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The Spiny Rat Mite *Echinolaelaps echidninus* (Berlese, 1887) (Dermanyssoidea: Laelapidae): Redescription of the Female with Emphasis on its Gnathosoma, Sense Organs, Peritreme and Pulvilli

Ashraf Ahmed Montasser
Department of Zoology, Faculty of Science, Ain Shams University, Cairo, Egypt

Abstract: The present Scanning Electron Microscopic (SEM) study includes redescription of female *Echinolaelaps echidninus* with emphasis on its gnathosoma, sense organs, peritreme and pulvilli which were rarely described in superfamily Dermanyssoidea. Chaetotaxy of dorsal shield revealed 40 pairs of setae, 22 on prosoma and 18 on opisthosoma. Epigynial plate carried 5 pairs of setae. Gnathosoma consisted of long basis capituli carrying median hypostome and 2 lateral pedipalps. Hypostome had dorsal labrum covered with finger-like processes, 2 lateral 3-segmented chelicerae and ventral labium carrying 4 lobulated plates. Function of labrum processes might be chemosensory while labium lobules might be mechanical, preventing solid material from entering the oral cavity. Palpal and foreleg tarsal organs comprised 10 and 16 sensillae, respectively. Sensillae of palpal organ were mostly chemoreceptors while those of tarsal organ were probably mechanoreceptors. Peritremal pit contained 4 rows of hand-like papillae and 5 concentric rows of minute papillae. Each pulvillus terminated with 2 medioventral claws. Pulvillus I had terminal integumental folds while each pulvillus II-IV had 2 lateral comb-like plates. Each plate carried 8-10 processes.

Key words: Acari, morphology, mouthparts, palpal organ, SEM, tarsal organ

Introduction

Mites are important group of arthropod pests affecting crops, animals and humans. The spiny rat mite, *Echinolaelaps echidninus* occurs throughout the world as a parasite of the Norway rat (brown rat), *Rattus norvegicus* and occasionally of other rodents (Keegan, 1956). *E. echidninus* received the attention of several authors since the start of twentieth century. It is the intermediate host of the protozoan *Hepatozoon perniciosum*, a parasite of rats (Miller, 1908). Junin virus, the cause of Argentinian hemorrhagic fever, has been isolated from *E. echidninus* in South America (Parodi *et al*., 1959).

Studies on *E. echidninus* were mainly concerned with surveys and host-parasite relationships (Yunker *et al*., 1959; Abdou, 1961; Degiust and Hartley, 1965; Theodor and Costa, 1967; Aamir *et al*., 1985; Linardi *et al*., 1984, 1985; Ugbomoiko and Obiamiwe, 1991; Soliman *et al*., 2001). Internal anatomy of *E. echidninus* through serial sections was investigated by Jakeman (1961). Physiological studies were also conducted on this mite including the oxygen uptake in relation to water balance (Kanungo, 1965), fluctuating humidities and frequency of blood meals on mite survival (Knulle, 1967) and kinetics of water exchange between the mite and the surrounding air (Wharton and Devine, 1968;

Devine and Wharton, 1973). Despite the above studies carried out on *E. echidninus*, detailed description of its mouthparts, peritreme, sense organs and pulvilli, or those of other dermanyssoids, remain sparse due largely to the minute size of these parts.

Considerable literatures were encountered in redescription of mite species with SEM (Desch, 1987; Bukva, 1995; Pence and Gray, 1996; Green and Baker, 1996; Tanskul and Linthicum, 1999). SEM was also useful in describing certain parts of mites such as the gnathosoma (Dusbabek *et al*., 1975; Shatrov, 1981; Paran, 1982; Mapstone *et al*., 2002), palpal organ (Leonovich, 1998; Leonovich and Staniukovich, 2002) and foreleg tarsal organ (Leonovich and Staniukovich, 2002; Soler Cruz *et al*., 2005). Description of *E. echidinimus* was only investigated with light microscopy in former studies of Keegan (1956) and Tipton (1960).

The present SEM study proffers redescription of *E. echidninus* with particular attention to the undescribed details of idiosoma, gnathosoma, peritreme, sense organs and pulvilli. These structures were rarely described in superfamily Dermanyssoidea which includes 15 families; most of them are parasites and disease carriers. Of these families, species of Dermanyssidae, Laelapidae and Macronyssidae are proven transmitters of diseases in birds, reptiles and mammals including man (Krantz, 1978). Detailed morphology of the gnathosoma, peritreme and pulvilli is an important step towards elucidation of the feeding behavior, respiration and attachment mechanism, respectively of this mite and hence its pathology. Sense organs such as palpal or tarsal organs are of primary importance in relation to orientation responses to humidity, temperature and chemical stimuli.

Materials and Methods

E. echidninus of the present study were recovered from *R. norvegicus* collected from Bilbeis area, about 60 km northeast of Cairo, Egypt. The study area and method of collection were described by Soliman *et al*. (2001). Mites were separately processed for mounting and identified according to Keegan (1956), Tipton (1960) and Krantz (1978).

