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Redescription of the camel spider *Rhagodes ahwazensis* Kraus, 1959 (Solifugae: Rhagodidae)

Переописание сольпуги *Rhagodes ahwazensis* Kraus, 1959 (Solifugae: Rhagodidae)

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KEY WORDS: Sun spider, camel spider, arachnids, Iran, Khuzestan Province, endemic, taxonomy, *Rhagodes*.

КЛЮЧЕВЫЕ СЛОВА: сольпуга, паукообразные, Иран, провинция Хузестан, эндемик, таксономия, *Rhagodes*.

ABSTRACT. *Rhagodes ahwazensis* Kraus, 1959, an Iranian endemic solifuge, known from the original description only based on a single male, is diagnosed and revised here. *R. ahwazensis* is redecribed herein on the basis of a new material from terra typica, the female is described for the first time.

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РЕЗЮМЕ. Дано переописание эндемичной Иранской сольпуги *Rhagodes ahwazensis* Kraus, 1959, известной только по оригинальному описанию единственного самца. В работе дано переописание *R. ahwazensis* на основании нового материала, собранного в типовом местонахождении, самуа этого вида описана впервые.

Introduction

Rhagodes Pocock, 1897 is a wide-spread genus of camel spiders distributed from north to east Africa, and through the Middle East to central Asia [Roewer, 1933; Birula, 1938; Harvey, 2003]. It is the largest genus in the family Rhagodidae, with 25 described species worldwide [Harvey, 2003; Maddahi *et al*., 2019]. With seven species, the highest species diversity of the genus *Rhagodes* occurs in Iran [Birula, 1905a, b; Roewer, 1933; Harvey, 2003; Maddahi *et al*., 2017, 2019]. The genus *Rhagodes* was mainly known from east of the country, where five species are represented. *Rhagodes ahwazensis* Kraus, 1959 was the first occurrence of the genus from the western regions of Iran [Kraus, 1959].

Kraus [1959] described the holotype of *R. ahwazensis* based on a male from southwest Iran (Fig. 1). He provided a brief description and characterized the species by considering the presence of bacilli on the coxae of legs I–III, spinulation of legs, and body coloration. There is no taxonomic study or locality record on the species in the literature after the original description. In the present study we revised the previously described diagnostic characters and provide a detailed redescription for both sexes. Moreover, illustrations of type material and a distribution map, as well as data on sexual dimorphism, are presented.

Material and methods

Specimens were collected during field-work to the southwest Iran from April to June 2017 at night by direct searching. All specimens were preserved in 75–80% alcohol and deposited at the Solifugae collection at the Zoological Museum, Ferdowsi University of Mashhad, Mashhad, Iran (ZMFUM). Moreover, a specimen from the arachnid collection of the Zoological Institute of the Russian Academy of Sciences, Saint Petersburg, Russia (ZISP) was included. Freshly collected materials were initially identified according to Kraus [1959] using an Olympus SZH40 stereomicroscope (Japan, Tokyo) and then compared with the holotype male from the Senckenberg Research Institute, Frankfurt am Main, Germany (SMF). A morphological variation section was provided to highlight differences from the holotype.

Measurements and ratios were made according to the methods used in Maddahi *et al*. [2019] from non-type materials. ETW/PPW (Eye tubercle width/Propeltidium width) measures the relative width of the eye tubercle to anterior margin of propeltidium. All segments except coxae were included in the measurements of legs. We use the cheliceral

Fig. 1. Localities of *Rhagodes ahwazensis* based on the present study (white circles) and the literature (black triangle).

Рис. 1. Местонахождения *Rhagodes ahwazensis* по материалам настоящей работы (белые кружки) и по литературным данным (черный треугольник).

terminology presented by Bird *et al*. [2015] in referencing cheliceral chaetotaxy and dentition. Setation of legs and the usage of term "spiniform setae" are after Botero-Trujillo [2014]. In the case of the application of the tarsal spinulation, bacilli, and the term "bristles" we followed Roewer's [1932, 1933] terminology.

Specimens were examined using an Olympus SZ-40 stereomicroscope (Japan, Tokyo). Diagnostic characters of the species were photographed with an Olympus DP-71 digital camera attached to an Olympus SZH10 stereomicroscope at the Ferdowsi University of Mashhad. Images of dorsal and ventral habitus were taken using a Canon Powershot SX150 IS digital camera. In order to provide a complete depth of field, several images were combined using Zerene Stacker focus stacking software (http://zerenesystems.com/stacker/). The general habitus is presented in Fig. 2.

