

A new species of *Tarsonemus* (Acari: Tarsonemidae) associated with the bark beetle, *Polygraphus proximus* (Coleoptera: Curculionidae: Scolytinae) from the Far East of Russia

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ABSTRACT — Larvae, males and females of a new species from the *minimax* species-group, *Tarsonemus striatus* **n. sp.** (Acari: Tarsonemidae) are described from the galleries of, and phoretic on, the bark beetle *Polygraphus proximus* Blandford, 1894 (Coleoptera: Curculionidae: Scolytinae) in the Far East of Russia.

KEYWORDS — Heterostigmatina; Tarsonemoidea; systematics; morphology; phoresy

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INTRODUCTION

Four-eyed fir bark beetle, *Polygraphus proximus* Blandford, 1894, is an invasive species and has become the major cause of death of fir trees in the Siberian and European parts of Russia (Kerchev 2014; Kononov *et al.* 2016). Originally inhabiting the Far East of Eurasia and nearby islands, including the Russian Far East, *P. proximus* has rapidly expanded its distribution westward (Kerchev 2014). Despite high economic importance of the four-eyed fir bark beetle, nothing is known about mites associated with it. During the study of mites associated with *P. proximus*, a new species, *Tarsonemus striatus* **n. sp.** (Acari: Tarsonemidae) from the *minimax* species-group, was revealed in native populations of the four-eyed fir bark beetle in the Far East of Russia.

The genus *Tarsonemus* Canestrini and Fanzago,

1876 is the largest in the family Tarsonemidae and includes more than 270 species (Lin and Zhang 2002; Magowski 2002, 2010; Lofego *et al.* 2005). Some *Tarsonemus* mites are known as a vector for the dispersal of fungal spores, carrying them in sporothecae located under the lateral parts of tergite C in females. Potentially they can carrying fungal spores on cerotegument on prodorsum and tergites C and D as was recently discovered by Rezende *et al.* (2015) for the genera *Daidalotarsonemus* De Leon and *Excelsotarsonemus* Ochoa and Naskręcki. The best studied case is the mutualistic association of *Tarsonemus krantzi* Smiley and Moser, 1974 and *T. ips* Lindquist, 1969 with *Ophiostoma minus* (Hedgcock) Syd. & P. Syd associated with southern pine beetle (*Dendroctonus frontalis* Zimmermann, 1968) in North America (Lombardero *et al.* 2003).

Lindquist (1986) divided the genus *Tarsonemus* into three subgenera: *Tarsonemus* s. str., *Chaetotarson-*

emus Beer and Nucifora, 1965 and *Floridotarsonemus* Attiah, 1970. Magowski (2010) created the subgenus *Schaarschmidtia* Magowski, 2010, which includes species previously placed in the *pyrrhidi* species-group of the subgenus *Tarsonemus* (Magowski and Moser 2003).

At least two groups of *Tarsonemus* are bark beetle associates: the subgenus *Schaarschmidtia* Magowski, 2010 and the *minimax* species-group (Magowski and Moser 2003; Magowski 2010).

The *minimax* species-group currently includes nine species: *T. minimax* Vitzthum, 1926, *T. crassus* (Schaarschmidt, 1959), *T. triarcus* Lindquist, 1969, *T. subcorticalis* Lindquist, 1969, *T. endophloeus* Lindquist, 1969, *T. krantzi* Smiley and Moser, 1974, *T. suskii* Smiley and Moser, 1974, *T. terebrans* Magowski and Moser, 2003, and *T. typographi* Magowski and Moser, 2003 (Magowski and Moser 2003). Magowski and Moser (2003) reviewed the *minimax* species-group and provided a key to its species. Most species of *minimax* species-group are associated with various bark beetles and distributed in Holarctic (Lindquist 1969; Smiley and Moser 1974; Magowski and Moser 2003). Detailed distribution and host range is discussed in Magowski and Moser (2003). The morphological distinctions between *minimax* species-group and other groups within subgenus *Tarsonemus* are not clearly defined because no differential diagnosis was provided in Magowski and Moser (2003). Magowski and Moser (2003) suggested that members of the *minimax* species-group are similar to the *gladifer* and *floricolus* species-groups, but the reference of two latter groups is an unpublished work of Magowski. Despite such vague diagnosis of *minimax* species-group, *Tarsonemus striatus* n. sp. undoubtedly belongs to this group because of the morphological similarity to *T. triarcus*, the member of this group, and similar ecology.

The aim of this article is to describe all developmental stages of *Tarsonemus striatus* n. sp. associated with the bark beetle *Polygraphus proximus*.

MATERIALS AND METHODS

Pieces of bark of Manchurian fir (*Abies nephrolepis*) containing adult four-eyed fir bark beetle (*Polygraphus proximus*) and its galleries were placed in plastic boxes and transported to the laboratory. In the laboratory pieces of bark and living beetles were inspected for mites using a Discovery V8 (Carl Zeiss, Germany) stereomicroscope. Most of the collected mites were mounted in Hoyer's medium. Some living beetles carrying phoretic tarsonemid mites were selected for SEM micrographs. The terminology follows that of Lindquist (1986), except the ventral subcapitular seta is labeled *su* (Seeman *et al.* 2016). All measurements are given in micrometers (μm) for the holotype, five female paratypes (in parentheses), three males and five larvae (ranges). For leg chaetotaxy the number of solenidia is given in parentheses. Scanning electron micrographs were made with the aid of JEOL-JSM-6510LV SEM microscope. DIC micrographs were taken using the Carl Zeiss Axio Imager A2 compound microscope and digital Camera Hitachi KP-HD20A. The holotypes and most paratypes of the new species are deposited in the mite collection of the Tyumen State University Museum of Zoology, Tyumen, Russia; two female paratypes of the new species are deposited in the acarological collection of the Zoological Institute of RAS, St. Petersburg, Russia.

RESULTS

Systematics

Family Tarsonemidae Canestrini and Fanzago, 1877

Genus *Tarsonemus* Canestrini and Fanzago, 1876

Type species: *Chironemus minusculus* Canestrini and Fanzago, 1876, by monotypy.

***Tarsonemus striatus* n. sp.
(Figures 1-11)**

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Description

Female (Figures 1-4, 11) — Length of idiosoma 180 (170-190), width 110 (105-125).