E. echidninus were washed several times using saline solution to remove debris. Specimens were fixed in 2.5% glutaraldehyde mixed in Phosphate Buffer Solution (PBS) at a pH of 7.4 at 4°C for 24 h. They were then rinsed twice with PBS at 10 min intervals. Specimens were next treated with 1% osmium tetraoxide at room temperature for 1 day for post-fixation. This was followed by rinsing twice with PBS and dehydrating with alcohol. To replace water in mites with alcohol, they were subjected to increasing concentrations of ethanol as follows 30, 50, 70, 80, 90 and 95% for 15 min each. They were then placed in absolute alcohol for 10 min for 2 changes. Finally, they were subjected to critical point drying in order to complete the dehydration process (Junkum *et al*., 2004). In order to view specimens, they were first attached with double-sided carbon tape to aluminum stubs so that they could be coated with gold in a sputter-coating apparatus (JEOL JFC-1200). The surface topography of specimens was viewed at 25 kV in a JEOL-JSM5600 scanning electron microscope (Japan) at Central Laboratories Unit, United Arab Emirates University, United Arab Emirates during May, 2005.

Results

Adult female *E. echidninus* was large, robust, oval and almost covered with sculptured dorsal shield (Fig. 1a-e). Lateral shoulders were markedly noticed on anterior 1/7 of the dorsal surface, particularly the left side (Fig. 1a). Body was 1000 µm in length and 690.2 µm in width. Dorsal shield was posteriorly rounded and rarely ornamented with transverse overlapping striations (Fig. 1a and 1d).

Posterior striations were considerably noticed (Figs. 1a and 1e). Dorsal shield measured 885 μm in length and 600 μm in width. It had 40 pairs of setae, 22 on the prosoma and 18 on the opisthosoma (Figs. 1a-c). Prosomal setae included 4 series namely j1-j5, z1-z3, s1-s7 and r1-r7. Opisthosomal setae also included 4 series namely J1-J5, px1-px3, Z1-Z5 and S1-S5. Nomenclature of setae was according to Costa (1961). Dorsal shield was broadest at the level of s2 or z2 setae (Fig. 1a). The majority of setae were simple and slender with fine longitudinal ribs (Fig. 1e). Most setae were long (90-162 μm) while few setae as r4 were small (36.4 μm).

Ventrally, *E. echidninus* had considerably sclerotized plates namely sternal, epigynial, anal and endapodal plates (Fig. 2a). Sternal plate anterior margin was almost straight and just behind the capitulum while its posterior margin was concave and slightly covered the anterior margin of the epigynial plate (Fig. 2b). The postero-lateral corners of that plate project distinctly between coxae II and III. Sternal plate carried 3 pairs of long pointed setae; the anterior setae were shorter than others. Length of sternal plate (200.8 μm at mid-line) was more or less equal to its width (205 μm at the level of the second setae). No pores were noticed on that plate (Fig. 2b). Two endapodal plates were located postero-lateral to the sternal plate and adjacent to the anterior margin of the epigynial plate (Fig. 2b and c). They appeared as polygonals with narrow anterior end and broad posterior one. Each plate carried long pointed seta. Epigynial plate, or genitoventral shield, was widely expanded posterior of coxae IV and extended to anal shield from which it was separated by a very thin strip of integument (Fig. 2a and c). Posterior margin of epigynial plate had a concavity closely matching rounded anterior margin of anal plate. Epigynial plate had 5 pairs of pointed setae; the 1st pair was much shorter than the remaining setae. Maximum width (338.5 μm) was measured at level of 4th pair of setae. Distance between 5th pair of epigynial setae was greater than the distance between 1st pair of setae. Anal plate was wider (189.1 μm) than long (123.6 μm) (Fig. 2d). It was almost triangular in shape with convex anterior side. Longitudinal anal opening was guarded with 2 rectangular leaves which in turn surrounded with elevated oval integument (Fig. 2e). Anal plate carried 3 setae; setae of the anterior pair were located posterolateral to anal leaves and approximately half as long as the posterior unpaired seta which located behind the anal plate (Fig. 2a and d). All the above plates were faintly ornamented. Integument adjacent to epigynial and anal plates contained horizontal striations (Fig. 2c and d). About 7 pairs of setae, measuring 41.1-112.8 μm, were noticed on the soft integument of ventral side (Fig. 2a).

