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Article

Solenostomes and lyrifissures in *Paraphytoseius santurcensis* De Leon (Acari: Phytoseiidae): comments and voucher photos

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Abstract

Many photos of solenostomes and lyrifissures, including large gd5, present in female and male *Paraphytoseius santurcensis* De Leon, 1965, that lacks seta S5, are given. A hypothetical model of *Paraphytoseius* having seta S5, as in *P. cracentis* (Corpuz and Rimando, 1966), is included in a line drawing showing all the solenostomes and the lyrifissures that may be present in a species of this genus.

Key words: Adenotaxy; lyrifissure; poroidotaxy; porotaxy; proprioreceptor; sigilla; solenostome gd5.

Introduction

A solenostome, also called a pore, is defined as the external opening of a gland or gland-like internal structure (e.g. the sperm induction pore in the sperm access system) (Walter 2005). In species of Phytoseiidae, a variable number of solenostomes are present on the dorsal shield that have consistent locations (Swirski *et al.* 1998). They were named by Athias-Henriot (1975a) as follows: gd1, gd2, gd4, gd5, gd6, gd8 and gd9. Solenostomes gd3 are located on the peritremal shield while solenostomes gd7 are absent in the Phytoseiidae. The shapes of the solenostomes can be crateriform, crescent, or punctiform.

A lyrifissure, also called a poroid, is defined as a cuticular proprioreceptor structure (Walter 2005) or just as sense organ. Under light microscopy, these may look like a round pit (cupule) in soft cuticle, or a slit in hard cuticle. When not differentiated as pit or slit, it is called a solenostome.

The study of the solenostomes has been called as adenotaxy and the study of lyrifissures as poroidotaxy, the terms coined by Athias-Henriot (1969b). These have been discussed by Johnston and Moraza (1991) in reference to Zerconidae and by Krantz and Redmond (1987) and Moraza (2004), both, in Macrochelidae. Based on silver nitrate reduction treatment of live adult and immature *Macrocheles perglaber* Filipponi and Pegazzano (Macrochelidae), Krantz and Redmond (1987) established that certain dorsal cuticular openings were found to be sites of glandular secretion called as crobylophores. Their reactivity tests showed an ontogenetic progression of dorsal gland activity, with those of tested larvae being non-reactive at all pore sites.

Most solenostomes and lyrifissures are very small to minute in the species of *Paraphytoseius*. It is only solenostome gd5 which is very large. It is located (on each left and right side) posterior to the bases of setae z5. It has been reported by every

phytoseiid researcher who has published on the species of this genus. It has been illustrated either as being crateriform or round in shape in different species but always near the base of seta z5. In other genera of Phytoseiidae, gd5 has been illustrated absent or located close to or away from the base of z5 (Swirski *et al.* 1998; Beard 2001; Abo-Shnaf and Moraes 2014; Karmakar and Gupta 2015). Lyrifissures, along with solenostomes, have been discussed briefly but illustrated very well without any names in the species of this genus by several authors (De Leon 1965; Ehara 1967; Tseng 1973; Schicha and Corpuz-Raros 1985; Ho and Lo 1989; Moraes *et al.* 2007). Because of being the largest solenostome on the dorsal shield of Amblyseiini, Athias-Henriot (1975a) called gd5 as a specialized and hypertrophied solenostome.

Species of *Paraphytoseius* possess long and thick landmark setae j1, j3, Z4, Z5 and s4 that are present on medium to large tubercles. Paired setae j1 are located close to each other at the anterior end of the dorsal shield where the anterior peritremal shield fuses with it. In this anterior area, the dorsal shield possesses an oval, lightly sclerotized cuticle. Lyrifissure id1 is present anterolateral to the base of j1 in this area. Solenostome gd1 is also present just posterior to the base of j3. These large setae are bent in the Hoyer's mounted specimens creating short to long anterior and lateral folds and artifacts looking similar to the solenostomes and the lyrifissures. Similar problems are present near the base of large and thick seta s4 that is located just posterior to the medial base of the lateral cleavage of the dorsal shield where solenostomes gd2 and gd4 are located. The same problems are present near large and thick setae Z4 and Z5 that are located very close to each other on very large tubercles at the posterior and lateral end of the dorsal shield where solenostomes gd8 and gd9 and lyrifissures idm5 and idm6 are located. This is not the case with species of most genera of Phytoseiidae as they do not have such large setae and large tubercles. Thus, studying solenostomes and lyrifissures in the species of this genus, including *Paraphytoseius santurcensis* De Leon, is very challenging.

The importance of studying solenostomes and lyrifissures and the history of development of the idiosomal adenotaxy and the poroidotaxy in Mesostigmata, is discussed by Krantz and Redmond (1987) and Johnston and Moraza (1991). Hirschmann (1960) used the signatures "*p*" for the pores present in the podonotal region and "*P*" for the pores present in the opisthonotal region. He recognized two kinds of pores. He called one kind as "Areaporen" (= solenostome) that was surrounded by a bordered area of cuticle looking as a slit-like opening and was associated with a gland. He called the other kind as "Anareaporen" (= lyrifissure) that was not surrounded by a bordered area of cuticle and was associated with some sensory function. Athias-Henriot (1969a, b, 1970, 1975a, b, 1977) provided organotaxy of the dorsal shield that included dermal glands (= solenostomes), lyrifissures (stress receptors), sigilla (muscle scars) and setae in terms of position, some, together, forming different territories.

Evans and Till (1979) described both kinds of pore-like structures, mentioned above, briefly in the mesostigmatic mites calling as porotaxy. They associated these with nearby setae on the dorsal shield of the female in: (1) central row as pj3 (pore associated with seta j3), pj4 (pore associated with seta j4), pj6 (pore associated with seta j6), pJ1 (pore associated with seta J1), pJ4 (pore associated with seta J4) and pJ5 (pore associated with seta J5); (2) middle row as pz1 (pore associated with seta z1), pz3 (pore associated with seta z3), pz4 (pore associated with seta z4), pz5 (pore associated with seta z5), pz6 (pore associated with seta z6), pZ3 (pore associated with seta Z3), pZ4 (pore associated with seta Z4) and pZ5 (pore associated with seta Z5); and (3) lateral

row as ps5 (pore associated with seta s5), ps6 (pore associated with seta s6), pS2 (pore associated with seta S2), pS3 (pore associated with seta S3), pS4 (pore associated with seta S4) and pS5 (pore associated with seta S5). Evans and Till (1979), for mesostigmatic mites, also named and labeled the pore-like structures on the ventral idiosoma of the female associating them with the nearby setae. Those on the sternal shield were designated as: (1) pst1 (pore associated with and located posterior to st1); (2) pst2 (pore associated with and located posterior to st2); (3) pst3 (pore associated with and located posterior to st3); and near posterior genital shield as: (4) pst5 (pore associated with and located on integument posterior to st5). They did not indicate if any pores were present on each paired metasternal shields. Even though they illustrated 5 pairs of pores on the ventral integument of the female (lateral to Zv1, posterolateral to Zv2, lateral to Zv3, medial to Zv4 and medial to Jv4), they did not name these. They also stated that the number of pore-like structures increase in number from larva to deutonymph, the latter also maintained in the adult stage. Krantz and Redmond (1987) confirmed same trend in different stages of *Macrocheles perglaber*. Aponte and McMurtry (1987) showed in a table which structures appeared in different stages of *Amblyseius colimensis* Aponte and McMurtry.

Swirski *et al.* (1998) have discussed and illustrated solenostomes on the dorsal shield and ventral idiosomal shields (but not on the integument around the genital and the ventrianal shields) of the females very nicely in several species of Phytoseiidae known from Israel. A recent publication by Abo-Shnaf and Moraes (2014) have also illustrated solenostomes and lyrifissures on the dorsal shield and ventral idiosoma of the females in the species of Phytoseiidae collected in Egypt. The most recent publication of Nuvoloni *et al.* (2015) have also illustrated the solenostomes and the lyrifissures on the dorsal shield and on the ventral idiosoma of the females in the species of Phytoseiidae collected in Brazil. But, none of the above mentioned authors have named all the solenostomes and the lyrifissures on the figures of their species.

Materials and methods

Ten paratype slides of *Paraphytoseius santurcensis* were borrowed from the Florida State Collection of Arthropods (FSCA), Gainesville, FL. These included 7 females, 2 males and 1 nymph. These were collected by De Leon in 1963 in Puerto Rico from *Hibiscus tiliacea* (*sic* for *Hibiscus tilliaceus*) and published 2 years later (De Leon, 1965). All the slides were remounted in Hoyer's medium in the laboratory of Dr. Harold Denmark, after the death of De Leon, in 1985 (Denmark, pers. comm., February 2015).

The paratype females and males were studied in the laboratory of the author in West Bloomfield, Michigan, USA. They were examined using an Acc-Scope 3000 trinocular phase-contrast microscope (Acc-Scope, New York, NY, USA) under 100–400x. The voucher photos were taken using a Canon EOS 550D camera. These photos were saved in Adobe Photoshop CS5™ and setal signatures added in Adobe InDesign™ program. The original magnification of the photos was 400X. As photos of the solenostomes and the lyrifissures were enlarged greatly in different magnifications, their exact magnifications are not given.

The system of Athias-Henriot (1969b, 1975a) and Aponte and McMurtry (1987) is followed for the dorsal idiosoma of the solenostomes and the lyrifissures. But, for the ventral idiosoma, instead of using pst1-pst5 given by Evans and Till (1979) or iv1-iv5 for these used by Johnston and Moraza (1991) for the lyrifissures notation, iST1-iST4 and iST5, iZV1, iZV2, iZV3 and iJV5 associating pores with nearby setae is used.

Different abbreviations used in the description and on the figures include the followings: (1) GS = genital shield, MES = metasternal shield, MM = muscle marks, PE = peritreme, SS = sternal shield, and VAS = ventrianal shield; (2) for the dorsal idiosomal setae: j1, j3, j4, j5, j6, J5; z2, z4, z5, Z1, Z4, Z5; s4; r3, R1 and the ventral idiosomal setae: PA, ST1, ST2, ST3, ST4, ST5; JV1, JV2, JV4, JV5; ZV1, ZV2, ZV3; (3) for the dorsal solenostomes: gd1, gd2, gd4, gd5, gd6, gd8, gd9; (4) for the dorsal lyrifissures: id1, id2, id3, id4, id7, id8, idl2, idl3, idl4, idm1, idm2, idm3, idm4, idm5, idm6, idx1, idx2, is1; and (5) for the ventral lyrifissures: iST1, iST2, iST3, iST5, iZV1, iZV2, iZV3.

Results

The specimens of *P. santurcensis* were almost 50 years old when examined in 2014. Many artifacts were present in several mites. In spite of these difficulties, most solenostomes and lyrifissures were seen clearly although some were hard to identify. They appeared to have very consistent patterns of their locations on the dorsal and the ventral idiosoma. Examination of more than 1 specimen was necessary to identify all these structures as all were not seen in the same specimen.