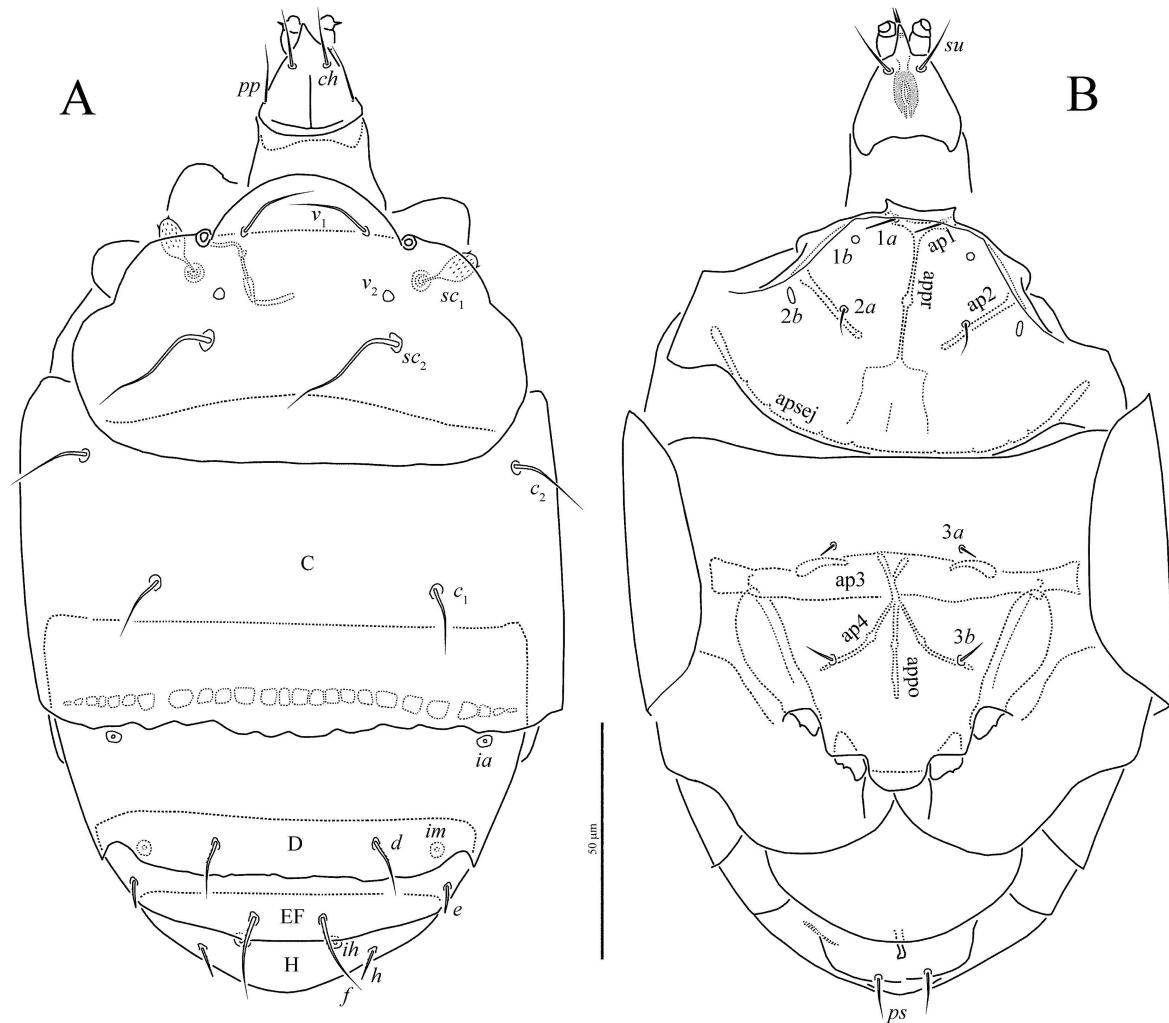


FIGURE 1: *Tarsonemus striatus* n. sp., female: A – dorsum of the body; B – venter of the body.

Gnathosoma — Gnathosomal capsule subtriangular, slightly longer than its width. Length of gnathosomal capsule 29 (27–29), width 23 (20–23). Dorsomedian apodeme well developed, extending nearly entire distance from union basally with circumcapitular apodeme to level of insertion of dorsal gnathosomal setae (*ch*). Gnathosoma with dorsal pair of setae *ch* 13 (13–14) subequal to subcapitular setae *su* 13 (12–13); both setae slender and smooth. Palpcoxal setae (*pp*) subequal to *ch*, slender and pointed. Palps short 8 (7–8) cylindrical, with short dorsolateral setae. Pharynx (Figure 2D) with well-developed muscular sheath and with in-

conspicuous pair of glandular structures at its posterior extremity.

Idiosomal dorsum (Figures 1A, 2A–C, 11C) — Prodorsal shield with distinct linear microsculpture (Figure 2A); margin of shield distinctively tri-arcuate anteriorly and laterally, although lateral arches sometimes inconspicuous if folded ventrally. Prodorsum without median apodeme. Tracheal trunks without sclerotized sacs. Pseudostigmatic organs capitate, ellipsoidal, finely spiculate but with two larger spicules apically, and completely covered by prodorsal shield. All hysterosomal tergites with fine longitudinal striation (Figures 2B–C, 11C).

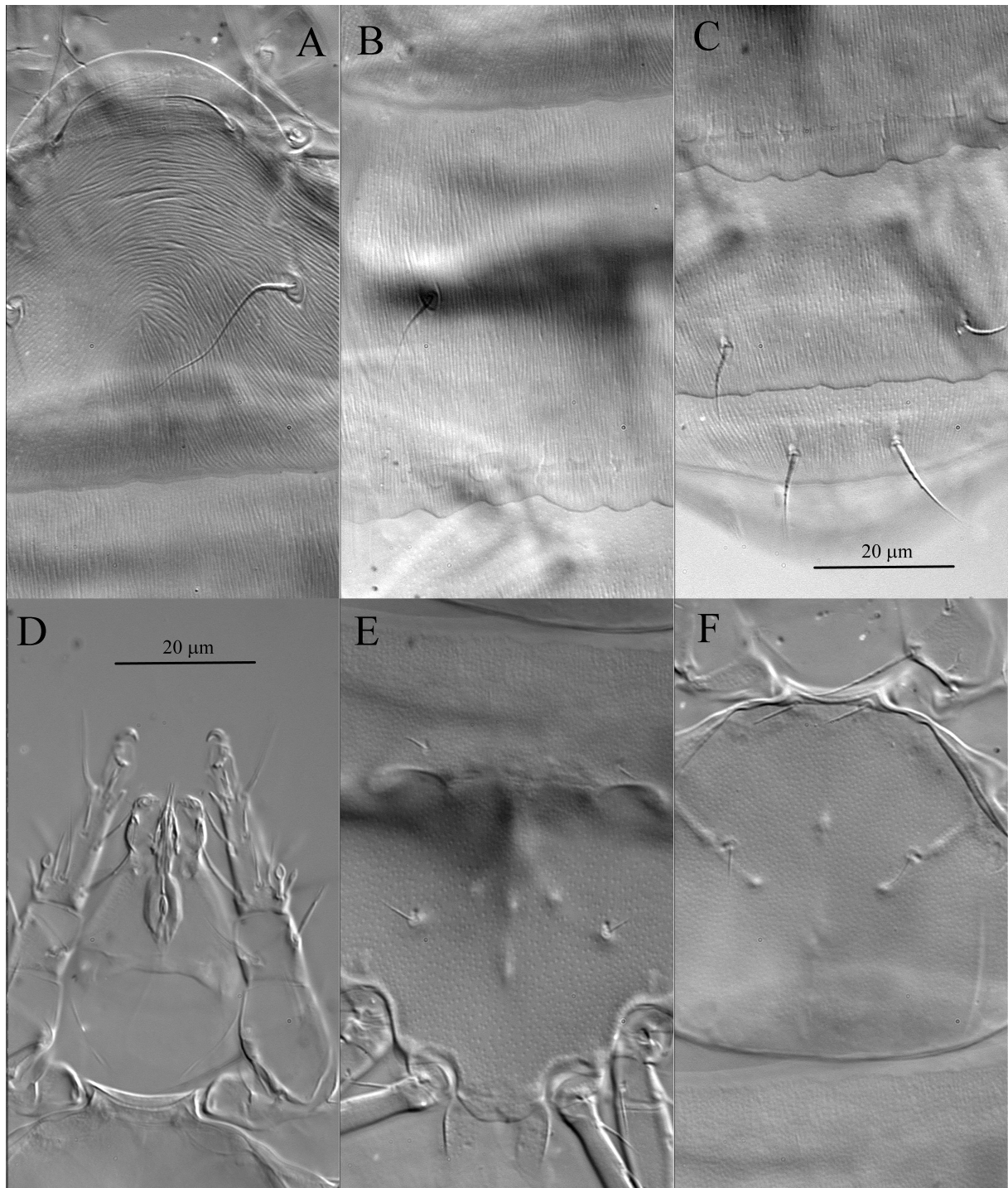


FIGURE 2: DIC micrographs of *Tarsonemus striatus* n. sp. female: A – central part of prodorsal shield; B – central part of tergite C; C – central parts of tergites D and EF; D – pharynx; E – central part of posterior sternal plate; F – central part of anterior sternal plate.

