Acarological Studies
Vol 2 (2): 59-68
doi: 10.47121/acarolstud.669572

RESEARCH ARTICLE

Biology of the oribatid mite *Acrotritia clavata* (Märkel, 1964) from the mangrove ecosystems of North Kerala, India

Syamjith PADINHARE KAITHAYIL[1,2], Ramani NERAVATHU[1]

[1] *Division of Acarology, Department of Zoology, University of Calicut, Kerala-673635, India*
[2] Corresponding author: pksyamjith@gmail.com

Received: 8 January 2020 Accepted: 9 February 2020 Available online: 29 July 2020

ABSTRACT: In this study, the development of the oribatid mite species *Acrotritia clavata* (Märkel, 1964) was studied for the first time under laboratory conditions in 2015. The postembryonic development was documented in plastic culture cells with a base of plaster of Paris-charcoal mixture (4:1 ratio) at room temperature of 28±2°C and relative humidity (RH) of 79±2%. The total duration of the life stages of *A. clavata* from egg to adult was 61-72 days in saline water (pH 7.9) collected from its natural habitat, which was used for rearing. Morphological features of all juvenile stages were studied. The present study revealed the morphology of all the juvenile stages and the duration of post-embryonic development of *A. clavata* collected from the mangrove ecosystem of North Kerala, India.

Keywords: Juveniles, mangrove, Oribatida, pneumatophores, biology, larviposition, moulting.

Zoobank: http://zoobank.org/65F8E951-F0DA-4C37-8D86-AA487B4BDBC4

INTRODUCTION

The dynamic mangrove ecosystem supports numerous soil microbes and a rich diversity of microarthropods (Chakraborty, 2011). Oribatid mites, which are commonly called moss mites or beetle mites, serve as one of the most numerically dominant groups of arthropods in every organic soil horizon (Wissuwa et al., 2013), and inhabiting a wide variety of microhabitats like the litter, humus layers, lichens, moss, algae and fungal cushions (Bücking et al., 1998). They also inhabit the marine environment (Schuster, 1979), including the bark of trees, mangrove pneumatophores and tidal debris (Syamjith and Ramani, 2013). However, knowledge of the real diversity and distribution of mangrove mites is far from complete (Chatterjee et al., 2018).

Oribatid mites have six life-cycle stages: pre-larva, larva, proto-, deuto-, tritonymph and adult (Søvik, 2004). The oribatid mite genus *Acrotritia* Jacot, 1923 (Euphthiracaridae), which comprises 31 species and 5 subspecies (Subias, 2004, updated in 2019). Biological studies on development have been conducted for relatively small groups of oribatid mites, including the immature stages of *Sabacarus* Ramsay and Sheals, 1969 and *Paratritia* Moritz, 1966 (Oribotriitidae), and juveniles of *Acrotritia clavata sextiana* (Lions, 1967) (Euphthiracaridae). The life cycle of the largest soil litter dwelling oribatid mite, *Steganacarus magnus* Nicolet, 1855 has also been recorded (Webb, 1978). Recently, the morphology of juveniles of a similar species *Acrotritia ardua* (Koch, 1841), was described and illustrated (Ermilov, 2011).

Pioneering work on oribatid mites provided data on the postembryonic development of two species of *Galumna* Heyden, 1826, two species of *Scheloribates* Berlese, 1908, and one species of *Rostrozetes* Woodring, 1965 (Haq and Ramani, 1984). Observations on the biology of oribatid mites by Woodring (1962) helped document all the developmental stages of *Ceratozetes cisalpinus* Berlese, 1908, *Scheloribates laevigatus* Koch, 1835 and *Oppia neerlandica* Oudemans, 1900, with the complete description of all stages. The fine structures of spermatophores and the spermatozoa of 10 species of Hermanniidae, Liacaridae, Hermanniellidae, Scutoverticidae, Achipteriidae, Euzetidae, Chamobatidae and Pelopidae were described Fernandez et al. (1991). The structure of the egg (Baran and Ayyildiz, 2000), and morphologies of the prelarva (Lions, 1967) and adult of *Acrotritia ardua*, (Koch, 1841) (Krivolutskiy, 1975; Weigmann, 2006) have been described and illustrated. And the relationship between female body size and egg number and size of *A. ardua* has been examined (Bingül et al., 2016). In addition, the extreme life history of Arctic populations of the littoral mite, *Ameronothrus lineatus* Thorell, 1871, was reported by Søvik (2004).

For most oribatid mite species, the data on the juvenile stages remain poorly known or unknown. The present work attempted to gather information in the duration of the life stages of *Acrotritia clavata* (Märkel, 1964) from mangrove ecosystems, which still represent a mostly unexplored realm as far as oribatid diversity is concerned. Moreover, this is the first attempt to establish the duration of the life stages, F_1 generation of *A. clavata* in the laboratory conditions.

MATERIALS AND METHODS

Study Site and Sample Collection

The mangrove dwelling oribatid mite, *A. clavata*, was selected for making detailed observations on its developmental biology. For that purpose, samples of soil, litter, dead pneumatophores, barks and decaying twigs were collected from the floor of a mangrove forest, namely Kadalundi- Vallikkunnu community reserve mangrove

(11°07′ 33.76″ N and 75°49′49.40″ E) in North Kerala, India (Fig. 1). The sampling was carried out between December 2013 to March 2014.