The gnathosoma, or capitulum, consisted of long basis capituli carrying median hypostome and 2 lateral pedipalps (Fig. 3a). Long well developed tritosternum between 2 small triangular integumental folds were originated at the base of the basis capituli (Fig. 3b). Tritosternal base was longer than broad, undivided and bifurcated into 2 long laciniae (Fig. 3b); each was anastomosed into numerous long processes (Fig. 3c). Deutosternl groove was a longitudinal median groove noticed on the ventral side of the basis capituli above the tritosternum (Fig. 3b). The groove contained about 6 horizontal rows; each had 2 or 3 spines (Fig. 3b-Inset). Gnathosomal setae were small and piliform (Fig. 3b). Hypostome carried dorsal labrum, 2 lateral chelicerae and ventral labium (Fig. 3d). Labrum is well developed and appeared as inverted pear shape with pointed tip. Labrum extensively covered with numerous finger-like processes, each had rounded tip (Fig. 3e). Chelicera consisted of 3 segments (Fig. 3d). The first one represented the base which carried other 2 segments. The latter formed terminal chela with 2 elongate edentate digits, the dorsal was slightly shorter than the ventral (Fig. 3d). The basal segment carried 1 median ventral seta. Labium appeared as inverted isosceles triangle, its tip observed in front of the deutosternal groove of basis capituli (Fig. 3a). Base of labium carried 2 median and 2 lateral plates (Fig. 3d). Each plate was lobulated on one side. Each median plate carried

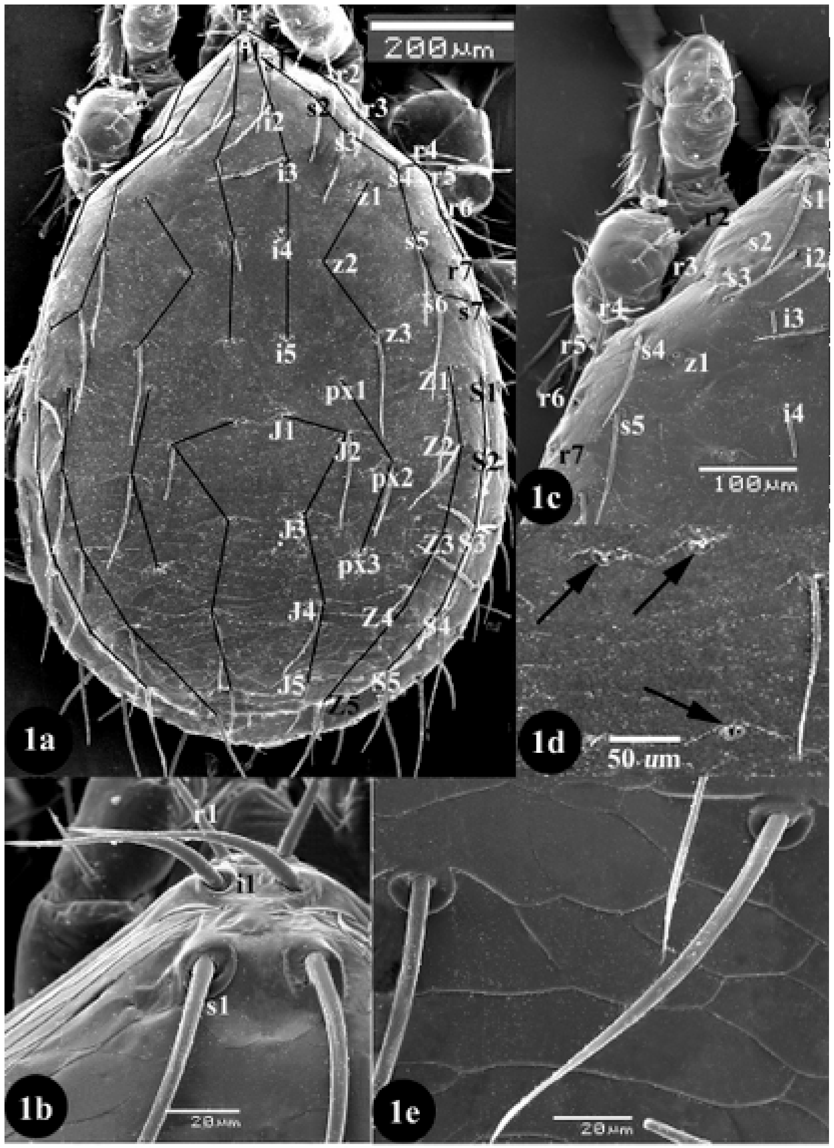

Fig. 1: Scanning electron micrographs of the dorsal surface of female *E. echidninus*. a. Chaetotaxy of the dorsal shield showing distribution of 40 pairs of setae. Black lines connect between setal sockets in each series which include i1-i5, z1-z3, s1-s7, r1-r7, J1-J5, px1-px3, Z1-Z5 and S1-S5. b. Terminal region of dorsal shield showing r1, i1 and s1 setae. c. Lateral area of the prosoma of dorsal shield showing r2-r7, s1-s5, z1, i2-i4 setae. d. Middle region of he dorsal shield showing some setal sockets (arrows) and rare striations. e. Posterior region of the dorsal shield showing long pointed setae and considerable striations