Abbreviations as follows: **Measurements.** CL — chelicera length; CH — chelicera height; CW — chelicera width; FFL — fixed finger length; FFML — fixed finger mucron length; MFL — movable finger length; MFML — movable finger mucron length; ETW — eye tubercle length; PPL — propeltidium length; PPW — propeltidium width (excluding exterior lobes); PL — palpus length; PMT — palpal metatarsus length; PT — palpal tarsal length; LI — first leg length; LIV — fourth leg length; TL — total length measured from distal tip of chelicera to posterior edge of the abdomen. **Cheliceral teeth character.** FD — fixed finger distal tooth; FM — fixed finger medial tooth; FP — fixed finger proximal tooth; MM — movable finger medial tooth; MP — movable finger proximal tooth; MPL — movable finger prolateral tooth: MPLC — movable finger prolateral carina; MT — movable finger terminal tooth; RFA — retrofondal anterior teeth; RF — retrofondal teeth; RFM — retrofondal medial tooth; RFP — retrofondal proximal tooth; RFSM — retrofondal submedial tooth. **Cheliceral setal pattern.** *mff* — movable finger fondal setae; *mpd* — movable finger prodorsal setae; *mpm* — movable finger promedial setae; *mpv* — movable finger proventral setae; *pdp* — prodorsal proximal setae; *pm* — promedial setae; *pv* — proventral setae; *pvd* — proventral distal setae; *pvsd* — proventral subdistal setae; *rlf* — retrolateral finger setae; *rlm* — retrolateral manus setae; *rlpc* — retrolateral proximal setal cluster; *vfs* — ventral flagellar seta. **Sense organs.** *lo* — lyriform organ; *mvo* — medioventral organ.