Extraction of Oribatid Mite Species

Live oribatid mites were extracted from dead and decaying pneumatophores and the bark of the mangrove plant, *Avicennia marina* (Forssk.) Vierh., through direct examination under a stereo zoom microscope or through extraction under an open brass funnel apparatus.

Experimental Design for Developmental Studies

The live mites detected under the stereo-zoom microscope were transferred with the help of a camel hair brush to plastic culture vials of 4 cm x 6cm basal area containing a mixture of Plaster of Paris and charcoal at a ratio of 4:1 ratio (Haq and Ramani, 2002). The bases were adequately moistened with saline water collected from the same habitat and maintained at room temperature of 28±2°C and relative humidity (RH) of 79±2%. The mites were reared on moistened leaf pieces, decayed pieces of moistened barks and pneumatophores of *A. marina* collected from their habitat. The culture cells containing the live individuals were regularly observed under a stereo-zoom microscope with the minimum light intensity. For easy observation, individual mite specimens with its ontogenic stages (larva, 3 nymphal stages) were reared separately in the culture cells. Frequent observations were made to collect information on various developmental characteristics such as incubation, hatching, active stages, quiescent periods and moulting.

Figure 1. Geographical description of mangrove ecosystems at Kadalundi-Vallikkunnu Community Reserve (Image accessed via Google Earth Pro Software).

Photography

Photographs of the mite species included in the study were made with a Cal Zeiss stereomicroscope (Stemi 2000-C) and processing of the images was done by using Zoom Browser EX Software.

Scanning Electron Microscopy (SEM)

SEM images of specimens of *A. clavata* were taken at the National Institute of Technology (NIT), Calicut by using a Hitachi SU6600 Variable Pressure Field Emission Scanning Electron Microscope (FESEM).

RESULTS

Larviposition

Unlike all other species of oribatid mites, oviposition was absent in *A. clavata* in the culture cells in the present study. The gravid females carried oval-shaped eggs, which contained embryos which gradually developed into prelarva, inside their bodies (Figs 2 A,B). After 14-18 days of development within the body cavity of the female mite, larviposition was observed, which was evidenced by the birth of a fully developed six-legged larva.

Duration of Life Stages

The newly emerged larva was very delicate and remained inactive for about 10 minutes, as shown in (Fig. 2C). Single larva was noticed from a single female specimen. It then it crawled on the substratum, and started wandering inside the culture cell in search of food. It showed a preference to feed on both fresh and dead algal filaments of *Microspora* sp. and the cortex tissue of the pneumatophore of *Avicennia marina.* After 5-6 days of active feeding, the larva became completely immobile, after which it enlarged its body size and moved into the 1st quiescent stage. The larval quiescence period, which extended for 3-5 days, was terminated by the moulting process and met-

amorphosed into the protonymph stage (Fig. 2D). The active period of the protonymph lasted for 3-4 days and then it stopped its feeding activity, became sluggish and then turgid condition, and then entered the 2nd quiescent phase of 5-6 days duration. On subsequent moulting, the deutonymph (Fig. 2E) that emerged and was a voracious feeder on decayed filaments of the green alga, *Microspora* sp. Feeding was evident through the formation of a food bolus in the digestive tract which could be clearly seen through the transparent body. The white colour of the deutonymph later changed to off-white. After an active feeding period of 3-5 days, it entered the 3rd quiescent phase of 6-9 days duration. The 3rd quiescent stage moulted into the transparent tritonymphal stage (Fig. 2F) which was the largest among all other nymphal stages. The tritonymph exhibited active feeding on dead pneumatophores for a period of 10–11 days and then it passed through the 4th and final quiescent stage of 7–9 days duration and moulted into the light brown coloured adult (Figs 2 G,H). Under laboratory conditions of 28±2°C and 79±2% RH, *A. clavata* completed its development from egg to adult within 61-72 days (Table 1). The newly emerged females produced eggs 8-11 days after their emergence but they remained inside their body cavity until larviposition, i.e., giving birth to larvae.

Table 1. Duration of development of life stages of Acrotritia clavata (Märkel, 1964) at 28±2°C, RH = 79±2% (in days).

Sl No	Egg	Larva	I Quiescent	Pro-tonymph	II Quiescent	Deu-tonymph	III Quies-cent	Tri-tonymph	IV Quies-cent	Total
1	14	5	3	4	5	5	6	11	8	61
2	17	6	3	3	5	3	6	10	8	61
3	14	4	3	4	5	5	8	11	9	63
4	18	6	5	4	6	5	9	10	9	72
5	17	6	3	4	5	5	7	9	7	63
6	16	5	4	3	5	4	6	10	9	62
7	16	5	4	3	5	5	6	9	9	62
8	17	5	3	3	6	4	6	10	8	62
9	15	5	3	4	5	4	7	11	7	61
10	15	5	3	4	5	4	7	11	10	64
Range	14-18	5-6	3-5	3-4	5-6	3-5	6-9	10-11	7-9	61-72

Morphological Description of Life Stages of *A. clavata* (Märkel, 1964)

Egg

Length: 173-185 µm; width: 57-62 µm. Small, oval, white, transparent and inside the body of the adult female.

Prelarva

Detected inside the body of weakly sclerotized females. Prelarva more or less oval in appearance enclosed inside the eggshell and possessing 3 pairs of monodactylous legs.

Larva

Dorsal region (Fig. 3A). Length: 173-186 µm; width: 74-82 µm.