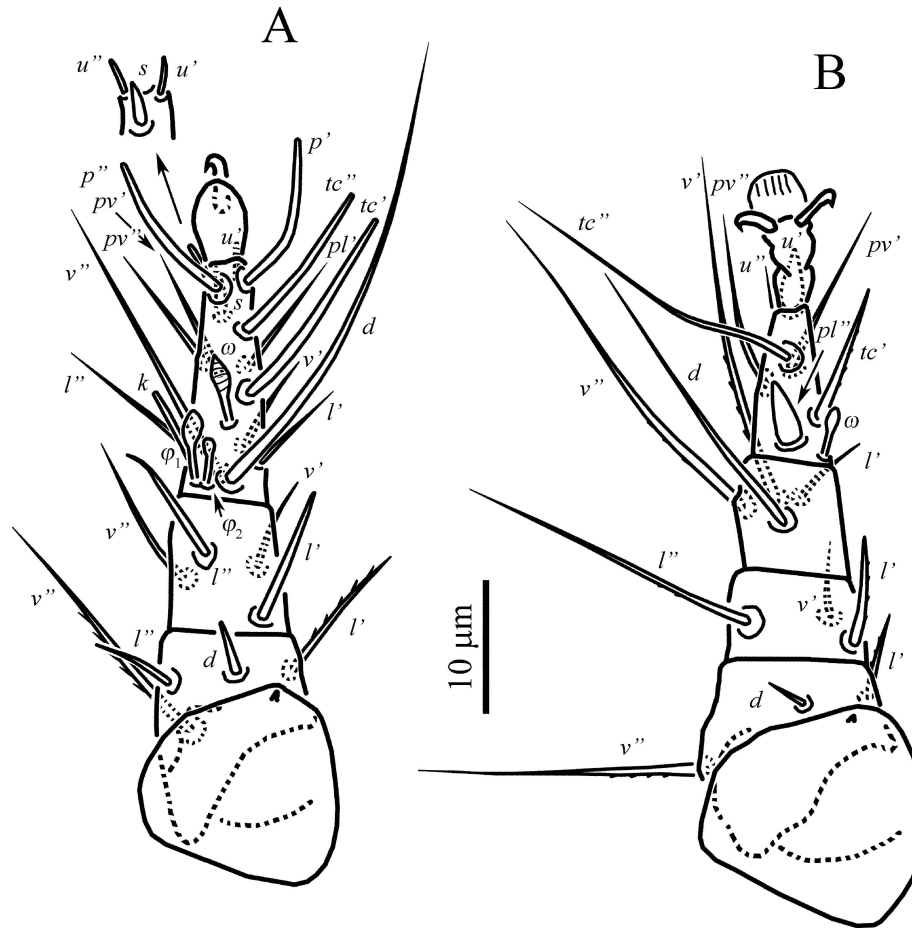


FIGURE 3: *Tarsonemus striatus* n. sp., female: A – left leg I in dorsal view; B – left leg II in dorsal view.

Setae v_1 , sc_2 , c_1 and c_2 smooth and pointed; setae d and f weakly barbed and pointed; setae e and h blunt-ended and weakly barbed. Posterior margin of tergite C distinctly undulate (Figures 2B–C, 11C), posterior margin of tergite D sometimes also weakly undulate. Lengths of dorsal setae: v_1 18 (17–19), sc_2 36 (34–36), c_1 21 (17–22), c_2 25 (22–26), d 14 (13–15), e 7 (6–7), f 20 (19–21), h 7 (6–7). Distances between setae: v_1 – v_1 26 (25–28), v_2 – v_2 36 (35–37), sc_2 – sc_2 39 (38–40), c_1 – c_1 60 (59–63), c_2 – c_2 97 (91–98), c_1 – c_2 34 (31–34), d – d 36 (34–37), e – e 71 (66–72), e – f 28 (26–30), f – f 15 (14–15), h – h 39 (36–39).

Idiosomal venter (Figures 1B, 2E–F) — Prosternal

apodeme (appr) extending posteriad only slightly beyond apodemes 2 (ap2), and with nodule between apodemes 1 (ap1) and ap2. Ap2 very slightly curved, and ending with small nodule medially. Sternal apodeme (apsej) well developed, continuous, and with few weak processes directed anteriorly. Anterior sternal plate with uniform, very small dimples (Figure 2F). Setae 1a needle-like; 2a pointed, smooth. Apodemes 3 (ap3) united medially to form one continuous, subsurface band across metapodosomal venter, and extending laterally beyond anterior extremities of trochanters III. Setae 3a and 3b minute, needle-like. Apodemes 4 (ap4) reach-

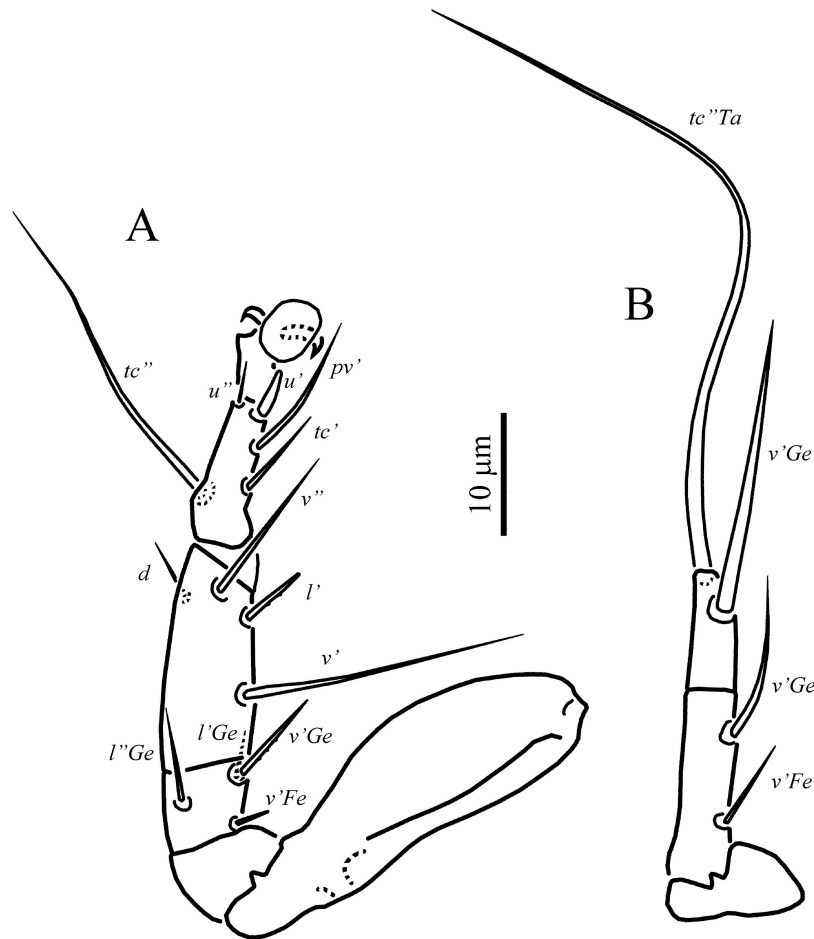


FIGURE 4: *Tarsonemus striatus* n. sp., female: A – left leg III in ventral view; B – left leg IV in ventral view.

ing slightly posteriad of $3b$ bases. Tegula rounded, short, flanked on either side by short, curved, conspicuous line. Posterior sternal plate with distinctly larger dimples in central part and smaller laterally (Figure 2E). Pseudanal setae smooth, pointed, about as long as distance between their bases. Lengths of ventral setae: $1a$ 7 (7), $2a$ 9 (7-9), $3a$ 4 (4), $3b$ 5 (5-6), ps 10 (7-10). Width of tegula 13 (12-13).

