously figured 14 pairs of dorsal opisthosomal setae, but later corrected the error (Pritchard and Baker, 1958). Ghai and Shenhmar (1984) following Pritchard and Baker (1951) also figured 14 dorsal opisthosomal setae. Sadana (1997) followed Pritchard and Baker's (1958) opisthosomal notation system. Baker and Tuttle (1987) modified their notation by renaming the dorsosublateral setae as dorsolaterals (DL) and the dorsolaterals

were renamed as lateral setae (L) (Table 2). Evans *et al.* (1993) followed Baker and Tuttle (1987), but mislabeled the lateral setae as dorsolaterals. Flechtmann *et al*. (1995) presented both systems. We will be using the standard notation of Grandjean (1939). The Grandjean notation was first applied to Tenuipalpidae by Quiros-Gonzalez (1986) and subsequent authors (Smiley

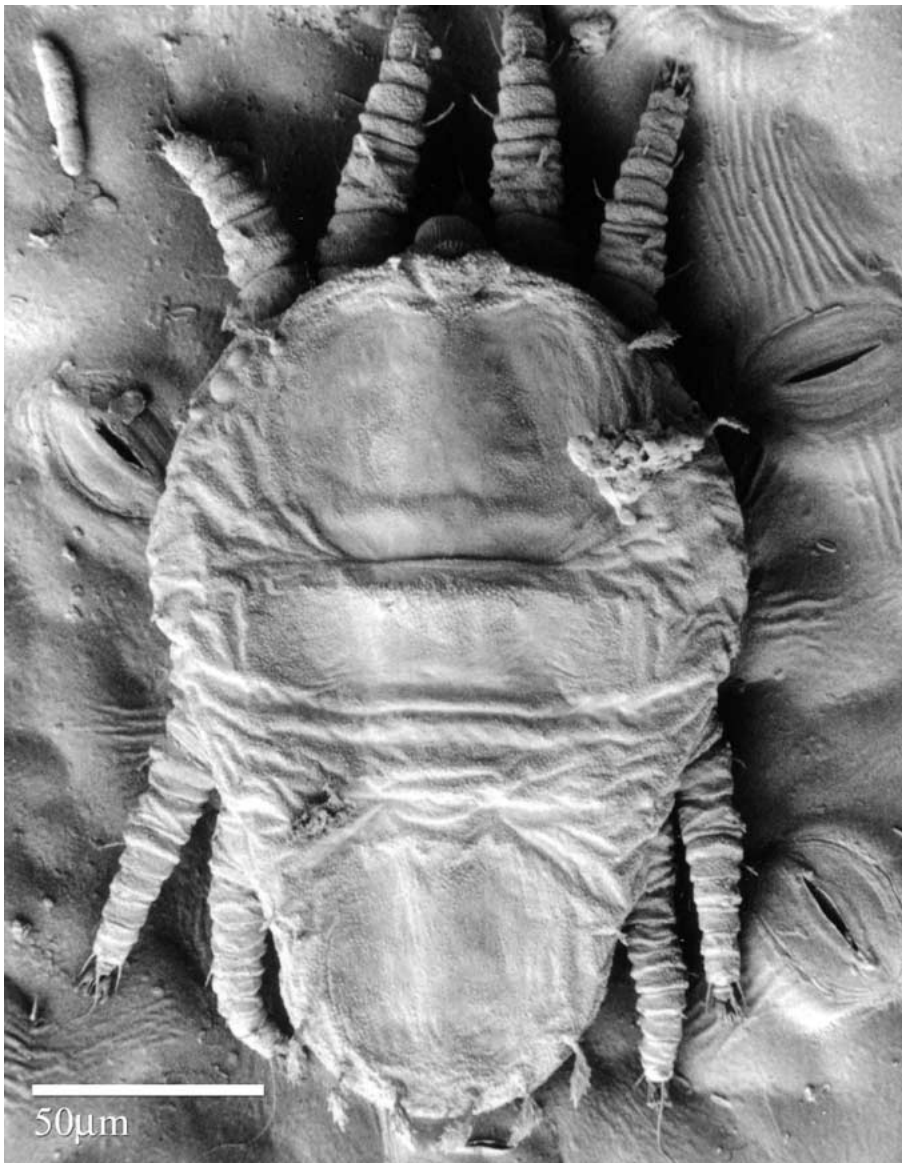

Figure 3. B. phoenicis protonymph.

and Gerson, 1995; Smiley *et al.*, 1996; Akbar and Khalid, 1999) confused setae in the E and F rows. The Tenuipalpidae has a maximum of 15 pairs of opisthosomal setae (excluding the genital and aggential setae) of which 13 pairs are dorsal (Lindquist, 1985). The maximum dorsal opisthosomal