The larva could be easily distinguished by the possession of 3 pairs of legs. The cuticle of the larva was weakly sclerotized, colourless and smooth. The rutella of the subcapitulum and its digits showed very little sclerotization and were light brown.

Prodorsum: Prodorsum relatively short with a broadly round rostrum; setae *ro*, *le* and *in* long, setiform and smooth; seta *ro* inserted at the tip of rostrum, seta *le* inserted anteromedial to seta *in*; length of setae varies in the sequence *in>ro>le*; bothridial cups not well developed; seta *ex* inconspicuous.

Notogaster: Notogaster with 10 pairs of setae (*c1*, *c2*, *c3*, *cp*, *d1*, *d2*, *e1*, *e2*, *h1* and *h2*) setae *ps1-3*, absent.

Ventral region: Infracapitulum stenarthric, setae *h*, *m*, *a* setiform, smooth, setae *m* little shorter than the other; epimeres with paired, smooth plates having weakly defined borders, epimeralsetal formula 3–1–2, all setae setiform, smooth, with flagellate tip; genital, aggenital, anal and adanal setae not developed.

Legs: All legs monodactylous.

Protonymph

Dorsal region (Fig. 3B). Length: 270-292 µm; width: 119-128 µm.

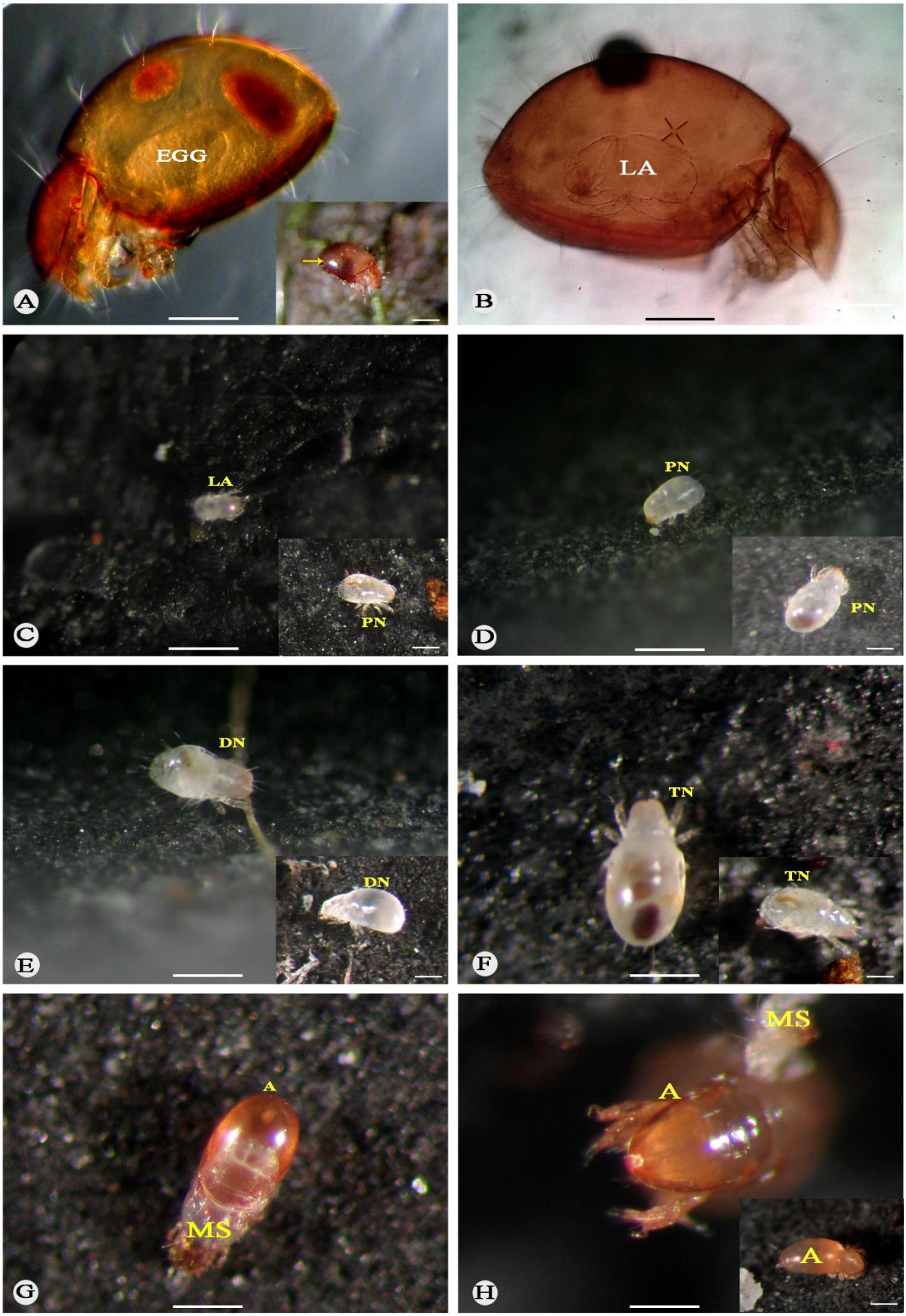

Figure 2. A. Adult of *Acrotritia clavata* showing egg inside the body, **B.** Adult of *A. clavata* with fully developed larva (LA), **C.** Newly emerged larva (LA) and protonymph (PN), **D.** Protonymph and its quiescent phase, **E.** Deutonymph (DN) feeding on dead filaments of *Microspora* sp. and quiescent deutonymph, **F.** Tritonymph (TN) and quiescent tritonymph, **G.** Moulting of quiescent tritonymph to adult (A) and moulting skin (MS) of quiescent tritonymph, **H.** Newly emerged adult (A) (Scale bar=1mm).