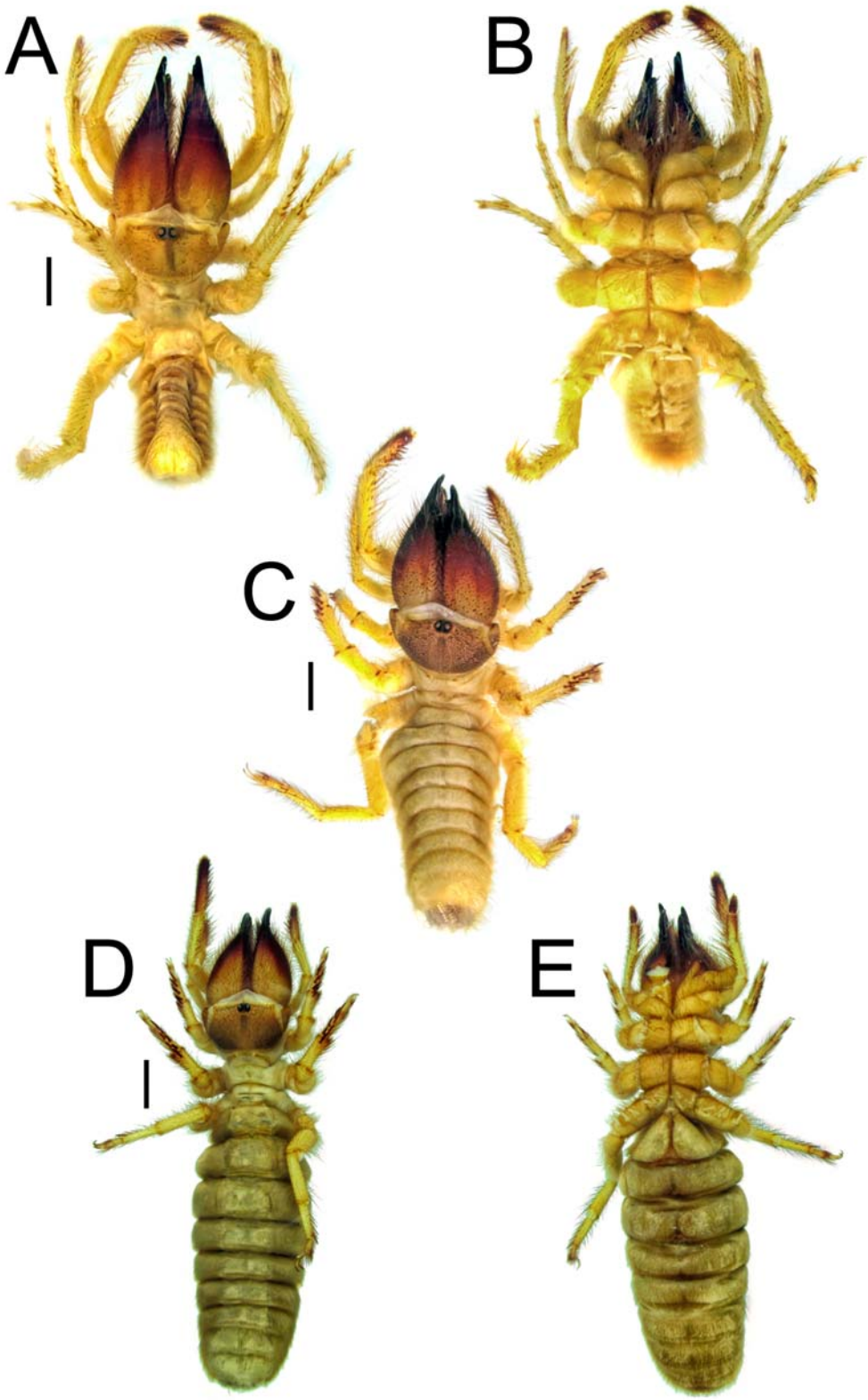

Fig. 2. Dorsal and ventral habitus of *Rhagodes ahwazensis*. A and B — SMF-10832-71, male holotype, C — ZMFUM-SOL-1156, male from terra typica, D and E — ZMFUM-SOL-1193, female from terra typica. Scale bars = 5.0 mm.

Рис. 2. Внешний вид *Rhagodes ahwazensis*, дорсально и вентрально. A и B — SMF-10832-71, голотип самец, C — ZMFUM-SOL-1156, самец из типового местонахождения, D и E — ZMFUM-SOL-1193, самка из типового местонахождения. Масштаб 5,0 мм.