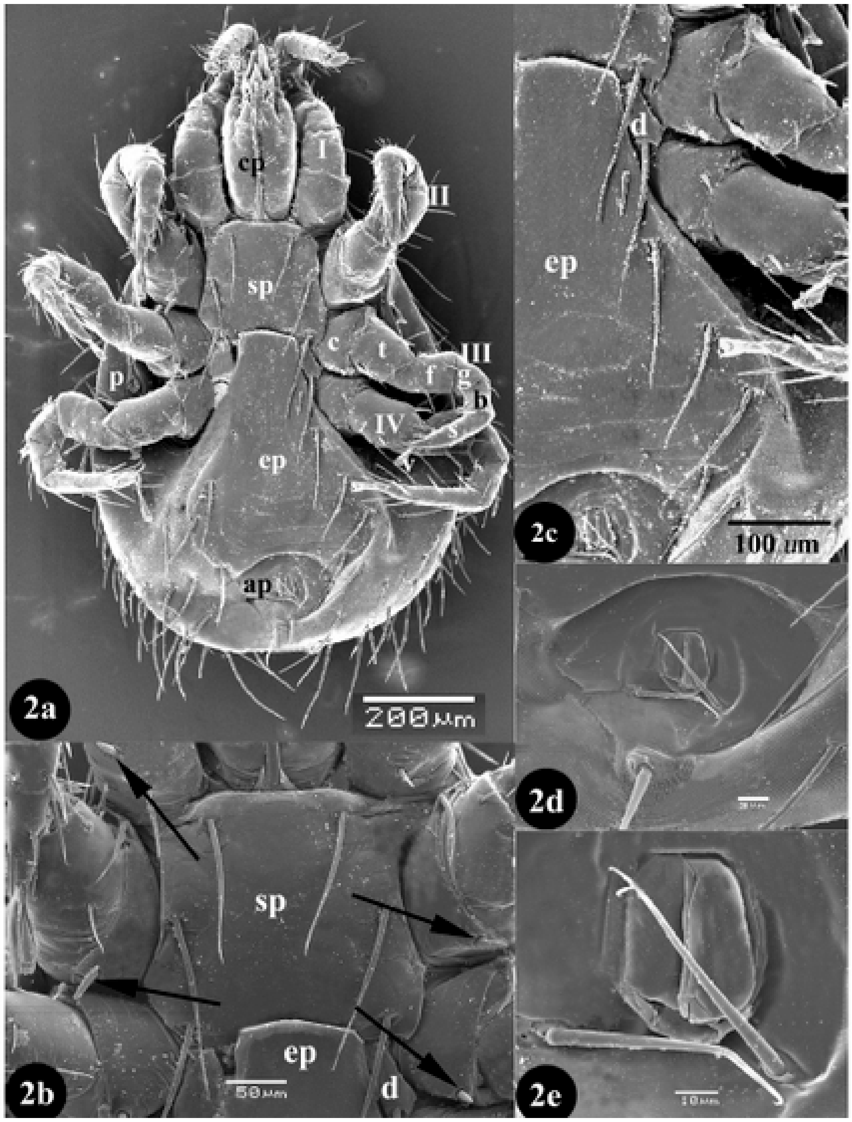

Fig. 2: Scanning electron micrographs of the ventral surface of female *E. echidninus*. a. Whole ventral side showing gnathosoma (gn), sternal plate (sp), epigynial plate (ep), anal plate (ap), peritreme (p), 4 pairs of legs (I-IV) and leg segments [coxa (c), trochanter (t), femur (f), genu (g), tibia (b), tarsus (s) and pulvillus (v)]. b. Sternal plate (sp), anterior margin of epigynial plate (ep), endapodal plate (d) and coxae of 1st 3 legs carrying short and stout lateral spurs (arrows). c. Epigynial plate (ep) carrying 5 pairs of pointed setae and endapodal plate (d) carrying 1 long pointed seta. d. Anal plate with anterior convex side and horizontal striations on the adjacent integument. e. Longitudinal anal opening with 2 posterolateral setae