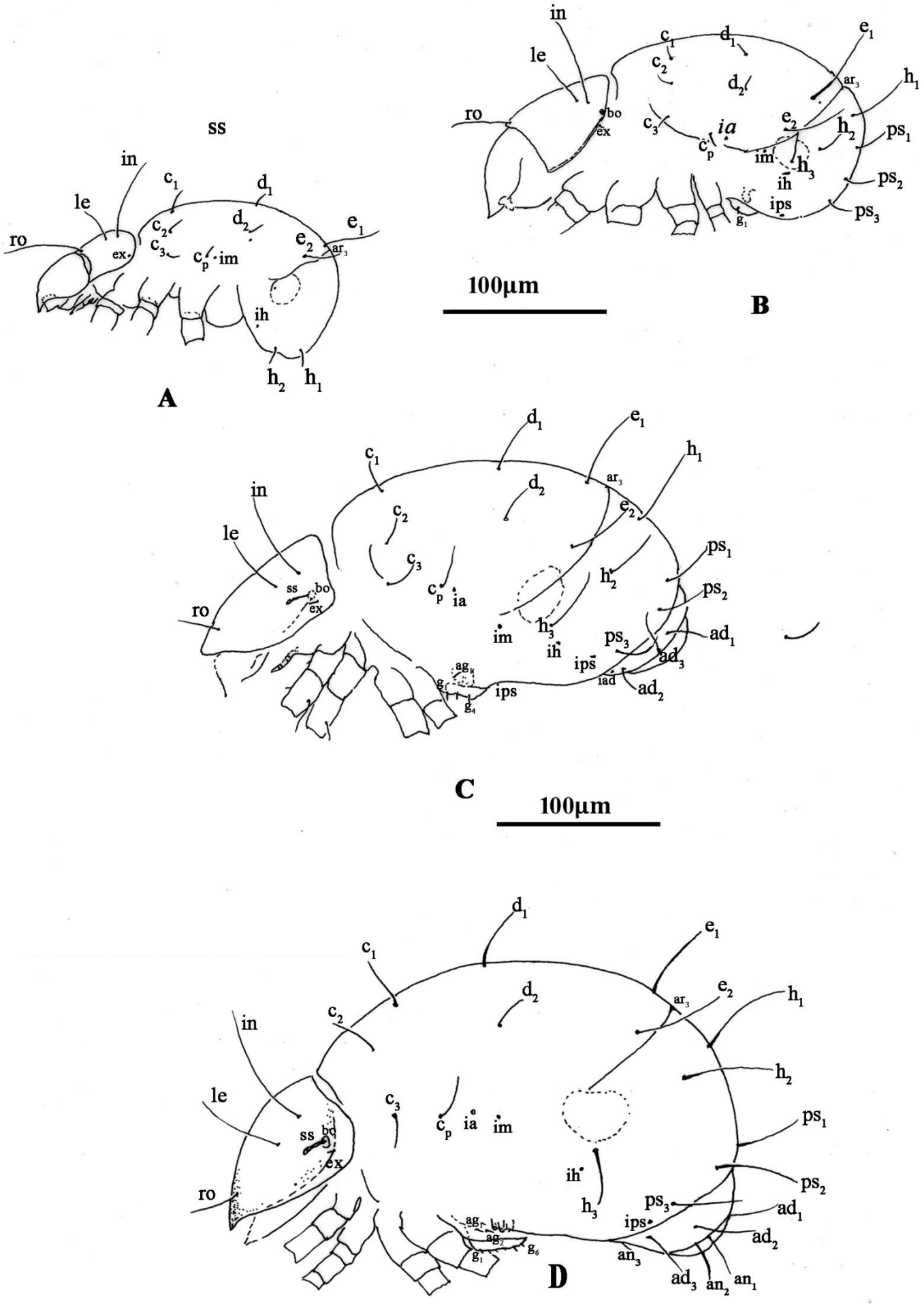

Figure 3. *Acrotritia clavata* (lateral view). **A.** Larva, **B.** Protonymph, **C.** Deutonymph, **D.** Tritonymph.

