

Article

Sigilla in four species of *Paraphytoseius* (Acari: Phytoseiidae): comments and voucher photos

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Abstract

A total of 9 pairs of sigilla on the podonotum (all in pair except single saI' but counted as a pair: saI', saI'', saII, saIII, saIV, saV, saVI, sp, and ss) and 7 pairs on the opisthonotum (saIX, saX, saXI, saXII, saXIII, saXIV, and sg) along with setae, solenostomes and lyrifissures in 9 females of 4 species and 3 males of 2 species of *Paraphytoseius* [*cracentis* (Corpuz and Rimando, 1966) = 3 non-paratype females; *multidentatus* Swirski and Shechter, 1961 = 2 paratype females; *orientalis* (Narayanan, Kaur and Ghai, 1960) = 2 non-type females and 1 non-type male; and *santurcensis* De Leon, 1965 = 2 paratype females and 2 paratype males] are compared and given in several voucher photos. These are similar in location to those described by Athias-Henriot (1975). They are very similar in all 4 species, with little difference in female and male, and thus appear to be of no taxonomic value in differentiating these species. Problems with sigilla, especially, near and posterior to j1-j1 and around the solenostome gd5, are discussed. It is established that sigilla on the opisthonotum (7 pairs: saIX, saX, saXI, saXII, saXIII, saXIV and sg) are well differentiated and clearly seen than those on the podonotum in these species and may be used for study in other species of Phytoseiidae. A hypothetical model of *P. cracentis* in a line drawing indicating all sigilla in relation to the dorsal setae, solenostomes, and lyrifissures is included.

Keywords: Adenotaxy; gd5; *Paraphytoseius*; poroidotaxy; sigilla, sigillotaxy; voucher photos.

Introduction

The sigilla (singular = sigillum) are muscle insertions ("scars"), usually visible as depressed and or striate regions ("scars") on plates, oval or irregular in shape and often in clusters (Walter 2005). The use of these as taxonomic characters is called sigillotaxy. These muscle insertions on the idiosoma have also been called as muscle marks and their significance explained by Prasad (2015) in locating certain solenostomes and lyrifissures in *Paraphytoseius santurcensis* De Leon, 1965, in which several dorsal setae are absent. Athias-Henriot (1969) discussed and illustrated 4 types of territorial muscle marks in gamasid family Ascidae which she called tm1, tm2, tm3 and tm4.

Athias-Henriot (1971, 1973, 1974, 1975) continued to publish on adenotaxy, poroidotaxy, and sigillotaxy for several years. In her last publication (1975), she discussed and illustrated sigilla on the dorsal shield of Amblyseiini along with the setae, the solenostomes, and the lyrifissures showing a relationship with all of these which she

called "Territoires organogères." In this work, she established 29 territories of which 14 territories were on the podonotum and 15 territories were on the opisthonotum as given below. Each territory included a combination of the dorsal seta, the solenostome, the lyrifissure, and the sigilla. But, when it had sigilla only and not the dorsal seta, the solenostome, and or the lyrifissure, no territorial number was assigned by her. These were:

(1) On podonotum (14 territories; and no territory assigned for ss, sp, and saI as consisted of sigilla only): C1 (j1; no solenostome; id1; no sigilla); C2 (j2; gd1; no lyrifissure; saII); C3 (j3; no solenostome; id5; saIII); C4 (j4; gd2; no lyrifissure; saIV); C5 (j5; gd5; no lyrifissure; saV); C6 (j6; no solenostome; id6; saVI); M1 (s4; no solenostome; id2; no sigilla); M2 (s5; gd4; id4; no sigilla); L1 (no seta; no solenostome; no lyrifissure; sl1); L2 (no seta; gd3; id3; sl2); L3 (no seta; gdp; id7; no sigilla); P1 (z3, z4; no solenostome; no lyrifissure; no sigilla); P2 (z6; no solenostome; no lyrifissure; no sigilla); R1 (r5; no solenostome; no lyrifissure; no sigilla); ss (no seta, no solenostome, no lyrifissure, sigilla ss only) - no territory assigned as consisted of sigilla ss only and had no seta, solenostome, or lyrifissure; sp (no seta, no solenostome, no lyrifissure, sigilla sp only) - no territory assigned as consisted of sigilla sp only and had no seta, solenostome, or lyrifissure; and saI (no seta, no solenostome, no lyrifissure, sigilla saI only) - no territory assigned as consisted of sigilla saI only and had no seta, solenostome, or lyrifissure.

(2) On opisthonotum (15 territories; no territory assigned for sg as consisted of sigilla only): C9 (J1; no solenostome; idm1; saIX); C10 (J2; no solenostome; idm2; saX); C11 (J3; no solenostome; idm3; saXI); C12 (J4; no solenostome; idm4; saXII); C13 (Z5; no solenostome; idm5; saXIII); C14 (J5; no solenostome; idm6; saXIV); M3 (S1; no solenostome; is1; no sigilla); M5 (Z3; no solenostome; no lyrifissure; no sigilla); M6 (Z4; gd8; no lyrifissure; no sigilla); L4 (S2; no solenostome; idl1; no sigilla); L6 (S4; no solenostome; idl3; no sigilla); L7 (S5; gd9; idl4; no sigilla); P3 (Z1; gd6; no lyrifissure; no sigilla); P4 (no seta; no solenostome; idx; no sigilla); R2 (R1; no solenostome; no lyrifissure; no sigilla); and sg (no seta, no solenostome, no lyrifissure, sigilla sg only) - no territory assigned as consisted of sigilla sg only and had no seta, solenostome, or lyrifissure. She also illustrated 2 groups of sigilla in middle of the peritremal shield which she called s/1 to the anterior group and s/2 to the posterior group [Athias-Henriot (1975), erroneously called j2 (to j3), j3 (to j4), j4 (to j5), j5 (to z5), z3 (to z2), and r5 (to r3)]. Sigilla VII and VIII are absent in Phytoseiidae and other Mesostigmata in the area of the dorsodisjugal furrow that separates the prodorsum from the opisthosoma (van der Hammen 1982).

Swirski *et al.* (1998), without naming sigilla (solenostomes and lyrifissures), illustrated these (without discussing or illustrating on the peritremal shield) in 20 species of Phytoseiidae in 18 genera from Israel. Most of the sigilla were very similar to those illustrated by Athias-Henriot (1975). Although, Swirski *et al.* (1998) used the adenotaxy and poroidotaxy as additional tools for the identification of some species, they did not use the sigillotaxy as a taxonomic tool for these species. Similar to Athias-Henriot (1975), they also stated that the position and the number of these sigilla, solenostomes, and lyrifissures were very stable in different species.

Athias-Henriot (1975) did not give sigillotaxy of the ventral idiosoma but Swirski *et al.* (1998) illustrated 3 pairs of sigilla on the genital shield, 2 pairs on the ventrianal shield, and called 2 pairs of small and narrow metapodal shields as inguinal sigilla (did not indicate any sigilla on the sternal shield). On their figures 41–65 of the anal shield,

the preanal shield, and the ventrianal shield, they illustrated 1–2 pairs of sigilla located, mostly, lateral to the pair of paraanal setae but, occasionally, posterior to the paraanal setae and lateral to the single postanal seta. They indicated these present or absent in *Eharius chergui* (Athias-Henriot, 1960). Similar to Athias-Henriot (1975), they did not discuss sigillotaxy of the male dorsal or ventral idiosoma.

Although, sigilla have been illustrated on the dorsal shield in different species of *Paraphytoseius* by various authors (Pritchard and Baker 1962 - *P. horrififer*; Corpuz and Rimando 1966 - *P. cracentis*; Moraes *et al.* 2007 - *P. ghanaensis*, *P. horrififer* and *P. orientalis*), none have been named or used as taxonomic tool for the identification of these species. The same situation has existed in most species of other genera of Phytoseiidae in which some of these have been illustrated but not named (McMurtry and Moraes 1985; Moraes *et al.* 1989; Ehara and Amano 2004; Moraes *et al.* 2007). Thus, the taxonomy of sigilla has received no attention in Phytoseiidae. The same situation exists in the species of the closely related but hypotrichous family Otopheidomenidae in which sigilla have been illustrated on the dorsal shield in different species (Prasad 2011; Prasad *et al.* 2011). However, they have not been named or stated if these were different or same in different species or similar to those proposed by Athias-Henriot (1975). Prasad (2015) also discussed the solenostomes and the lyrifissures in *P. santurcensis* indicating these similar to those in *P. orientalis*. These sigilla in the opisthonotal area are clear to observe and identify but are difficult to identify to their exact identity in the podonotal area near setae j1 and j3 that are placed on large tubercles and near the large solenostome gd5 which, on each side, is surrounded by several sigilla groups that are located very close to each other.

The author had females and males of several species of *Paraphytoseius* at hand, including paratypes and non-paratype specimens, that indicated sigilla very well. Thus, this study was conducted with the following objectives: (1) Name the sigilla in the females and males of 4 species based on Athias-Henriot (1975); (2) Note if some sigilla were species-specific or sex-specific; (3) Compare sigilla of *Paraphytoseius* in some other genera and species of Phytoseiidae; (4) Conclude if sigillotaxy is of any taxonomic value in *Paraphytoseius* representing Phytoseiidae; and (5) Create a hypothetical model of the sigilla in a line drawing indicating relation to the setae, the solenostomes, and the lyrifissures.

In the present study, voucher photos of more than 1 specimens of each species are included to show the variation from specimen to specimen in different species and from female to male. A few of these show enlarged views of some of the sigilla to reveal their details. A central dark area, representing possible depression (Walter 2005) in each sigillum, surrounded by a rim-like border, is clearly evident in most sigilla which are not so clearly visible in low magnifications. Some of the sigilla can be seen surrounded, in part or all around, by dark areas indicating depressions and giving different reticulation patterns.

Materials and methods

The details of 12 specimens of different species of *Paraphytoseius* included in this study [*P. cracentis* (Corpuz and Rimando, 1966) = 3 non-paratype females; *P. multidentatus* Swirski and Shechter, 1961 = 2 paratype females; *P. orientalis* (Narayanan *et al.*, 1960) = 2 non-type females and 1 non-type male; and *P. santurcensis* De Leon, 1965 = 2 paratype females and 2 paratype males] were as follow:

(1) *P. cracentis* (Figs. 2–4) - (a) Slide #4, female #2, non-type, collected by A. Sayaboc on 10.III.1973, from santol leaves (*Sandoricum koetjape*, Meliaceae), UP Los Baños campus, College, Laguna Province, Philippines, Florida State Collection of Arthropods (FSCA) [identification of *P. cracentis* on slide #4, Figure #2, corrected to *P. orientalis* by V. Prasad in 2015] (Fig. 2); (b) Slide #2, female #1, non-type, collected by J.M. Sotto on 26.III.1977, from kollo-kollot leaves (*Urena lobata*, Malvaceae), Pintor, Gamu Municipality, Isabela Province, Philippines, Florida State Collection of Arthropods (FSCA) (Fig. 3); (c) Slide #1, female #1, non-type, collected by author (VP) on 22.IX.1972, from mixed vegetation near a lake, Vellayani, Kerala state, India, author's collection # VP72-237 (Fig. 4).

(2) *P. multidentatus* (Figs. 5, 6) - (a) Slide #1, female #1, paratype, collected by E. Swirski on 23.VIII. 1960, from *Urena lobata* plant (Malvaceae), Victoria Mt. Forest, Hong Kong, Florida State Collection of Arthropods (FSCA) (Fig. 5); (b) Slide #2, female #1, paratype, collected by E. Swirski on 13.VIII.1960, from *Jasminum* sp. plant (Oleaceae), Tai Po Hui (N.T.), Hong Kong, Israel Museum (Fig. 6).