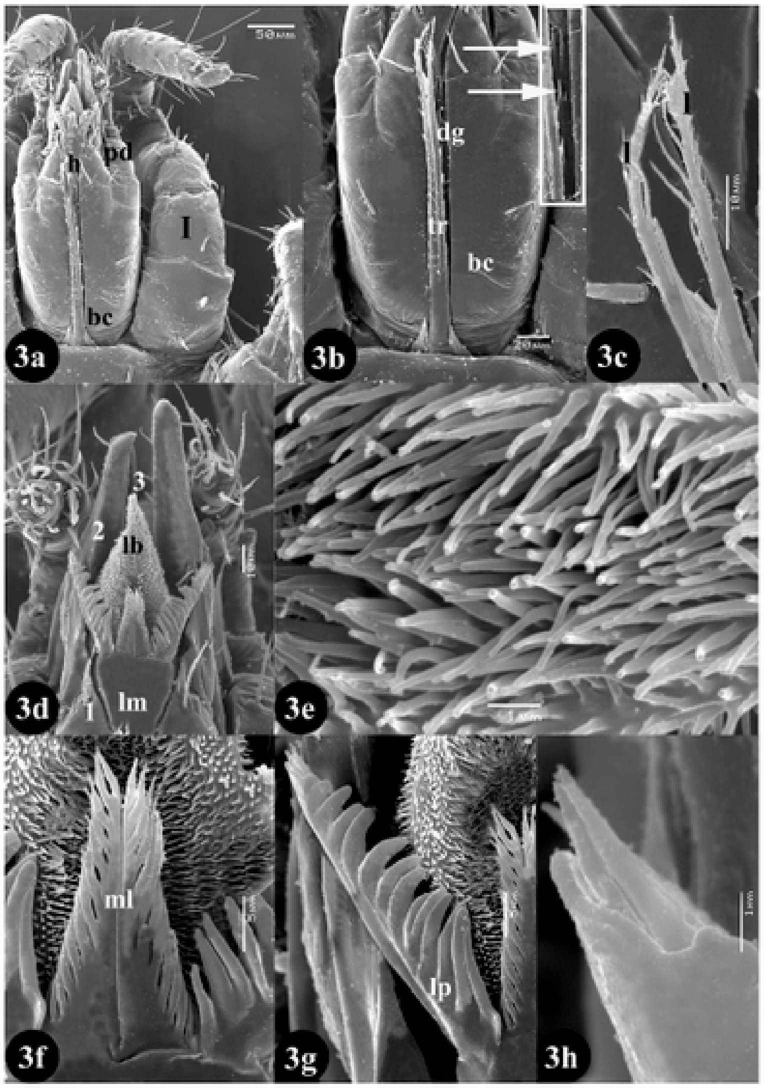

Fig. 3: Scanning electron micrographs of the gnathosoma of female *E. echidninus*. a. Whole capitulum consisting of long basis capituli (bc) carrying median hypostome (h) and 2 lateral pedipalps (pd). First leg (I) was adjacent to the gnathosoma. b. Tritosternum (tr), with 2 integumental triangles guarding its base, below the deutosternal groove (dg) on the ventral side of the basis capituli (bc). Inset showing spines (arrows) in the deutosternal groove. c. Terminal anastomosing of tritosternal laciniae (l). d. Hypostome carrying dorsal labrum (lb), ventral labium (lm) and 2 lateral chelicerae (ch). Each chelicera consisted of 3 segments (1-3). e. Hair-like processes covering the labrum. f. Median plates (ml) of the labium, each carrying 12 lobules. g. Lateral plate (lp) of the labium carrying 13 lobules. h. Terminal setae on the lateral plate of the labium