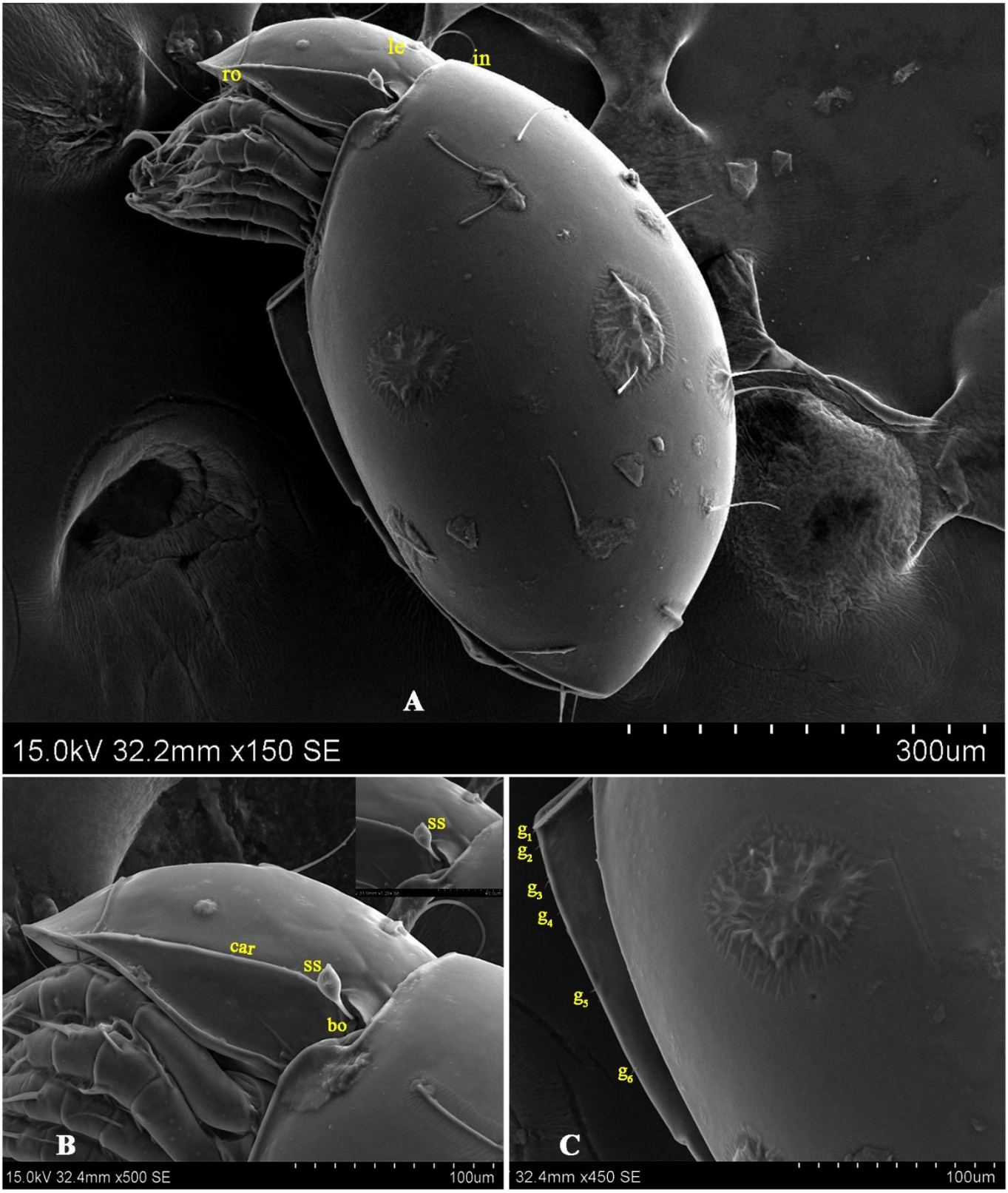

Figure 4. SEM image of *Acrotritia clavata* (lateral view). **A.** Aspis with prodorsal setae (*in*, *le* and *ro*), **B.** Enlarged view of aspis showing clavate sensillus (ss), bothridium (bo) and lateral carina (car), **C.** Genital plate with 6 pairs of small fine genital setae (*g1-6*).

Larger than the larva and easily identified by the presence of 4 pairs of legs. Body almost cylindrical in appearance, and not ptychoid. One pair of genital suckers present.

Prodorsum: Comparatively short and reaching about half the length of the notogaster; rostrum widely rounded, all prodorsal setae, smooth with flagellate tip; length of setae *in>ro>le*; bothridium and setae *ex* present.

Notogaster: Notogastral surface smooth, 14 pairs of smooth setae inserted on the notogaster, setae *h3*, *ps1*, *ps2* and *ps3* newly added in this stage, setae *e1*, *h1* long-

est, other setae much shorter; distinct simple transverse linear groove (*ar3*) present, posterior to setae of *e*- series.

Ventral region: Infracapitulum stenarthric, setae *h*, *m*, *a* setiform and smooth; epimeral plates with weakly defined borders; epimeral setal formula 3–1–2–1, all setae setiform, smooth, longest with flagellate tip, 1 pair of genital setae and one pair of genital suckers present; anal and adanal setae not developed.

Deutonymph

Dorsal region (Fig. 3C). Length: 306-314 µm; width: 146-160 µm.

Prodorsum: Prodorsal integument smooth; rostrum elongated; prodorsal setae smooth and of varying size, seta *in* the longest, length of prodorsal hairs varies in the order *in*>*le*>*ro*; seta *ex* conspicuous; sensillus clavate; bothridial cups well developed.

Notogaster: Notogastral integument delicate, smooth; number of notogastral setae same as that of the protonymphal stage, setae *e1*, *e2*; *h1-3* and *ad1-3* long with flagellate tip; lyrifissures *ia*, *im* and *ip* clearly visible in lateral view.

Ventral region: Infracapitum stenarthric type, bearing 3 pairs of simple, smooth setae; epimeralsetal formula 3–1–3–2, all setae smooth and setiform; genital plates with 4 pairs of simple, minute genital setae (*g1-4*) and 2 pairs of genital suckers; 2 pairs of minute aggenital setae present on the lateral margins of the aggenital plates; 3 pairs of long, smooth, adanal setae (*ad1-3*) present; anal setae absent.