Solenostomes on the dorsal idiosoma of the female (Figs. 1–4, 7, 8)

Out of 8 pairs of solenostomes, 2 pairs (gd5 and gd8) were seen consistently in all females and males. In the remaining 6 pairs, some of them were seen in different females but not in the same female indicating that a sufficient number of specimens is required to identify these clearly as stated also by Tixier (2012). The solenostomes identified were as follows (see Athias-Henriot, 1975a): (1) gd1 (Figs. 1, 2, 7) - lateral and slightly posterior to base of seta j3; (2) gd2 (Figs. 1, 2, 7) - medial and adjacent to base of seta z4; (3) gd3 - on middle of peritremal shield, could not be seen; (4) gd4 (Figs. 1, 2, 7) - posterior to base of seta s4 and posterior to lower margin of cleavage; (5) gd5 (Figs. 1, 2, 8) - posteromedial and adjacent to base of tiny seta z5; (6) gd6 (Fig. 2) - postero-lateral to base of seta j6 and anteromedial to base of Z1; (7) gd8 (Figs. 1, 7) - on large tubercle anteromedial to base of seta Z4; and (8) gd9 (Figs. 1, 7) - in between bases of setae Z4 and Z5. Solenostome gd7 is considered absent in Phytoseiidae (Swirski *et al.* 1998). All solenostomes were minute and punctiform except gd5 which was very large, crescent shaped and similar in female and male (Figs. 1, 6). Little variation was seen in the size in different specimens. A central opening was present in the middle of the crescent shaped edges called outer rims (Fig. 8).

Solenostomes on the ventral idiosoma of the female (Fig. 12)

The most important pair of solenostome gv3 (after Athias-Henriot, 1977, 1978) is reported present well apart and posterior to JV2 on the ventrianal shield in the phytoseiid mite *Dictydionotus desertus* (Chant) [now *Neoseiulus desertus* (Chant)] and placed very close to each other just posteromedial to JV2 on this shield in *Cydnodromus fallacoides* Tuttle and Muma [now *Neoseiulus fallacoides* (Tuttle and Muma)] by Tsolakis and Ragusa (2010) [They called JV3, to JV2, in this publication]. This solenostome was not present on the ventrianal shield of the female *P. santurcensis* in the present study. This solenostome is absent in the illustrations of De Leon (1965, 1967) also.

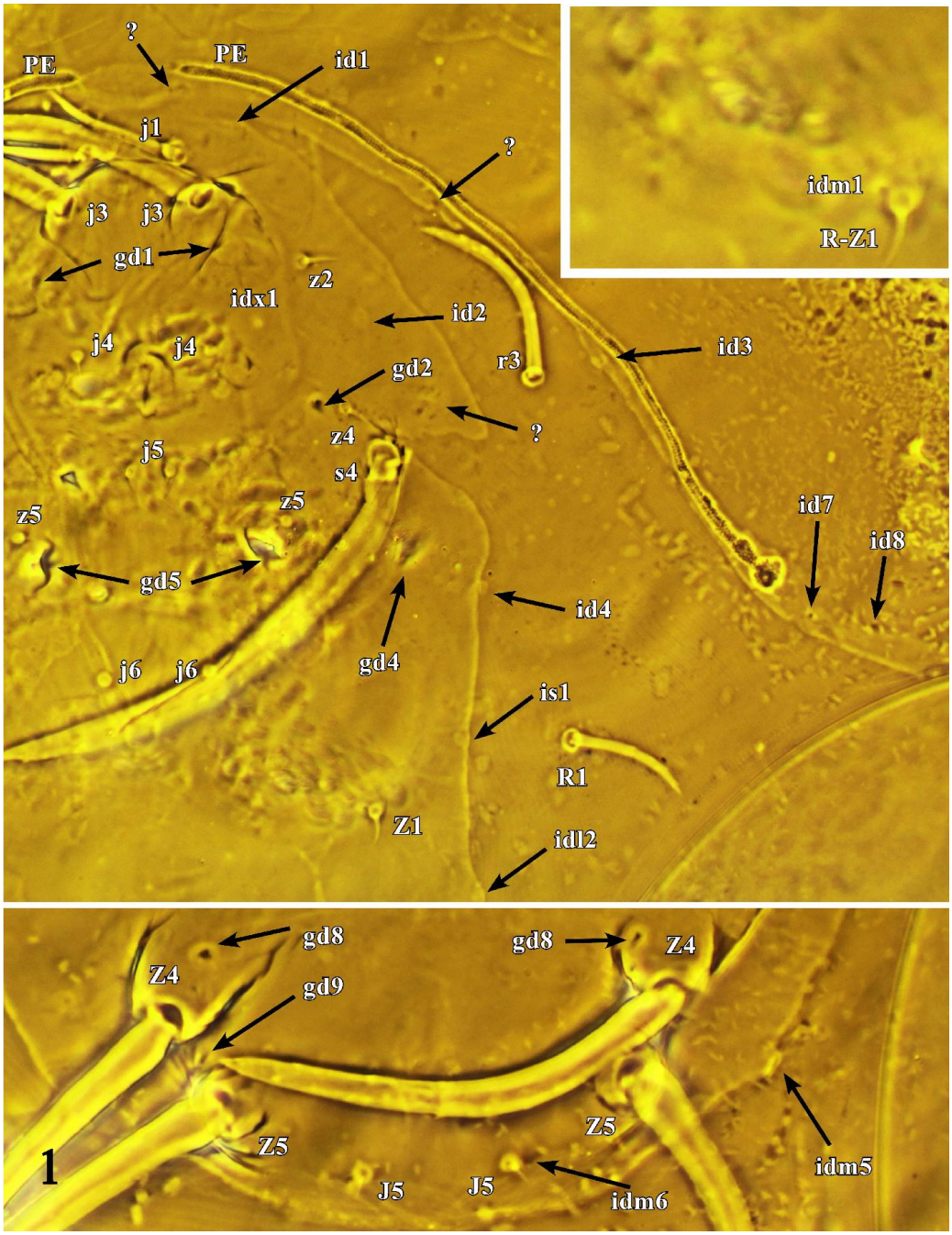

Figure 1. *Paraphytoseius santurcensis*: Dorsal view of idiosoma in female showing peritremes, dorsal setae, muscle marks (MM), solenostomes (gd1, gd2, gd5, gd8 and gd9), and lyrifissures (id1, id2, id3, id4, id7, id8, idl2, idm5, idm6 and is1). Some unidentifiable structures (?) also seen [Paratype, slide 3, female 3, FSCA].

Lyrifissures on the dorsal idiosoma of the female (Figs. 1–5, 9–11)

A total of 19 pairs of lyrifissures was observed on the dorsal idiosoma in *P. santurcensis* of which 16 pairs were on the dorsal shield and 3 pairs were on the peritremal shield. The 7 pairs of lyrifissures located on the lateral side of the dorsal

shield and posterolateral to seta z2 (id2, id4, idl2, idl3, idl4, idm5 and is1) were seen easily in almost all females but some present in the central and middle area of the dorsal shield between j6 and J5 (id6, idm2, idm3, idm4 and idm6) were, sometimes, hard to distinguish. All of the lyrifissures appeared light in color, roughly round to oval, and looked like tiny plates or small muscle marks (sigilla). Some of the muscle marks (MM, Figs. 2–4) were useful for locating some lyrifissures on the opisthonotum posterior to the paired setae j6 where the central row of the setae J1, J2, J3 and J4 and middle row of the setae Z1, Z2 and Z3 were absent [absent also in other species of *Paraphytoseius*]. Even though lateral row setae S2, S4 and S5 were absent in *P. santurcensis* [setae S1 and S3 are absent in Phytoseiidae], the lyrifissures were always present in those locations, showing some relationship with mites of the holotrichous family Ascidae (S1 and S3 present in Maxinia) and Blattisociidae (S3 present in Opilioseius) in which these setae are present (Lindquist and Moraza, 2010, 2012).

Of 16 pairs of lyrifissures on the dorsal shield, 6 pairs (id1, id2, id4, id6, idx1 and is1) are located on the podonotum (Figs. 1–5, 9–11) and remaining 10 pairs (idl2, idl3, idl4, idm1, idm2, idm3, idm4, idm5, idm6 and idx2) on the opisthonotum (Figs. 1–5, 10, 11). The 6 pairs on the podonotum (anterior to posterior) are (see Athias-Henriot, 1975a): (1) id1 (Figs. 1–4, 9, 10) - lateral to base of j1; (2) id2 (Figs. 1–4) - posterolateral to base of z2 and anterolateral to base of z4; (3) id4 (Figs. 1–4) - posterolateral to base of s4; (4) id6 (Fig. 3) - posterolateral to base of seta j6; (5) idx1 (Figs. 1–4, 10) - posterior to j3 [called idx1 anterolateral to j4 by Aponte and McMurtry (1987) in *Amblyseius colimensis* - idx1 accepted in this work; id1a anterolateral to j4 by Beard (2001) in *Neoseiulus*; and idx posterolateral to J4 by Abo-Shnaf and Moraes (2014) in *Amblyseius swirskii* Athias-Henriot]; and (6) is1 (Figs. 1-5, 11) - anterior to idl2 and medial or anterior to base of R1 [called is1 posterolateral to Z1 by Aponte and McMurtry (1987) in *A. colimensis* - is1 accepted in this work; same is1 but anterior to R1 by Beard (2001) in *Neoseiulus*; and called as id7 anterolateral to Z1 by Abo-Shnaf and Moraes (2014) in *A. swirskii* which is reported posterior to stigmata on the peritremal shield by Aponte and McMurtry (1987) and Beard (2001)]. This lyrifissure is1 appears to be variable in location and may be located anterior, lateral or slightly posterior to base of R1.

Of the remaining 10 pairs located on the opisthonotum (Figs. 1–5, 10, 11), 6 pairs (idm1, idm2, idm3, idm4, idm5 and idm6) are located in the central and the middle row posterior to j6 and anterior to J5 and 4 pairs (idl2, idl3, idl4 and idx2) in the lateral row on the lateral margin between absent S2 and present or absent S5. The 6 pairs [middle anterior to middle posterior] include (see Athias-Henriot, 1975a): (1) idm1 (Figs. 1, 2, 5, 7, 10) - medial to base of seta Z1 almost in transverse line with absent seta J1 (J1 absent in *Paraphytoseius* but present in several other genera of Phytoseiidae); (2) idm2 (Figs. 2, 3) - posterior to idm1 in transverse line with absent seta J2 (J2 absent in *Paraphytoseius* but present in several other genera of Phytoseiidae); (3) idm3 (Figs. 2, 3) - posterior to idm2 in transverse line with absent seta J3 (J3 absent in *Paraphytoseius* but present in only 1 genus, *Macrocaudus*, of Phytoseiidae); (4) idm4 (Fig. 6, male) - posterior to idm3 in transverse line with absent seta J4 [idm4 anteromedial to Z4 in *A. swirskii* per Abo-Shnaf and Moraes, 2014]; (5) idm5 (Figs. 1, 5, 10, 11) - posterior to base of absent S5 [in some specimens appears like solenostome] (seta S5 absent in *P. santurcensis* but present in *P. cracentis* in which idm5 is located just posterior but close to base of S5; present in several other genera of Phytoseiidae); and (6) idm6 (Figs. 1, 10) - anterolateral but very close to base of seta J5.