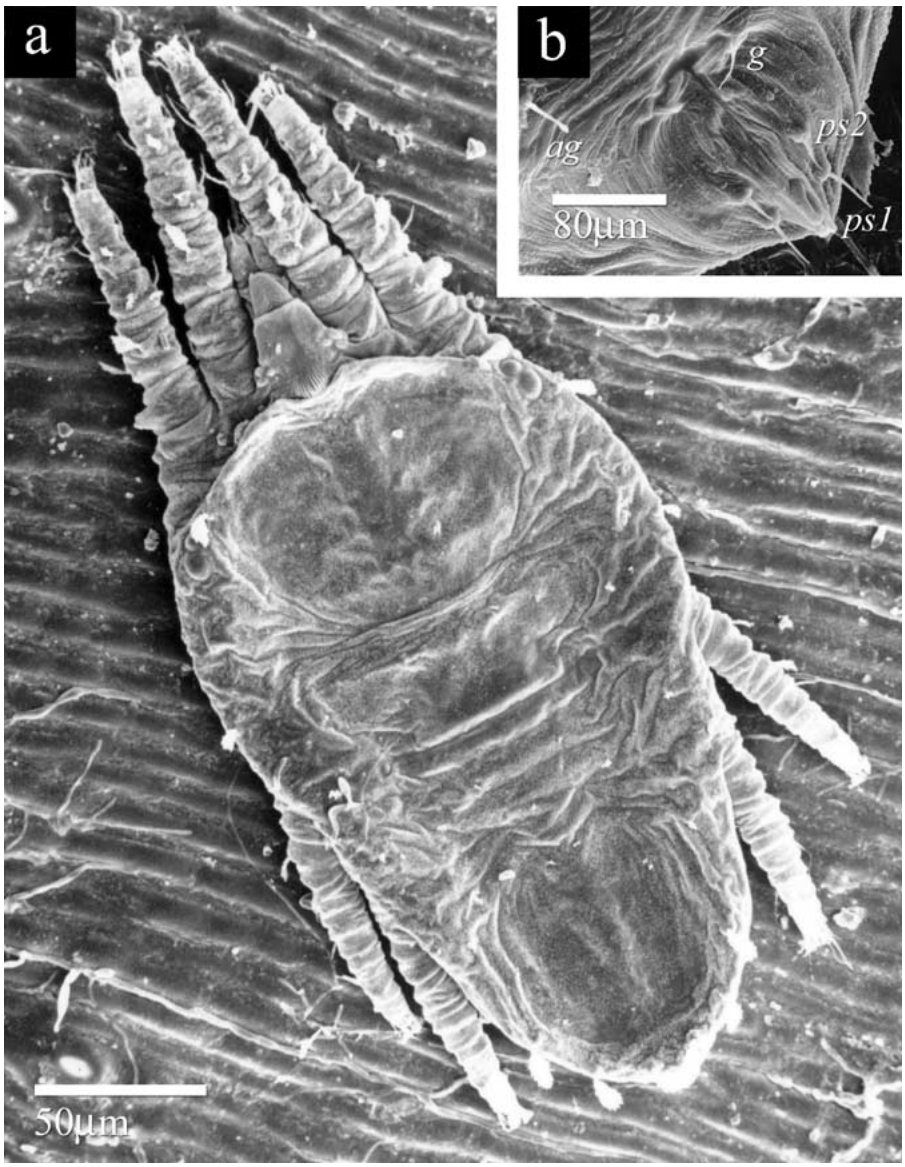

Figure 4. B. phoenicis deutonymph. (a) Dorsal view. (b) Ventral view of anal and genital regions. Aggenital setae: *ag*; genital setae: *g*; pseudanal setae: ps_1, ps_2.

chaetotaxy for the family consists of three pairs each in the C, D, and E rows and two pairs each in the F and H rows. The PS ($ps_{1–2}$) setae are ventral to ventrocaudal. The genus *Brevipalpus* has a maximum of 10 pairs of dorsal opisthosomal setae with two pairs each in the C (c_1, c_3,), D (d_1, d_3), E (e_1,

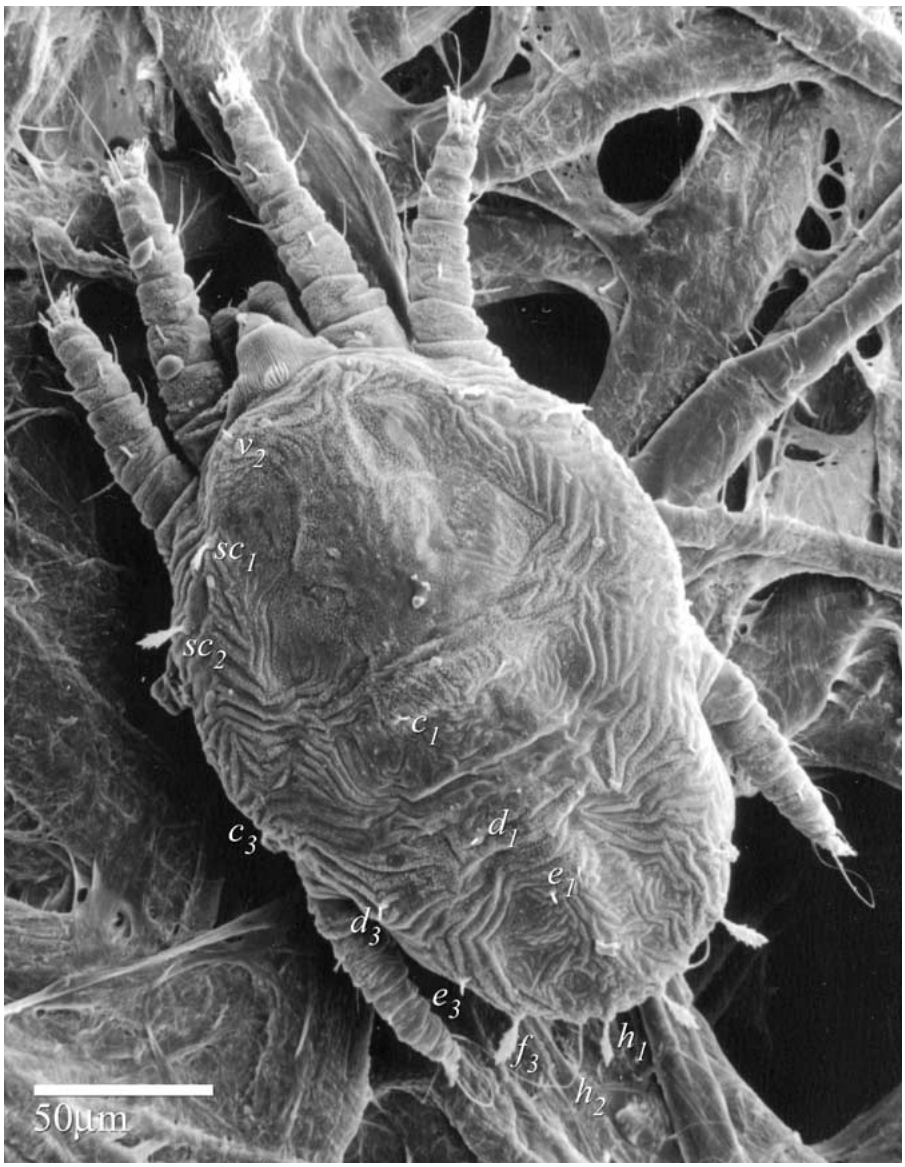

Figure 5. B. phoenicis larva. Prodorsal setae: v_2, sc_1 and sc_2; dorsal opisthosomal setae: c_1, c_3, d_1, d_3, e_1, e_3, f_3, h_1, h_2.

e_3), F (f_2, f_3), and H (h_1, h_2) rows (Figures 1, 3, 4, 5, and 11). Setae c_2, d_2, and e_2 are absent in *Brevipalpus*. In *B. phoenicis* and *B. obovatus*, seta f_2 is absent. *Brevipalpus californicus* retains setal pair f_2 in a marginal or nearly marginal position. There is some uncertainty as to whether the f_1 or f_3 setal