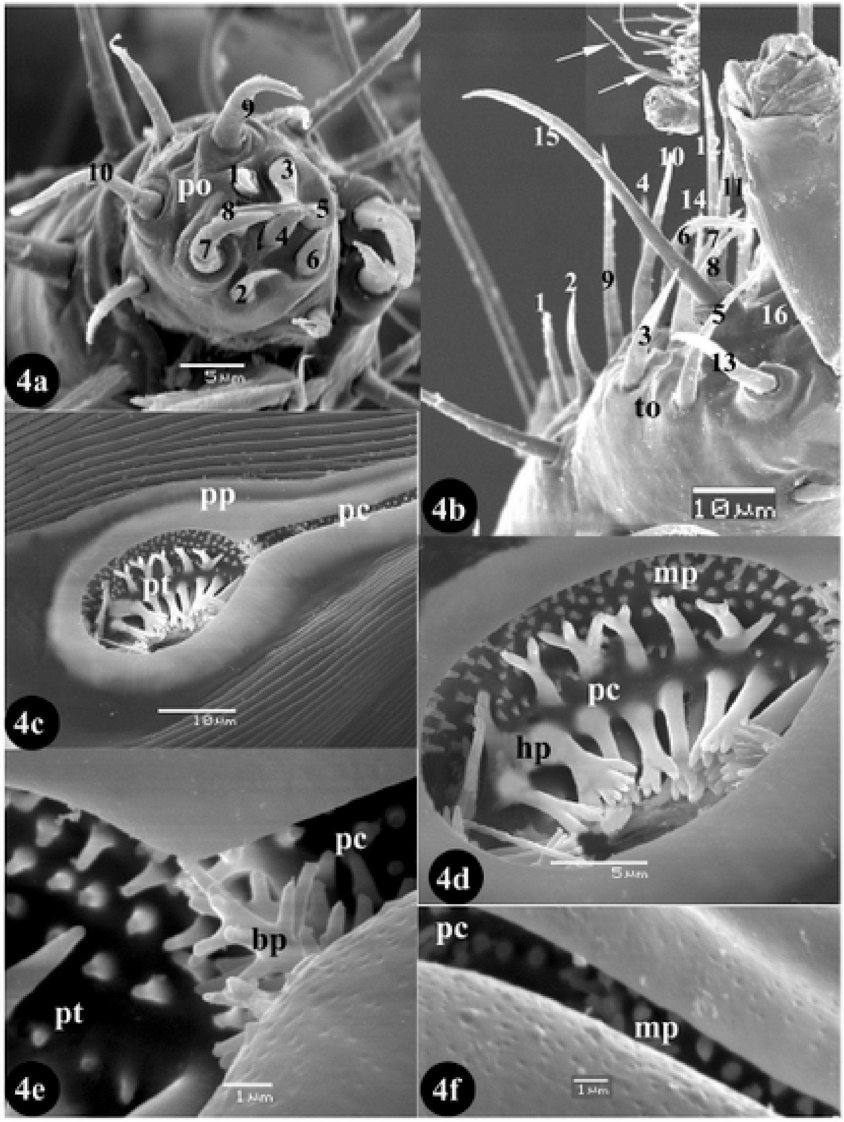

Fig. 4: Scanning electron micrographs of the palpal organ and the peritreme of female *E. echidninus*. a. Palpal organ (po) consisting of 10 terminal setae (1-10) on the 1st leg. b. Left foreleg tarsal organ (to) consisting of 16 terminal setae (1-16). Inset showed sensillae 15 and 16 (arrows) in the right foreleg tarsus. c. Peritremal plate (pp) surrounding peritremal pit (pt) and peritremal canal (pc). d. Peritremal pit (pt) containing rows of hand-like papillae (hp) and concentric rows of minute pear-shaped papillae (mp). e. Neck region between peritremal pit (pt) and peritremal canal (pc) crowded with medium branched papillae (bp). f. Peritremal canal (pc) containing minute papillae (mp)