Tritonymph

Dorsal region (Fig. 3D). Length: 327-340 µm; width: 210-224 µm.

Body off–white in colour. Largest among the juvenile stages and easily distinguishable due to the larger size, presence of 3 pairs of genital suckers and the off-white colouration. Tip of the rostrum sclerotized with light brown colouration.

Prodorsum: Extended into an elongated rostrum; prodorsal surface ornamented with very fine granules, prodorsal integument pale brown in colour; carinae developed as narrow line below the bothridium; all prodorsal setae well developed, smooth, setiform with flagellate tips.

Notogaster: 14 pairs of setae, setae of series *e1*, *h1* and *ps1* longer than the rest; notogastral integument smooth and delicate.

Ventral region: Infracapitulum stenarthric type with 3 pairs of simple, smooth setae; epimeralsetal formula 3–1–3–3, all setae setiform, smooth, setae *1b, 3c* and *4c* equal in size and with flagellate tip; anogenital plates conspicuous; 6 pairs of minute, simple genital setae (*g1-6*) present; 3 pairs of adanal and 3 pairs of anal setae present on the fused ano-adanal plates, seta *an3* small, located near the interlocking triangle area.

Legs: All legs monodactylous.

Adult

(Figs 4 A-C). Length: 622-743µm; width: 534-581 µm.

Prodorsum: Prodorsum with a pair of lateral carina; setae on aspis more delicate than those of other species of the genus, the posterior most pair conspicuously long and somewhat curved; length of setae: *in*>*le*>*ro*>*ex*; lamella incised medially and above bothridium; exobothridial setae small; sensilli with a narrow stalk and clubbed head, rough, almost smooth; bothridium not distinctly spiral in top view, but appears as a distinctly spiral structure in semi-oblique view; entire prodorsal surface punctated.

Notogaster: Notogaster with 14 pairs of fine, short, rigid setae, without sign of shagreen appearance, setae *c1* and *c2* considerably remote from anterior margin, setae *c3* closer to margin; opening of latero-opisthosomal gland distinct; 5 lyrifissures and 2 vestigial setae present on both sides; ornamented with punctations under higher magnification (400x).

Ventral region: Infracapitulum with seta *h* longer than their mutual distance; palps 3 segmented with a setal formula of 2–2–7, palp tarsus carries a single solenidion (*ω)*; epimeralsetal formula 3–1–3–3, all setae smooth and setiform; genito-aggenital plates almost smooth, genital plates carry 6 pairs of small, fine setae, 2 pairs of short, smooth aggenital setae, inserted one behind the other; 3 pairs of anal (*an1-3*) detected, of which seta *an*3 the smallest; 3 pairs of long, setiform adanal setae, *ad*1 inserted conspicuously far from *ad2* and *ad3*.

Legs: All legs monodactylous with strong claw, chaetotaxy of leg I: 3–2(2)–4(1)–15(1).

DISCUSSION

The present study described the embryonic development of the oribatid mite species, *Acrotritia clavata*, under laboratory conditions. The reproductive pattern of oribatids inhabiting mangrove ecosystems shows variation, depending on their environmental, physiological and morphological characteristics (Schulte, 1976; Ernst, 1995; Karasawa and Hijii, 2004). The species A. clavata completed its development from egg to adult within 61-72 days. This species was found associated with mangrove litter, dead pneumatophores and from algal cushions (*Microspora* sp.) growing on the barks and twigs of the mangrove plant, *Avicennia marina*. In the culture cells, both aggregation and wandering was observed; some crawled on the substratum and started wandering, apparently in search of food (Schulte et al., 1975; Schulte, 1976; Convey, 1994; Bücking et al., 1998; Søvik, 2004). Krisper and Schuster (2008) observed aggregations in littoral Ameronothridae; such aggregations are hypothesized to be protection against wave action (Schulte et al., 1975; Bücking et al., 1998; Søvik, 2004). The individual difference in duration of development could be attributa-

ble to the difference in the microhabitat and life style of the oribatid mites (Luxton, 1966). Moreover, the feeding and breeding habits of the intertidal oribatids have to be synchronized with tidal rhythms (Chatterjee et al., 2018) which were not possible under laboratory conditions.

In the present study, the adult females of *A. clavata* had developed pre-larvae inside their body cavities. The occurrence of a pre-larval stage has been reported as a feature in many oribatids (Behan-Pelletier 1999; Krivolutskiy, 1975; Liu and Chen, 2015) and is very common among phthiracaroids. In the present study, females of *A. clavata* carrying mature pre-larvae gave birth to fully developed larvae among the feeding substrates in the culture cells, and no oviposition was noticed. Prelariviposition and lariviposition have been previously reported in terrestrial oribatids (Clement and Haq, 1984). Members of the littoral Ameronothridae are also known to be mainly larviparous (Luxton, 1966; Bücking et al., 1998; Søvik, 2003). Viviparity is commonplace among littoral mites, suggesting that this provides an advantage by eliminating the vulnerable egg stage and/or by reducing the washing effects of tidal waves (Luxton, 1964, 1967).