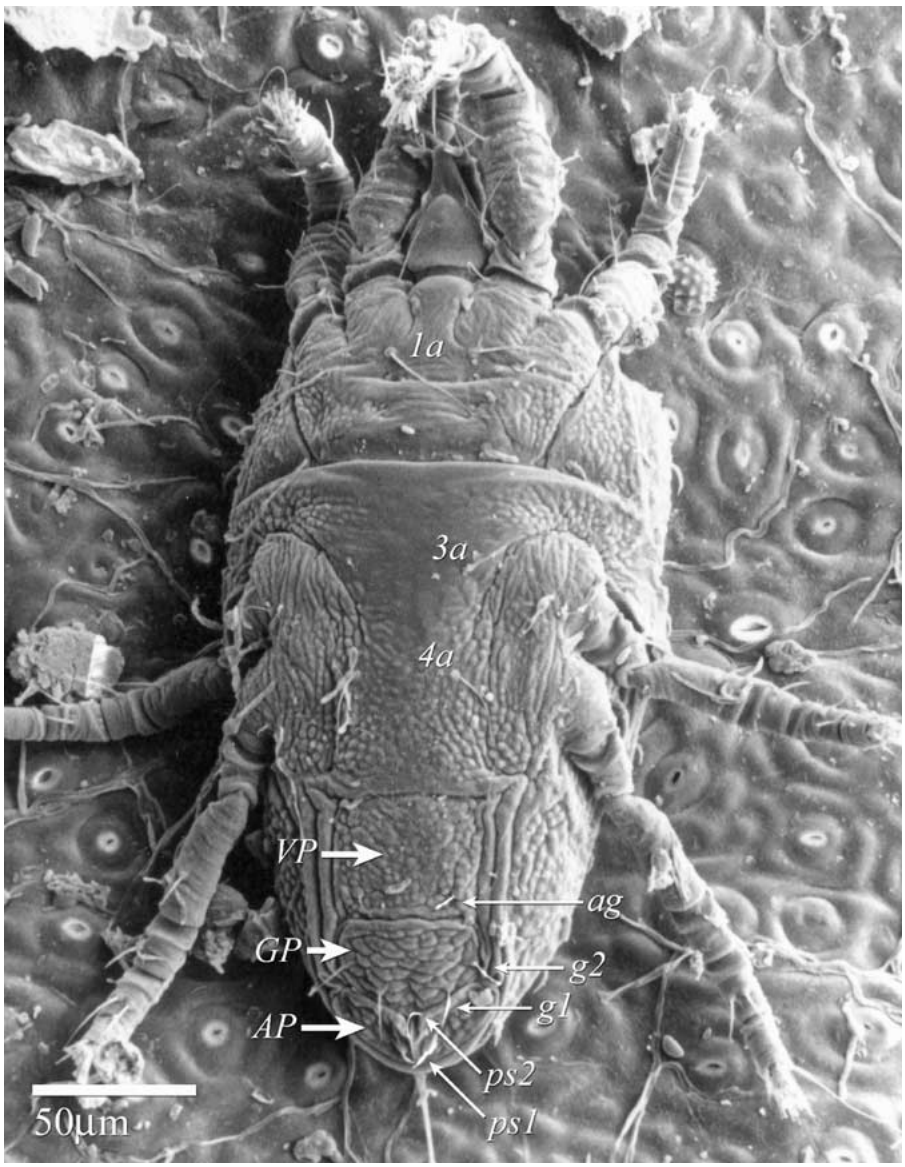

Figure 6. Ventral view of *B. phoenicis*. Ventral plate: VP; genital plate: GP; anal plates: AP; ventral setae: *1a*, *3a*, *4a*; aggential setae: *ag*; genital setae: g_1, g_2; pseudanal setae: ps_1, ps_2.

pair is lost in the Tenuipalpidae (Lindquist, 1985; Quiros-Gonzales, 1986). Kethley (1990) figured the dorsal opisthosoma of *Tenuipalpus* having only f_1 and f_3 setae. We consider the f_1 setae absent.

The ventral opisthosoma of the adult *Brevipalpus* has two pairs of pseudanal (ps_1, ps_2) setae, two pairs of genital (g_1, g_2) setae, and one pair of