Legs (Figures 3-4) — Legs: chaetotaxy (including unguinal setae u' , u'' on tibiotarsus I and u'' on tarsi II and III) of leg I: $Fe4-Ge4-TiTa6(2\phi)+10(1\omega)$; leg II: $Fe3-Ge3-Ti4-Ta7(1\omega)$; leg III: $FeGe1+3-Ti4-Ta5$. Lengths of legs: I 60 (56-60), II 58 (55-58), III 53 (49-

54), IV 32 (30-33). Leg I (Figure 3A). Solenidion ω capitate, with slightly pointed tip; solenidia ϕ_1 and ϕ_2 capitate; seta k 7 (6-7) rod-shaped, slightly longer than solenidion ϕ_1 . Lengths of solenidia: ω 6 (6) = ϕ_1 6 (5-6) > ϕ_2 4 (3-4). Seta d of femur slightly thickened, blunt-ended and smooth; seta s slightly thickened, spiniform; unguinal setae (u) short, blunt-ended; setae l'' of femur, (l) and v' of genu blunt-ended and smooth; seta l' of femur distinctly barbed and slightly blunt-ended, seta v'' of femur distinctly barbed and pointed; other leg setae (except eupathidia) pointed and smooth. Femur with weak flange near base of seta v'' . Leg II (Fig-

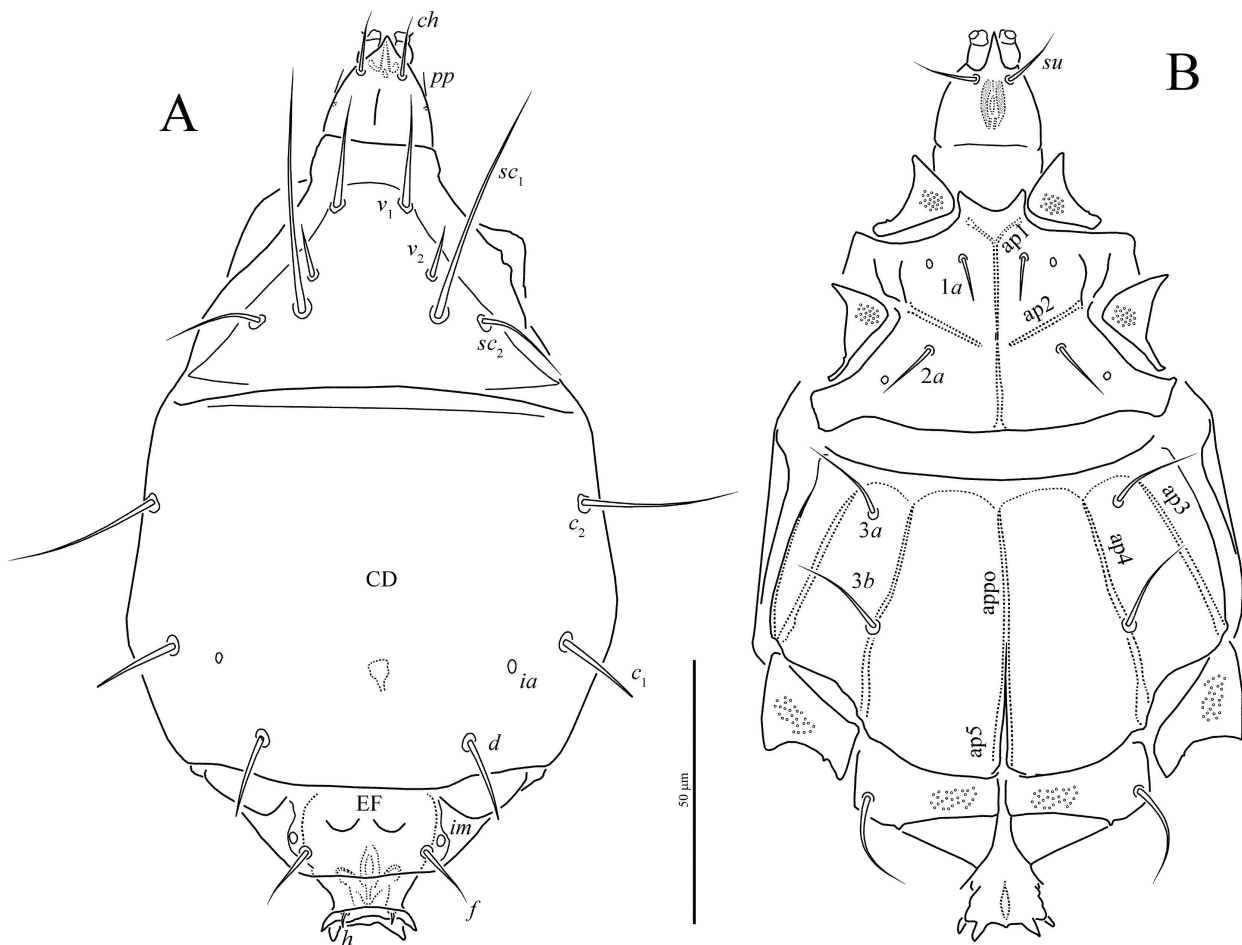


FIGURE 5: *Tarsonemus striatus* n. sp., male: A – dorsum of the body; B – venter of the body

ure 3B). Solenidion ω 4 (4) capitate. Setae pl'' and u' spine-like; setae l' of femur, l' of genu, and tc' of tarsus blunt-ended and weakly barbed; seta d of femur needle-like; setae v' of genu and l' of tibia slightly blunt-ended and smooth; setae v'' of femur, l'' of genu, and (v) of tibia long, pointed and weakly barbed; other leg setae pointed and smooth. Leg III (Figure 4A). Setae v' of femur and l' of genu needle-like; setae v' of genu and l' of tibia blunt-ended and weakly barbed; seta u' slightly thickened, spiniform; other leg setae pointed and smooth. Leg IV (Figure 4B). Seta v' of femur slightly blunt-ended, smooth; other leg setae pointed and smooth.

Male (Figures 5-8) — Length of idiosoma 125-150,

width 85-95.

Gnathosoma — Gnathosomal capsule, including pharyngeal structures, similar to that of female. Length of gnathosomal capsule 21-23, width 16-20. Lengths of gnathosomal setae: ch 11-13, su 10-12.