(3) *P. orientalis* (Figs. 7–13) - (a) Slide #5, female #1, non-type, collected by author (VP) on 24.I.1973, from eggplant leaves (Solanaceae), Sabour, Bhagalpur district, Bihar state, India, author's collection # VP73-18 (Figs. 7, 8); (b) Slide #3, female #6 (Figs. 9–11) and (c) Slide #2, male #1, non-types, collected by author (VP) on 24.I.1973, from eggplant leaves (Solanaceae), Bhubaneswar, Orissa (now Odisha) state, India, author's collection # VP73-93 (Figs. 12, 13).

(4) *P. santurcensis* (Figs. 14–17) - (a) Slide #1, female #1 (Fig. 14); (b) Slide #3, female #3 (Fig. 15); (c) Slide #8, male #1 (Fig. 16); and (d) Slide #9, male #2 (Fig. 17); all paratypes, collected on 5.IX.1963, by D. De Leon, from *Hibiscus tileacea* [*sic* for *tileaceus*] (Malvaceae), Santurce, Puerto Rico, Florida State Collection of Arthropods (FSCA).

The 2 non-type female slides of *P. cracentis*, 1 paratype female slide of *P. multidentatus*, and 2 paratype female and 2 paratype male slides of *P. santurcensis* were borrowed by the author from the Florida State Collection of Arthropods (FSCA), Gainesville, Florida, USA. One paratype female slide of *P. multidentatus* was borrowed from Dr. Leonid Friedman, Zoological Museum, George S. Wise Faculty of Life Sciences, Department of Zoology, Tel Aviv, Israel by Dr. Gregory A. Evans which was examined by this author. The remaining 1 non-type female slide of *P. cracentis* and 2 female and 1 male slides of *P. orientalis* were from the author's collection which were mounted in Hoyer's medium on 3x1 inch (75x25 mm) glass slides.

All specimens were studied in the laboratory of the author in West Bloomfield, Michigan, USA. They were examined using an Acc-Scope 3000 phase-contrast microscope (Acc-Scope, New York, NY, USA) under 100–400x. The voucher photos were taken using a Canon EOS550D camera (Canon U.S.A., Inc., One Canon Park, Melville, NY 11747, USA). The mites were photographed after mounting this camera on the trinocular phase-contrast microscope. These photos were saved in Adobe Photoshop CS5™ and setal signatures added in Adobe InDesign™ program (Adobe Systems, Inc., 345 Park Avenue, San Jose, CA 95110-2704, USA). The original magnification of the photos was 200–400X. As photos of the solenostomes and the lyrifissures were enlarged greatly, their magnifications are not given.

The system of Athias-Henriot (1975) is used to name the sigilla on the dorsal shield of different species of *Paraphytoseius*. But, for those sigilla present on the genital shield and the ventrianal shield, the author has followed his own system naming (from anterior

to posterior) as sgI, sgII, sgIII for those present on the genital shield and svI and svII for the ones present posterior to anus on the ventrianal shield. The naming of primary and secondary metapodal shields as inguinal sigilla by Swirski *et al.* (1998) has not been followed as these, traditionally, have been called as primary and secondary metapodal shields by almost all acarologists

Voucher photos included in the present study will be placed on the website of Indira Publishing House (www.indirapublishinghouse.com). The link of this site will be provided to Florida State Collection of Arthropods and others, from where specimens were borrowed.

Results

When examined in 2014, the specimens of *P. cracentis* from India were about 42 years-old (collected in 1972) and from Philippines 37 years-old (collected in 1977); *P. multidentatus* from Hong Kong 54 years-old (collected in 1960); *P. orientalis* from India 41 years-old (collected in 1973); and *P. santurcensis* 51 years-old (collected in 1963). In spite of being old and having some artifacts on them, sigilla were not so difficult to identify. They appeared to have very consistent patterns of their locations on the dorsal idiosoma as given by Athias-Henriot (1975). Examination of more than 1 specimen was necessary to identify all the sigilla as some were not seen clearly in the same specimen. Only minor variation was observed. Tixier (2012) suggested to examine the minimum of 15 specimens for the species description and good evaluation of the sigilla variations.

(A) Hypothetical model of sigilla in *Paraphytoseius* (Fig. 1)

The hypothetical model of *P. cracentis* female was constructed with help of the real specimens of this study as it possessed seta S5* (*absent in *P. multidentatus*, *P. orientalis*, and *P. santurcensis*). It shows the location of 16 pairs of sigilla on the dorsal shield (counting sa' and sa" as 2 pairs; 9 pairs on the podonotum and 7 pairs on the opisthonotum) in relation to the dorsal setae, the solenostomes, and the lyrifissures. The podonotum anterior to R1 in this species possesses 9 pairs of setae (j1, j3, j4, j5, j6; z2, z4, z5; and s4) of which j1 and j3 are located on large tubercles very close to each other. Sigilla saII and sp located in this area are difficult to identify in the slide mounted specimens as they appear blurred in appearance. The sigilla saI' (in between paired seta j4) are single and easily seen. Four sigilla groups (saI", saV, saVI, and ss) in between j5-j6 and surrounding large solenostome gd5 are clustered together and almost continuous with each other and, thus, difficult to identify in the slide mounted specimens. However, 6 pairs of sigilla (saIX, saX, saXI, saXII, saXIII, saXIV) on the opisthonotum in between Z1 and J5 of *P. cracentis* are single, oval to elongate, placed separately from each other on each side, and easy to identify in the slide mounted specimens. No sigilla was seen on the peritremal shield in the present study and, therefore, not included in the hypothetical model.

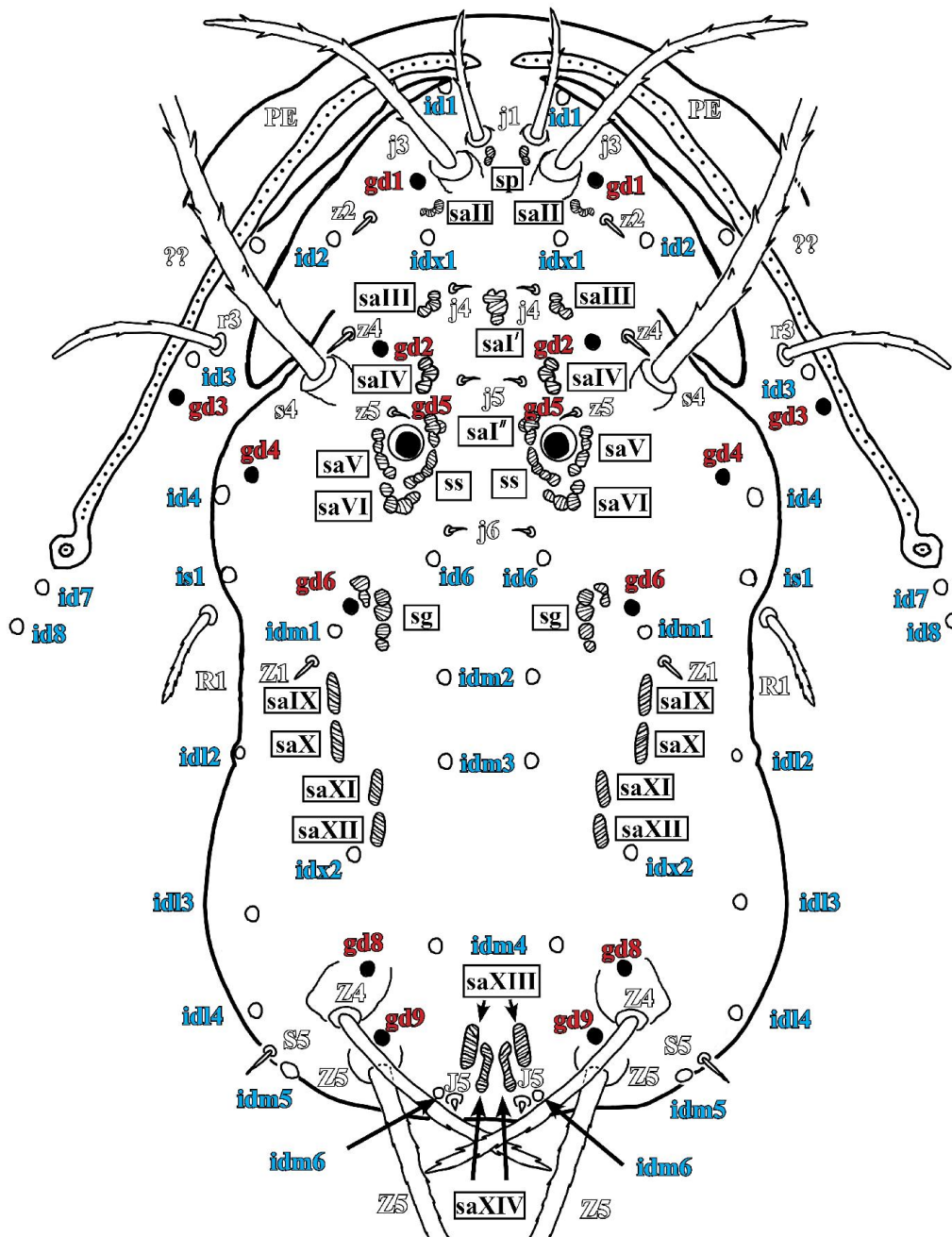


Figure 1. Hypothetical model of *cracentis* species group of *Paraphytoseius* showing setae, solenostomes (gd), lyrifissures (id), and sigilla (sg) in approximate locations on the dorsal idiosoma [Solenostomes = 7 pairs on DS + 1 pair on PE; = 8 pairs] [Lyrifissures = 16 pairs on DS + 3 pairs on PE; = 19 pairs] [Sigilla = 9 pairs on podonotum + 7 pairs on opisthonotum = 16 pairs (+ 2 pairs on peritremal shield: not seen and not included in this model)].

(B) Sigilla in 4 species of *Paraphytoseius*

(1) *P. cracentis* (Corpuz and Rimando, 1966) (Figs. 2–4; 2 = *P. orientalis*):

Females - Study of 2 non-type females collected in Philippines in 1973 and 1 female collected in India in 1972 revealed the following sigilla that included 9 pairs on

the podonotum (counting saI' and saI'' as 2) and 7 pairs on the opisthonotum [Note that female #2 on slide #4 identified as *P. cracentis* by Corpuz-Raros in 1973 was re-identified by this author in 2015 being *P. orientalis*].