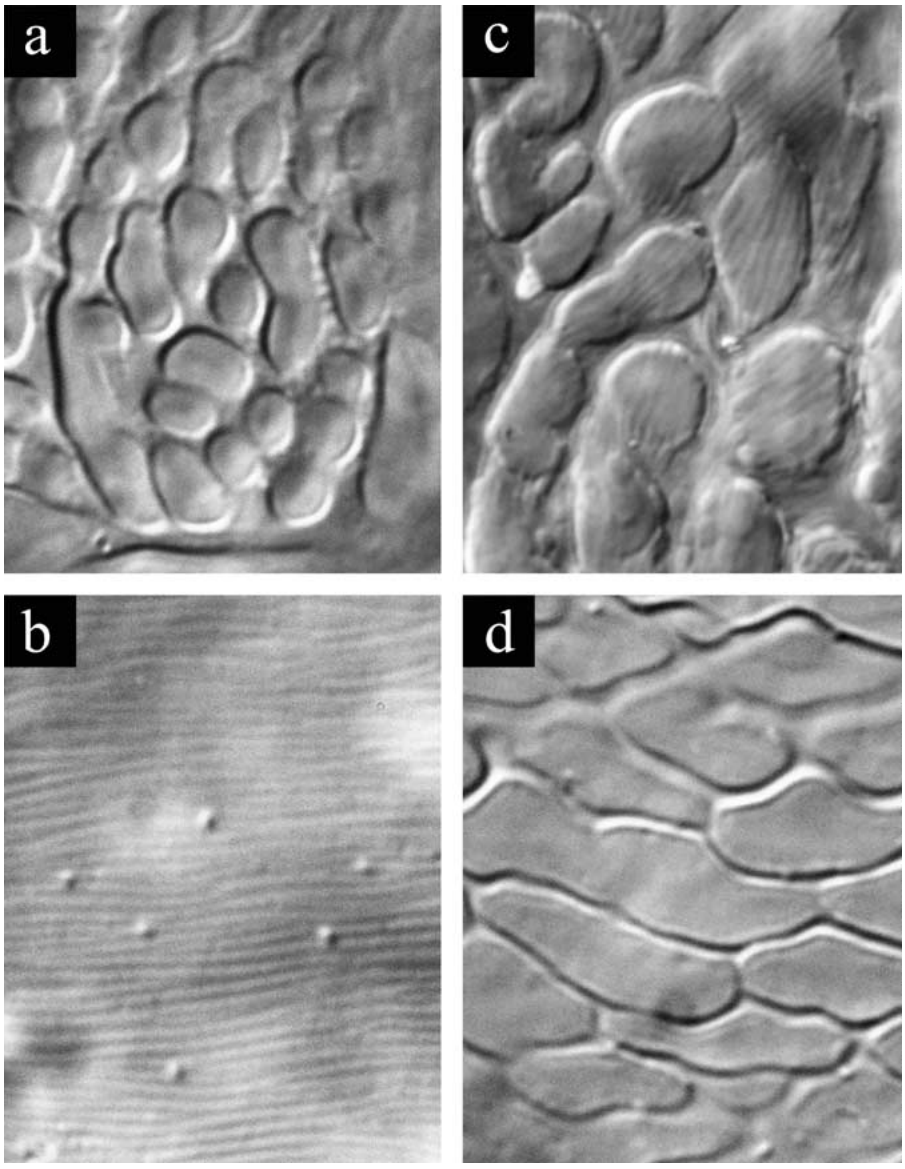

Figure 7. DIC photographs of cuticular features in *Brevipalpus*. (a) Verrucose; (b) striate; (c) aerolate; (d) colliculate.

aggential setae (*ag*) (Figures 4b, 6, and 12). The pseudanal setae are present in the larva and the aggenital setae are added in the protonymph (PN), the first pair of genital setae added in the deutonymphs (DN) and the second pair of genital setae added in the adult. The leg coxae of the podosomal venter of the Tenuipalpidae and all Acariformes are fused to the venter, making the trochanter the first movable segment. Since the coxae of all legs are fused to the podosoma we use the term coxal fields. The coxal field of leg I has three setae in the adult (*1a*, *1b*, and *1c*). Coxal fields of legs II to IV each have two pairs (*2a*, *2b, 3a*, *3b*, *4a*, *4b*) of setae. Setae *1a*, *3a*, and *4a* are frequently not counted in the number of setae on the coxal fields, but have been called the medioventral propodosomal setae. Setal pairs *3a* and *4a* are important taxonomically as the anterior medioventral propodosomal or IC_3 and posterior medioventral propodosomal or IC_4 setae, respectively.

In *B. phoenicis*, the base of coxal fields of legs I and II are colliculate (Figure 7d) to finely verrucose (Figure 7a) while the area between setae *1a* and the sejugal apodeme is striate (Figures 6 and 7b) and the area between setae *3a* and *4a* is smooth to finely verrucose. Sometimes a finely colliculate area is visible between the *4a* setae. The region between coxal fields of legs III and IV and the bases of setae *3a* and *4a* is colliculate to verrucose. The area posterior to the *4a* setae is uniformly verrucose. The ventral plate and anal plates are uniformly verrucose (Figures 6 and 12), while the genital plate is areolate (Figure 7d) to colliculate. The genital setae of *B. phoenicis* are thicker than the *ag* and *ps* setae, whereas they are similar in length in *B. obovatus* and *B. californicus*.

The adult female of *B. obovatus* is similar to *B. phoenicis* ventrally. However, in *B. obovatus* the region between coxal fields of legs III and IV, the

Table 3. Number of setae for each leg of *B. californicus*, *B. obovatus* and *B. phoenicis*[a]

Leg segment	Leg I	Leg II	Leg III	Leg IV
Tarsus	8 (ω)	8 (ω)[1] 8 (2ω)[2]	5	5
Tibia	5	5	3	3
Genu	3	3	1	1
Femur	4	4	2	1
Trochanter	1	1	2	1

[a] The tarsus of leg II in *B. obovatus*[1] has one *omega* (ω) while the same leg in *B. californicus*[2] and *B. phoenicis*[2] has two *omega*. The numbers of setae for all other leg segments are the same for all three species.

bases of setae *3a* and *4a*, the area posterior to the *4a* setae, ventral plate, genital plate, and anal plates are more uniformly colliculate. *B. californicus* differs from *B. phoenicis* in being finely striate (Figure 7b) between the *3a* and the *4a* setae, with a more irregular colliculate area behind the *4a* setae, and a genital plate that is areolate to colliculate.