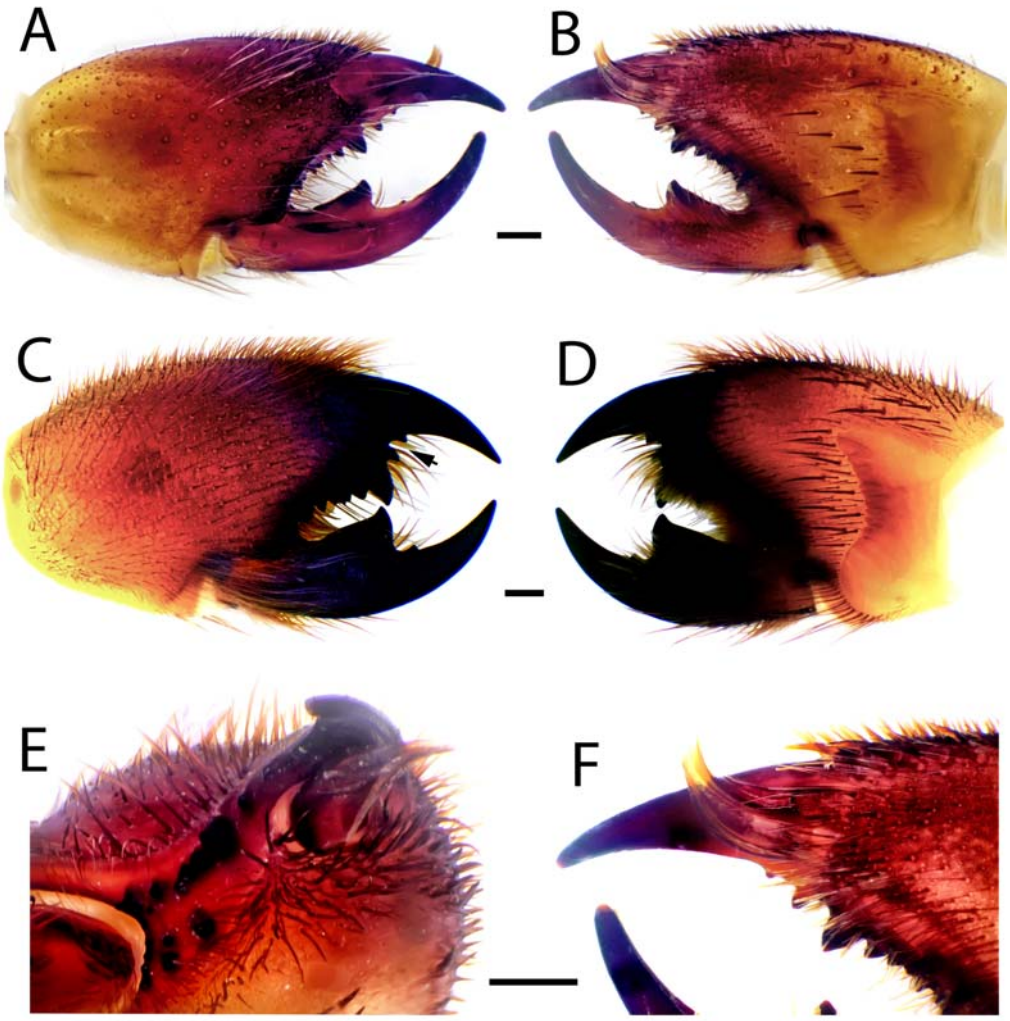

Fig. 3. Retrolateral (left) and prolateral (right) cheliceral views of *Rhagodes ahwazensis* (A–D), fondal teeth (E) and male flagellum (F). A, B, E and F — male holotype (SMF-10832-71), C and D — female (ZMFUM-SOL-1193). Arrow in Fig. 3C indicate the teeth FM and FD. Scale bars = 1.0 mm.

Рис. 3. *Rhagodes ahwazensis*, хелицеры (A–D), ретролатерально (слева) и пролатерально (справа), зубцы у основания верхней хелицеры (E) и флагеллум самца (F). A, B, E и F — голотип самец (SMF-10832-71), C и D — самка (ZMFUM-SOL-1193). Стрелка на Рис. 3C указывает зубцы FM и FD. Масштаб 1,0 мм.

Taxonomy

Family Rhagodidae Pocock, 1897
Genus *Rhagodes* Pocock, 1897
Rhagodes ahwazensis Kraus, 1959
Figs. 2–4.

Rhagodes ahwazensis: Kraus, 1959: 95, fig. 1 (♂)

MATERIAL EXAMINED (9 ♂♂ 2 ♀♀). **IRAN: Khuzestan Province:** 2 ♂♂ 1 ♀ (ZMFUM-SOL-1193-5), 25 km NE Ahwaz, 10 km E Veys, Omm Aghrib village (31°28′52″N, 48°58′16″E), 20 m a.s.l., 21 & 23.iv.2017, leg. H. Maddahi; 3 ♂♂ (ZMFUM-SOL-1153-1156-1157), same data in 24.v.2017 to 26.vi.2017, leg. H. Maddahi & H. Maraghi; 1 subadult ♂ 1 ♂ (ZMFUM-SOL-1159 &1161), Ramhormoz-Ramshir road, 17 km S Ramhormoz, Deyme protected area (31°08′45″N, 49°29′15″E), 194 m a.s.l., 28.iv.2017 to 6.v.2017, leg. E. Jafari khah; 1 ♂ (ZMFUM-SOL-1158), same data in 26.iv.2017, leg. H. Maddahi; 1 ♀ (ZISP-858, as *Rhagodes* sp.), Arabistan, Tscheschme-Rogan (well or spring) (unidentified site from the vicinity of Rud-e Zard, a village in the Central District of Haftkel County), 31.xii.1903 to 1.i.1904, leg. N. Zarudny; holotype: ♂ (SMF-10832-71), 20 km NE Ahwaz, near Tehran, 20–30.iii.1958, leg. W. Frank.

DIAGNOSIS. The species is easily distinguished from the closely related species by general coloration. Males of the species can be distinguished from other related congeners based on two characters: (1) flagellum does not cover any portion of the FD tooth on prolateral view of the fixed finger, and (2) no portion of ventral surface of flagellum is visible in retrolateral view of chelicera (Figs. 3A, B). *Rhagodes ahwazensis* can be distinguished from the species *R. eylandti* by having larger and more robust chelicerae (smaller A/CP ratio) and higher FFML/MFML ratio (>1).

DESCRIPTION.

Male.