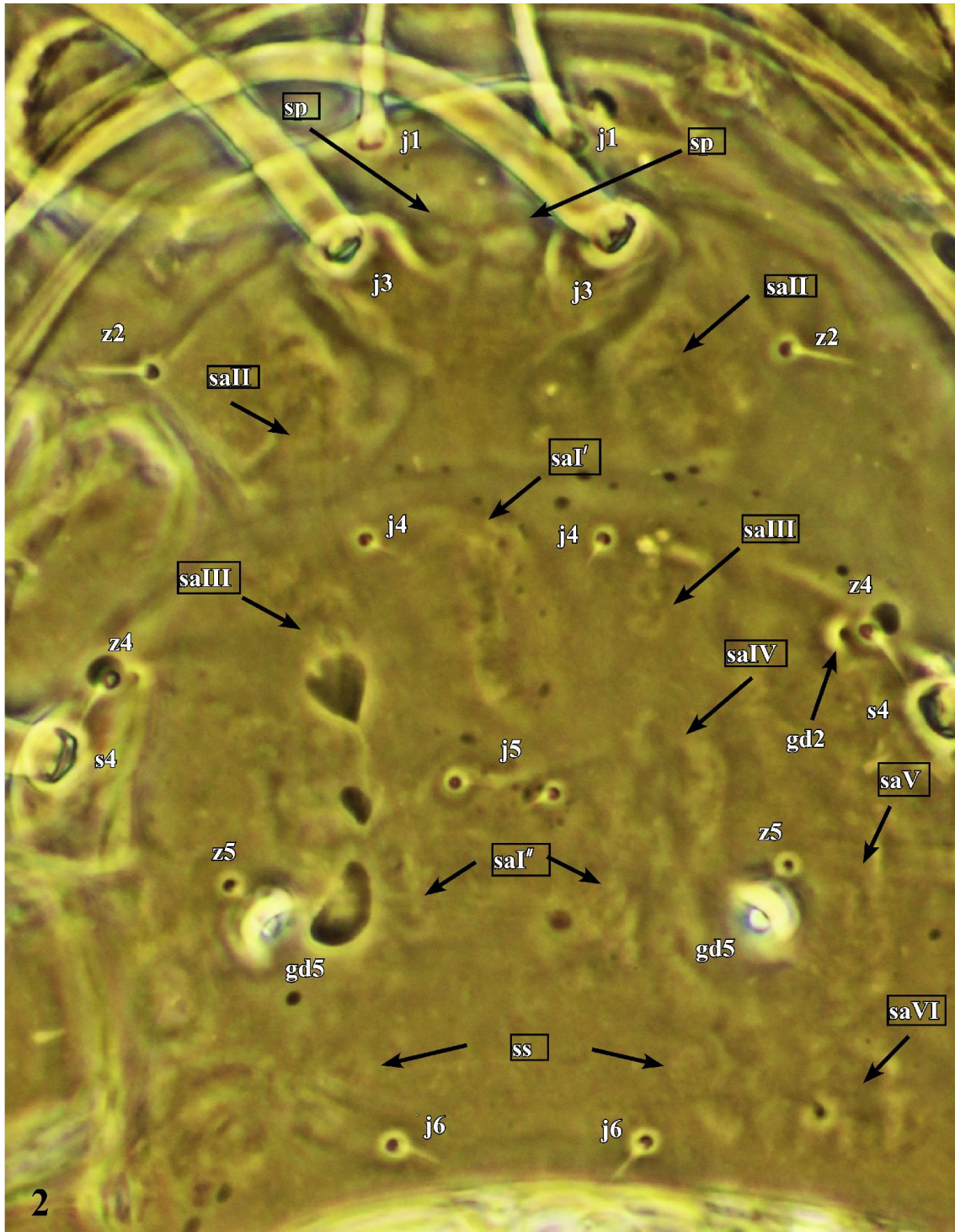


Figure 2. *Paraphytoseius cracentis* (re-identified as *P. orientalis* by this author) - Sigilla on podonotal shield in middle of setae j3, j6, and s4 [FSCA - Non-type, Philippines, 1973, slide #4, female #2].

Dorsum (a) Podonotum (Fig. 2, *P. orientalis*) - Nine pairs of sigilla in between j1 and j6 include (anterior to posterior): (1) sp - Vertically elongate sigilla extending posteromedially from the medial side of seta j1 to medial side of seta j3, appearing to consist of 3–4 muscle scars. (2) saI' - Vertically elongate and single sigilla in between j4-j4 extending posteriorly to anterior of j5-j5, appearing to consist of 4–5 muscle scars. (3) saI'' - Vertically elongate sigilla posterior to j5 and medial to gd5, consisting of about 4-5 muscle scars. (4) saII - Semicircular sigilla medial to z2, consisting of about 4 muscle scars. (5) saIII - Small and vertically elongate sigilla posterolateral to j4, consisting of about 3 muscle scars. (6) saIV - Roughly vertically elongate sigilla lateral to j5 and medial to gd5, consisting of about 5-6 muscle scars. (7) saV - Vertically elongate sigilla lateral to z5 and gd5, consisting of about 3-4 muscle scars. (8) saVI - About round sigilla posterolateral to gd5 and lateral to j6, appearing to consist of about 4-5 muscle scars. (9) ss - About round sigilla anterolateral to j6 consisting of about 3-4 muscle scars. All of these sigilla on the podonotum are not so clear and appear smudged or vague in appearance in this specimen.

(b) Opisthonotum (Figs. 3 and 4, *P. cracentis*) - Seven pairs of sigilla in between Z1 and J5 include (anterior to posterior): (1) sg - Vertically elongate sigilla anterior, posterior, and medial to Z1 extending from opisthonotum to podonotum, consists of about 5-6 muscle scars. (2) saIX - Single and narrowly elongate, oval and vertical sigilla posteromedial to Z1 (in area of absent seta J2) consisting of 1 muscle scar on each side. Poroid idm2 is located medial to saIX. (3) saX - Very similar to saIX, single and narrowly elongate and vertical sigilla posterior to saIX, consisting of 1 muscle scar on each side. (4) saXI - Very similar but posteromedial to saX, single and narrowly elongate and vertical sigilla (in area of absent seta J3), consisting of 1 muscle scar on each side. Poroid idm3 is located medial to saXI. (5) saXII - Very similar to saXI, single and narrowly elongate and vertical sigilla posteromedial to saXI, consisting of 1 muscle scar in female from India (Fig. 4) but short and oval in female from Philippines indicating variation in females of same species from different countries. (6) saXIII - Very similar to saXII, single and narrowly elongate but oval and vertical sigilla medial to setae Z4 and Z5, consisting of 1 muscle scar. (7) saXIV - Very similar to saXIII, single and narrowly elongate to oval and vertical sigilla posteromedial to saXIII, medial to Z5, and anterior to J5, consisting of 1 muscle scar.

Venter (a) Genital shield (Fig. 4, Bottom left, *P. cracentis*) - Three pairs of sigilla, each consisting of 1 elongate and oval muscle scar include (anterior to posterior): (1) sgI - Most anteriorly placed and located posterior to the genital opening. (2) sgII - Anteriorly placed and located posterior to sgI almost in middle of the genital shield. (3) sgIII - Anteriorly placed and located posterolateral to sgII almost in middle of the genital shield but farther away from each other than sgII placed closer to each other. (b) Ventrianal shield (Fig. 4, Bottom right, *P. cracentis*) - Two pairs of sigilla (sv1 and sv2), each consisting of 1 small and roughly oval muscle scar, located in between paraanal and postanal seta on lateral margin of the ventrianal shield.

(2) *P. multidentatus* Swirski and Shechter, 1961 (Figs. 5 and 6):

Females - Study of 2 paratype females, both collected in Hong Kong in 1960, revealed the following sigilla that included 9 pairs on the podonotum (counting saI' and saI'' as 2 pairs, sp not seen) and 7 pairs on the opisthonotum.

Dorsum (a) Podonotum (Fig. 5, *P. multidentatus*) - All sigilla similar to those as in *P. cracentis*. But, sigilla sp not clearly visible in *P. multidentatus* as setae j1 and j3

placed very close to each other due to a semicircular fold of the dorsal shield in between these setae. Vertically located single sigilla saI' is clearly seen posteromedial to j4.

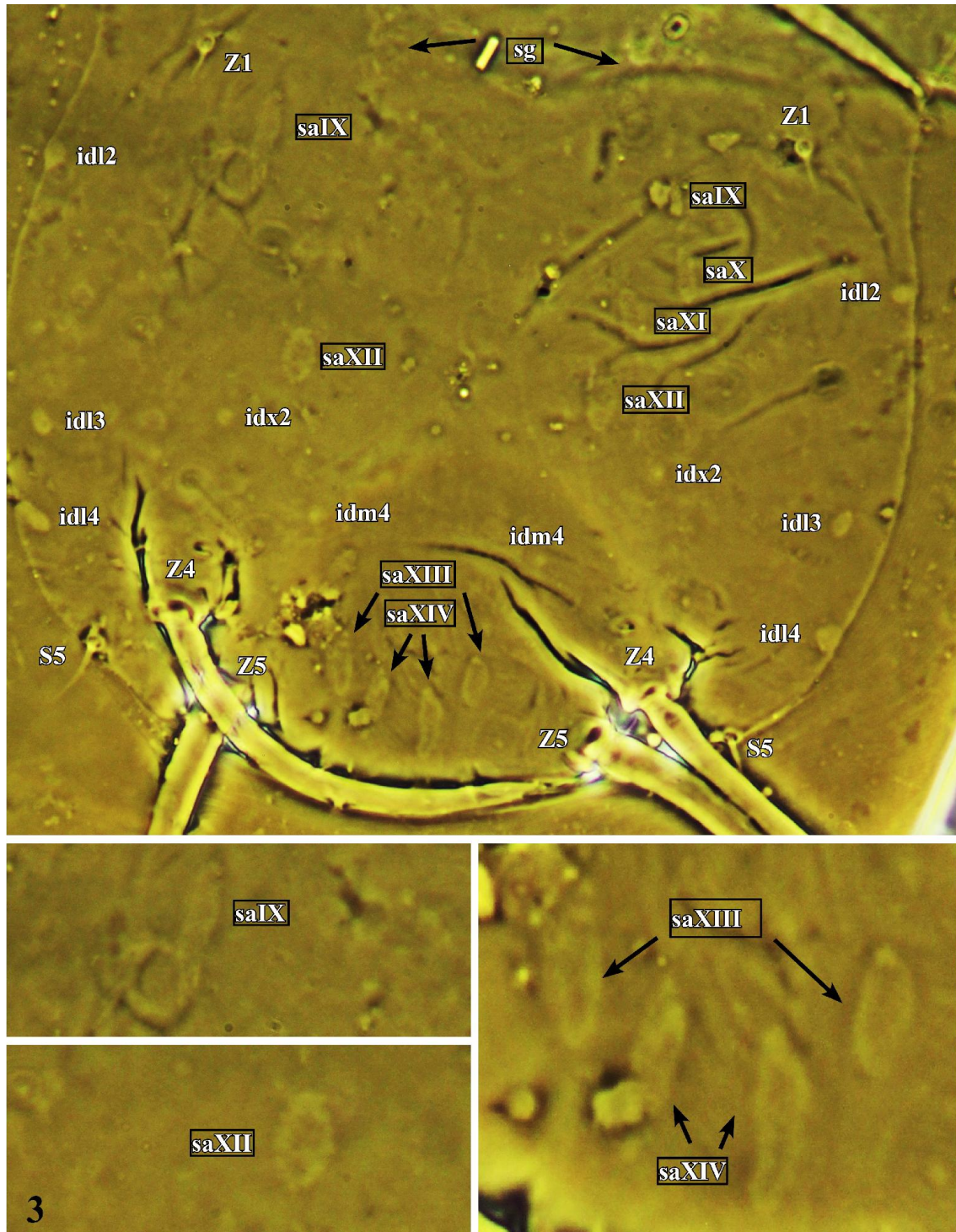


Figure 3. *Paraphytoseius cracentis* - Top: Sigilla on opisthonotal shield in middle of setae Z1 and Z5 (note that sigilla saX and saXI on left are not visible but they are clearly visible on right); Bottom left: Enlarged left sigilla saIX and saXII; Bottom right: Enlarged sigilla saXIII and saXIV [FSCA - Non-type, Philippines, 1977, slide #2, female #1].