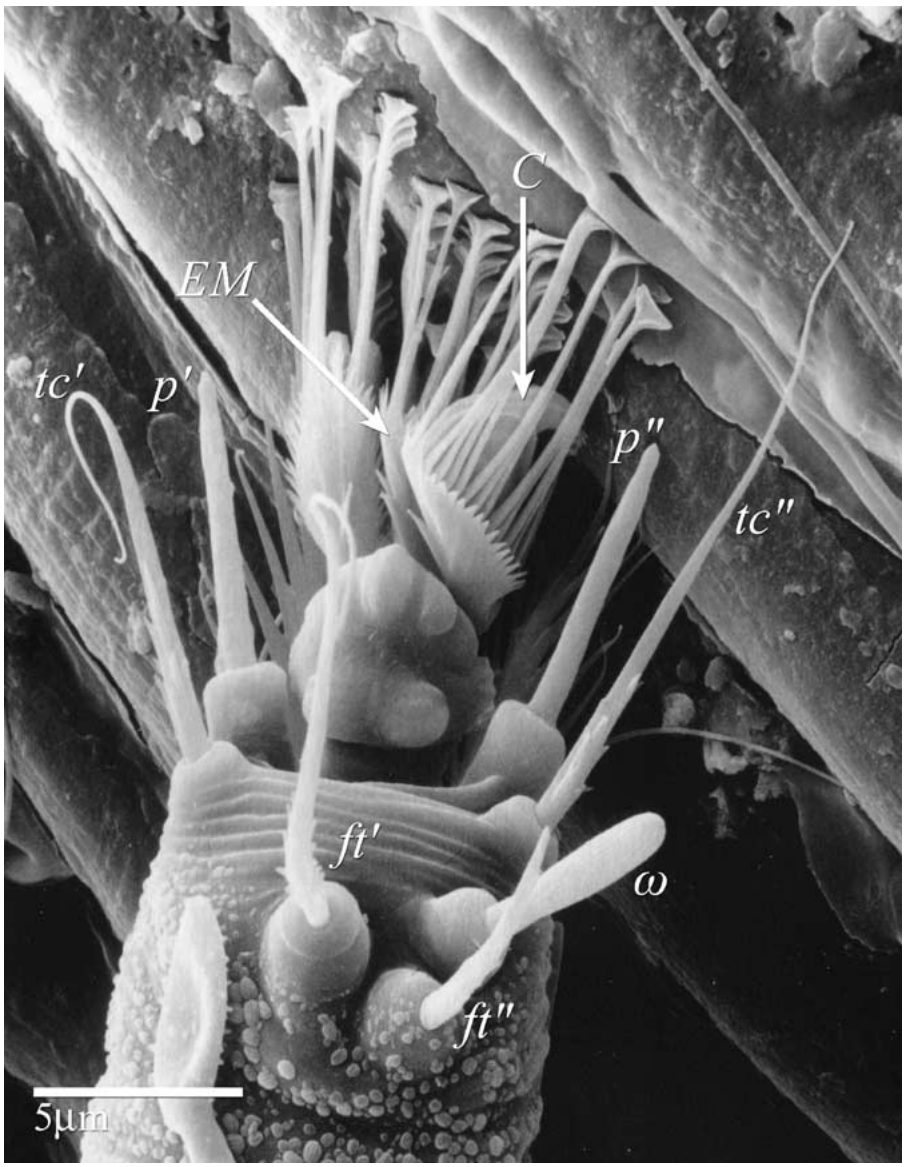

Figure 8. Distal part of tarsus I of *B. phoenicis*. Empodium: EM; claw: C; Leg setae – prorals: *p*; tectals: *tc*; festigials: *ft*; solenidion: *ω*.

The chaetotaxy for each leg segment (trochanter, femur, genu, tibia, and tarsus) of three *Brevipalpus* species are shown in Table 3. The leg chaetotaxy for *B. phoenicis*, *B. obovatus*, and *B. californicus* (Table 3) are identical except for the number of *omega* (ω) on tarsus II. The chaetotaxy of the leg

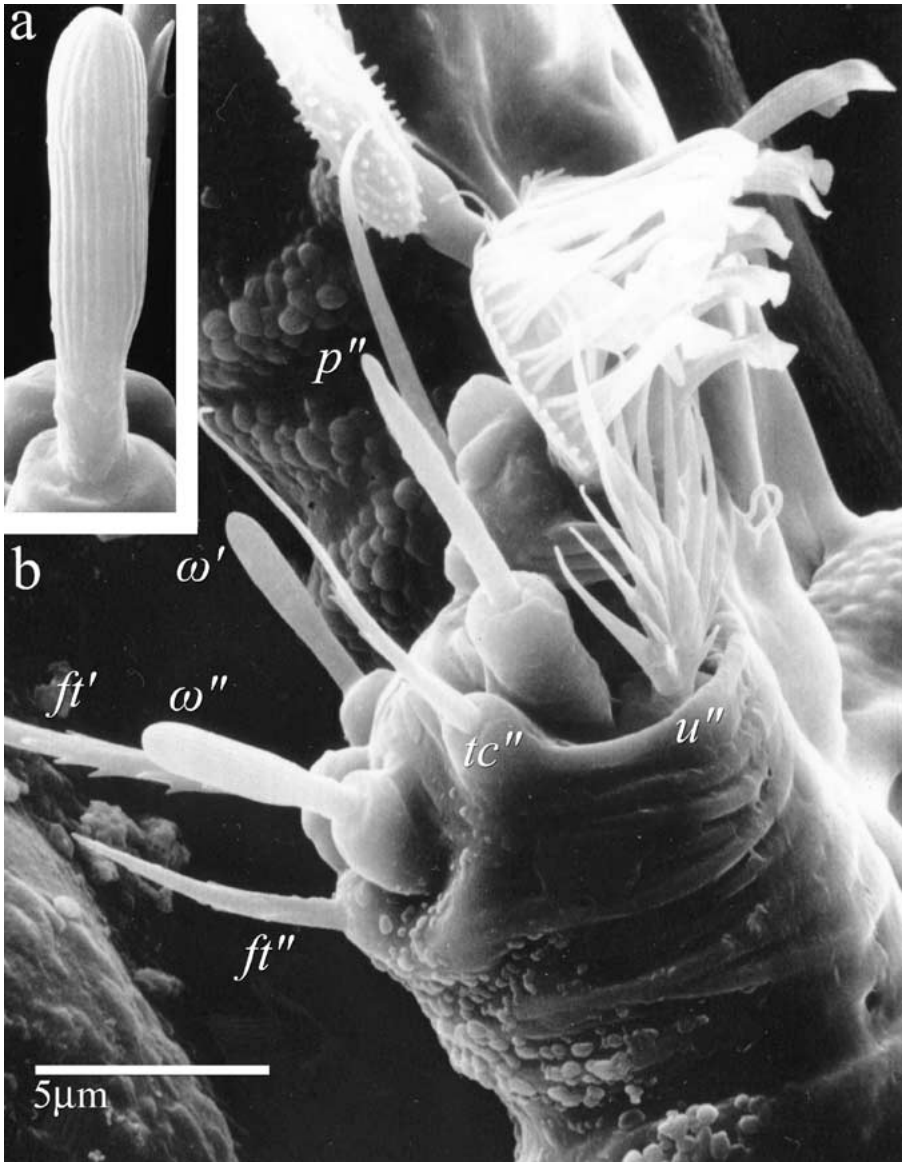

Figure 9. Tarsus II of *B. phoenicis*. (a) Closeup view of *omega* (ω). (b) Lateral view of the tarsus of leg II. Leg setae – prorals: *p*; tectals: *tc*; festigials: *ft*; solenidion: ω; unguinals: *u*.

tarsi in the Tenuipalpidae can be difficult to determine because the setae are concentrated at the distal end of the segment (Figures 8 and 9). The tarsi of legs I and II in *Brevipalpus* have eight normal setae, a pair of palmate ungunials (*u*), a pair of eupathidial prorals (*p*), a pair of tectals (*tc*), and an uneven pair of fastigials (*ft*) (Figures 8 and 9). In addition, the tarsus of leg I has a single solenidion (Figures 8, 9a and b) and the tarsus of leg II has one or two *omega* (Figure 8). The tarsi of legs III and IV have a pair of palmate unguinals, a pair of tectals, and a single fastigial seta, but one fastigial seta and the proral setae have been lost. All pretarsi in the adult have paired claws and an empodium each with 10–12 pairs of tenent hairs. The bases of the paired claws (Figures 8 and 9b) and the empodium are covered with a serrated sheath from which the tenent hairs emerge (Figure 8). The femur, genu, and tibia of legs I and II each have a single dorsal seta and from two to four lateral or ventral setae. Tibia III and IV each have a single dorsal seta and a pair of ventral setae. The femur and genu of legs III and IV each have one to three lateral and ventral setae and no dorsal setae.