Idiosomal dorsum (Figures 5A, 8A-B) — Prodorsal shield weakly sclerotized, with poorly defined edges, subtriangular, with weak linear microsculpture and small uniform dimples (Figure 8A). All dorsal setae smooth; setae c_1 and d blunt-ended; other dorsal setae pointed. Tergite CD with delicate longitudinal striation and very small dimples (Figure 8B). Tergite EF smooth, with two arch-like lines. Cupules ia situated posteromedially to bases of c_1 ;

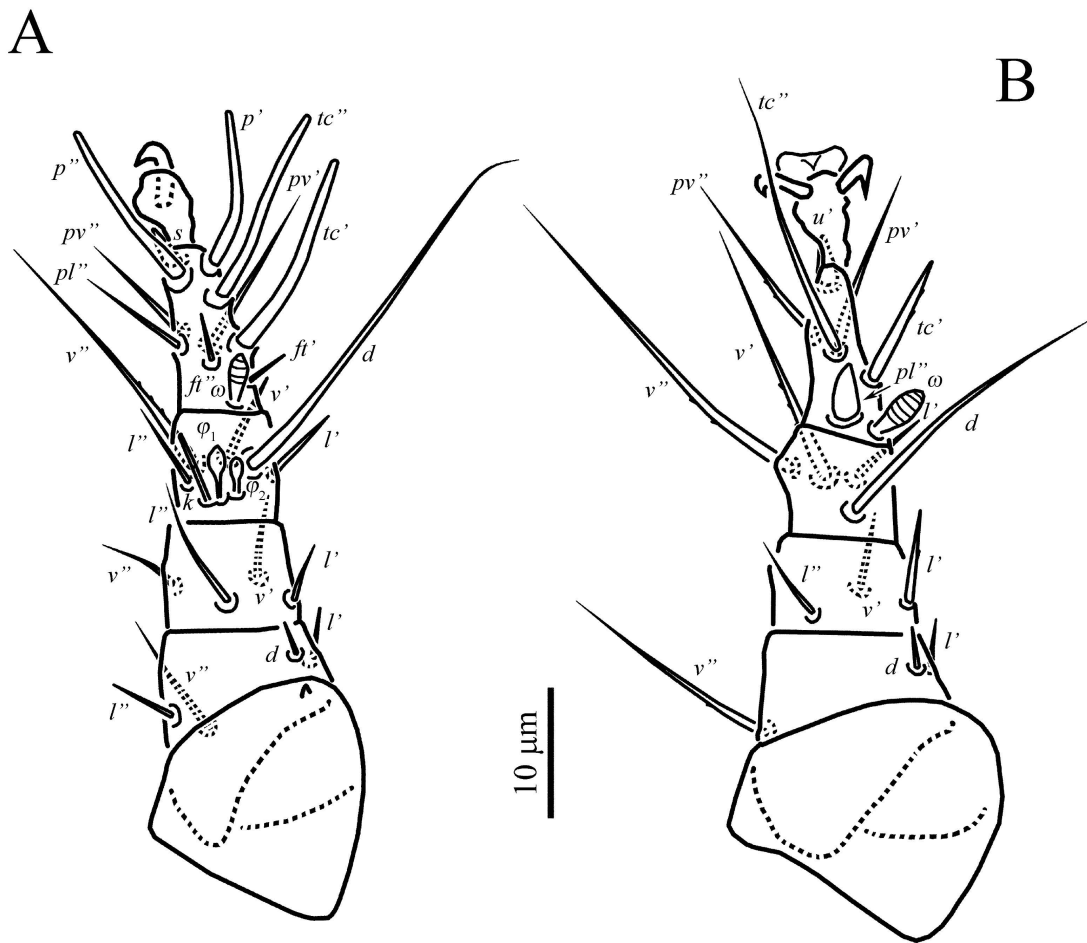


FIGURE 6: *Tarsonemus striatus* n. sp., male: A – left leg I in dorsal view; B – left leg II in dorsal view.

cupules *im* situated just anterolaterally to bases of setae *f*. Lengths of dorsal setae: v_1 18-22, v_2 10-12, sc_1 43-48, sc_2 18-19, c_1 13-16, c_2 27-31, d 14-18, f 12-14. Distances between setae: v_1-v_1 12-13, v_2-v_2 22-23, sc_1-sc_1 26-28, sc_2-sc_2 42-43, c_1-c_1 68-77, c_2-c_2 74-84, c_1-c_2 28-29, $d-d$ 35-40, $f-f$ 21-23.

Idiosomal venter (Figures 5B, 8C) — Appr extending posteriorly to posterior edge of prosternal plate, but weakened along its posterior half between ap_1 and ap_2 . Ap_2 straight, not uniting with appr. Apsej indistinct. Setae $1a$ and $2a$ inserted well behind ap_1 and ap_2 , respectively. All ventral setae smooth; setae $1a$ needle-like, other ventral setae pointed. Anterior and posterior sternal plates with

uniform, very small dimples (Figure 8C). Ap_3 , ap_4 , and apodemes 5 (ap_5) well developed. Setae $3a$ inserted between anterior ends of ap_3 and ap_4 ; setae $3b$ inserted on ap_4 . Lengths of ventral setae: $1a$ 7-8, $2a$ 11-12, $3a$ 18-21, $3b$ 17-20.

Legs (Figures 6-7) — Legs: chaetotaxy of leg I: $Fe_4-Ge_4-Ti_6(2\phi)-Ta_{10}(1\omega)$; leg II: $Fe_3-Ge_3-Ti_4-Ta_6(1\omega)$; leg III: $Fe_1-Ge_3-Ti_4-Ta_6$; leg IV: $Tr_1-FeGe_{1+2}-Ti_1(1\phi)-Ta_3$. Lengths of legs: I 53-59, II 51-62, III 64-71, IV 50-66. Leg I (Figure 6A). Solenidia on tibia and tarsus I as in female. Lengths of solenidia: ω 3-4 > ϕ_1 4-5 > ϕ_2 3; seta k 5-6. Seta d , (l) of femur, l' , v' of genu, l' , v' of tibia, and (ft) of tarsus blunt-ended and smooth; seta s slightly thick-