Terrestrial oribatids possess two types of lariviposition in which larvae either emerge from the egg found inside the gravid female and are then deposited (true larviparity or viviparity), or larvae may hatch soon after deposition, a phenomenon termed ovoviviparity (Bücking et al., 1998). Intertidal mites of the genus *Ameronothrus* Berlese, 1896 inhabiting the littoral zone and estuaries show larviparity as an ancestral plesiotypic trait (Ermilov, 2011; Lions, 1966; Luxton, 1964). Larviparity has several advantages over oviparity in intertidal mites which are constantly exposed to flooding; occurrence of lariviposition would help to overcome the washing effects of tidal currents (Lions, 1966). The occurrence of viviparity in salt-marsh acarines under tidal conditions shows that it provides an ecological advantage (Chakraborty, 2011). However, details are lacking on the feeding and reproductive traits of marine/mangrove littoral inhabiting intertidal oribatids (Ermilov, 2011).

During the present study, the completion of studies on the feeding and biological aspects of the subject intertidal zone oribatid mite was a difficult task because of some limitations in the laboratory conditions. Concerning the reproduction of littoral oribatid mites, there has not been a detailed study (Pfingstl, 2013). The mangrove environment undergoes temporal changes in tidal rhythms, temperature and wind, salinity (Luxton, 1990) so it was found difficult to provide such specified natural climatic conditions in the laboratory for the successful establishment of the species.

In depth studies on the physiology, ecology and feeding biology of individual intertidal oribatid species is essential for the confirmation/elucidation of their active role in extremely productive ecosystems like mangroves.

Funding

This work has been supported by the University Grants Commission (UGC), New Delhi, India by providing financial assistance in the form of a Rajiv Gandhi National Fellowship (RGNF-SRF).

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

The first author is grateful to Dr. Roy A. Norton, Professor (Rtd.), State University of New York, Syracuse, USA for supplying the relevant literature for the confirmation of the identity of the species.

REFERENCES

Baran, S. and Ayyildiz N. 2000. Systematic studies on *Rhysotritia ardua* (C.L. Koch) (Acari, Oribatida) in Erzincan and Erzurum Plains. Turkish Journal of Zoology, 24: 231-236.

Behan-Pelletier, V.M. 1999. Oribatid mite biodiversity in agro ecosystems: Role for bioindication. Agriculture. Ecosystems & Environment, 74 (1-3): 411-423. doi: 10.1016/S0167-8809(99)00046-8

Bingül, M., Taşdemir, A., Zeytun, E., Doğan, S. and Ayyıldız, N. 2016. The relationship between female body size and egg number and size of *Acrotritia ardua* (Koch, 1841) (Acari, Oribatida, Euphthiracaridae). 8th Symposium of the European Association of Acarologists (EURAAC-2016), 11-15 July, Valencia, Spain, p. 88.

Bücking. J., Ernst, H. and Siemer, F. 1998. Population dynamics of phytophagous mites inhabiting rocky shores - K-strategists in an extreme environment? In: Arthropod Biology: Contributions to Morphology, Ecology and Systematics. Ebermann, E. (Ed.). Biosystematics and Ecology Series, 14: 93-143.

Chakraborty, S.K. 2011. Mangrove ecosystem of Sundarbans, India: Biodiversity, ecology, threats and conservation. In: Mangroves: Ecology, biology and taxonomy. Metras, J.N. (Ed.). NOVA Publishers, New York, USA, 83-112.

Chatterjee, T., Pfingstl, T. and Pešić, V. 2018. A checklist of marine littoral mites (Acari) associated with mangroves. Zootaxa, 4442 (2): 221-240. doi: 10.11/zootaxa.4442

Clement, A. and Haq, M.A. 1984. Biology of *Pelokyllamalabarica* (Acari: Oribatei). In: Acarology VI. Griffiths, D.A. and Bowman, C.E. (Eds). Ellis Howood Ltd, Chichester, England, 847-854.

Convey, P. 1994. Sex ratio, oviposition and early development of the Antarctic oribatid mite *Alaskozetes antarcticus* (Acari: Cryptostigmata) with observations on other oribatids. Pedobiologia, 38: 161-168.

Ermilov, S.G. 2011. Morphology of juvenile stages of *Acrotritia ardua* (Koch, 1841) (Acari, Oribatida, Euphthiracaridae). North-Western Journal of Zoology, 7: 132-137.

Ernst, H. 1995. Endogenous circatidal activity rhythm in a littoral mite, *Bdella septentrionalis* (Acarina, Bdellidae). Acarologia, 36: 315-324.

Fernandez, N.A., Alberti, G. and Kümmel, G. 1991. Spermatophores and spermatozoa of oribatid mites (Acari: Oribatida). Part I: Fine structure and histochemistry. Acarologia, 32: 261-286.

Haq, M.A. and Ramani, N. 1984. Postembryonic development of *Paralamellobates bengalensis* (Acari: Oribatei) parasitic on *Dioscorea alata*. In: Acarology VI. Griffiths, D.A. and Bowman, C.E. (Eds). Ellis Howood Ltd, Chichester, England, 819-825.

Haq, M.A. and Ramani, N. 2002. Sampling, extraction and identification of oribatid mites. In: Mites, their identification and management. Yadav, P.R., Chauhan, R. Putatunda, B.N. and Chhiliar, B.S. (Eds). ICAR Centre of Advanced Studies, Department of Entomology CCSS, Haryana Agricultural Univeristy, Hisar, India, 195-212.