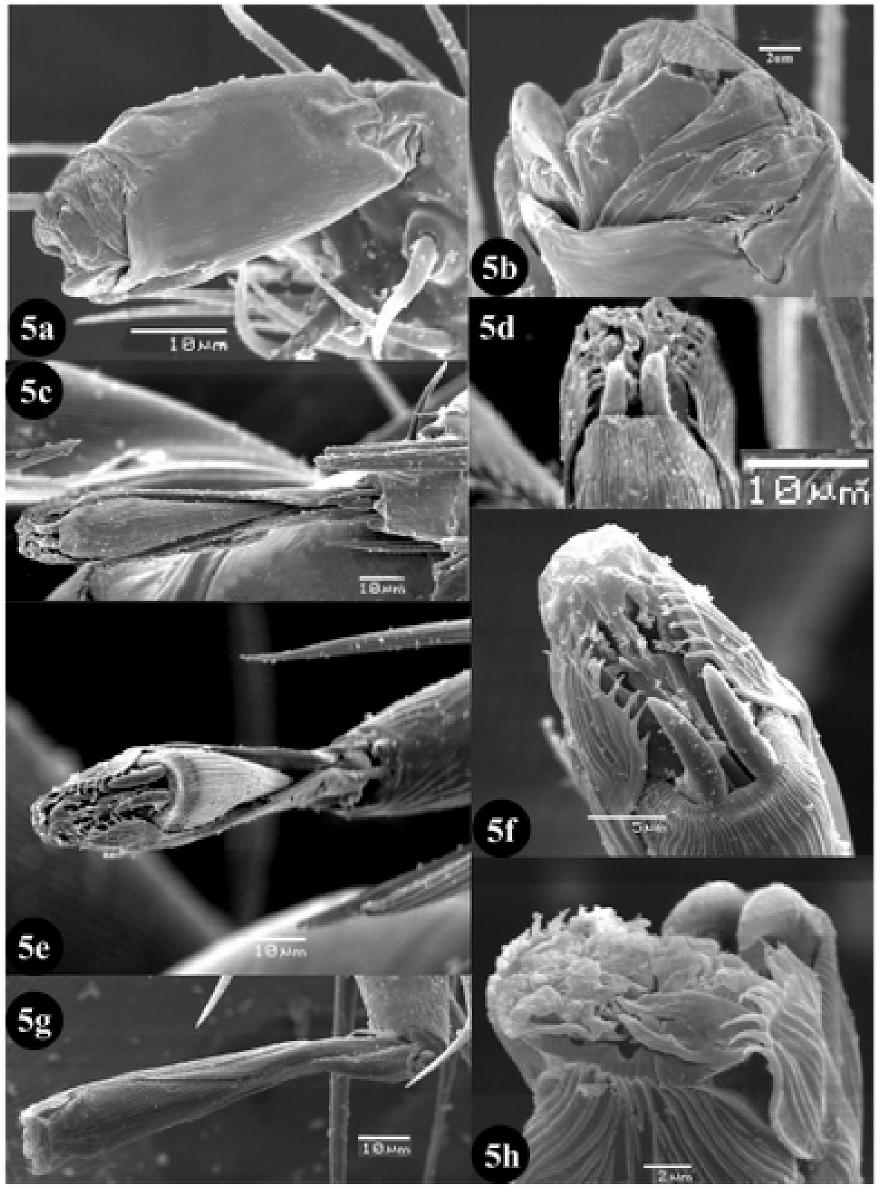

Fig. 5: Scanning electron micrographs of the pulvilli of female *E. echidninus*. a. Pulvillus of 1st leg showing its smooth surface and terminal folds. b. As in a showing terminal region with overlapping integumental folds and 2 curved claws. c. Pulvillus of 2nd leg showing longitudinal integumental ridges and 2 lateral folds at its base. d. As in c showing 2 terminal medioventral claws and 2 lateral comb-like plates. (e and f) and (g and h) were as in (c and d) but for 3rd and 4th legs, respectively

externally allocated 12 lobules, the terminal 2 had common base (Fig. 3f). Lateral plates were longer than median ones (Fig. 3d), each carried 13 internally allocated lobules which became smaller towards the apex (Fig. 3g). Each lateral plate terminated with 3 or 4 pointed setae (Fig. 3h).

Sense organs in *E. echidninus* included the palpal and foreleg tarsal organs (Fig. 4a and b). SEM showed a sensorial cluster in the tip of the terminal segment of the 6-segmented pedipalp (Fig. 4a). This cluster, or palpal organ, comprised 10 setiform sensillae which can be characterized according to their location, shape, size, tip, socket and surface of the wall. Sensillae 1 and 2 were the smallest, curved, peg-like with sharp tips, without sockets and located in the middle of the cluster. Sensillae 3-6 were conical, straight, larger than sensillae 1 and 2 and without sockets. Sensillae 7 and 8 were medium sized, curved, aligned with sensillae 1 and 2, had sharp tips and apparent sockets. The base of the socket was raised. Sensillae 1-8 had smooth walls. Sensillae 9 and 10 were the longest, curved, with apparent sockets and longitudinal ribs.

The tarsal organ was dorsally located in the tip of the foreleg tarsus (Fig. 4b). It comprised 16 setiform sensillae that can be primarily divided, according to their length, into 6 groups. Other characters as the location, shape, tip, socket or surface will be considered. Sensillae 1 and 2, 1st group, were the shortest, thinnest, posteriorly located and with pointed tips. Sensillae 3 and 4 were much broader with sharply pointed tips. Sensillae 5-8 were longer and thinner than sensillae 3 and 4. Sensillae 9-12 were twice as long as sensillae 1 and 2. Sensillae 1-12 were without sockets. Sensillae 13 and 14 were medium sized and with apparent sockets. Sensillae 15 and 16 were the longest and with raised sockets. Sensillae 3-16 had longitudinal ribs on their walls.

Peritreme extended anteriorly to the margin of coxa II from an oval pit situated laterally between 3rd and 4th coxae (Fig. 2a). Peritreme was a hardly sclerotized plate surrounding the pit with posterior small extension and anterior peritremal canal (Fig. 4b). The oval pit contained 4 longitudinal rows of 5-8 hand-like papillae in addition to 5 concentric rows of numerous minute pear-shaped papillae (Fig. 4c and d). Each hand-like papilla was a stalk-like and carried 2-7 terminal branches. The point connecting between the pit and the canal was crowded with medium-sized branched papillae (Fig. 4d). Peritremal canal contained 1 or 2 rows of minute papillae (Fig. 4e).

Four pairs of walking legs were located on the ventral surface; each carried coarse medium-long sized setae and divided into 6 segments (Fig. 2a). Beginning with the most proximal, they were coxa, trochanter, femur, genu, tibia and tarsus. The latter hanged terminal pulvillus. The respective lengths of legs (including pulvilli) were as follows: I-512.8 µm, II-594.9 µm, III-625.6 µm and IV-759 µm. Coxae of the 1st 3 legs were adjacent to the sternal plate while those of the 4th one were adjacent to the anterior $^1/_3$ of the epigynial plate. Segments of legs II and III were somewhat uniform in size. Ventral surface of coxa I had a stout, short, lateral spur and a long median seta (Fig. 2b). Each of coxae II and III carried a short, stout, posteriorly directed, ventral spur (Fig. 2b). Pulvillus of 1st leg had smooth surface and terminated with curved claws and overlapping integumental folds (Fig. 5a and b). Each pulvillus of 2nd, 3rd and 4th legs carried a pair of medioventral curved claws and a pair of lateral comb-like plates (Fig. 5c-5h). Each plate carried 8-10 processes (Fig. 5d, f and h). Two lateral folds were observed at the base of each pulvillus (Fig. 5c, e and g). Integument of pulvilli 2-4 had longitudinal ridges (Fig. 5c-5h).