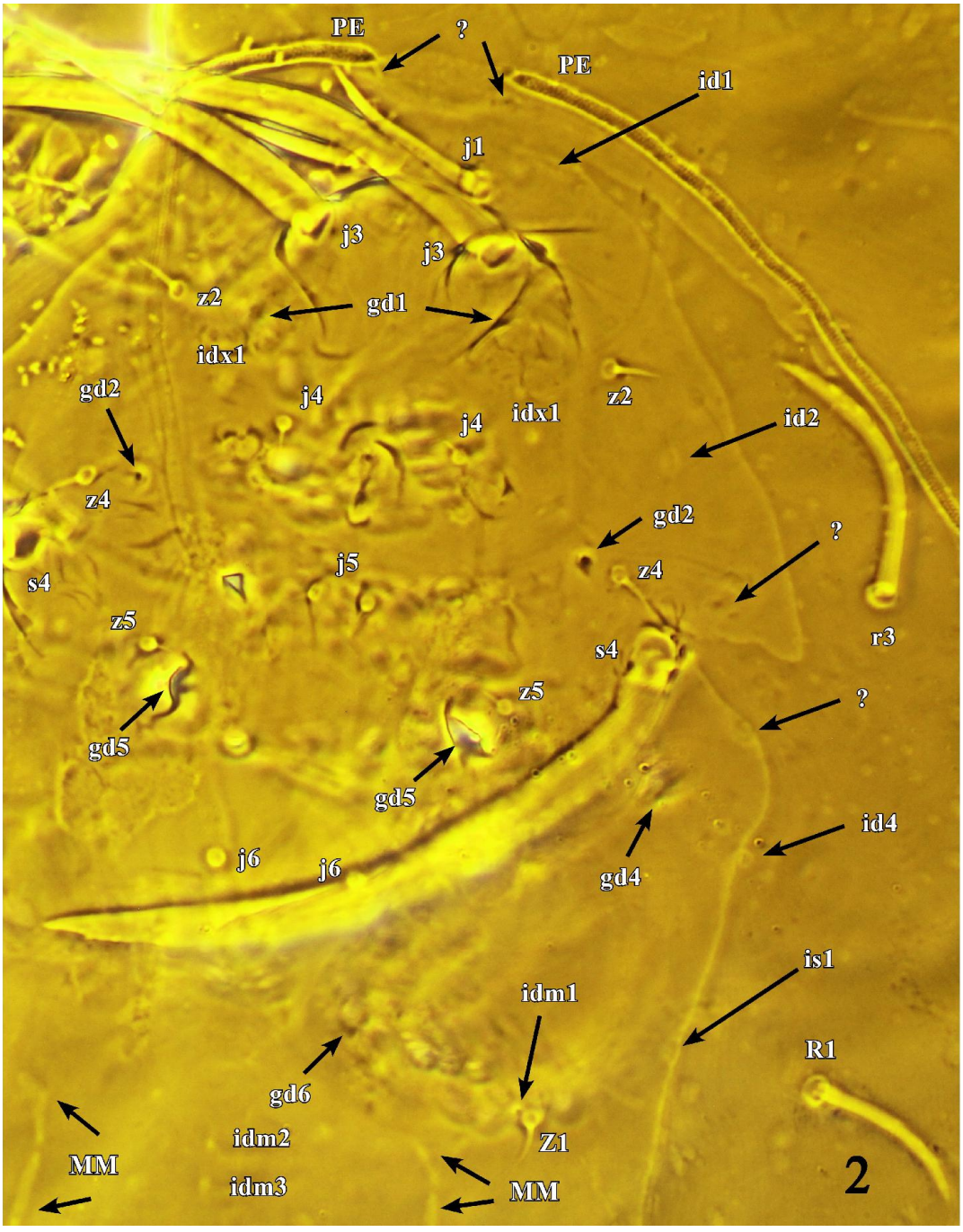

Figure 2. *Paraphytoseius santurcensis*: Dorsal view of idiosoma in female in enlarged view showing peritremes, dorsal setae, muscle marks (MM), solenostomes (gd1, gd2, gd4 and gd5), and lyrifissures (id1, id2, id4, idm1, idm2, idm3, idx1 and is1). Some unidentifiable structures (?) present [Paratype, slide 3, female 3, FSCA].

The remaining 4 pairs (idl2, idl3, idl4 and idx2) located in the lateral row on the lateral margin of the opisthonotum between absent S2 and present or absent S5 include (Figs. 1, 5, 6, 11): (1) idl2 (Figs. 1, 3, 5, 11) - lateral to base of absent seta S2 [called

idl1 lateral to S2 by Aponte and McMurtry (1987) in *A. colimensis*; same idl1 but anterolateral to S2 by Abo-Shnaf and Moraes (2014) in *A. swirskii*; but called idl2 lateral to S2 by Beard (2001) in *Neoseiulus* - idl2 accepted in this work; S2 absent in *Paraphytoseius* but present in many genera of Phytoseiidae); (2) idl3 (Figs. 5, 11) - lateral to base of absent seta S3 (S3 absent in Phytoseiidae including *Paraphytoseius* but present in Ascidae and Blattisociidae); (3) idl4 (Figs. 5, 11) - posterolateral to Z4 and posterior to base of absent seta S4 (S4 absent in *Paraphytoseius* but present in many genera of Phytoseiidae); and (4) idx2 (Fig. 6, male) - lateral to absent seta J3 (J3 absent in *Paraphytoseius*) [called idx2 anterior to gd8 by Aponte and McMurtry (1987) in *A. colimensis* - idx2 accepted in this work; idx anteromedial to gd8 and anterior to Z4 by Beard (2001) in *Neoseiulus*; and absent in *A. swirskii* per Abo-Shnaf and Moraes (2014)].

Solenostomes and lyrifissures on the peritremal shield of the female (Figs. 1, 9)

The 3 pairs of lyrifissures on the peritremal shield were located as follow: (1) id3 (Figs. 1, 9) - on middle of peritremal shield posterolateral to r3; (2) id7 (Figs. 1, 9) - posterior to peritremal stigmata; appears punctate like a small solenostome and (3) id8 (Figs. 1, 9) - posterior to id7.

Athias-Henriot (1975a) called solenostome gdp on the peritremal shield present posterior to stigmata and lyrifissure id7 in Amblyseiini. Aponte and McMurtry (1987) called it id8 in *A. colimensis* which is accepted in this work.

Lyrifissures on the ventral idiosoma of the female (Fig. 12)

There are, at least, 9 pairs of lyrifissures on the ventral idiosoma of the female of which 2 pairs are on the sternal shield, 1 pair on the metasternal shields, and 6 pairs on the integument posterolateral to the genital shield and the ventrianal shield of *P. santurcensis*. All or some of these have been illustrated in different species of *Paraphytoseius*, including *P. santurcensis*, and different species of Phytoseiidae, and some have been named as: (1) Ss1 (located posterior to seta ST1), Ss2 (located posterior to seta ST2), ms (located on anterior margin of metasternal shield), and p (pore, for lyrifissure located on integument lateral to genital shield and ST5) by Aponte and McMurtry (1987) in *A. colimensis*; and (2) Same above 4 pairs as pst1, pst2, pst3, and pst5 (Evans and Till 1979).

The lyrifissures located on the ventral idiosoma of Zerconidae have been named by Johnston and Moraza (1991) as iv1, iv2 (both on sternal shield), iv3 (on metasternal shield), and iv5 (on genital shield). They did not report any lyrifissures lateral to ventrianal shield in their *Zercon zelawaiensis* Sellnick. In Phytoseiidae, iv5 is located on the integument posterolateral to the genital shield. In addition, usually, about 6–7 pairs of lyrifissures are present on the integument lateral or posterior to the ventrianal shield. In some publications, these lyrifissures have been named associating with the nearby setae.

In this work, the lyrifissures have been named as associated with the nearby setae. Thus, the 4 pairs of ventral lyrifissures (from anterior to posterior) commonly seen in *P. santurcensis* have been called as: (1) iST1 - crescent, oblong, or punctiform posterior to base of ST1 on the sternal shield; (2) iST2 - crescent, oblong, or punctiform posterior to base of ST2 on the sternal shield; (3) iST4 - punctiform anterior to base of ST4 on the metasternal shield; (4) iST5 - small and round to oval, on the integument, lateral to ST5. In addition to above 4 pairs, 5 pairs of ventral lyrifissures are present around the

ventrianal shield. These have been named as (1) iZV1 - small and round to oval, on the integument, lateral to seta ZV1; (2) iZV2 - small and round to oval, on the integument, lateral to seta ZV2; (3) iZV3 - small and round to oval, on the integument, lateral to seta ZV3. Lyrifissures iJV4 (lateral to seta JV4) and iJV5 (medial to seta JV5) are also seen in some females.

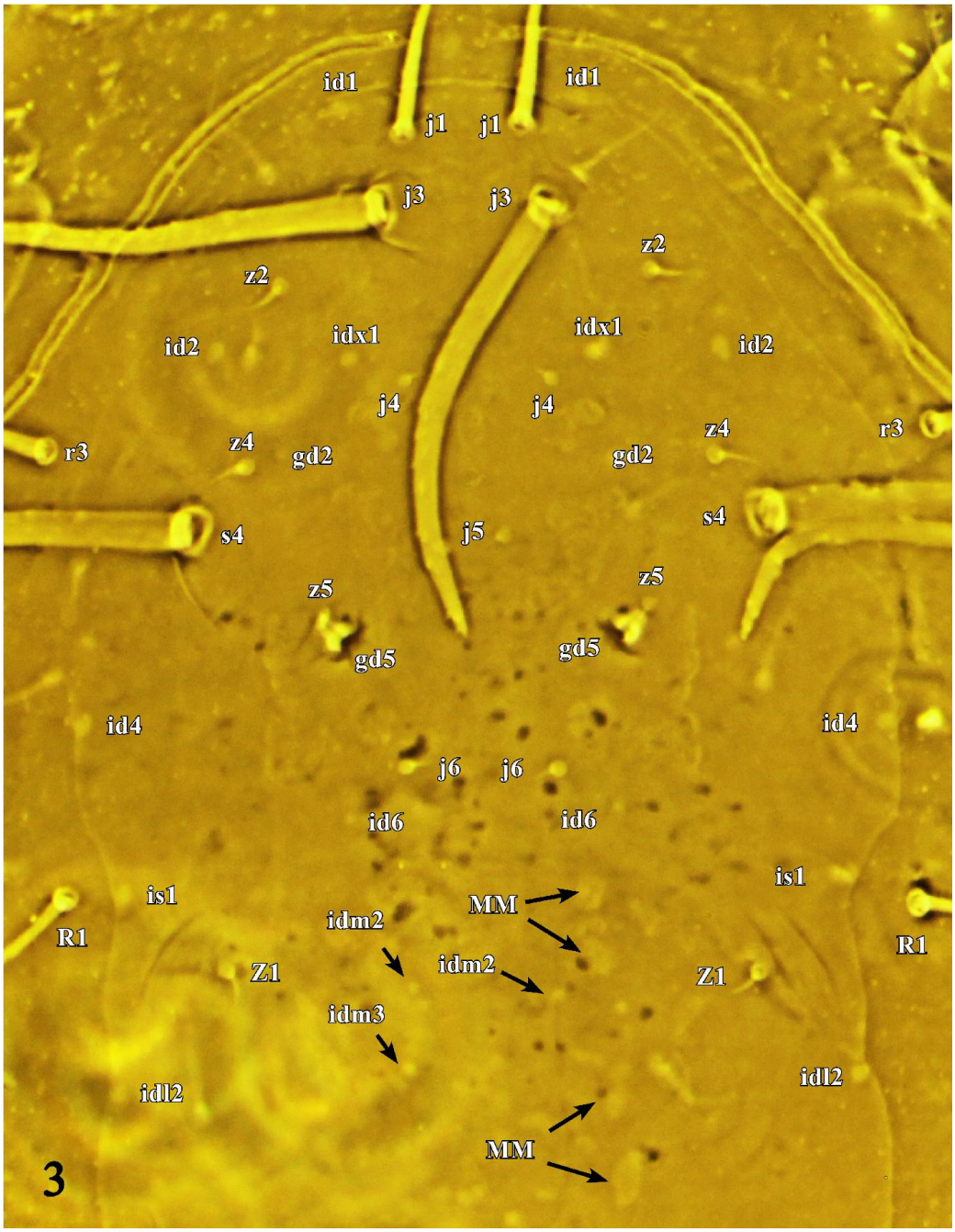

Figure 3. *Paraphytoseius santurcensis*: Dorsal view of idiosoma in another female showing peritremes, dorsal setae, muscle marks (MM), solenostomes (gd5), and lyrifissures (id1, id2, id4, idm2, idm3, idx1 and is1) [Paratype, slide 7, female 7, FSCA].