Karasawa, S. and Hijii, N. 2004. Morphological modifications among oribatid mites (Acari: Oribatida) in relation to habitat differentiation in mangrove forests. Pedobiologia, 48: 383-394.
doi: 10.1016/j.pedobi.2004.05.003

Krisper, G. and Schuster, R. 2008. *Fortuynia atlantica* sp. nov. thalassobiontic oribatid mite from the rocky coast of the Bermuda Islands (Acari: Oribatida: Fortuyniidae). Annales Zoologici (Warszawa), 58 (2): 419-432.
doi: 10.3161/000345408X326753

Krivolutskiy, D.A. 1975. Family Euphthiracaridae Jacot, 1931. In: Key to soil inhabiting mites. Sarcoptiformes. Ghilyarov, M.S. (Ed.). Nauka Press, Moscow, Russia, 374-377. [In Russian]

Lions, J.C. 1966. Contribution à l'étude du genre *Rhysotritia* (Acarien, Oribate): *Rhysotritia clavata sextiana* n. subsp. Vie et Milieu, 17: 779-794. [In French]

Lions, J.C. 1967. La prélarve de *Rhysotritia ardua* (C.L. Koch) 1836 (Acarien, Oribate). Acarologia, 9: 263-283. [In French]

Luxton, M. 1964. Some aspects of the biology of saltmarsh Acarina. 1st International Congress of Acarology, 2-7 September 1963, Fort Collins, Colorado, USA, 172-182.

Luxton, M. 1966. Laboratory studies on the feeding habits of saltmarsh acarina, with notes on their behaviour. Acarologia, 8: 163-175.

Luxton, M. 1967. The ecology of salt-marsh Acarina. The Journal of Animal Ecology, 36 (2): 257-277.
doi: 10.2307/2911

Luxton, M. 1990. Local distribution and habitat of mites (Acari) on the sea coast of New Zealand. Journal of the Royal Society of New Zealand, 20 (4): 419-426.
doi: 10.1080/03036758.1990.10426720

Märkel, K. 1964. The Euphthiracaridae Jacot, 1930 and their genera (Acari, Oribatei). Zoologische Verhandelingen, 67: 1-78. [In German]

Pfingstl, T. 2013. Revealing the diversity of a once small taxon: the genus *Selenoribates* (Acari, Oribatida, Selenoribatidae). ZooKeys, 312: 39-63.
doi: 10.3897/zookeys.312.5478

Schulte, G. 1976. Gezeitenrhythmische Nahrungsaufnahme und Kotballenablage einer terrestrischen Milbe (Oribatei: Ameronothridae) im marinen Felslitoral. Marine Biology, 37: 265-277. [In German]
doi: 10.1007/BF00387612

Schulte, G., Schuster, R. and Schubart, H. 1975. On the distribution and ecology of Ameronothridae (Acari, Oribatei) in terrestrial, limnic and marine habitats. Veröffentlichungen des Instituts für Meeresforschung in Bremerhaven, 15: 359-385. [In German]

Schuster, R. 1979. Soil mites in the marine environment. In: Recent Advances in Acarology. Rodriguez, J.G. (Ed.). Academic Press, New York, USA, 1: 593-602.
doi: 10.1016/B978-0-12-592201-2.50084-1

Søvik, G. 2003. Observations on ovoviviparity and mixed-parity mode in Arctic populations of *Ameronothrus lineatus* (Acari, Oribatida). Acarologia, 43: 393-398.

Søvik, G. 2004. The biology and life history of Arctic populations of the littoral mite *Ameronothrus lineatus* (Acari, Oribatida). Experimental and Applied Acarology, 34: 3-20.
doi: 10.1007/978-94-017-0429-8_2

Subías, L.S. 2004. Listado sistemático, sinonímico y biogeográfico de los ácaros oribátidos (Acariformes: Oribatida) del mundo (excepto fósiles). 536 pp. Available http://bba.bioucm.es/cont/docs/RO_1.pdf (Last accessed: 8 November 2019). [In Spanish]

Syamjith, P.K.and Ramani, N. 2013. Association of a mangrove dwelling euphthiracarid mite, *Acrotritia clavata* (Märkel 1964) (Acari: Oribatida) with the epiphytic alga, *Microspora* sp. International Journal of Acarology, 39: 615-619.
doi: 10.1080/01647954.2013.862568

Webb, N. 1978. Observations on *Steganacarus magnus*: General biology and life cycle. Acarologia, 19 (4): 686-696.

Weigmann, G. 2006. Hornmilben (Oribatida). In: Die Tierwelt Deutschlands und der angrenzenden Meeresteile. Dahl, F. (Ed.). Goecke & Evers, Keltern, 76 Teil, 1-520. [In German]

Wissuwa, J., Salamon, J.A. and Frank, T. 2013. Oribatida (Acari) in grassy arable fallows are more affected by soil properties than habitat age and plant species. European Journal of Soil Biology, 59: 8-14. doi: 10.1016/j.ejsobi.2013.08.002

Woodring, J.P. 1962. Oribatid pteromorphs, pterogasterine phylogeny and evolution of wings, Annals of the Entomological Society of America, 55: 394-402. doi: 10.1093/aesa/55.4.394

Edited by: İbrahim Çakmak
Reviewed by: Two anonymous referees

Citation: Padinhare Kaithayil, S. and Neravathu, R. 2020. Biology of the oribatid mite *Acrotritia clavata* (Märkel, 1964) from the mangrove ecosystems of North Kerala, India. Acarological Studies, 2 (2): 59-68.