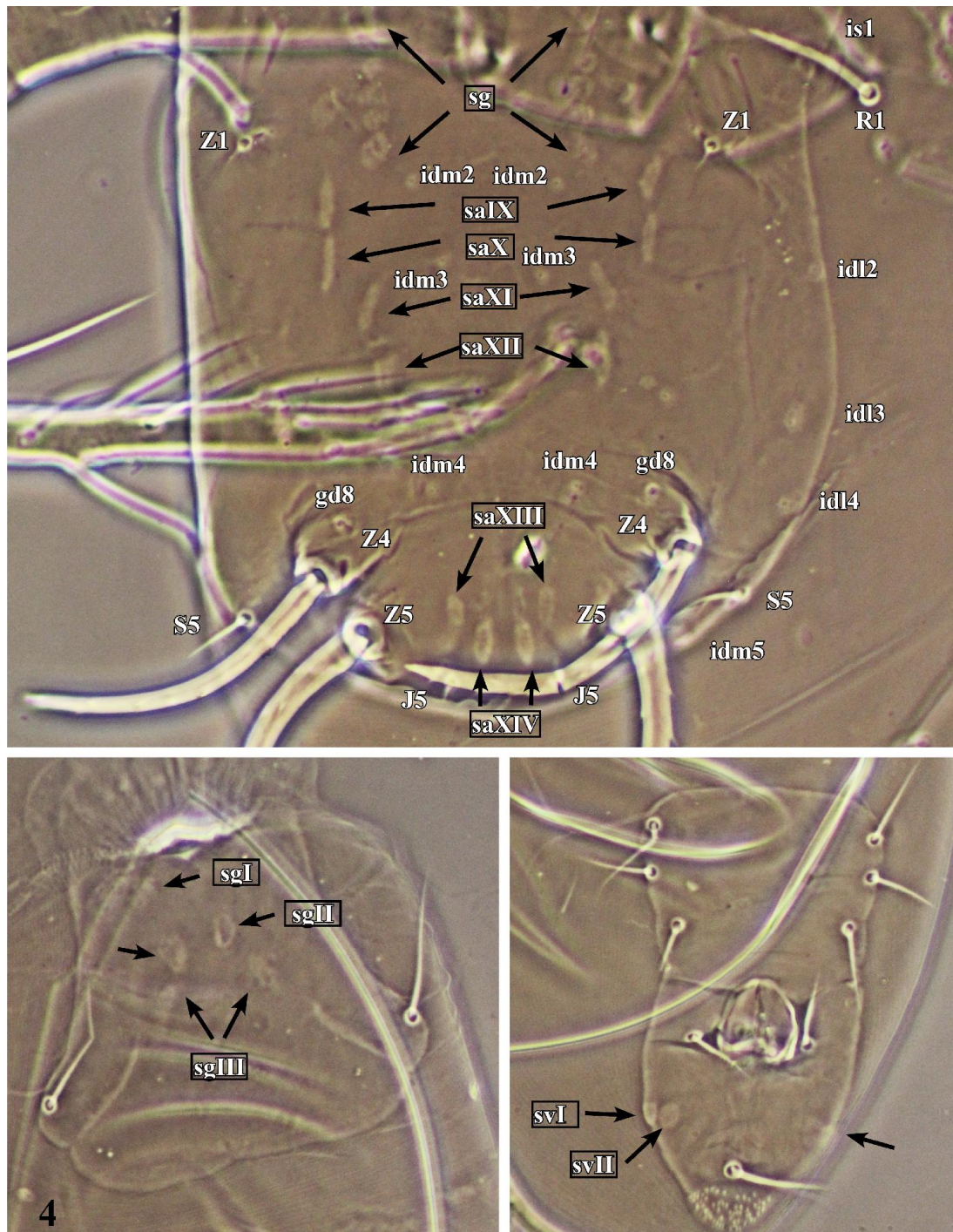


Figure 4. *Paraphytoseius cracentis* - Top: Sigilla on opisthonotal shield in middle of setae Z1 and Z5; Bottom left: Three pairs of sigilla on genital shield (sgI, sgII, and sgIII); Bottom right: Two pairs of sigilla (svI and svII) on ventrianal shield [India, Kerala, 1972, VP72-237, slide #1, female #1].

(b) Opisthonotum (Figs. 5 and 6, *P. multidentatus*) - Elongate to semicircular sigilla sg medial to Z1 appear to consist of 5–6 muscle marks. Sigilla saIX and saX are narrowly elongate as in *P. cracentis*. Sigilla saXI is different in *P. multidentatus* than in *P. cracentis* as it is not as elongate and is short and narrow on left and short and oval on

right in former indicating variation. Sigilla saXII in former species is also not as narrow and elongate but is short and oval even when 1 female was collected from *Urena lobata* and other female from *Jasminum* sp. Sigilla saXIII and saXIV are mostly elongate and located in between the bases of Z5 but are oval also in both species showing some variation in the shape and the size.

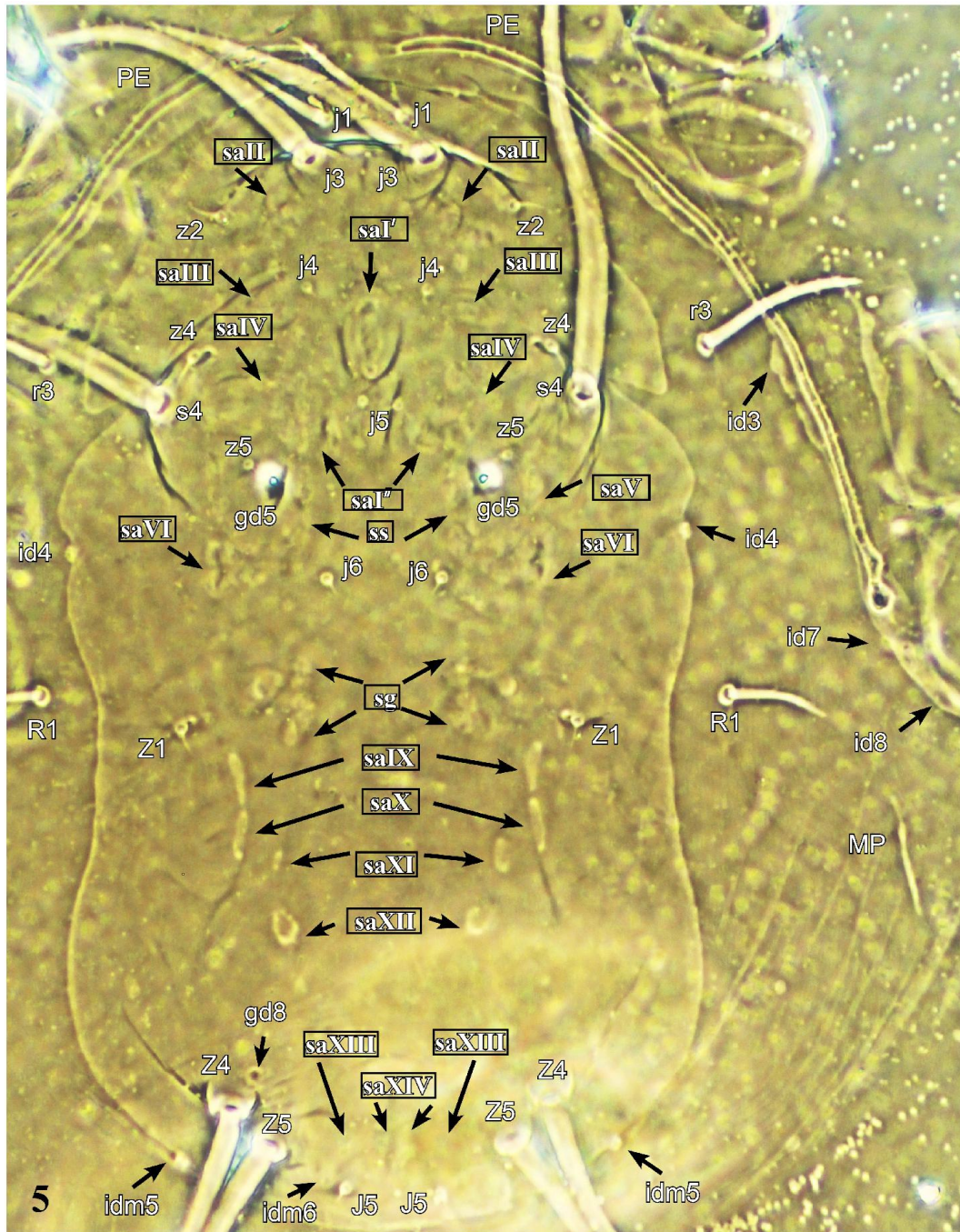


Figure 5. *Paraphytoseius multidentatus* - Sigilla on dorsal shield in relation to dorsal setae, solenostomes, and lyrifissures. A narrowly elongate primary metapodal shield (MP) present on right [FSCA - PARATYPE, Hong Kong, 1960, slide #1, female #1, *Urena lobata*].

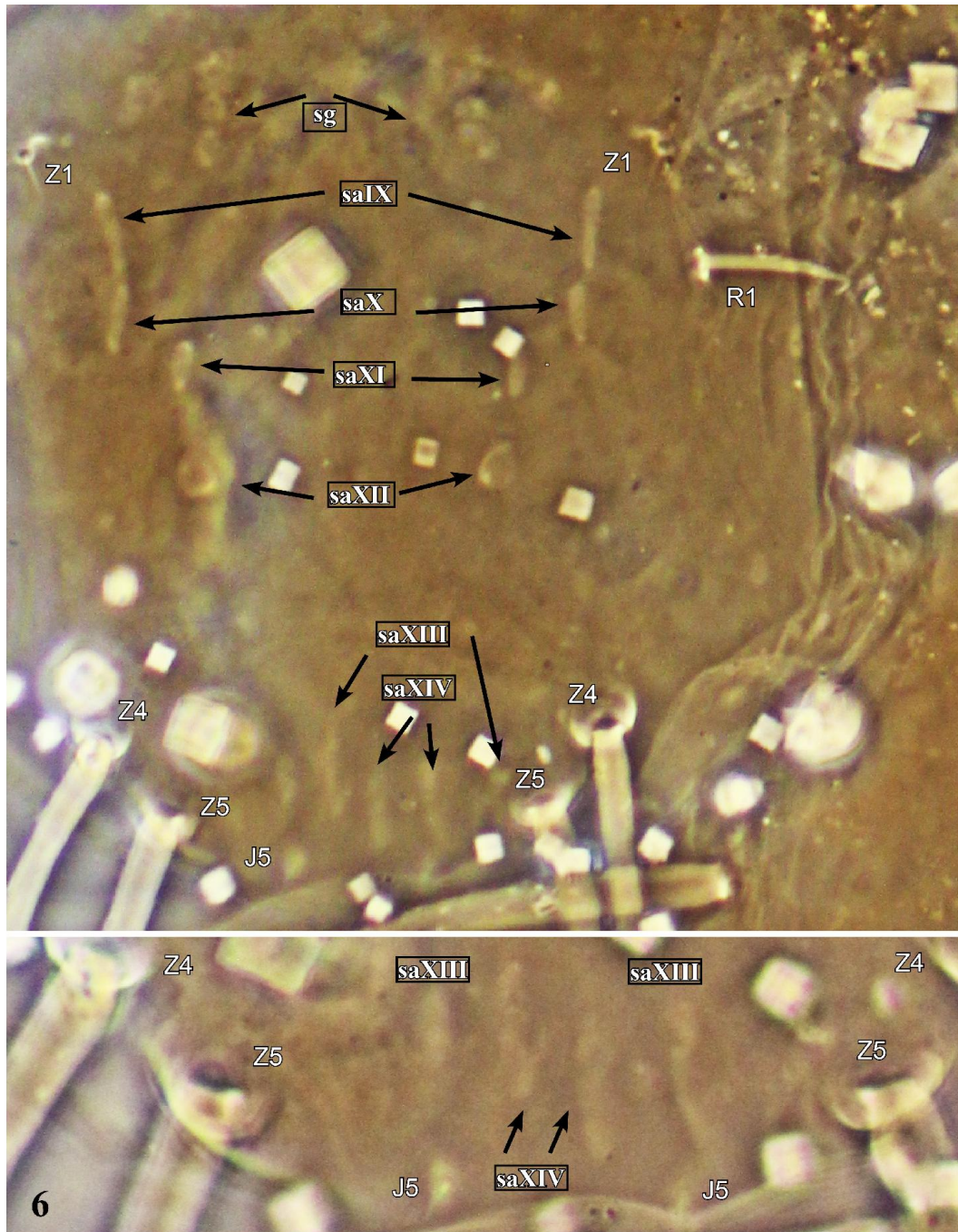


Figure 6. *Paraphytoseius multidentatus* - *Top*: Sigilla on opisthonotal shield in middle of setae Z1 and J5 (saIX, saX, saXI, saXII, saXIII, saXIV, and sg); *Bottom*: Enlarged sigilla XIII and IV [Israel Museum - PARATYPE, Hong Kong, 1960, slide #2, female #1, *Jasminum* sp.].

(3) *P. orientalis* (Narayanan *et al.*, 1960) (Figs. 2, 7–13):

Females - Study of 1 non-type female collected in Philippines in 1973 (Fig. 2) and 2 non-type females collected in 2 different states (Bihar and Orissa) of India in 1973 (Figs. 7–13) revealed the following sigilla that included 9 pairs on the podonotum (counting saI' and saI'' as 2 pairs; sp barely visible; Fig. 2) and 7 pairs on the opisthonotum.