Discussion

A number of factors influence the appearance of certain characters in *Brevipalpus*. The Tenuipalpidae are generally called flat mites. *Brevipalpus* mites are not flat, but have a central ridge that when flattened during slide mounting can cause artifacts such as deeper grooves or longitudinal striations to form. Such changes in appearance may lead to difficulty in using existing identification keys. In *Brevipalpus* the amount of reticulation on the propodosoma and opisthosoma can vary with age and amount of feeding of the mite (Morishita, 1954; Haramoto, 1969; Ochoa, 1985; Evans *et al.*, 1993). In addition, mounting techniques can also affect how the ornamentation of the propodosoma and opisthosoma appear under light microscopy. Specifically, overclearing and overheating of specimens mounted in Hoyer's or Berlese's media can cause the central area of the propodosoma to appear completely smooth. Table 4 summarizes the taxonomic characters for separating *B. californicus*, *B. obovatus*, and *B. phoenicis*.

The LTSEM can provide opportunities to discover new characters useful in the identification and separation of these mites. Close examination of the dorsal surfaces of immature and adult *Brevipalpus* specimens revealed oval to round wax-like microplates (Figure 2b and c) that range in size from 0.33 to 0.5 μm. In the adults, each microplate is somewhat flattened with 1–12 striae (Figure 2b and c) while the microplates appear to be globular

Table 4. Morphological characters used to separate *B. californicus*, *B. obovatus*, and *B. Phoenicis*

Character	*B. californicus*	*B. obovatus*	*B. phoenicis*
Gnathosoma			
1. Palp genual seta	Setiform with four to six barbs	Setiform with two to four barbs	Setiform with two to four barbs
Leg			
2. *Omega* on tarsus leg II	2	1	2
Propodosoma			
3. Propodosomal pores	Present	Present	Present, may be obscure
4. Anterior projection of prodorsum (rostral shield)	Extending beyond base of femur of leg I	Not extending beyond base of femur of leg I	Not extending beyond base of femur of leg I
5. Central rostral projection	Long and pointed	Blunt	Long and pointed
6. Division between central and medial rostral projections	Deep	Shallow	Shallow
7. Central portion of prodorsum (between propodosomal grooves)	Irregular to uniform reticulations	Smooth to rugose	Smooth with isolated aerole
8. Medial region of prodorsum	Uniform reticulations	Uniform reticulations	Elongate reticulations, smooth anteriorly
9. Lateral region of prodorsum	Wrinkled	Smooth to rugose	Rugose
Opisthosoma			
10. Opisthosomal setal pair f_2	Present	Absent	Absent
11. Shape of opisthosomal setae	Setiform	Lanceolate, serrate	Lanceolate, serrate to finely serrate

12. Furrow between c_1 and c_3, extending to h_2	Indistinct	Narrow	Well developed
13. Central area between c_1 and d_1 setal pairs	Uniform reticulations	Large reticulations	Rugose
14. Central area between d_1 and e_1 setal pairs	An indistinct groove starting at d_1 and ending at e_1; area between grooves rugose	Well developed transverse reticulations	Distinct groove starting at d_1 and extending to e_1
15. Central area between e_1 and h_2 setal pairs	Irregular reticulations	Irregular reticulations; more 'U' shaped posteriorly	Six to eight 'V' to 'U' shaped ridges; reduced posteriorly
16. Median area between setae c_1, d_1, e_1 and lateral furrow to f_3	Reticulate	Reticulate; posterior to f_3 more wrinkled	Reticulate
17. Lateral area between lateral furrow and c_3, d_3 and e_3	Rugose	Rugose with posterior region between f_3 and h_1 more wrinkled	Rugose with posterior region between f_3 and h_1 more wrinkled

in nymphs. The microplates average 34.3 per 10 μm^2 in reticulated areas compared to 41 per μm^2 in flat areas of the prodorsum.

Variation in *Brevipalpus phoenicis* nymphs has been reported by Attiah (1956) in specimens from Egypt, Manson (1963) from India, Knorr (1968) from Florida, Prieto Trueba (1984) from Cuba, Ochoa (1985) and Evans *et al*. (1993), from Costa Rica. Gonzalez (1975) dismissed most of the reported variation as confusion of immature instars resulting in the misidentification of nymphs and stated the actual variation in *B. phoenicis* was minimal. While there probably have been misidentifications, the work of Prieto Trueba (1984), Ochoa (1985), and Evans *et al*. (1993), suggests *B. phoenicis* nymphs are variable. Ochoa (1985) reported three types of variation (typical, AA, and AB) and Evans *et al*. (1993) reported three intermediate forms based on variation in the dorsal propodosomal and opisthosomal setae. Table 5 was based on 200 nymphs from a colony started from a single female *B. phoenicis* collected from lowland citrus in Costa Rica (Ochoa, unpublished data). The variation in the setal shapes from setiform to lanceolate pilose occurred primarily in propodosomal setae v_2 and opisthosomal setae rows C, D, and E. The f_3 and the H setae were lanceolate pilose in all specimens. In addition to the propodosomal and opisthosomal setae, variation was noted in the shape of the dorsal setae on tibia and genu of legs I and II. These setae were setiform in the 'typical' and AB types of *B. phoenicis* and lanceolate in type AA. Evans *et al.* (1993) reported that only the 'typical' form was found above 1100 m, but that all three forms occurred at lower elevations in the Pacific

Table 5. Intraspecific variations of the dorsal propodosomal and opisthosomal setae in *B. phoenicis* nuymphs (L – lanceolate setae; S – setiform setae)

Setae	Typical	Type AB	Type AA
v_2	S	L	L
sc_1	L	L	L
sc_2	L	L	L
c_1	S	S	L
c_3	S/L	L	L
d_1	S	S	L
d_3	S	L	L
e_1	S	S/L	L
e_3	S	L	L
f_3	L	L	L
h_2	L	L	L
h_1	L	L	L

coastal region of Costa Rica. In addition, Evans *et al*. (1993) reported the AB variant of Ochoa (1985) corresponded to the deutonymph of *B. phoenicoides* Gonzalez (1975).