Coloration. ***Prosoma***. Propeltidium and anterolateral propeltidial lobe yellowish-brown with brown setae and bristles; lateral margin of anterolateral propeltidial lobe yellow;

eyes light brown, ocular tubercle dark grey to black, two small dark brown bristles projecting forward; parapeltidium, mesopeltidium and metapeltidium yellow (Fig. 2A). Chelicerae do not uniformly colored, dorsally and laterally yellowish-brown to ocher yellow in proximal part, reddish-brown in median part and dark brown in distal part, with two light brown dorsal parallel stripes, ventrally yellow; fingers reddish-brown to dark brown, mucra dark brown to blackish-brown (Figs 2A, 3A, B). Pedipalps yellow except for dark brown tarsus and distal portion of metatarsus, with light-brown setae (Figs. 2A, B); legs uniformly yellow except for brown to dark brown distal half of tarsus of legs I, with abundant small- to medium-sized yellow to light-brown setae (Figs 2A, 4A, C, D); unguiculus light brown and pedunculus yellow (Fig. 4D); malleoli white (Fig. 2B). ***Opisthosoma.*** Overall yellow, each opisthosomal tergite with a yellowish-grey rectangle, making a yellowish-grey dorsal longitudinal stripe which ends before 9th tergite, 9th and 10th tergites entirely yellow, anal segment yellow (Fig. 2A); opisthosoma dorsally and ventrally covered with yellow to light-brown setae, pleura densely covered with dark-yellow setae (Fig. 2A, B).

Measurements. Males (n = 6). TL 35.34–50.12; CL 10.00–16.12; CH 4.50–7.40; CW 3.30–5.14; FFL 6.55–8.51; MFL 5.71–7.54; FFML 2.48–2.95; MFML 2.32–2.81; PPL 3.94–5.87; PPW 4.70–8.52; ETW 1.43–2.04; PL 14.64–20.24; PMT 3.80–5.31; PT 0.92–1.34; LI 13.50–16.82; LIV 20.24–27.34; CL/CH 2.01–2.22; CL/CW 3.03–3.13; ETW/PPW 0.23–0.30; FFL/CL 0.52–0.65; FFML/MFML 1.04–1.07; A/CP 2.92–3.47.

Chelicerae. Shape. When fingers are closed, the apex of MT reaches the median portion of the fixed finger mucron and MP lies proximal to FP. ***Dentition.*** The fixed finger with a single row of three median teeth and three series of fondal teeth, the former comprises large FP, FM and small FD, and the latter includes a row of six retrofondal teeth (3 RFA, RFM, RFSM, and a relatively large RFP), a row of three PF and two to three irregularly-spaced basifondal teeth; fond basally with row of five to six denticles, mostly present on prolateral surface; the movable finger with a single row of median teeth, including large MP, small MM, and a series of prolateral teeth with a small MPL and a well-developed MPLC (Fig. 3A, B, E). Dental formula FD-FM-FP-(6RF) (3PF) (see Bird *et al*., 2015, plates 58, 64 I, J). ***Flagella.*** Comprising of two paraxially immovable, tube-like flagella at the prolateral view of fixed finger. They project forward from the distal end of the row of *pvd* seta and rise up as high as a quarter of the circle's perimeter to form a single horn-like flagella (diploflagella) (see Bird *et al*., 2015: 140, plates 30F, 31D). At prolateral view of the fixed finger, flagella do not cover FD. At retrolateral view, ventral surface of flagella is not visible (Fig. 3A, B, F).

Chaetotaxy. Prolateral view. Paturon (manus & fixed finger). A longitudinal row of 12 brown, well-developed, regularly-spaced and distally directed *pdp* setae, increasing in length and robustness from proximal to distal, and a row of *secondary pdp* setae; four irregular rows of straight to curved acuminate, distally directed *pvd* setae, except proximal ones close to the interdigital articulation which are plumose in distal half; *vfs* setae slightly longer than *pvd* setae, curved and distally directed; a row of long acuminate *pvsd* setae; weak, short *pm* setae sparsely scattered among stridulatory setae; a narrow, longitudinal field of slightly curved, ventrodistally to distally directed *pv* setae, increasing in length and thickness distally (Fig. 3B). *Stridulatory apparatus*. Comprising 10 parallel, regularly-spaced and distally directed stridulatory setae (Rhagodidae type; see Bird *et al*., 2015: 43, fig. 9D), and with 11 stridulatory ridges (Fig. 3B). ***Movable finger.*** Series of straight to slightly curved, dorsodistally directed *mpd* setae, the apical-most setae is longer; series of straight, ventrodistally directed *mpv* setae, distally increasing in length, thickness and curvedness; a narrow field of straight, non-plumose, distally directed *mpm* setae (Fig. 3B). *Movable finger fondal setae*. A short series of straight to mostly devoid of plumose *mff* setae. ***Retrolateral view. Paturon.*** Four series of several long, thin, irregularly distributed, distally directed *rlf* setae, proximal series are longer than the row closest to the teeth; dorsally to dorsodistally directed *rlm* setae, covering the rest of retrolateral surface, increasingly becoming more robust and sclerotized from proximoventral to dorsodistal (Fig. 3A). ***Movable finger.*** With two longitudinal cluster of *rlpc* setae: a dorsal small longitudinal cluster of acuminate to significantly reduced plumose, distally directed *rlpc* setae, increasing in length and robustness from proximal to distal part, and a ventral longitudinal cluster of non-plumose *rlpc* setae (Fig. 3A). **Sense organs.** With two ventrally located lyriform organs, near the interdigital articulation, and an oval medioventral organ (mvo) on the ventral margin of the stridulatory plate (see Bird *et al*., 2015: 200, plate 6).