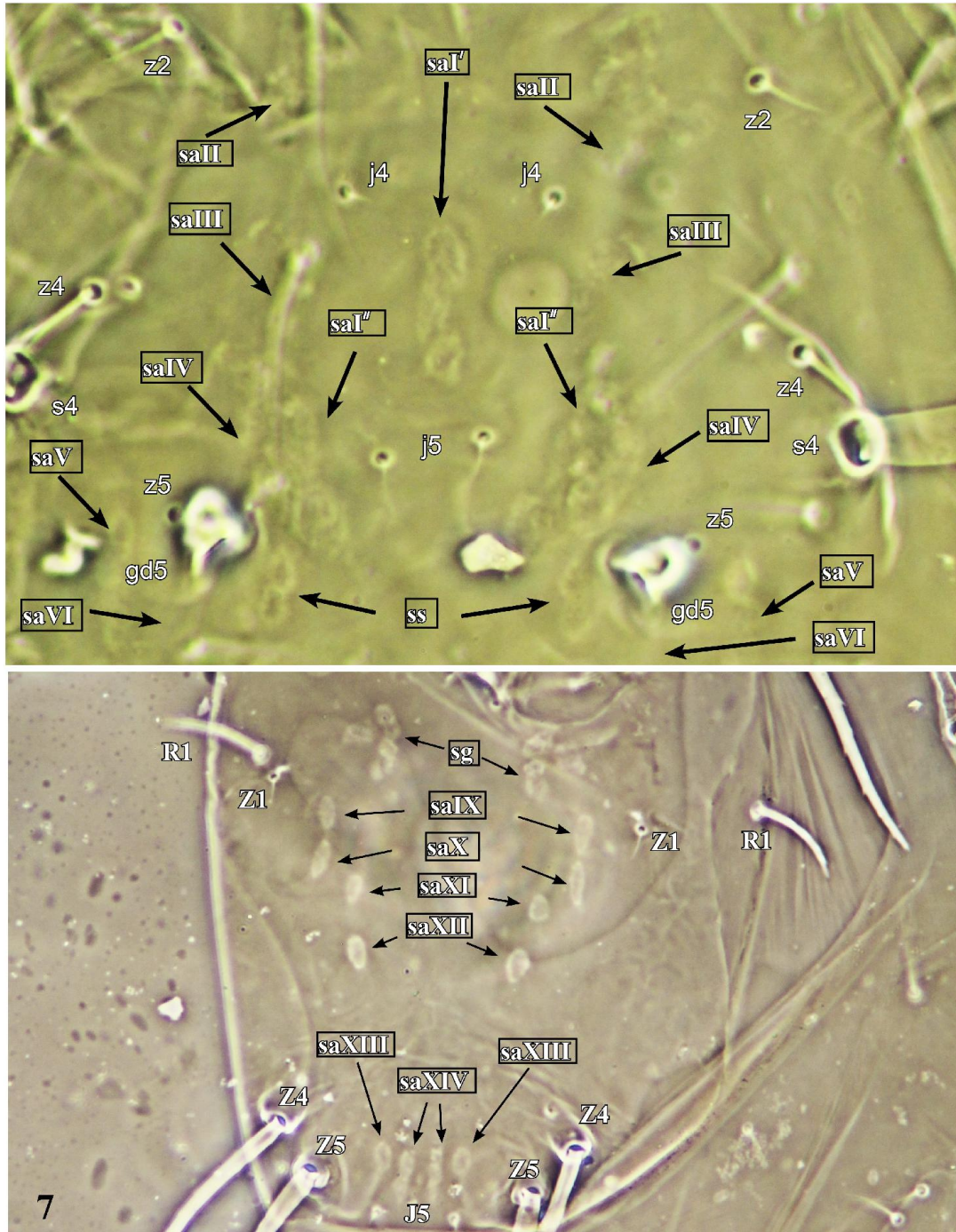


Figure 7. *Paraphytoseius orientalis* - *Top*: Anterior dorsal shield showing setae, sigilla, and solenostome gd5 (India, MP, 1972, VP72-347, slide #1, female #2, 400x). *Bottom*: Sigillotaxy of dorsal shield in relation to dorsal setae (or their pores) and solenostomes [India, Bihar, 1973, VP73-18, slide #5, female #1].

Dorsum (a) Podonotum (Figs. 7, 9, and 10, *P. orientalis*) - All 9 pairs of sigilla shown in *P. orientalis* are similar to those in *P. multidentatus*. Sigilla sp posteromedial to j1 and saII posterolateral to j3 and medial to z2 are vaguely seen. These sigilla on the podonotum, similar to *P. cracentis* and *P. multidentatus*, are less defined than those on the opisthonotum.

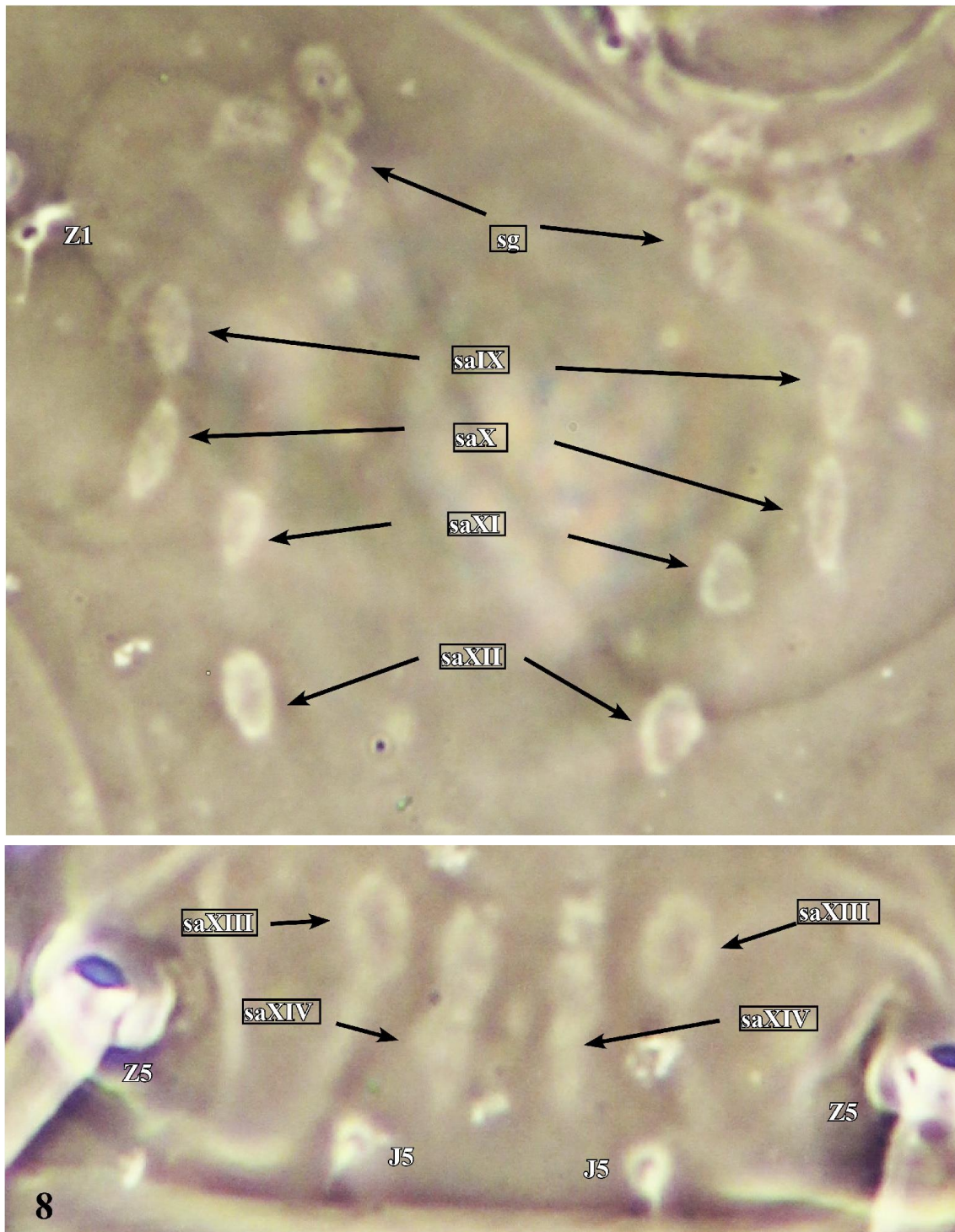


Figure 8. *Paraphytoseius orientalis* - Enlarged sigilla sg, saIX, saX, saXI, saXII, saXIII, and saXIV on podonotum [India, Bihar, 1973, VP73-18, slide #5, female #1].

(b) Opisthonotum (Figs. 7–9, and 11, *P. orientalis*) - All 7 pairs of sigilla shown in *P. orientalis* are similar to those in *P. multidentatus* and show same variation being elongate to oval. Elongate sigilla saIX and saX and oval sigilla saXI and saXII are clearly seen. Elongate sigilla saXIII and saXIV in between Z5 are also seen clearly.

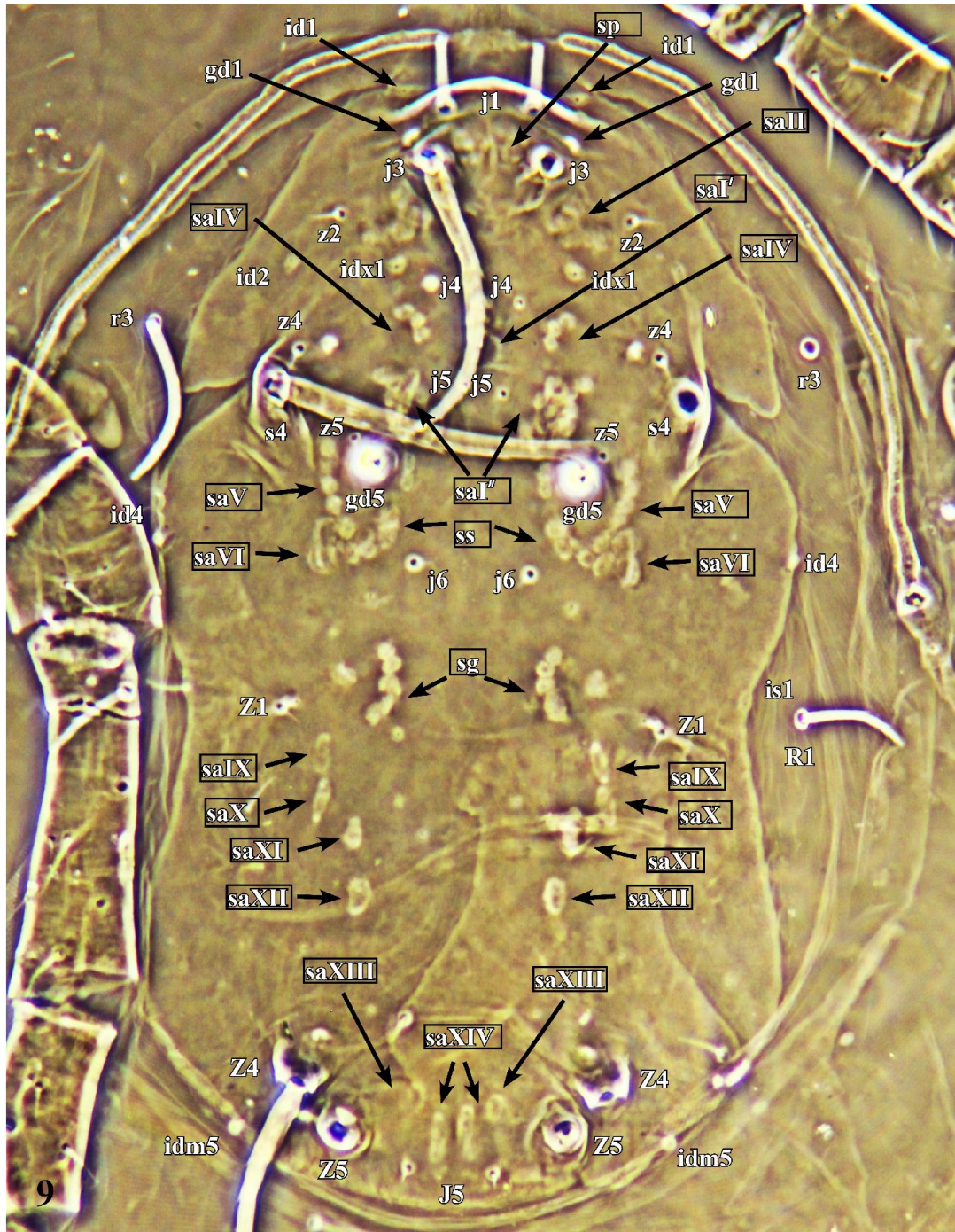


Figure 9. *Paraphytoseius orientalis* - Sigillotaxy of dorsal shield in relation to dorsal setae (or their pores), some solenostomes, and lyrifissures [India, Orissa, 1973, VP73-93, slide #3, female #6].