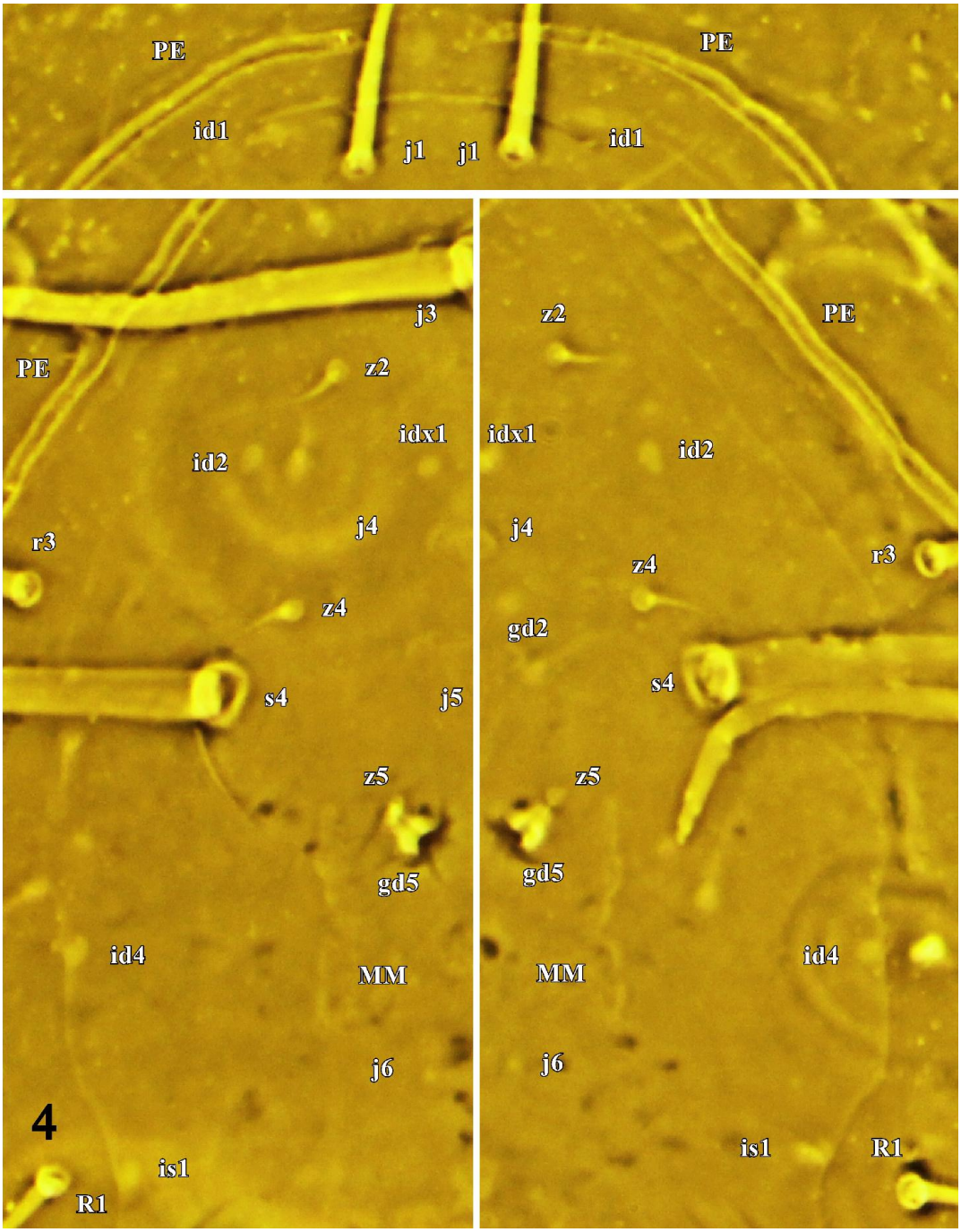

Figure 4. *Paraphytoseius santurcensis*: Enlarged dorsal view of anterior idiosoma in a female showing dorsal setae, muscle marks (MM), solenostomes (gd2 and gd5), and lyrifissures (id1, id2, id4, idx1 and is1) [Paratype, slide 7, female 7, FSCA].

In some species of *Paraphytoseius* (unpublished), a 6th pair of lyrifissures on the integument lateral to the ventrianal shield is present. In addition to the above 9 pairs of lyrifissures, 2 additional pairs are also present on the integument lateral to setae ZV3 and JV4 in some species of Phytoseiidae as in *Neoseiulus apeuthus* Beard, 2001. All of

these appear to be arranged in 4 vertical lines as given by Lindquist and Evans (1965) for ventral idiosomal setae JV1-JV5, ZV1-ZV3, UR5-UR7, and R5-R7.

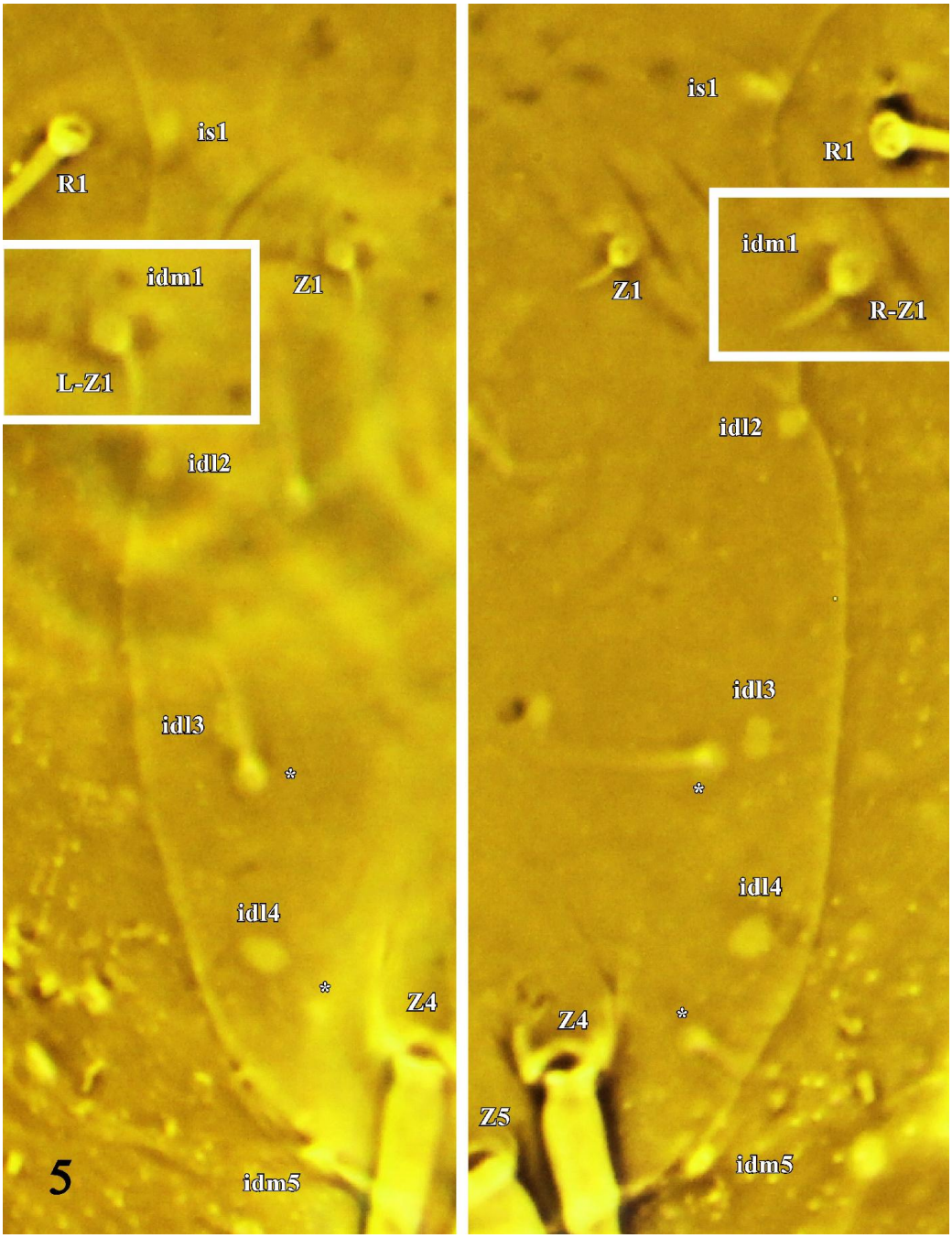

Figure 5. *Paraphytoseius santurcensis*: Enlarged dorsal view of posterior idiosoma in a female showing dorsal setae and lyrifissures (idl2, idl3, id4, idm1, idm5, idx1 and is1). Some ventral setae (*) also seen [Paratype, slide 7, female 7, FSCA].

Solenostomes on the dorsal idiosoma of the male (Fig. 6)

Most of the solenostomes, except for gd5 and gd8, could not be identified.