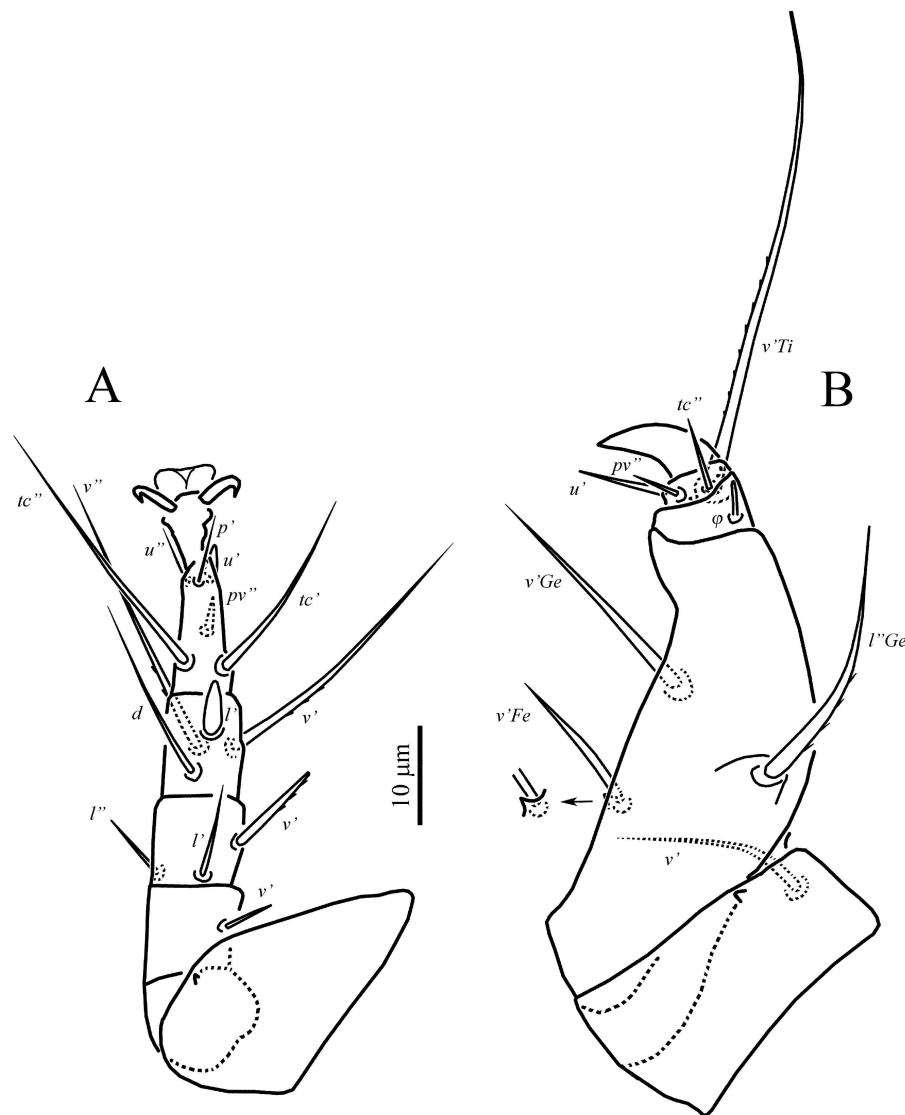


FIGURE 7: *Tarsonemus striatus* n. sp., male: A – left leg III in dorsal view; B – left leg IV in dorsal view.

ened, spiniform; setae v'' of tibia weakly barbed and pointed; other leg setae (except eupathidia) pointed and smooth. Leg II (Figure 6B). Solenidion ω 5 capitate. Setae pl'' and u' spine-like; setae l' of genu and tc' of tarsus blunt-ended and weakly barbed; seta d , l' of femur, v' of genu, and l' of tibia needle-like; setae v'' of femur, (v) of tibia and pv'' of tarsus long, pointed and weakly barbed; other leg setae pointed and smooth. Leg III (Figure 7A). Setae v' of femur and l'' of genu needle-like; setae v' of

genu blunt-ended and weakly barbed; setae l' of tibia u' , pv'' of tarsus thickened, spiniform; other leg setae pointed and smooth. Leg IV (Figure 7B) stout. Trochanter conspicuously punctate (Figure 8C). Femorogenu robust, with small projection near base of seta v' of femur. Setae l'' of genu and v' of tibia weakly barbed, blunt-ended; all tarsal setae needle-like; other leg setae pointed and smooth. Seta v' of tibia almost as long as leg IV. Tarsal claw strongly developed. Solenidion ϕ 4 rod-shaped.

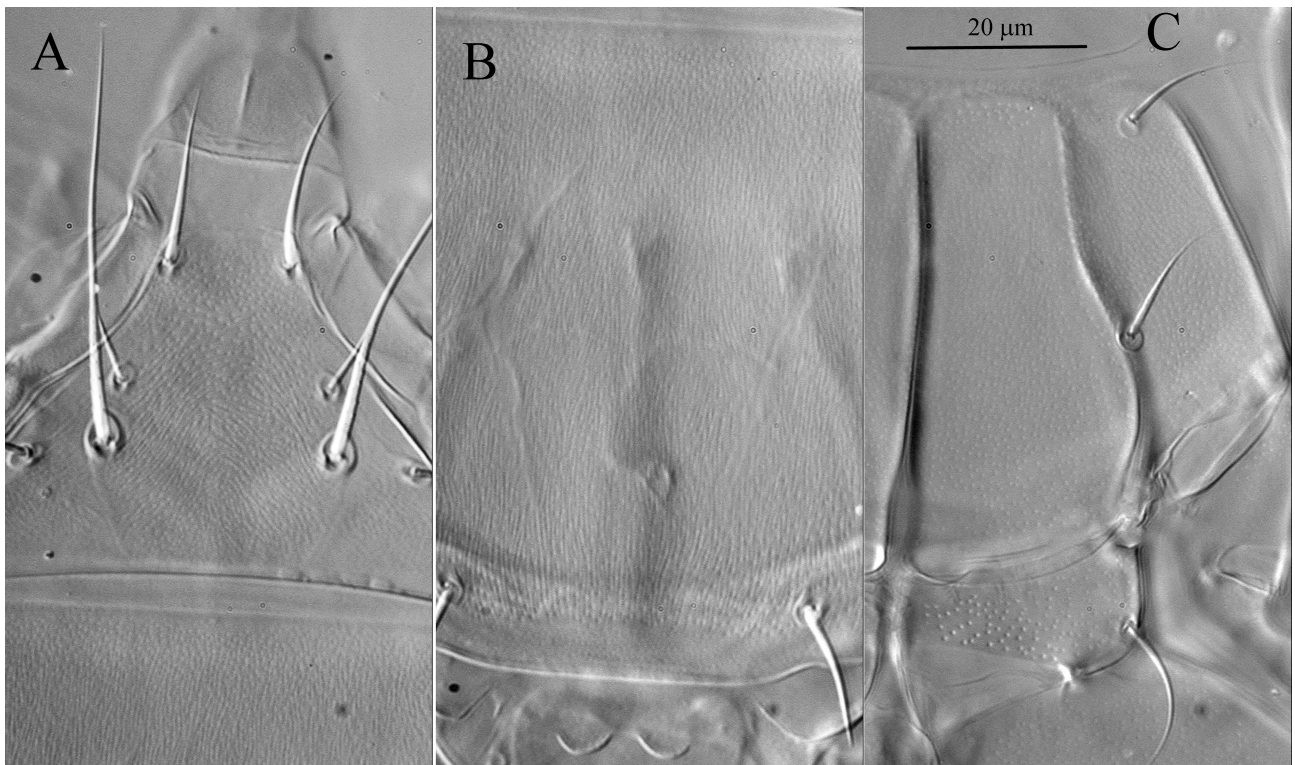


FIGURE 8: DIC micrographs of *Tarsonemus striatus* n. sp. male: A – central part of prodorsal shield; B – central part of tergite CD; C – right part of posterior sternal plate.