Male (Figs. 12 and 13, *P. orientalis*) - Study of 1 non-type male of *P. orientalis* collected in Orissa state of India in 1973 (VP73-93) revealed the sigilla that included 8 pairs on the podonotum (counting saI' and saI'' as 2 pairs) and 7 pairs on the opisthonotum.

Dorsum (a) Podonotum (Figs. 12 and 13, *P. orientalis*) - All 9 pairs of sigilla shown in male of *P. orientalis* are similar to those of females in *P. multidentatus*. Three sigilla

(saV, saVI, and ss) similar to the female are placed close to each other and mostly surround the medial, lateral, and posterior area of the large solenostome gd5. These are adjacent to each other and located anterolateral to j6.

(b) *Opisthonorotum* (Figs. 12 and 13, *P. orientalis*) - All 7 pairs of sigilla shown in male of *P. orientalis* are similar to those of females in *P. multidentatus* and of females of *P. orientalis* except that sigilla saIX and saX are not as narrowly elongate as seen in the females but round to oval. Sigilla saXI and saXII are small and oval.

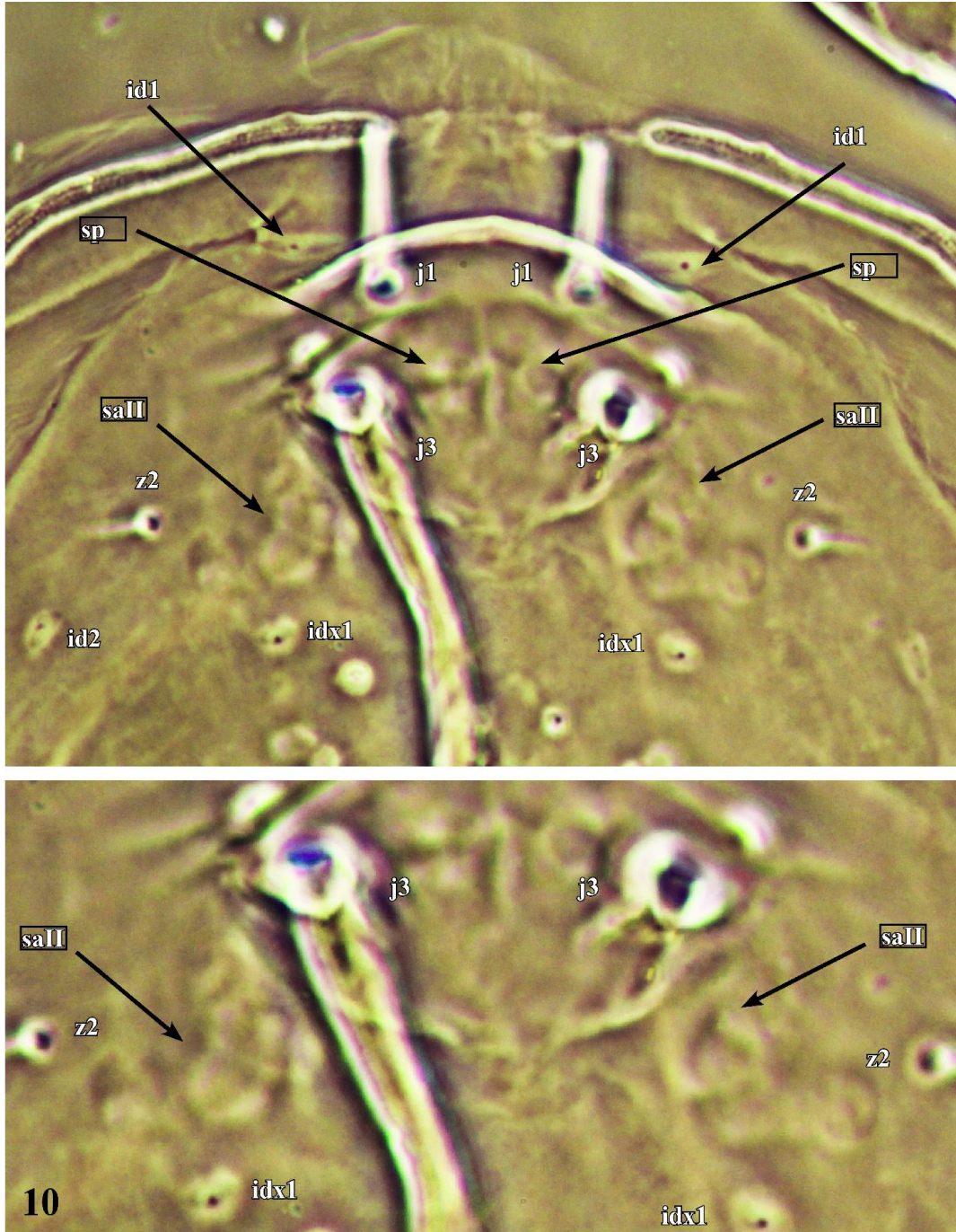


Figure 10. *Paraphytoseius orientalis* - Enlarged sigilla saII posterolateral to base of j3, medial to z2, and anterior to lyrifissure idx1 on anterior podonotum [India, Orissa, 1973, VP73-93, slide #3, female #6].

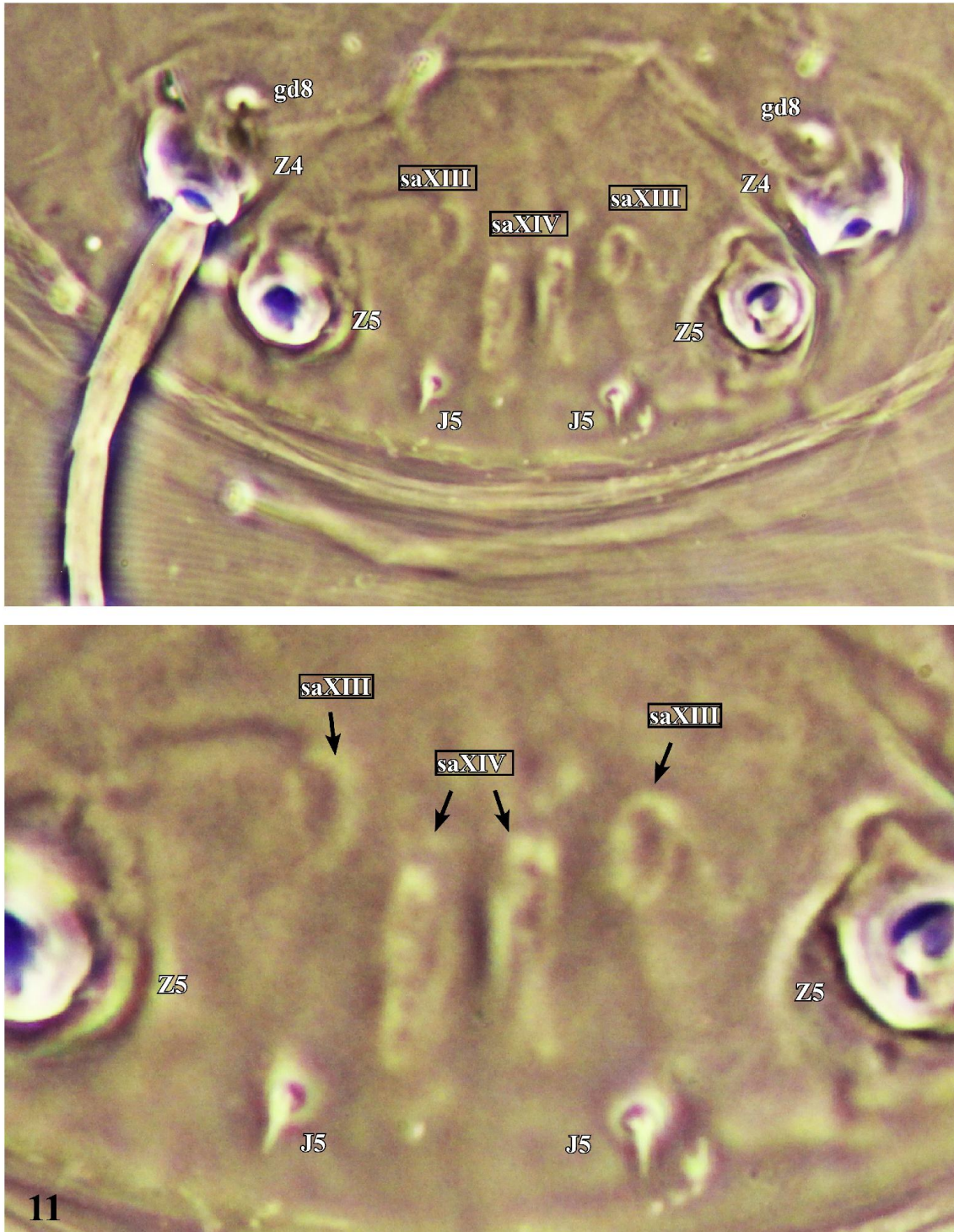


Figure 11. *Paraphytoseius orientalis* - Enlarged sigilla saXIII and saXIV anterior to J5 and in between bases of Z5 on posterior opisthonotum [India, Orissa, 1973, VP73-93, slide #3, female #6].

(4) *P. santurcensis* De Leon, 1965 (Figs. 14–17):

Female - Study of 2 paratype females collected in Puerto Rico in 1963 (published in 1965) revealed the following sigilla that included 9 pairs on the podonotum (counting saI' and saI'' as 2 pairs) and 7 pairs on the opisthonotum.