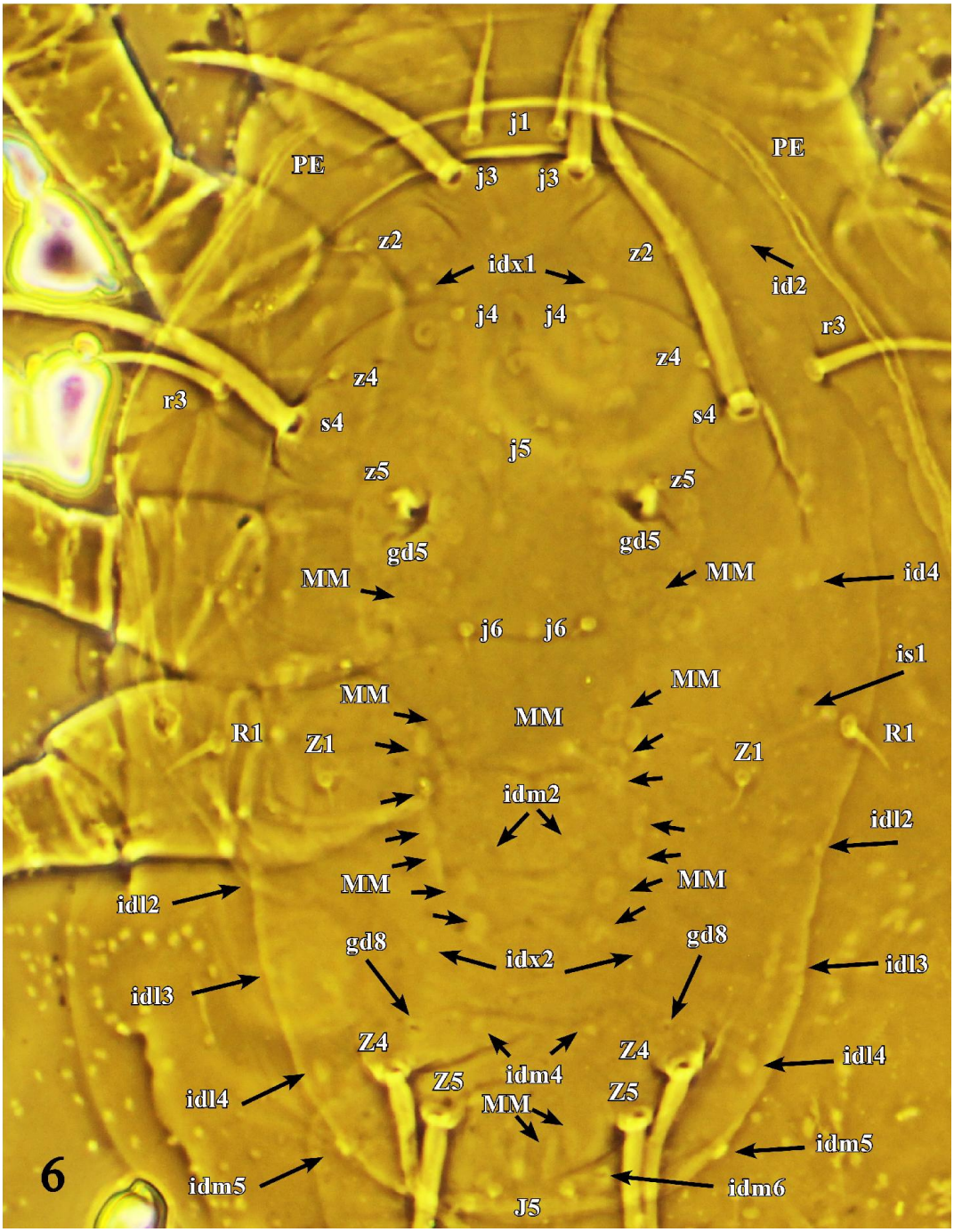

Figure 6. *Paraphytoseius santurcensis*: Dorsal view of idiosoma in a male showing peritremes, dorsal setae, muscle marks (MM), solenostomes (gd5 and gd8), and lyrifissures (id2, id4, idl2, idl3, idl4, idm2, idm4, idm5, idm6, idx1 and is1) [Paratype, slide 3, male 2, FSCA].

Solenostomes on the ventral idiosoma of the male

No solenostomes were identified on the ventral idiosoma of the male in *P. santurcensis*.

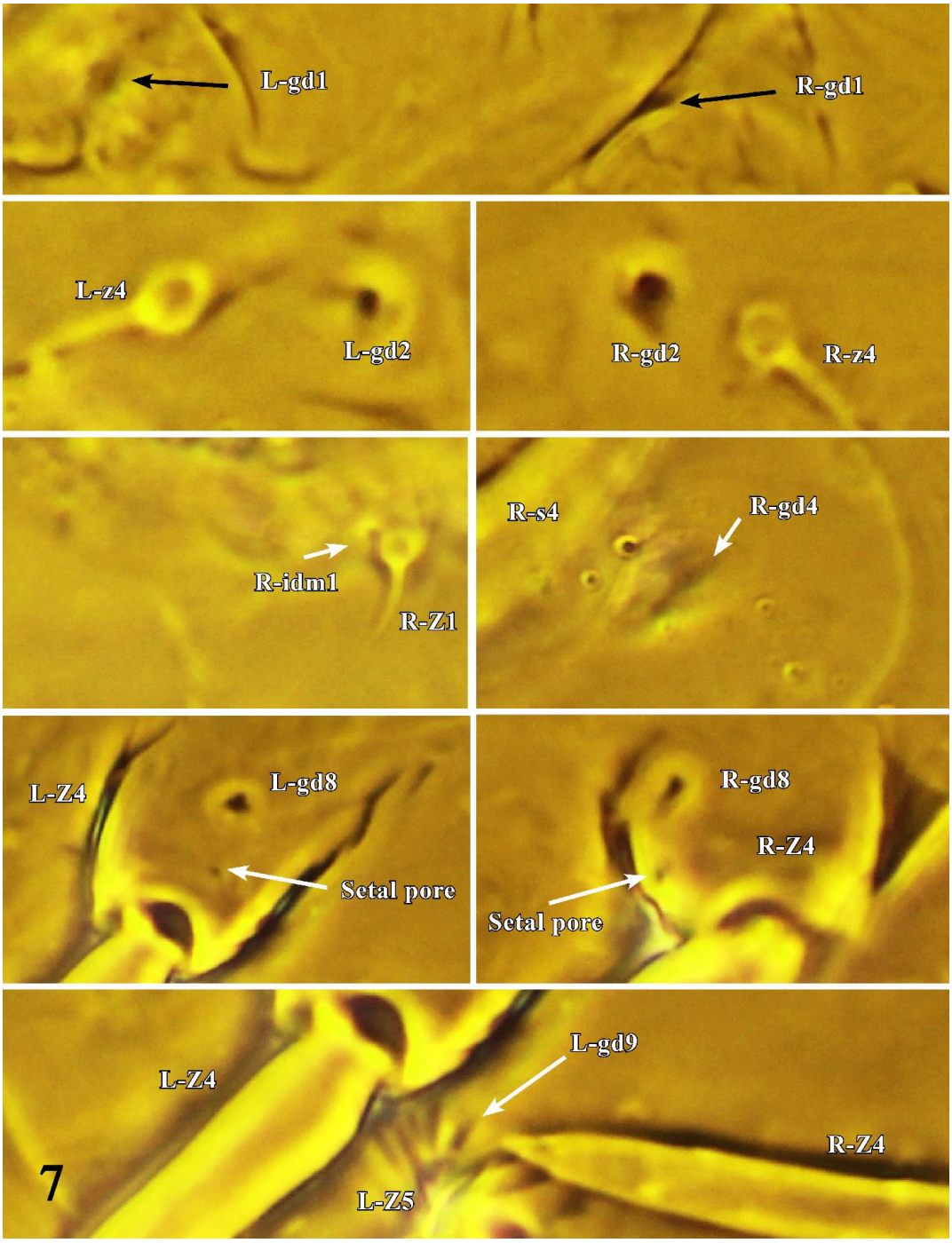

Figure 7. *Paraphytoseius santurcensis*: Enlarged views of left and right (L, R) solenostomes gd1, gd2, gd4, gd5, gd8, gd9 and lyrifissure idm1 in a female [Paratype, slide 3, female 3, FSCA].

Lyrifissures on the dorsal idiosoma of the male (Figs. 6, 10)

Most of these were identified and found present in the same locations as in the female. Several muscle marks (Fig. 6, MM, shown with arrows) and artifacts made

identification of some lyrifissures very difficult. Lyrifissure idm6 lateral to seta J5 was seen clearly in 1 male (Fig. 10).

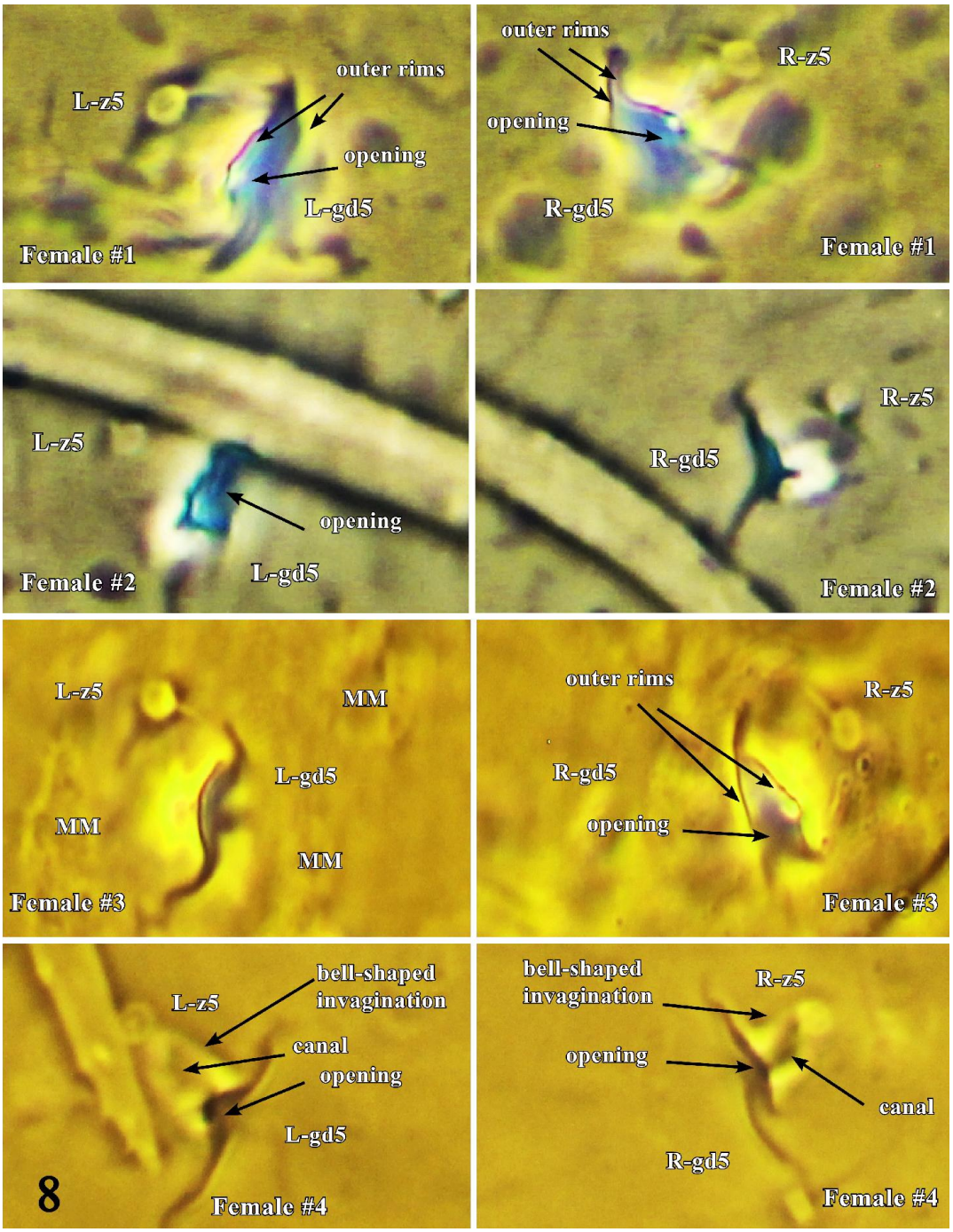

Figure 8. *Paraphytoseius santurcensis*: Solenostome gd5 located posteromedial to left and right (L, R) seta z5 on the dorsal shield in 4 females indicating outer rims, central opening, bell-shaped invagination, and inner canal leading to internal gland. Muscle marks (MM) seen around gd5 [Paratype, slides 1-4, females 1-4, FSCA].