The *omega* on tarsus II in *B. phoenicis* showed variation in size and shape ranging from both *omega* being equal in length to the paraxial *omega*

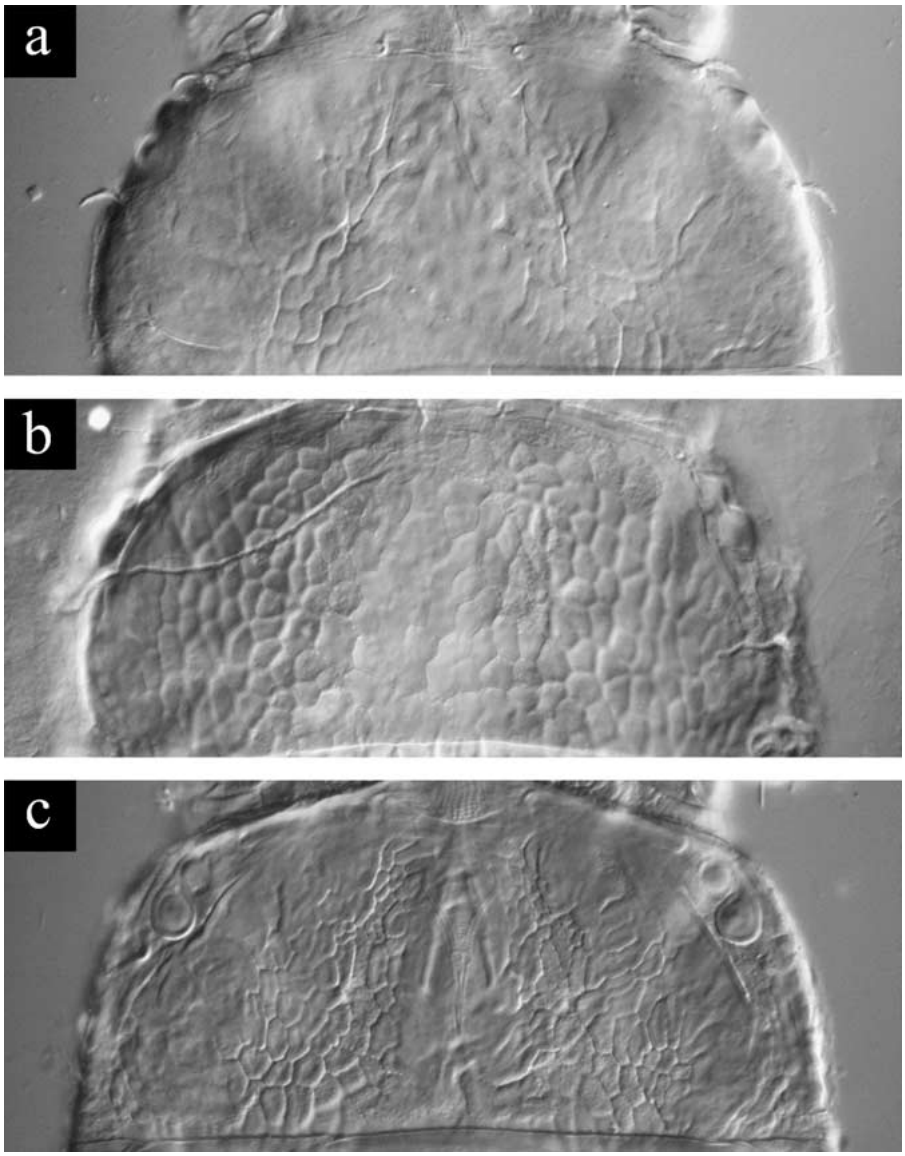

Figure 10. DIC photograph of dorsal propodosoma *Brevipalpus*. (a) *B. phoenicis*; (b) *B. californicus*; (c) *B. obovatus*.