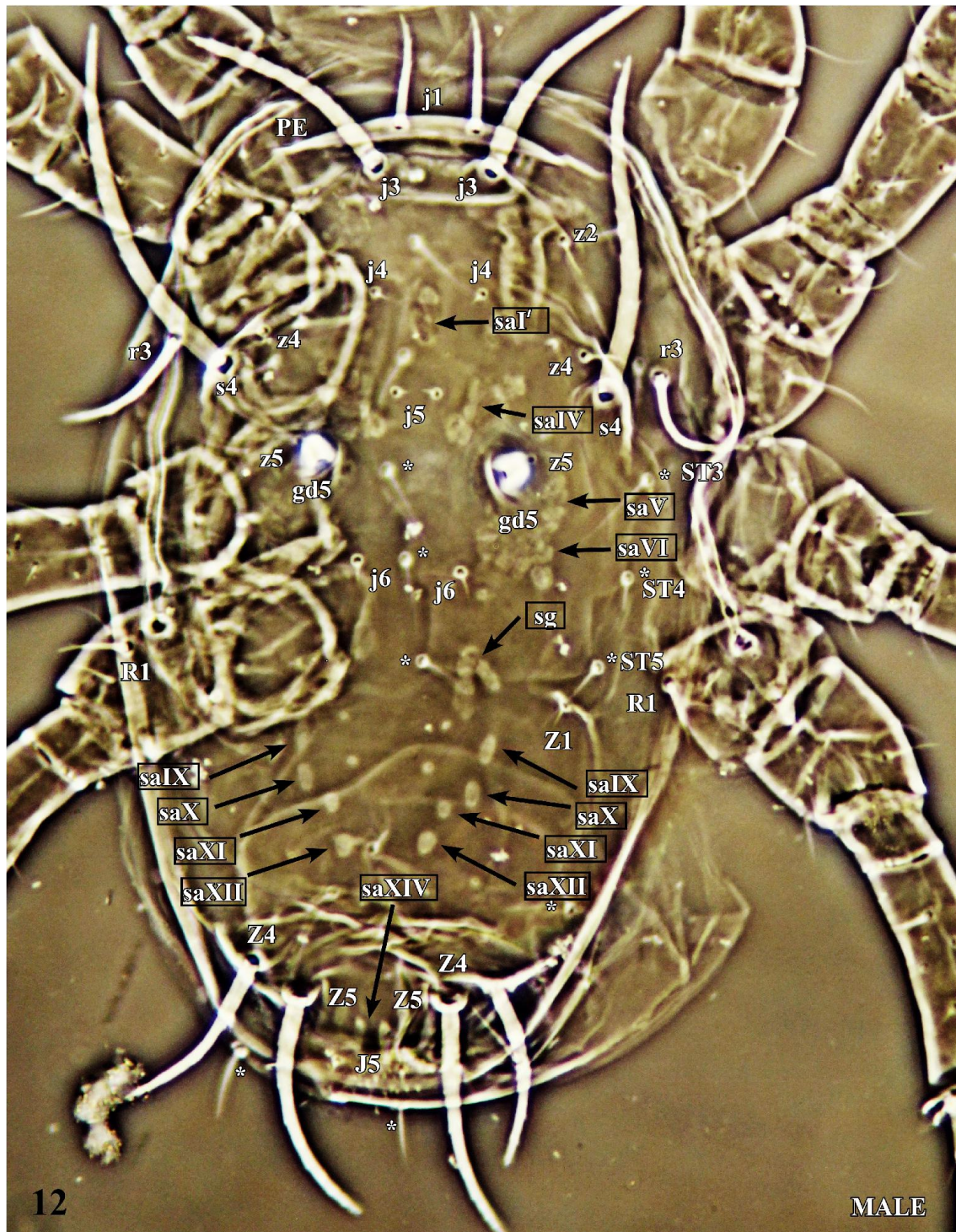


Figure 12. *Paraphytoseius orientalis* - Sigillotaxy of dorsal shield in relation to dorsal setae (or their pores), some solenostomes, and lyrifissures (* = some ventral setae) [India, Orissa, 1973, VP73-93, slide #2, male #1].

Dorsum (a) Podonotum (Figs. 14 and 15, *P. santurcensis*) - Sigilla sp in between j1 and j3 are barely visible due to distortion of the area from the presence of a semicircular fold of the dorsal shield. Single sigilla saI' present in between and posteromedial to j4 and others as saII, saIII, saIV, saV, and saVI are seen clearly in Fig. 14 but they appear

smudged, large, well spread (Fig. 15), and not as defined as seen in other 3 species discussed above. However, these appear very similar to as shown in Fig. 2 for *P. orientalis* (was misidentified as *P. cracentis* by Corpuz-Raros in 1973).

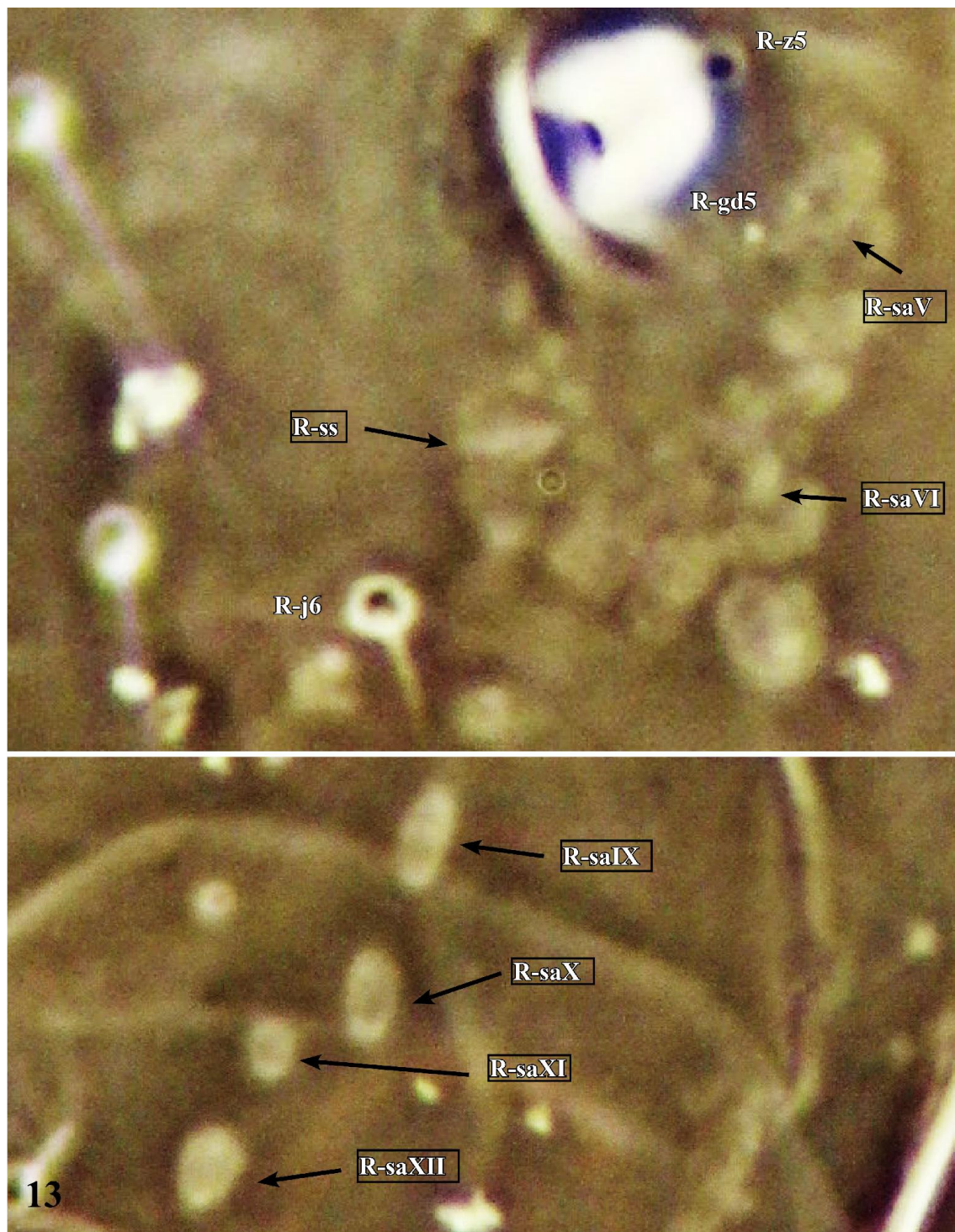


Figure 13. *Paraphytoseius orientalis* - *Top*: Enlarged sigilla of podonotal shield around right gd5 showing right ss, saV and saVI. *Bottom*: Enlarged sigilla of opisthonotal shield showing right oval to elongate sigilla saIX, saX, saXI and saXII [India, Orissa, 1973, VP73-93, slide #2, male #1].



Figure 14. *Paraphytoseius santurcensis* - Anterior dorsal shield showing sigilla (sp? - not visible), saI', saI'', saII, saIII, saIV, setae j1, j3, z2, z4, z5, and gd5 [FSCA - PARATYPE, Puerto Rico, 1963, slide #1, female #1].

(b) *Opisthonotum* (Fig. 15, *P. santurcensis*) - Sigilla sg, mostly anteromedial to Z1 and extending elongate anteriorly in the podonotal area also appear clear but smudged, large, and poorly defined and showing variation. But saIX and saX posteromedial to Z1, as in *P. multidentatus* and *P. orientalis*, are short, narrowly elongate and not

smudged in *P. santurcensis*. The reason for this smudge appearance in this female is not clear to the author (as discussed later in 2 males - this condition is not present).

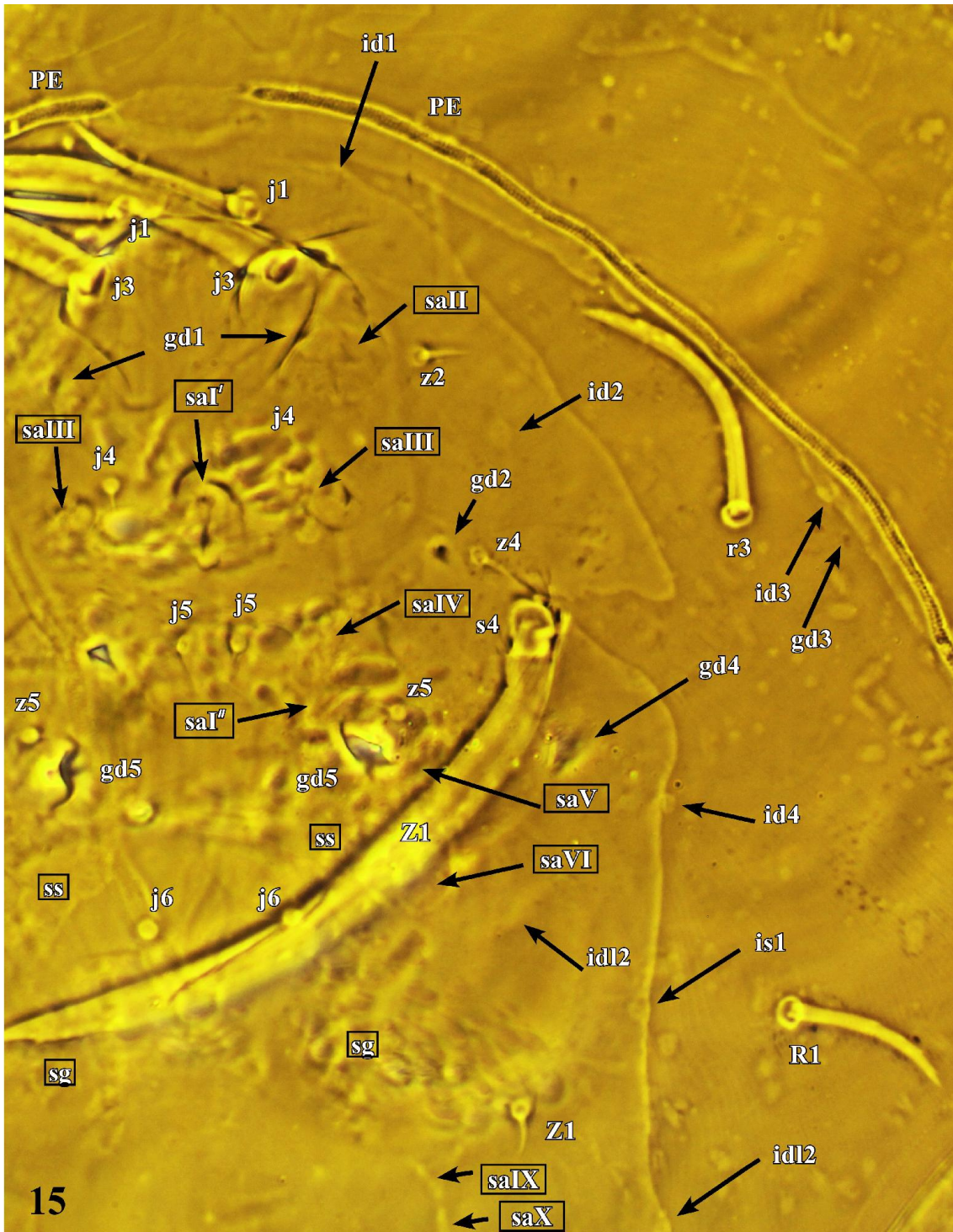


Figure 15. *Paraphytoseius santurcensis* - Anterior idiosoma showing peritremes, dorsal setae, solenostomes (gd1, gd2, gd3, gd4, and gd5), lyrifissures (id1, id2, id3, id4, is1, and idl2), and sigilla (saI, saII, saIII, saIV, saV, saVI, saIX, saX, sg, and ss) [FSCA - PARATYPE, Puerto Rico, 1963, slide #3, female #3].