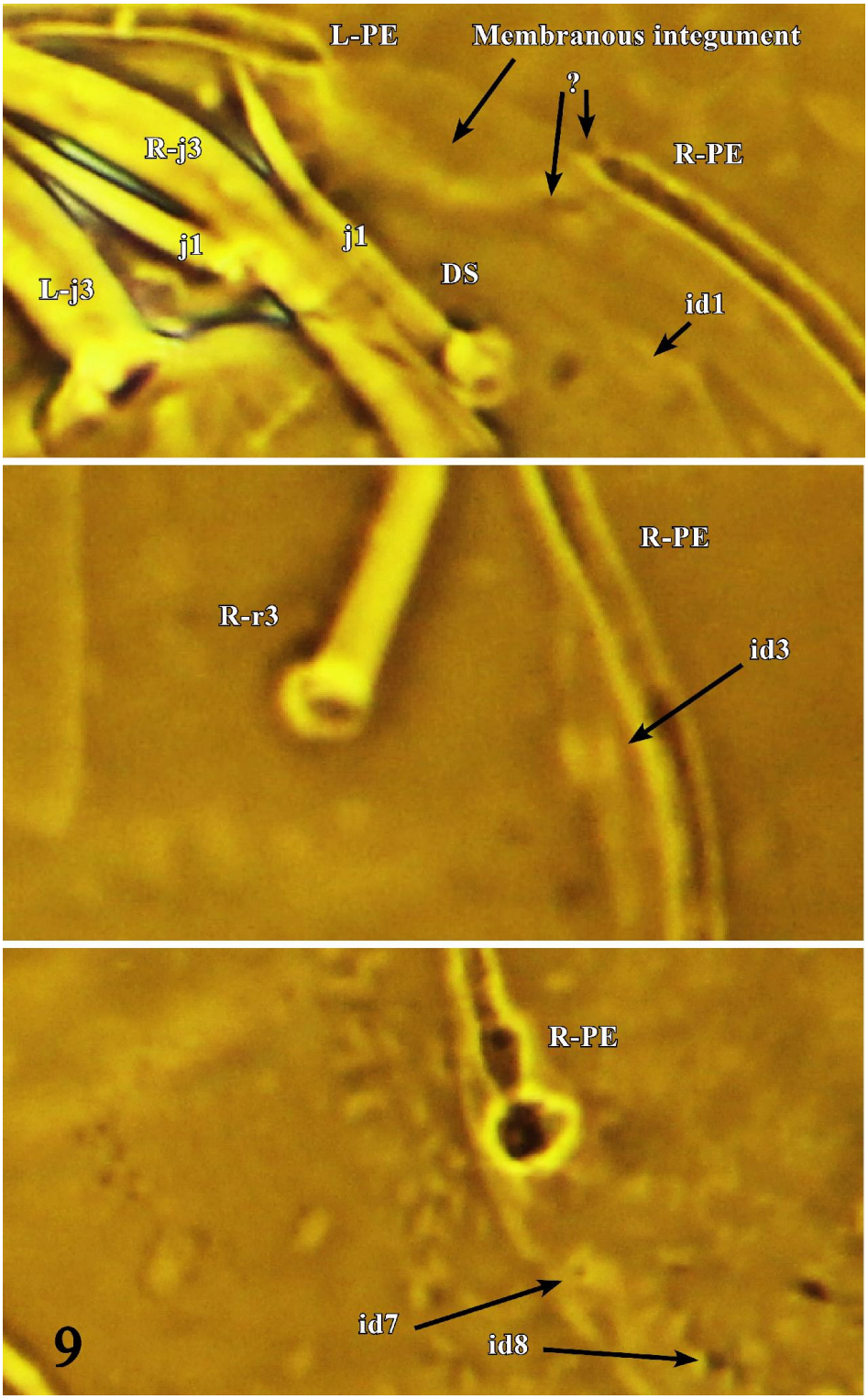

Figure 9. *Paraphytoseius santurcensis*: Enlarged anterior dorsal shield (DS) with anterior peritremes (PE) and right peritremal shield; setae j1, j3, and r3; and lyrifissures id1, id3, id7 and id8. An unidentified lyrifissure-like structure (?) seen on right near tip of peritreme [Paratype, slide 3, female 3, FSCA].

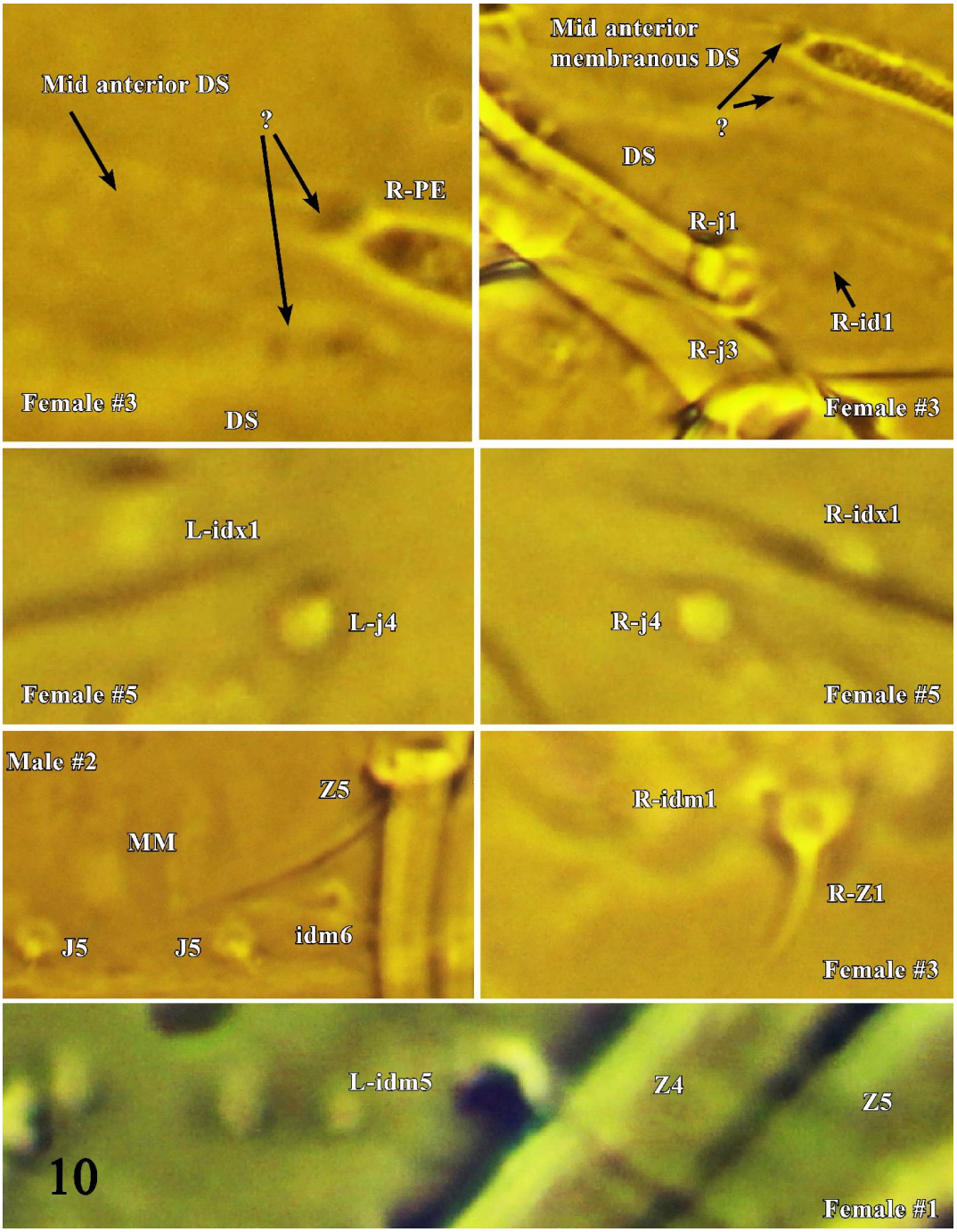

Figure 10. *Paraphytoseius santurcensis*: Enlarged lyrifissures idm1, idm5 and idx1 in a female and idm6 in a male. Some unidentifiable structures (?) also seen [Paratypes, slide 3, female 3, and slide 9, male 2, FSCA].

Lyrifissures on the ventral idiosoma of the male (Fig. 13)

Only 2 pairs of lyrifissures iZV1 and iZV2 were seen on the anterolateral margin of the large and shield-shaped ventrianal shield in 1 male.