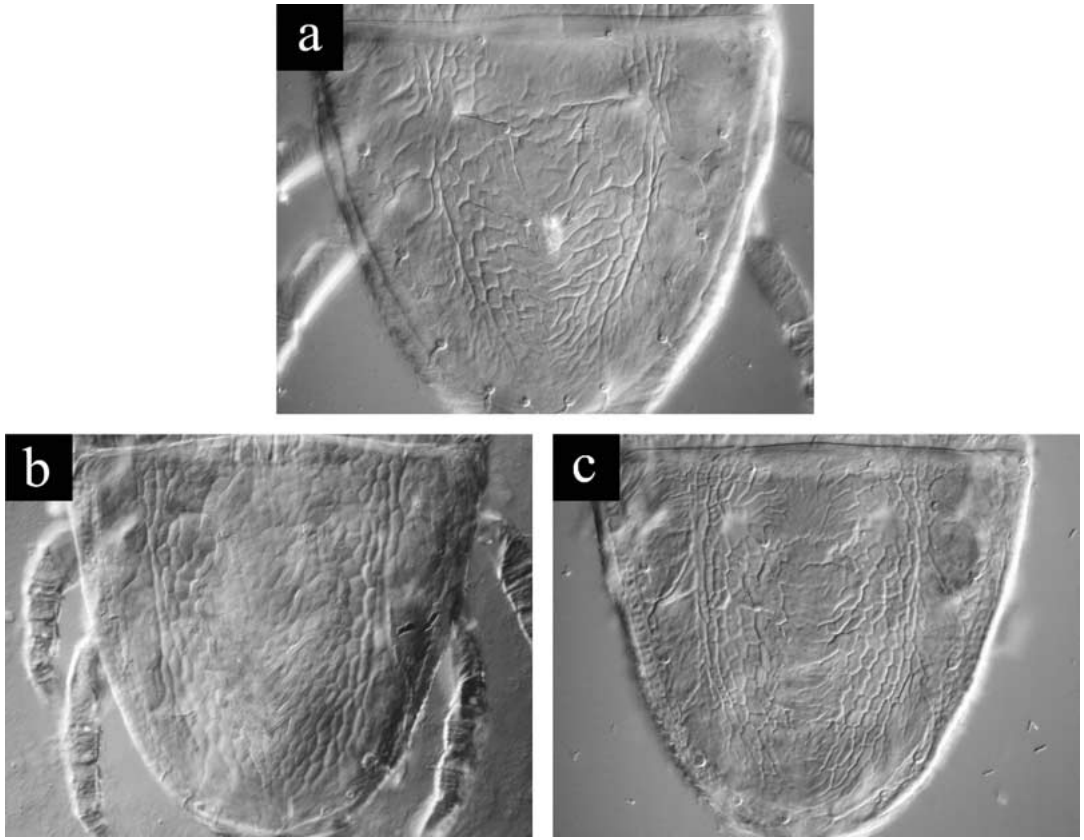

Figure 11. DIC photograph of dorsal opisthosoma of *Brevipalpus*. (a) *B. phoenicis*; (b) *B. californicus*; (c) *B. obovatus*.

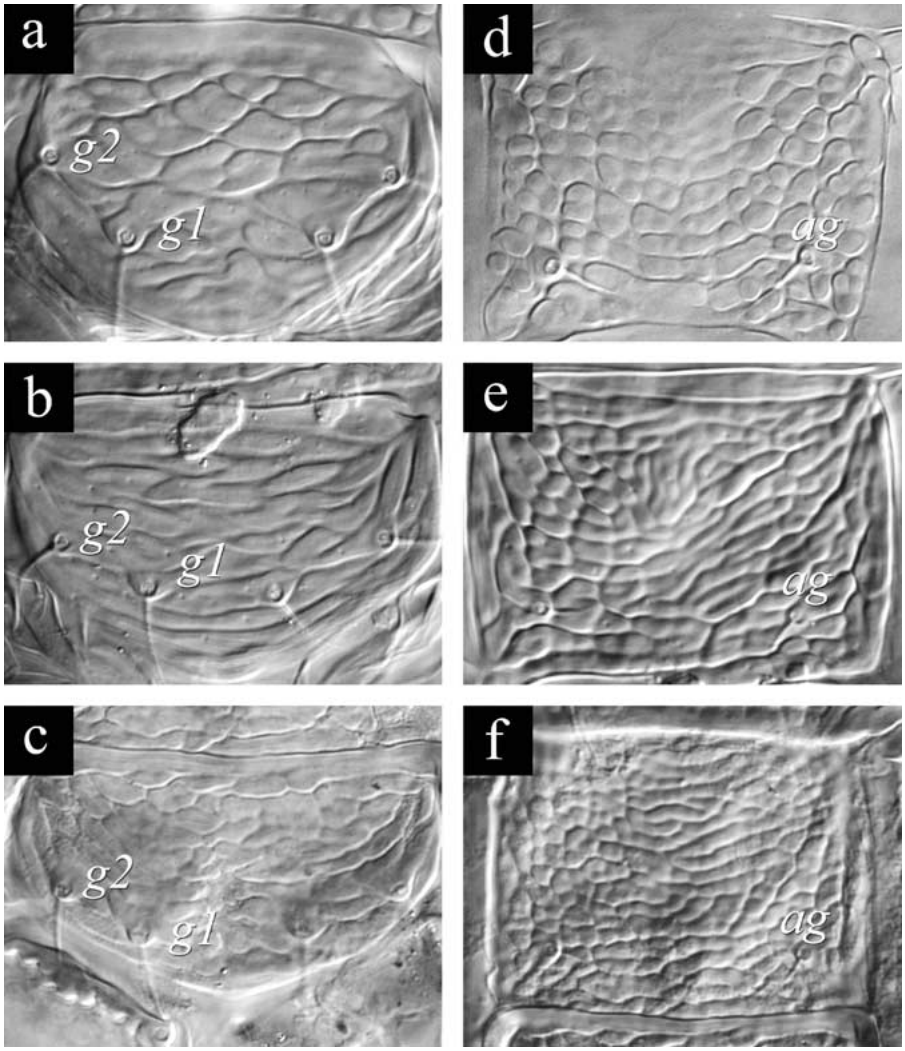

Figure 12. DIC photograph of genital (a, b and c) and ventral plates (d, e and f) of *Brevipalpus*. (a) *B. phoenicis*; (b) *B. californicus*; (c) *B. obovatus*; (d) *B. phoenicis*; (e) *B. californicus*; (f) *B. obovatus*. Aggenital setae: *ag*; genital setae: g_1, g_2.

appearing smaller. The paraxial *omega* in two different populations of *B. phoenicis* on citrus in Costa Rica (200+ specimens in one population and 2000+ specimens in the second) ranged from shorter than the paraxial *omega* to longer and more slender than the antaxial *omega* (Ochoa, unpublished data). In some specimens, one tarsus II had only a single *omega*, while the other tarsus II had two *omega* (De Leon, 1967). This condition has been observed in a few specimens from Florida (6), Argentina (4), Colombia (1),

and Costa Rica (12) out of more than 6000 *B. phoenicis* examined (Ochoa, unpublished data).

In *B. californicus* (Figures 10b, 11b, 12b, and e) the propodosoma can vary with age, feeding, and mounting techniques. The intraspecific propodosomal variation in *B. californicus* can range from a smooth area in the central part of the anterior propodosoma, irregular reticulation in the central part of the anterior to a third variation where the reticulation across the anterior portion of the propodosoma is evenly reticulate. This variation was used to separate species (Pritchard and Baker, 1958; Evans *et al.*, 1993) (see also Table 1). The region of the opisthosoma between e_1, e_3 to f_2 can have a uniform reticulation, whereas the typical *B. californicus* has irregular reticulations. The lateral setae, c_3, d_3, e_1, e_3, f_2, f_3, h_1, and h_2 in protonymphs and deutonymphs range from being lanceolate to strongly barbed.

Variation in the propodosoma of *B. obovatus* (Figure 10c) ranges from specimens with reticulations that fade along the anterior margin to specimens where the reticulations reach the anterior margin (Baker and Tuttle, 1987). In addition, the propodosomal pore is difficult to see in the more reticulated specimens. Baker (1949) reported that nymphal instars of *B. obovatus* have a tendency to show variation in the size of the opisthosomal setae c_3, f_3, h_1, and h_2.

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