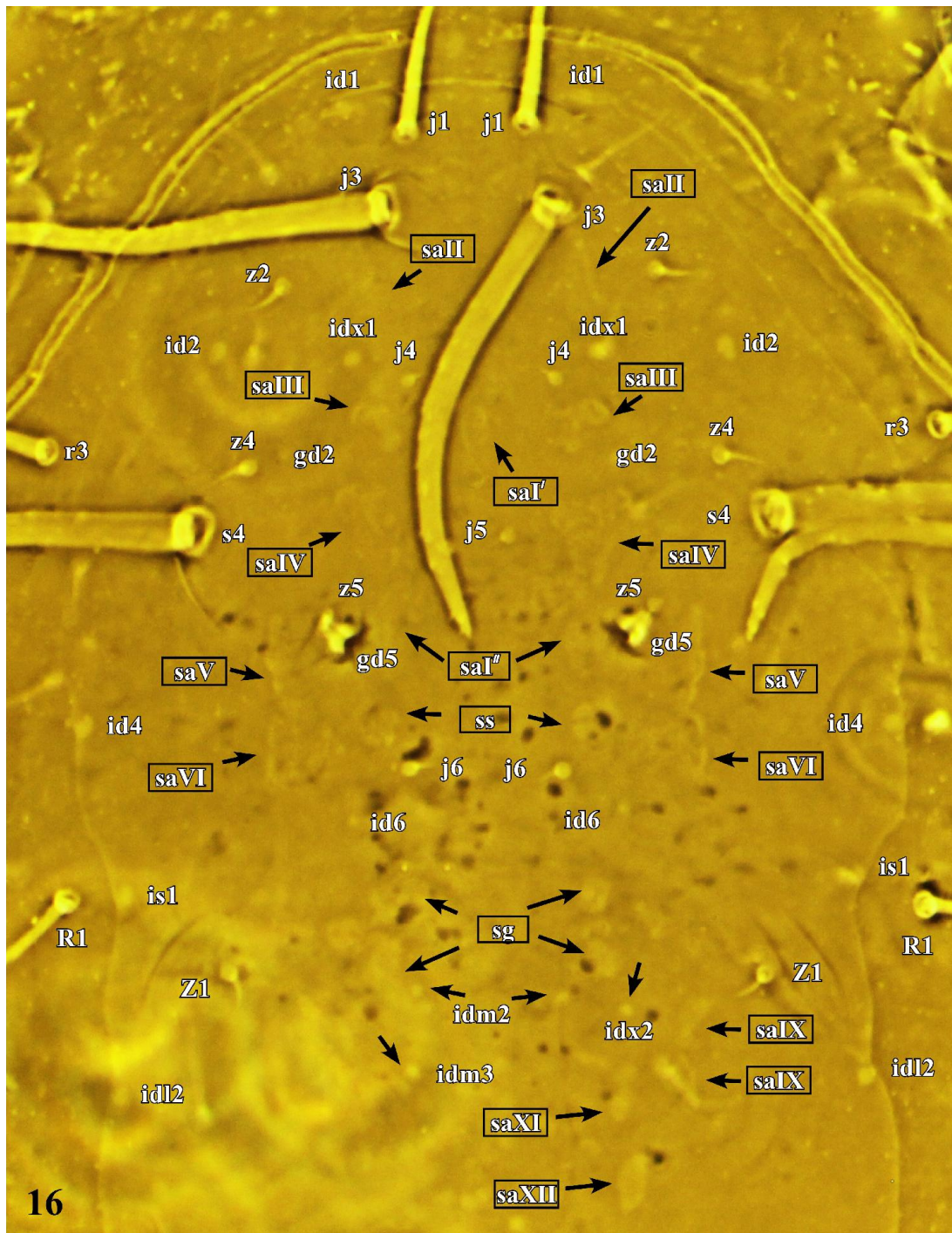


Figure 16. *Paraphytoseius santurcensis* - Anterior idiosoma showing peritremes, dorsal setae, solenostomes gd5, lyrifissures (idx1, id1, id2, id3, id4, is1, and idl2), and sigilla (saI, saII, saIII, saIV, saV, saVI, saIX, saX, sg, and ss) [FSCA - PARATYPE, Puerto Rico, 1963, slide #8, male #1].

Males (Figs. 16 and 17, *P. santurcensis*) - Study of 2 paratype males of *P. santurcensis* collected in Puerto Rico in 1963 revealed the following sigilla that included 9 pairs on the podonotum (counting saI' and saI'' as 2 pairs) and 7 pairs on the opisthonotum.

(b) Opisthonotum (Figs. 16 and 17, *P. santurcensis*) - All 7 pairs of sigilla shown in male of *P. santurcensis* on the opisthonotum are similar to those in male *P. orientalis*. Sigilla saXI, saXII, saXIII, and saXIV are similar in both species also.

Discussion

Genus *Paraphytoseius* belongs in the subfamily Amblyseiinae, in which setae z3 and s6 are absent, and possesses all sigilla described by Athias-Henriot (1975). In her work, she had stated that gd5 in the adult of this genus was a specialized and hypertrophied solenostome. From the study of this author in 4 species of this genus here and as given in Prasad (2015), confirm her opinion.

(1) *Sigilla saI, sp, ss, and sg* - As per Athias-Henriot (1975), sigilla saI, sp, and ss are present on the podonotum while sigilla sg are present on the opisthonotum. This sigilla sg was found to extend from opisthonotum to the podonotum in the present work. Thus, some researchers may call it as podonotal sigilla while others as opisthonotal sigilla. Athias-Henriot (1975) called sg as opisthonotal sigilla.

Athias-Henriot (1975) called 3 groups of sigilla on podonotum as saI which included a single anterior one located in between setae j4 and paired posterior ones located in between left and right gd5. Why did she call these 3 groups of sigilla as saI is not clear to the author. Possibly, it is based, in part, on her more general, previous work (Athias-Henriot, 1971). In the present work, single anterior one is counted as a pair [similar to counting of single postanal seta as pair] and named as saI' while the paired posterior is named as saI". It is not clear to the author either as to why she called sigilla sg. Possibly, it is in the intercalary region, where podonotal and opisthonotal plates join or remain separate.

Athias-Henriot (1975) did not name sigilla saVII and saVIII. These are considered absent in Phytoseiidae and closely related families Ascidae, Blattisociidae, Otopheidomenidae, and Podocinidae, all belonging to superfamily Phytoseioidea on the basis of sperm access system and some other morphological characteristics. It appears as she followed the theoretical concepts or speculations of van der Hammen (1970), as stated by Evans (1992), regarding reduction of dorsal (tergital) structures of segments VII and VIII in the area of the dorsodisjugal furrow in the mesostigmatic mites.

(2) *Sigilla in female and male* - It is evident from the above study of 4 species (3 species considering *P. multidentatus* as junior synonym of *P. orientalis*) of *Paraphytoseius* that sigilla are similar in the females of all species studied showing little variation in the shape but not in the location on the dorsal shield that were same in all the species. However, shape of some sigilla on the opisthonotum of the males was different than those in the females. It was also noted that 6 pairs of sigilla on the opisthonotum were easy to identify and name than those present on the podonotum, especially around solenostome gd5. Of all these, the 4 pairs (saIX, saX, saXI, and saXII) were well developed, separate from each other, and easy to compare in different species. The remaining 2 pairs (saXIII - in between and just medial to Z5 and saXIV - just anterior to J5) were also easy to identify in most females and males.

(3) *Are sigilla of any taxonomic value in species identification?* - It is apparent from above study of 4 species (3 species considering *P. multidentatus* as junior synonym of *P. orientalis*) that sigilla are not species specific. Thus, these are of no taxonomic value in the identification of the species in *Paraphytoseius*.

(4) *Are sigilla of any taxonomic value in Phytoseiidae and related sister family Otopheidomenidae?* - It is not appropriate to answer this question at this time as the

present study includes the study of genus *Paraphytoseius* only. Swirski *et al.* (1998) illustrated, without naming, sigilla in species of different genera and species of Phytoseiidae from Israel in which they vary in different species. Moraes *et al.* (2007), without discussing and without naming, illustrated sigilla in *P. orientalis* that appear to be similar to those discussed before in the species of *Paraphytoseius*. However, they illustrated all sigilla together that were present around gd5, lateral to j5, j6, and medial to Z1.

(5) *Sigilla in related family Ascidae* - Lindquist and Makarova (2012) illustrated dorsal idiosoma of *Maxinia arctomontana* n. gen. and n. sp. (a hypertrichous family and closely related to hypotrichous families Phytoseiidae and Otopheidomenidae) indicating dorsal setae [j1, j3, j4, j5, j6; J1, J2, J3, J4, J5; z1, z2, z3, z4, z5, z6; Z1, Z2, Z3, Z4, Z5; s1, s2, s3, s4, s5, s6; S1, S3, S4, S5; r2, r3, r4, r5; and R1]. They indicated many solenostomes and lyrifissures in this illustration without showing solenostome gd5 and without naming these. They also illustrated many sigilla between j4 and J5 without naming which appear to represent saI', saI'', [sp and saII - not illustrated], saIII, saIV, saV, saVI, ss on the podonotum; and sg, saIX, saX, saXI, saXII, saXIII, and saXIV on the opisthonotum. The last 6 pairs, as in this study but not exactly alike, are single, separate from each other, and easy to identify and name based on Athias-Henriot (1975).

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سجیلا در چهار گونه *Paraphytoseius* (Acari: Phytoseiidae): تفسیرها و تصویرهای مستند

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چکیده

همه ۹ جفت سجیلا روی پدونوتوم (همه ه صورت جفتی به جز saI هر چند به صورت جفت در نظر گرفته می شود: saI', saI'', saII, saIII, saIV, saV, saVI, sp, و sg) همراه با موها، سولنوستومها و لیریفیشرها در ۹ ماده از چهار گونه و سه نر از دو گونه از *Paraphytoseius multidentatus* Swirski and Shechter, 1961 = ماده پاراتیپ؛ *orientalis* (Narayanan, Kaur and Ghai, 1960) = ۲ ماده غیرپاراتیپ و ۱ نر غیرپاراتیپ؛ و *santurcensis* De Leon, 1965 = ۲ ماده پاراتیپ و ۲ نر پاراتیپ [مورد مقایسه قرار گرفتند و چند تصویر مستند ارایه شده است. این سجیلاها از نظر مکان قرارگیری شبیه آنهایی هستند که اتیاس-هنریوت (۱۹۷۵) توصیف کرد. آنها در ۴ گونه بسیار شبیه به هم هستند و تفاوت اندکی در نر و ماده، و بنابراین به نظر می رسد ارزش تاکسونومیک برای جداسازی این گونهها ندارند. مشکلات همراه سجیلا، به ویژه در نزدیکی و پس از موهای j1-j1 و پیرامون سولنوستوم gd5 بحث شده است. ثابت شد که سجیلا روی اپیستونوتوم (۷ جفت: saX, saXI, saXII, saXIII, saXIV و sg) به خوبی تشخیص داده شده و در این گونهها نسبت به آنهایی که روی پدونوتوم قرار دارند به وضوح دیده می شوند و ممکن است برای مطالعه در دیگر گونههای فیتوزئید مورد استفاده قرار گیرند. مدل فرضی گونه *P. cracentis* به صورت ترسیم خطی نشان دهنده همه سجیلاها در ارتباط با موهای پشتی، سولنوستومها و لیریفیشرها آورده شده است.

واژگان کلیدی: ادنوتاکسی؛ *Paraphytoseius*؛ gd5؛ پروئیدوتاکسی؛ سجیلا؛ سجیلوتاکسی؛ تصویرهای مستند.

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