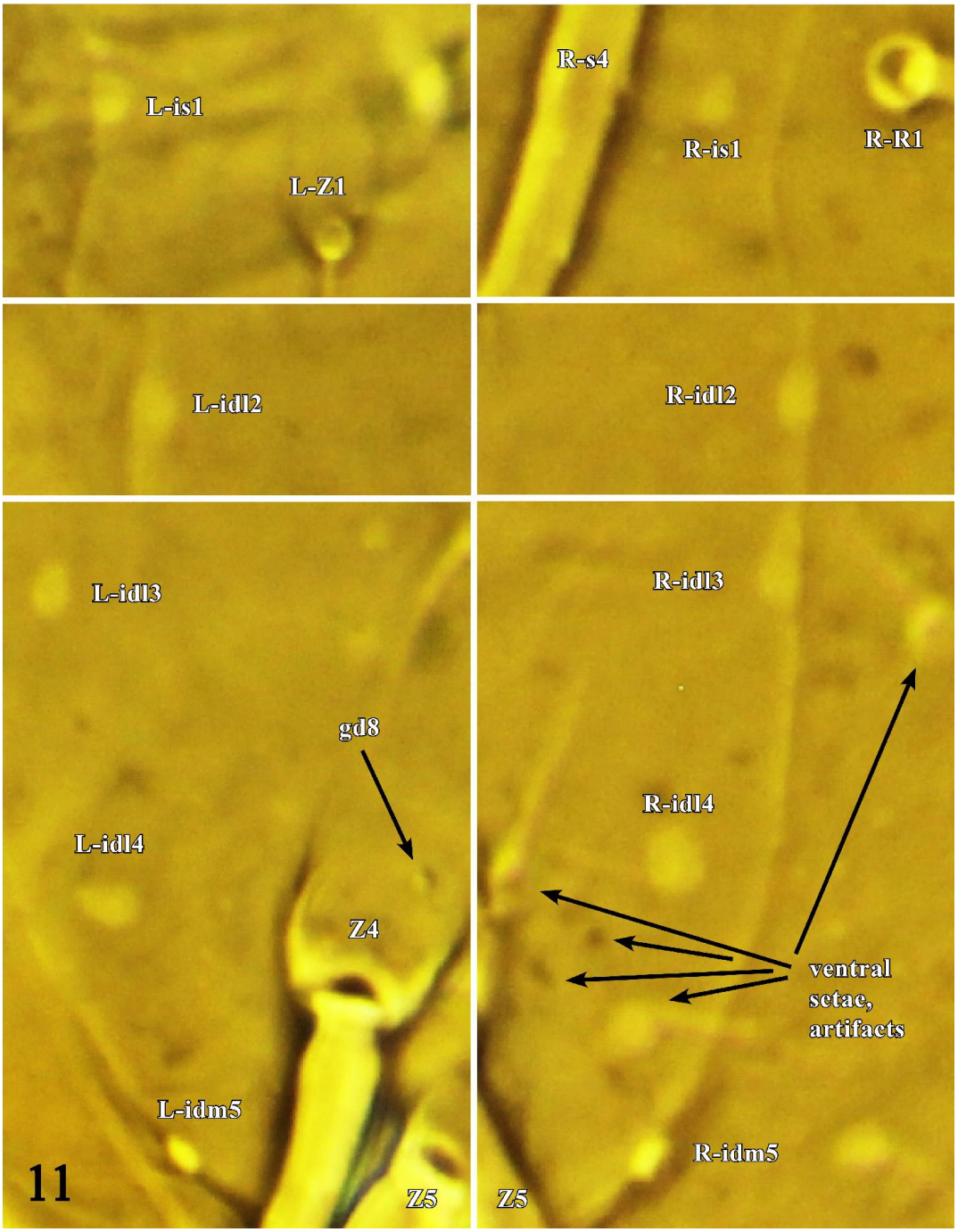

Figure 11. *Paraphytoseius santurcensis*: Enlarged lyrifissures on left and right (L, R) posterior dorsal shield (idl2, idl3, idl4, idm5 and is1). Part of setae s4, Z1, Z4, Z5, R1, some ventral setae and artifacts also seen [Paratype, slide 5, female 5, FSCA].

The lyrifissures on the dorsal and ventral idiosoma of females and males of *P. santurcensis* appear like small, round to oval tiny plates. Therefore, these have been named as "platiform" to compare with those called as "punctiform" or "crescent-shaped" lyrifissures.

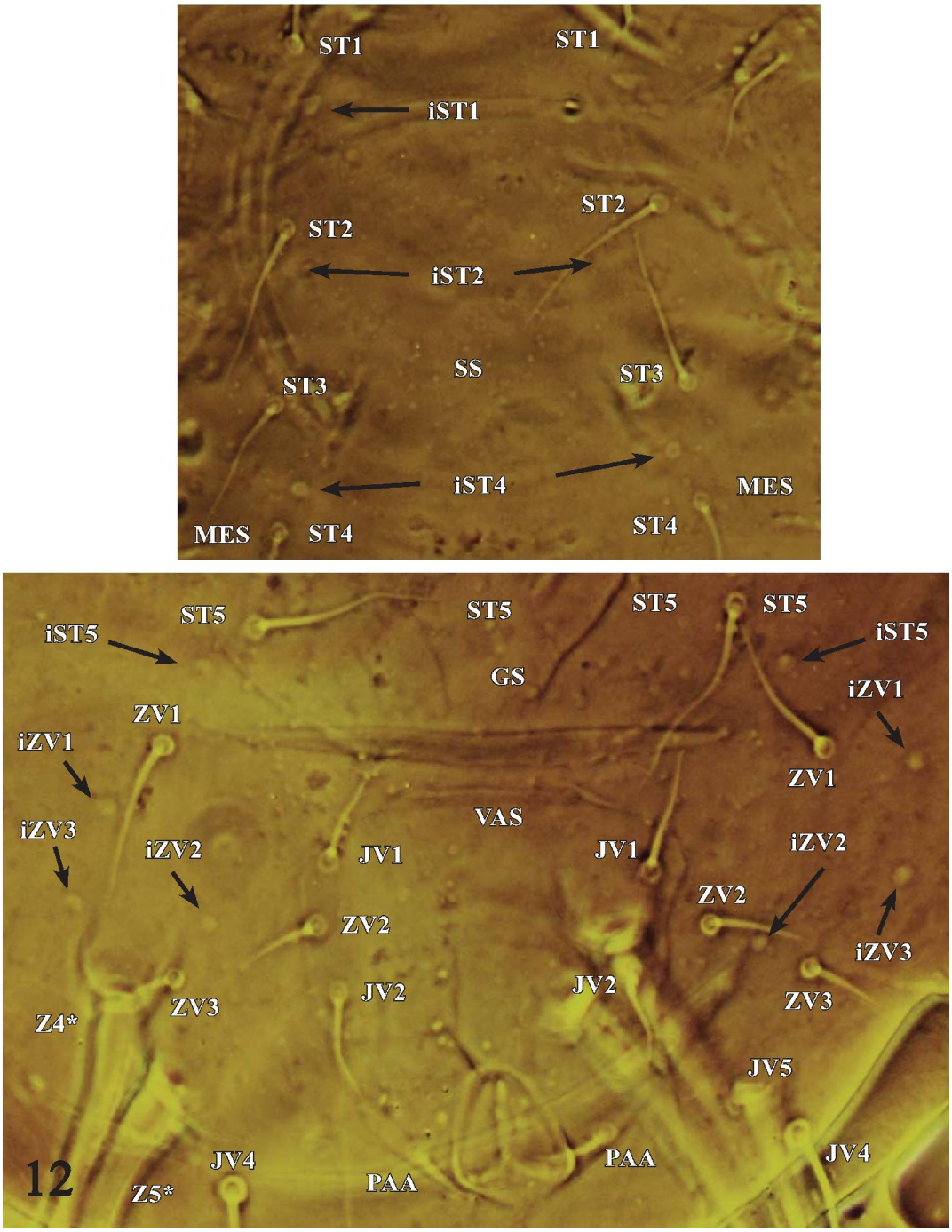

Figure 12. *Paraphytoseius santurcensis*: *Top* - Sternal shield (SS) and metasternal shields (MES) with setae and lyrifissures iST1, iST2 and iST4. *Bottom* - Lyrifissures iST5, iZV1, iZV2 and iZV3 around genital shield (GS) and ventrianal shield (VAS) [Paratypes, Top - slide 4 and female 4 and Bottom - slide 5, female 5, both, FSCA].

Abou-Setta *et al.* (1991) illustrated 3 pairs of lyrifissures on the sternogenital shield (crescent shaped posterior to ST1 and ST2, and punctiform just anterior to ST4) and 4 pairs of lyrifissures on the anterolateral margin of the ventrianal shield (1 punctiform

pair posterior to ST5 but located on the anterior margin of the ventrianal shield, and 3 punctiform pairs lateral to JV1, ZV2 and ZV3) in the male of *Iphiseiodes quadripilis* (Banks). But, they did not indicate the presence of any lyrifissures lateral to the ventrianal shield. In addition to these 7 pairs of ventral lyrifissures, they also illustrated 1 pair of solenostomes gv3 in between but posterior to the bases of ZV2.

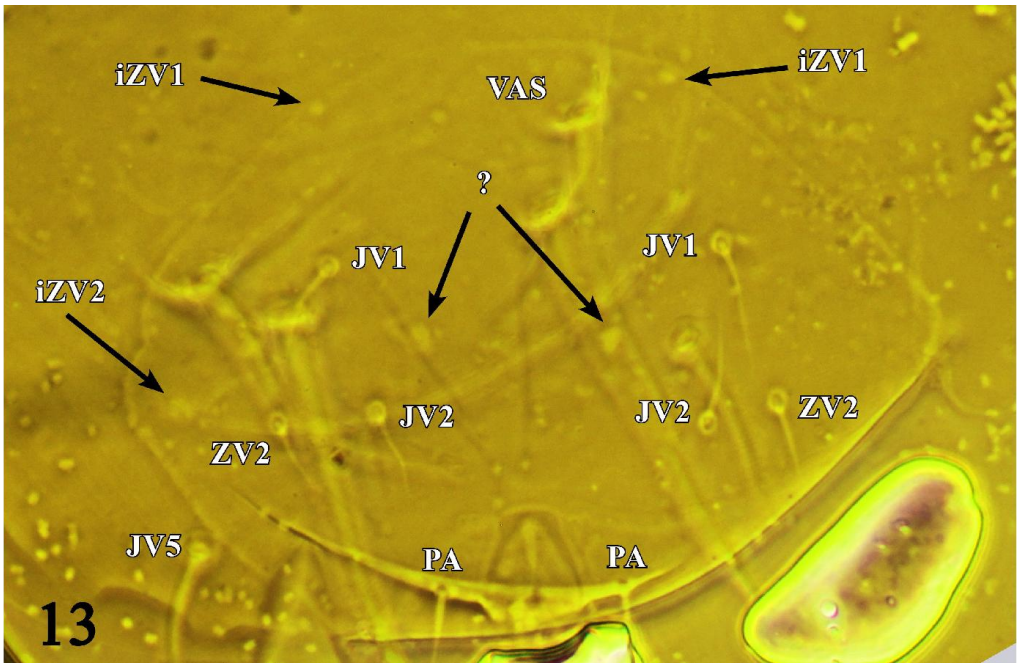

Figure. 13. *Paraphytoseius santurcensis*: Ventrianal shield (VAS) with 3 pairs of preanal setae JV1, JV2 and ZV2. Lyrifissures iZV1 and iZV2 seen on shield [Paratype, slide 9, male 2, FSCA, 400x].

Solenostomes and lyrifissures in the hypothetical model of Paraphytoseius species (Fig. 14)

The hypothetical model of the solenostomes and the lyrifissures in *Paraphytoseius* indicates some muscle marks present on the opisthonotal shield in middle area of absent setae J2-J4. Solenostome gd3 and lyrifissures id3, id7 and id8 are present on the peritremal shield.

This model shows the maximum possible number of solenostomes being 8 pairs [all on the dorsal shield unless indicated otherwise]: gd1, gd2, gd3 (on the peritremal shield), gd4, gd5, gd6, (gd7 absent in Phytoseiidae), gd8 and gd9. The solenostome gd8 is shown at the base of large tubercles of seta Z4 and gd9 is shown on the large tubercle of seta Z5 just posterior to seta Z4.

In this model, the maximum possible number of lyrifissures are 19 pairs on the dorsal idiosoma. Of these, 16 pairs are on the dorsal shield and 3 pairs on the peritremal shield. Of these 16 pairs on the dorsal shield, 6 pairs are in the podonotal region and 10 pairs in the opisthonotal region. This figure shows that the holotrichous *Paraphytoseius* species have similar number of "pores" as the genera with more setae, such as species of *Amblyseius* shown by Aponte and McMurtry (1987).