Bacilli. All coxae of first three pairs of legs with long light brown bacilli, which are rather well visible on the coxae of legs III. Their number differ among coxae and they are mostly placed at coxae of legs II and III (from 6 to 13 on each coxa) (arrows at Fig. 4E).

Spinulation. Tarsus of legs II–IV ventrally without spiniform setae; metatarsus of legs II and III ventrally with 1.2 and metatarsus of legs IV with 1.2.2 spiniform setae (Fig. 4C, D); metatarsus of legs II and III dorsally with a series of six brown spiniform setae; tibia of legs II and III with one dorsal apical spiniform setae (Fig. 4A).

Opisthosoma. Genital sternite of adult males with concave internal margin and sclerotized posterior margin, opercula of the genital sternite with two lobes extended laterally and a central longitudinal opening; posterior half of 3rd and 4th abdominal sternites with two symmetrically located paired spiracles; anal segment hemispherical, longitudinal anal slit entirely located on the ventral surface of the anal segment.

MORPHOLOGICAL VARIATION

Coloration. Propeltidium and anterolateral propeltidial lobe greyish-brown; chelicerae dorsally dark brown in median part and blackish-brown in distal part; malleoli with greyish-black margin only in one specimen (ZMFUM-SOL-1161); dorsal longitudinal stripe of opisthosoma light yellow, ocher yellow, or greyish-yellow (Fig. 2C).

Chelicerae. Dentition. Fixed finger without RFSM tooth only in one specimen (ZMFUM-SOL-1159); three to five irregularly-spaced basifondal teeth. ***Chaetotaxy.*** A longitudinal row of 10 or 11 *pdp* setae; three rows of *pvd* setae; few distal *pv* setae are slightly plumose in the freshly collected specimens. Stridulatory apparatus with 10 to 14 stridulatory setae and 10 to 15 stridulatory ridges. Few *mpm* setae are plumose in some freshly collected materials.

Bacilli. The number of bacilli differ from 6 to 22 on each coxa.

Spinulation. Tarsus of legs II and III ventrally with 1, 1.1 or 1.2 spiniform setae and tarsus of legs IV ventrally with 1.1, 1.1.1 or 1.2.2 spiniform setae; metatarsus of legs II and III ventrally with 2.2 spiniform setae; tibia of legs II and