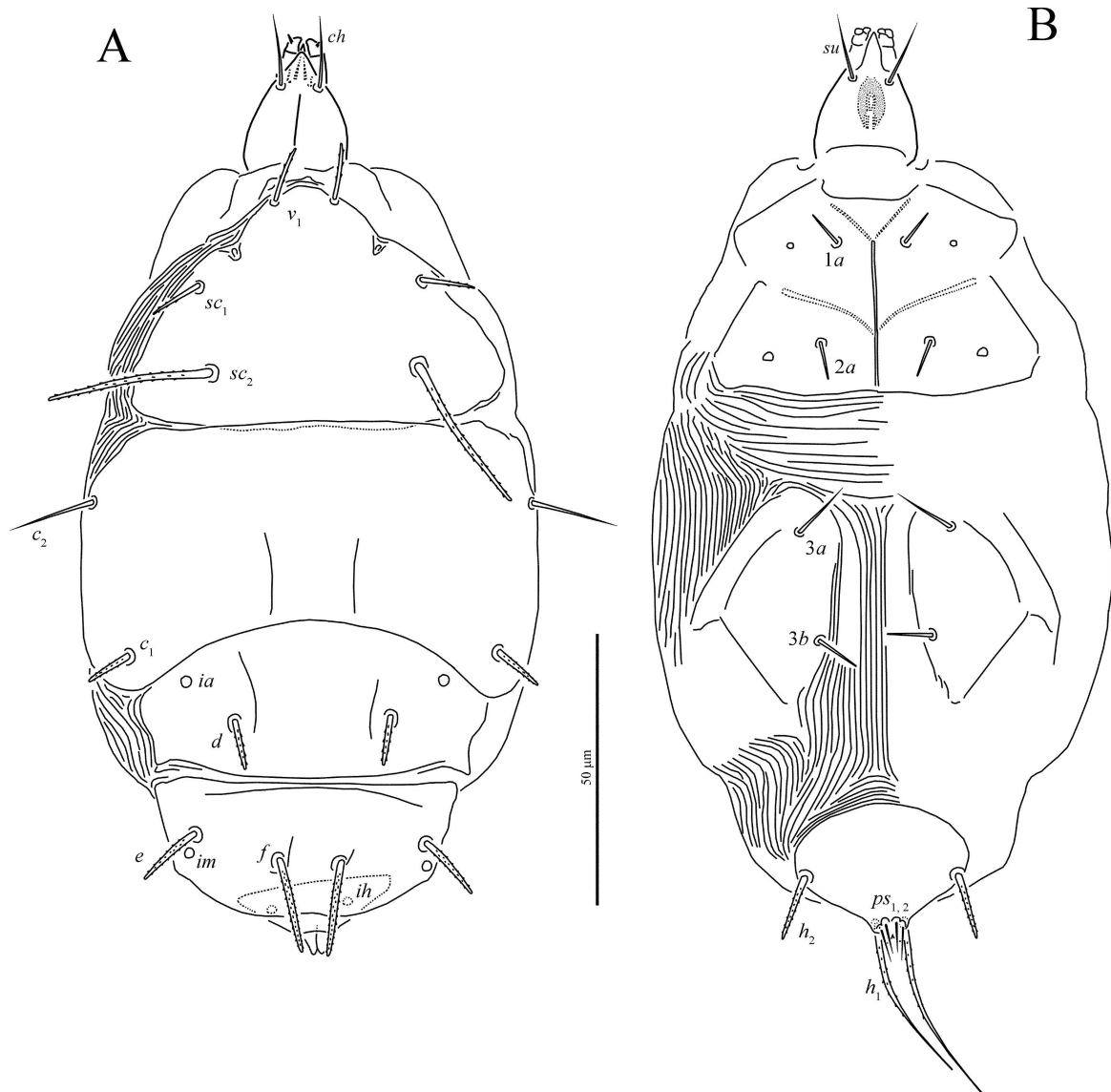


FIGURE 9: *Tarsonemus striatus* n. sp., larva: A – dorsum of the body; B – venter of the body.

Larva (Figures 9, 10) — Length of idiosoma 140–150, width 83–92.

Gnathosoma — Gnathosomal capsule, including pharyngeal structures, similar to that of female, but palpcoxal setae not evident. Length of gnathosomal capsule 25–28, width 19–20. Lengths of gnathosomal setae: *ch* 13–14, *su* 11–13.

Idiosomal dorsum (Figure 9A) — Dorsal shields of idiosoma weakly sclerotized, smooth. Prodorsal shield subtriangular. Dorsal setae *c*₂ smooth, pointed; other dorsal setae distinctly blunt-ended and barbed. Posterior margin of tergite C deeply concave. Segment HPs almost completely covered by tergite EF. Setae *h*₁ long, slightly rounded at the

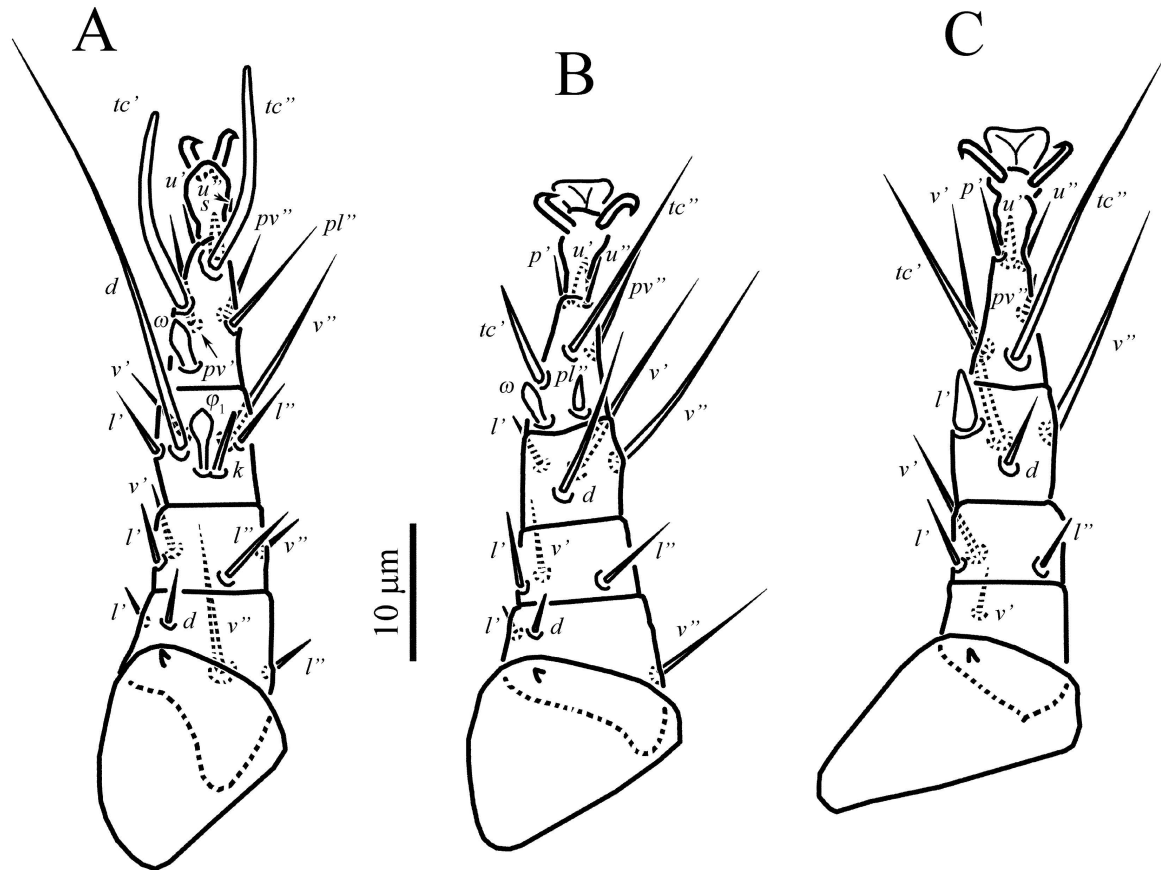


FIGURE 10: *Tarsonemus striatus* n. sp., larva: A – right leg I in dorsal view; B – right leg II in dorsal view; C – right leg III in dorsal view.

tip. Lengths of dorsal setae: v_1 9-10, sc_1 10-11, sc_2 28-29, c_1 9-11, c_2 17-18, d 10-11, e 14-16, f 17-21, h_1 31-33, h_2 14. Distances between setae: v_1-v_1 10, sc_1-sc_1 40-41, sc_2-sc_2 37-40, c_1-c_1 67-69, $d-d$ 29-30, $e-f$ 16-17, $f-f$ 8-11, h_1-h_1 5, h_2-h_2 15.

Idiosomal venter (Figure 9B) — Ventral plates of idiosoma weakly sclerotized, smooth. Ap1 longer than in adults, ap2 curving posteromedially, not uniting with appr. All ventral setae smooth; setae 1a, 2a and 3b needle-like, other ventral setae pointed. Lengths of ventral setae: 1a 7, 2a 7, 3a 10-13, 3b 8-9, $ps_{1,2}$ 5-7.