Discussion

Redescription of *E. echidninus* with SEM in the present study greatly supported the diagnostic characters previously mentioned by Keegan (1956) and Tipton (1960). These characters included the body length, shape of sternal, epigynial and anal plates and spurs on coxae I-III. However, the present study revealed 5 pairs of setae instead of 4 pairs on the epigynial plate noticed by Tipton (1960). This may be due to the 1st pair was much smaller than other setae and difficult to observe by light microscope.

Dorsal shield in acarines provides a degree of protection from desiccation and predation (Krantz, 1978). Chaetotaxy of the dorsal shield of *E. echidninus* has been described for the first time in the present study. It revealed 40 pairs of setae that considerably resembled the chaetotactic pattern of the genera *Haemolaelaps* and *Laelaps* described by Costa (1961). Number of setae in that pattern was 39 pairs where it lacked the px1 setae.

Gnathosomal structure of *E. echidninus* consisting of median hypostome and 2 lateral pedipalps on long basis capituli, ventral tritosternum and the 3-segmented chelicerae were greatly matched with those of the generalized gamasid mite described by Krantz (1978). The terminal 2 elongated segments of each chelicera, one fixed dorsal and other movable ventral, were common in blood sucking mesostigmatic (Krantz, 1978) and asitigmatic mites (Mapstone *et al*., 2002) and were specialized for piercing host tissues. Wernz and Krantz (1976) suggested the role of the tritosternum as a fluid transporter, directing prey fluids to the prebuccal region. Tipton (1960) mentioned that labrum of *E. echidninus* was only lanceolate and grooved to the apex. Krantz (1978) mentioned that labrum dorsally bordered the buccal cavity and function as a pre-pharyngeal valve preventing loss of food. Finger-like processes with rounded tips covering the labrum and lobulated plates covering the labium in the present study have not previously described and their function is uncertain. Function of labrum processes might be chemosensory while that of labium plates might be mechanical, preventing any solid material from entering the oral cavity. Interpretation of the function of the above components is tentative. Further investigation including physiological studies is required to aid in the complete understanding of the feeding mechanism in gamasid mites.

Palpi are simple sensory appendages equipped with terminal chemosensory sensillae that aid the acarine in locating its food (Krantz, 1978). In the present study, each pedipalp consisted of 6 segments terminated with palpal organ which moved freely via articulations between palpal segments. This holds up its primary function for food acquisition. This greatly resembled that observed in gamasid mites and argasid ticks while in ixodids, palpal organ was located in a depression of the 3rd palpal segment (Krantz, 1978). In *E. echidninus*, palpal organ consisted of 10 setiform sensillae forming a cluster terminal to the pedipalp. Eight of these sensillae were small-medium sized and broad with pointed tips. These features support the olfactory or chemosensory function as described in gamasid mites (Leonovich, 1998; Leonovich and Staniukovich, 2002). The longest 2 sensillae with longitudinal ribs probably had a mechanoreceptor function as mentioned in the above studies. Tarsus I carried a cluster of 16 sensillae, most of them were long and needlelike with longitudinal ribs in the wall. Function of these sensillae most likely to be mechanoreceptive. This was in great accordance with those described in other gamasid mites (Leonovich and Staniukovich, 2002; Soler Cruz *et al*., 2005).

SEM of the peritreme revealed an oval pit and anterior canal reaching coxa II. Peritremal canal contained minute pear-shaped papillae. This was in great agreement with that described in *Ornithonyssus bacoti* (Green and Baker, 1996). Peritremal pit contained 4 rows of 5-8 hand-like papillae and 5 concentric rows of numerous minute papillae. Both papillae appeared to have delicate walls which may share in the process of respiration in the present mite as they were adjoining both the body cavity and the atmospheric air. In addition, hand-like papillae terminated with 2-7 branches which might increase the respiratory surface. Contents of peritremal pit were rarely described in suborder Gamasida where in his description of a generalized gamasid mite, Krantz (1978) stated that peritreme surrounded a stigmatal opening at the level of coxae II-IV. The present study revealed no openings in or near the peritreme.

It is generally accepted that the claws are used to interlock with macroscopical asperities of the substrate. If the diameter of the substrate asperities is lower or equal to the diameter of the claw tip and the substrate is stiff enough to prevent its penetration by claws, the claws slide over the substrate (Dai *et al*., 2002). In the present study, claws were small, curved and ventrally located in front of longitudinal integumental ridges. Accordingly, the probable function of claws in *E. echidninus* is supporting the attachment with the host skin. The comb-like plates noticed lateral to II-IV pulvilli might contribute to remove debris at the attachment site of the host skin, particularly during the detachment of the mite. Instead of the above plates, integumental folds beside the claws were observed terminal to pulvillus I. These folds may cause the mite to lean on the host skin particularly during feeding where the forelegs were anteriorly directed beside the gnathosoma. Longitudinal ridges on the ventral side in all pulvilli made this surface rough which might share in firm attachment with the host skin during feeding and/or oviposition. This was in great accordance with the pulvillus role previously mentioned in oviposition of *Culex quinquefasciatus* (Kupp *et al*., 2000).

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