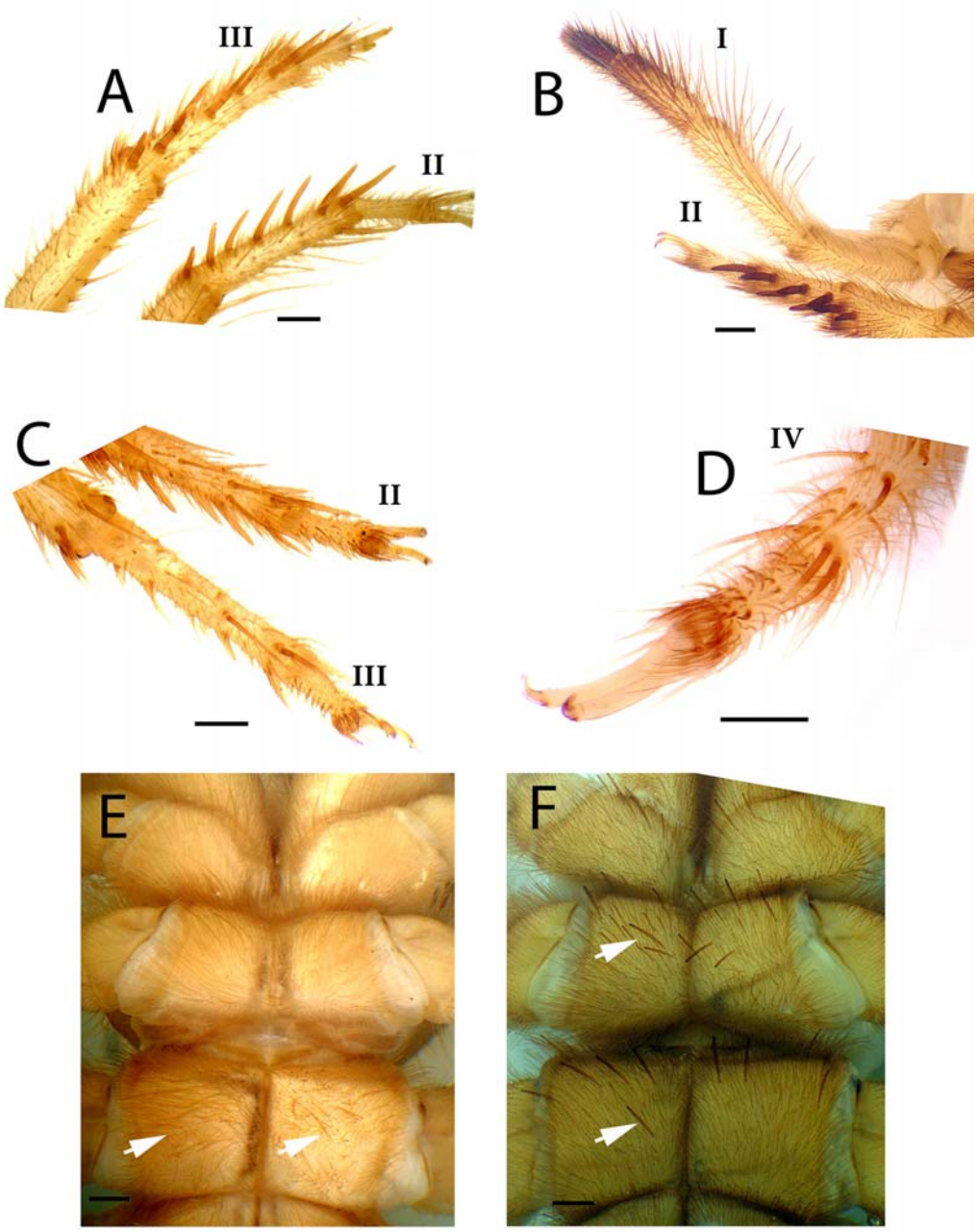

Fig. 4. Right legs (A–D) and bacilli (E and F) of *Rhagodes ahwazensis*. A, C, D and E — male holotype (SMF-10832–71), B and F — female (ZMFUM-SOL-1193). Scale bars = 1.0 mm.

Рис. 4. Правые ноги (A–D) и бациллы (E и F) *Rhagodes ahwazensis*. A, C, D и E — голотип самец (SMF-10832-71), B и F — самка (ZMFUM-SOL-1193). Масштаб 1,0 мм.

III with two dorsal apical spiniform setae and one to three extra spinule.

Female.

Coloration. Similar to that of male. Propeltidium and anterolateral propeltidial lobe greyish-brown (Fig. 2D); chelicerae dorsally and retrolaterally with larger yellowish-brown proximal portion (Figs 2D, 3C, D). Pedipalps with reddish-brown metatarsus (Fig. 2D). First pair of leg with dark-brown tarsus and reddish-brown metatarsus (Figs 2D, 4B). Opisthosoma ocher yellow with a lighter dorsal longitudinal stripe (Fig. 2D, E). Body covered with darker setae than male.

Measurements. Female. TL 57.34; CL 13.08; CH 6.72; CW 5.32; FFL 8.72; MFL 8.06; FFML 2.65; MFML 2.51; PPL 5.14; PPW 7.10; ETW 1.60; PL 17.64; PMT 5.20; PT 1.32; LI 14.12; LIV 22.12; CL/CH 1.94; CL/CW 2.45; ETW/PPW 0.22; FFL/CL 0.66; FFML/MFML 1.05; A/CP 2.95.