Legs (Figure 10) — Legs: chaetotaxy of leg I: Fe4-Ge4-Ti6(1 ϕ)-Ta8(1 ω); leg II: Fe3-Ge3-Ti4-Ta7(1 ω); leg III: Fe1-Ge3-Ti4-Ta6. Lengths of legs: I 46-47, II 44-46, III 46-47. Leg I (Figure 10A). Solenidia on tibia and tarsus I capitate. Lengths of solenidia: ω 4 = ϕ_1 4; seta k 5. All setae of leg I smooth. Seta d , (l) of femur, all setae of genu, l'' , v' of tibia, and (u) of tarsus needle-like; seta s slightly thickened, spini-form; other leg setae (except eupathidia) pointed and smooth. Leg II (Figure 10B). Solenidion ω 3-4 capitate. All leg setae smooth. Setae pl'' and u' spine-like; setae d , l' of femur, l' , v' of genu, l' of tibia, and u'' of tarsus needle-like; seta tc' of tar-

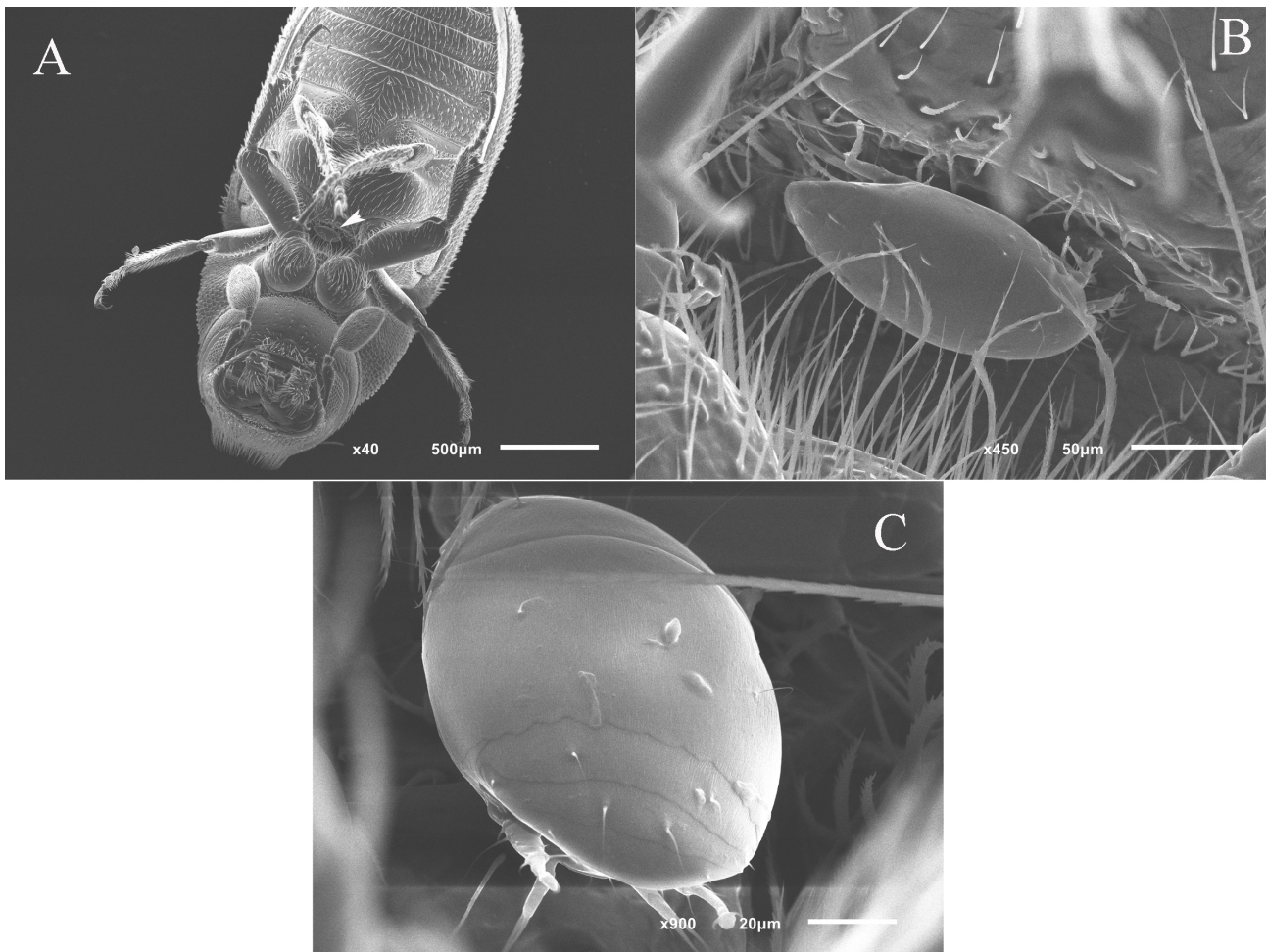


FIGURE 11: SEM micrographs of *Tarsonemus striatus* n. sp. females, phoretic on four-eyed fir bark beetle, *Polygraphus proximus*: A – ventral view of the beetle with phoretic mite (arrow); B, C – detailed view.

sus slightly thickened, blunt-ended; other leg setae pointed. Leg III (Figure 10C). All leg setae smooth. Setae *v'* of femur and (*l*) of genu needle-like; setae *l'* of tibia *u'*, *pv''* of tarsus thickened, spiniform; other leg setae pointed and smooth.

Type material — Female holotype, slide AK280816, Primorsky Krai, Lazo reg., 43°30'04.6"N, 133°34'47.1"E, 902 m.a.s.l., 28 August 2016, between coxae I and II of adult bark beetle *Polygraphus proximus* Blandford, 1894 under the bark of Manchurian fir (*Abies nephrolēpis*), coll. A.A. Khaustov. Paratypes: 18 females, same data; 1 female, 3 males and 5 larvae, same locality and date, but in the galleries of *Polygraphus proximus* under the bark of Manchurian fir.

Etymology — The specific epithet of the new species is derived from Latin word *striatus* meaning *striate* and refers to the presence of distinct linear microsculpture on the idiosomal tergites of the female and male.

Differential diagnosis — The female of the new species is very similar to *T. triarcus* Lindquist, 1969, described from North America, in having a triarcuate prodorsal shield, continuous ap3, and similar shape and position of idiosomal setae. The female of the new species differs from *T. triarcus* by the presence of distinct linear microsculpture on the idiosomal tergites (absent in *T. triarcus*), undulate posterior margin of tergite C (not undulate in *T. triarcus*), and by the absence of seta *pv''* on tarsus III (present

in *T. triarcus*). The male of the new species differs from the male of *T. triarcus* by the presence of weak linear microsculpture on the idiosomal tergites (absent in *T. triarcus*) and presence of a short projection near the base of seta *v'* of femur IV (absent in *T. triarcus*).

REMARKS ON PHORESY OF *Tarsonemus striatus* n. sp.

Many of adult bark beetles with attached phoretic females of *Tarsonemus striatus* n. sp. were collected during this study. All phoretic mites were attached to the small area between coxae I and II of the host beetle (Figure 11). In most cases only one individual of the phoretic mite was attached to one individual of bark beetle. Very rarely two individuals of mites were attached to one individual of the host beetle. A similar phoretic behavior was recently documented with aid of SEM microscopy for another bark beetle associate, *Tarsonemus (Schaarschmidtia) bistridentati* Magowski and Khaustov, 2006 phoretic on six-toothed spruce bark beetle *Pityogenes chalcographus* L. in western Siberia (Khaustov *et al.* 2016).

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