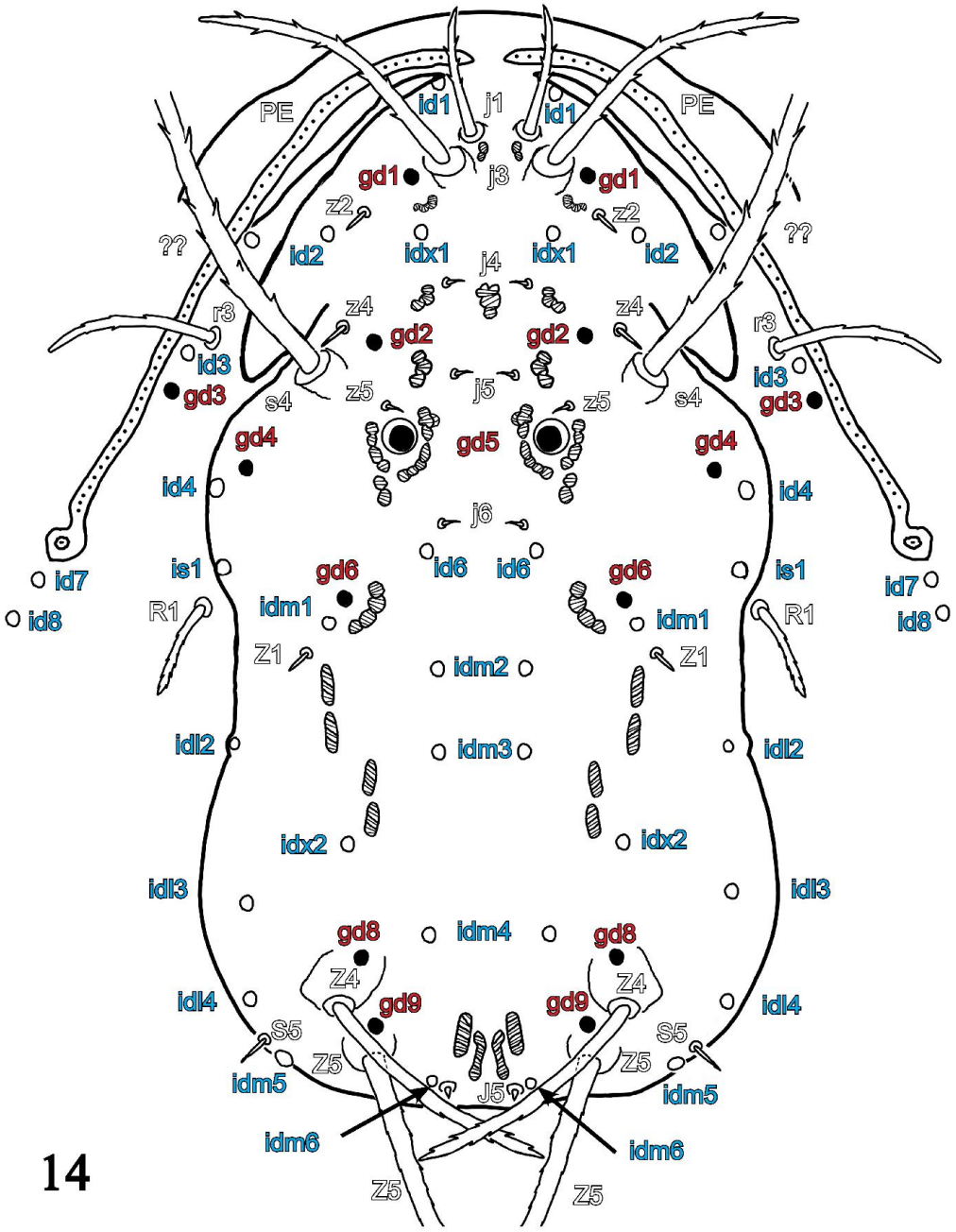

Figure 14. Hypothetical model of *cracentis* species group of *Paraphytoseius* showing setae, solenostomes (gd) and lyrifissures (id, is, idx) in approximate locations on the dorsal idiosoma [Solenostomes = 7 pairs on DS + 1 pair on PE, = 8 pairs] [Lyrifissures = 16 pairs on DS + 3 pairs on PE, = 19 pairs].

Discussion

Taxonomic status of P. santurcensis

Matthysse and Denmark (1981), without giving any details, reported that *P. santurcensis* was a junior synonym of *P. multidentatus* Swirski and Schechter, 1961.

Schicha and Corpuz-Raros (1985) reported that this synonymy was doubtful as the former had an additional short, rod-shaped macroseta present on genu of leg III and genu IV but they did not discuss if the solenostomes and lyrifissures were similar or dissimilar in both species. Chant and McMurtry (2003) reported *P. multidentatus* as a junior synonym of *P. orientalis*. They also reported examining the type of *P. santurcensis* but did not discuss if the solenostomes and lyrifissures were similar or dissimilar in these 2 species. As of 2014, *P. santurcensis* has not been proven to be identical to *P. orientalis* as all differentiating characters of both species have not been studied and comparative data on these 2 species have not been presented.

Solenostomes and lyrifissures on the dorsal idiosoma in the female P. santurcensis

De Leon (1965) stated his new species, *P. santurcensis,* being similar to *P. multidentatus* but different from the latter in having, one of the differentiating characters: dorsal shield with 10 pairs of pores [only 4 pairs illustrated in *P. multidentatus* near z4, z5, Z1, and Z4 in the original publication of Swirski and Shechter (1961)]. Neither Swirski and Schechter (1961) nor De Leon (1965) illustrated solenostomes or lyrifissures on the peritremal shield. In the present study, as stated before, a total of 7 pairs of solenostomes (1 additional pair gd3 on middle of peritremal shield not seen) and 16 pairs of lyrifissures were observed on the dorsal shield (not including 3 pairs seen on the peritremal shield) of the female *P. santurcensis*. Thus, a total of 23 pairs of solenostomes and lyrifissures were observed on the dorsal shield of *P. santurcensis*. In addition, 3 pairs of lyrifissures were also observed on the peritremal shield of the female.

Schicha and Corpuz-Raros (1985) illustrated 13 pairs of solenostomes and lyrifissures on the dorsal shield of female *P. multidentatus*. Moraes *et al.* (2007) illustrated 15 pairs of solenostomes and lyrifissures on the dorsal shield of female *P. orientalis*. All of these authors illustrated 5 pairs of lyrifissures on the lateral margin of the dorsal shield posterior to the lateral concavity and posterior to seta Z1. These were not named but represent (from anterior to posterior) lyrifissures (as given in the hypothetical model, Fig. 14): idl2 (anterior to idl3 and posterior to R1, in area of absent S2), idl3 (anterior to idl4, in area of absent S3), idl4 (lateral to Z4, in area of absent S4), idm5 (lateral to Z5 and posterolateral to Z4, in area of absent S5) and idm6 (anterior to J5). All of them also illustrated a pair of solenostome (but did not name) gd8 located near the tubercle just anterior to the base of seta Z4. While all of them also illustrated lyrifissure idm5 in the area of absent S5, the latter [Moraes *et al.* 2007] also illustrated idm3 anterior to idm4 in *P. orientalis* and or *P. horrifer*. On the other hand, Ho and Lo (1989), in *P. multidentatus*, illustrated 18 pairs of solenostomes and lyrifissures on the dorsal shield that included all mentioned above but added some additional lyrifissures also (including is1 on the lateral margin of the dorsal shield anterior to base of seta R1) and did not include lyrifissure id1 located lateral to base of j1 or j3. This lyrifissure id1, as seen in this study (Figs. 1–4, 9, 10) located lateral to base of seta j1 is light in color and round to oblong in shape and is easily confused with some artifacts present in the anterior end of the dorsal shield (indicated with ? in Figs. 1, 2, 9, 10).

It is evident from the above that although most solenostomes and lyrifissures were not difficult to observe, some were not as clear and difficult to determine. It was clear that lyrifissures located on the lateral border of the dorsal shield posterior to the base of z2, illustrated by many authors mentioned above, were clear to observe as were solenostomes gd5 and gd8.

Solenostomes and lyrifissures on the dorsal idiosoma in the male P. santurcensis

Although De Leon (1965) did collect 3 males, he did not discuss or illustrate solenostomes or lyrifissures on the dorsal idiosoma. The solenostomes gd5 and gd8 were seen in the present study but others could not be identified. However, most lyrifissures as present in the females, were seen. Neither Schicha and Corpuz-Raros (1985), nor Ho and Lo (1989), in male of *P. multidentatus*, or Moraes *et al.* (2007), in male of *P. orientalis*, discussed or illustrated the solenostomes or the lyrifissures.

Solenostomes and lyrifissures on the ventral idiosoma in the male of P. santurcensis

De Leon (1965) did not discuss or illustrate solenostomes or lyrifissures on the ventral idiosoma. Schicha and Corpuz-Raros (1985) and Ho and Lo (1989) did not illustrate any of these on the ventrianal shield although they illustrated 3 pairs of preanal setae on this shield. Moraes *et al.* (2007) did not illustrate or discuss these in the male of *P. orientalis*. As given in the result section, 2 pairs of lyrifissures (iZV1 and iZV2) were seen on the ventrianal shield of the male in the present study.

Difficulties in the identification of the solenostomes and the lyrifissures in P. santurcensis

Most solenostomes, except for large gd5 located immediately posterior to base of seta z5 and small gd8 located on the tubercles just anterior to the base of seta Z4, were difficult to identify with certainty. This was possibly because specimens were almost 50 years old, and had large and thick setae, and many artifacts. However, identification of most lyrifissures, especially on the lateral opisthonotum, was not difficult. Another problem was encountered in the case that some of the lyrifissures looked like solenostomes. For example, idm1 located near medial base of seta Z1 (Figs. 1, 2, 5, 7, 10), idm5 located lateral to base of seta Z5 (Figs. 1, 5, 10, 11), idm6 located lateral to seta J5 (Fig. 1) and id7 located posterior to stigmata on the endopodal part of the peritremal shield (Figs. 1, 9).

Conclusion

Based on the above studies, it is evident that solenostomes and lyrifissures in *P. santurcensis* are similar to those in *P. orientalis*. It is also evident that several specimens are necessary to study the solenostomes and lyrifissures as all of these may not be seen in only one specimen.

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سولنوستوم‌ها و لیریفیشرها در *Paraphytoseius santurcensis* De Leon (Acari: Phytoseiidae): تفسیرها و تصویرهای مستند

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چکیده

تصاویر فراوانی از سولنوستوم و لیریفیشرها، شامل gd5 بزرگ، موجود در جنس ماده و نر *Paraphytoseius santurcensis* De Leon, 1965 که موی S5 ندارند، ارایه شده است. مدل فرضی از جنس *Paraphytoseius* دارای موی S5، همانند آنچه در *P. cracentis* (Corpuz and Rimando, 1966) دیده می‌شود به صورت ترسیم خطی نشان‌دهندهٔ همهٔ سولنوستوم‌ها و لیریفیشرهایی که ممکن است در یک گونه از این جنس وجود داشته باشد، ارایه شده است.

واژگان کلیدی: ادنوتاکسی، لیریفیشر، پروئیدوتاکسی، پروتاکسی، پروپریورسپتور، سجیلا، سولنوستوم gd5.

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