Chelicerae. Shape. Similar to that of male. In adult specimens the apex of MT touch the mucra of the fixed finger when fingers are closed. ***Dentition.*** Similar to those of male. Teeth comparatively larger, especially FP and MP which are markedly enlarged (Fig. 3C, D); FM and FD with

different orientation related to other fixed finger teeth and projected ventrodistally to distally (arrows at Fig. 3C); tiny RFSM. ***Chaetotaxy. Prolateral view. Paturon.*** Similar to those of male. With thinner *pdp* setae rather than male; four rows of irregularly-spaced plumose *pvd* setae, densely spaced proximally in the *pvd* row close to the interdigital articulation, few distal *pvd* setae are robust, longer and non-plumose; *pv* setae are slightly larger than male (Fig. 3D). *Stridulatory apparatus.* Similar to that of male. With slightly longer stridulatory setae and more extended stridulatory ridges (Fig. 3D). ***Movable finger.*** Similar to those of male. Series of plumose, distally directed *mpd* setae, the apical-most ones longer, slightly curved, non-plumose and dorsodistally directed; acuminate to plumose *mpm* setae (Fig. 3D). *Movable finger fondal setae*. A short series of slightly plumose *mff* setae. ***Retrolateral view. Paturon.*** *rlf* and *rlm* setae similar to those of male (Fig. 3C). ***Movable finger.*** Similar to that of male, plumose dorsal clump of *rlpc* setae (Fig. 3C). **Sense organs.** Similar to those of male.

Bacilli. 5 to 11 brown prominent bacilli on each coxa of legs I–III (Fig. 4F).

Spinulation. Tarsus of legs II–III ventrally with one spiniform seta and tarsus of legs IV ventrally with 1.1 spiniform setae; metatarsus of legs II and III ventrally with 1.1 or 1.2 and metatarsus of legs IV with 1.1.2 spiniform setae; metatarsus of legs II and III dorsally with a series of six brown stout spiniform setae (Fig. 4B); tibia of legs II and III with two dorsal apical spiniform setae and one or two extra spinule (Fig. 4B).

Opisthosoma. Similar to that of male. Genital sternite with less concave internal margin, opercula of the genital sternite with smaller opening than male.

Discussion

Rhagodids were mainly described on the basis of a small set of characters, consequently, a large number of species are only known based on inadequate original descriptions [Walter, 1889; Kraepelin, 1901; Birula, 1905b, 1938; Roewer, 1933, 1941, 1960; Caporiacco, 1937, 1939]. There are dozens of species known from a single sex or from few specimens and their taxonomic identity needs to be re-examined. Moreover, intraspecific variations and sexual dimorphism are rarely studied within the family Rhagodidae. In this contribution, we re-described *R. ahwazensis* (♂♀) and provided a detailed description of the species. A similar study has been carried out by Maddahi *et al*. [2019] on the species *R. eylandti* (Walter, 1889), presenting a high level of male intraspecific color variation and sexual dimorphism.

According to the results of the present study, the intraspecific variation of the male *R. ahwazensis* was not significant in contrast to variation seen in males of *R. eylandti*. This lack of color variation may correspond to the narrow distribution range of the former. *Rhagodes ahwazensis* also showed a low level of sexual dimorphism in comparison to *R. eylandti* (Fig. 2). The female of *R. ahwazensis* is darker than males, with smaller and thicker bacilli, and smaller malleoli. Main sexual differences of the species were seen in the cheliceral characters as below: slightly longer stridulatory setae and more extended stridulatory ridges presented in female; *pvd* setae are totally plumose in female except few distal setae; *mpd, mpm*, *mff* and dorsal clump of *rlpc* setae are not plumose or mostly devoid of plumosity in males (Fig. 3); FM and FD oriented ventrodistal to distal in female (Fig. 3C); higher CL/CH and CL/CW ratios in males, representing more robust and broader chelicerae in males.

The number of dorsal apical spiniform setae on the tibia of legs II & III which was frequently used in the identification keys of the rhagodid species [Roewer, 1933], was previously shown to be a variable, impractical diagnostic character for the species *R. eylandti* [Maddahi *et al*., 2015]. In the examined specimens of *R. ahwazensis*, significant variation was observed in length, thickness and number of these setae.

The application of tarsal spinulation at the genus level taxonomy of the rhagodid species is controversial and has been repeatedly criticized [Turk, 1960; Reddick, 2008; Maddahi *et al*., 2015]. According to our result, the number of ventral spiniform setae on the tarsus of legs II–IV was variable among the studied specimens and even between different tarsi of a single specimen.

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