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**Podapolipoides chorthippus** n. sp.
(Acari: Prostigmata: Podapolipidae),
an ectoparasite of *Chorthippus* sp.
(Orthoptera: Acrididae) from southern Iran

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**Original research**

**ABSTRACT**

The ectoparasitic mite *Podapolipoides chorthippus* Majidi and Hajiqanbar n. sp. (Acari: Prostigmata: Podapolipidae), is described and illustrated from Fars province, southern Iran. Colonies of mites were recovered from pronotum and near hindwing bases of acridid grasshoppers, *Chorthippus* sp. (Orthoptera: Acrididae: Gomphocerinae). This is the first parasitism record of the genus *Podapolipoides* on grasshoppers of the genus *Chorthippus*.

Keywords ectoparasite; mite; Heterostigmata; grasshoppers; Gomphocerinae

Zoobank http://zoobank.org/A4CEBBCB-0059-4259-A824-8FBCB4408D0D

This article is dedicated to the memory of Hamidreza Hajiqanbar who unfortunately passed away after submitting the manuscript, on 14 October 2021 in a tragic car crash.

**Introduction**

Symbiotic relationships, including parasitism, with arthropods have been frequently evolved among different groups of mites. One of the most sophisticated ones is Prostigmata (Acari: Acariformes) which is comprised of species that occupy various habitats (Walter et al. 2009). Some species of this lineage are phoretic or parasitic on insects, mostly classified in Parasitengona and Heterostigmata cohorts, yet some other families like Cheyletidae and Dytiscacaridae have evolved parasitism (Walter et al. 2009; Mortazavi et al. 2018). Within Heterostigmata, the family Podapolipidae Ewing, 1922 with 32 genera and more than 290 described species, is one of the largest families in Prostigmata (Majidi et al. 2019). Members of this family are highly specialized obligate parasites of insects of five orders namely, Coleoptera, Orthoptera, Blattodea, Heteroptera and Hymenoptera (Husband & O'Connor 2014; Seeman 2021).

Five genera of podapolipids parasitise orthopterans: *Locustacarus* Ewing, 1924 with four species (Rahmatzaei et al. 2021); *Podapolipus* Rovelli & Grassi, 1888 with 31 species (Lindquist & Sidorchuk 2019); *Podapolipoides* Regenfuss, 1922 with 32 genera and more than 290 described species, is one of the largest families in Prostigmata (Majidi et al. 2019). Members of this family are highly specialized obligate parasites of insects of five orders namely, Coleoptera, Orthoptera, Blattodea, Heteroptera and Hymenoptera (Husband & O'Conner 2014; Seeman 2021).

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This study, we described a new species of *Podapolipoides* recovered from the acridid grasshopper, *Chorthippus* sp., from southern Iran and compared it with morphologically closely related species.
Materials and Methods

Collected grasshoppers were preserved in vials with 96% ethanol. Subsequently, grasshoppers and alcohol sediments from the vials were examined for parasitic mites. Host grasshoppers were collected from Latifi region, located in Fars province, Southern Iran in 2017. Colonies of mites were separated from pronotum and near wing bases of acridid grasshoppers, *Chorthippus* sp. (Orthoptera: Acrididae: Gomphocerinae) (Figure 1). Mite specimens were cleared in Nesbitt’s solution and mounted in Hoyer’s medium. Morphology of the mites was studied using a compound microscope (Olympus BX51, Tokyo, Japan) equipped with phase contrast illumination. Photographs were taken with the aid of Samsung i70 digital camera. All measurements in the descriptions are given in micrometers for the holotype and five paratypes (in parentheses). The terminology follows Lindquist (1986). Details of geographical position have been recorded using GPS mobile device. Setae with no longer than the diameters of setal acetabulae are considered as microsetae and those with only acetabulae and no setal remnants are assigned as vestigial setae. The host insect was identified with the help of Dr. Mustafa Ünal (Abant Izzet Baysal Üniversitesi, Turkey).

Results

**Family Podapolipidae Ewing, 1922**

**Genus Podapolipoides Regenfuss, 1968**

Type-species: *Podapolipoides (Podapolipus) grassii* (Berlese, 1897), by original designation.
**Podapolipoides chorthippus Majidi and Hajiqanbar n. sp.**

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**Diagnosis**

Larval females with dorsal setae \( d \) (7–8) short, simple and pointed; \( f \) serrate; \( h_2 \) simple, pointed and slightly thickened; \( v_1 \) (2–4), \( v_2 \) (5–10); \( 1a \) \( m \), \( 2a \) \( m \), \( 3b \) \( m \) (m–4). Males with dorsal setae \( sc_2 \) 86 and \( c_2 \) 118 long, \( sc_2 \) extending beyond bases of setae \( c_2 \).

**Type-host**

*Chorthippus* sp. (Orthoptera: Acrididae: Gomphocerinae). Attachment site on host: On pronotum and near wing bases (Figure 1).

**Type-material**

Holotype female (MM20170303) and paratypes (9 adult females, 1 male, 22 larval females) found in, Fars Province, Southern Iran, 27°41ʹN, 54°24ʹ E and altitude 799 m, 3 III 2017; collected by Maryam Majidi; deposited in the Acarological Collection, Department of Entomology, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran. One adult female and one larval female are deposited in Zoological Institute, University of Hamburg, Hamburg, Germany.

**Description**

**Adult female** — (Figure 2)

*Gnathosoma* (Figure 2A) — Gnathosoma length 62 (52–62), width 55 (53–60); cheliceral stylets robust, length 16 (16–27); pharynx oval and well developed, length 41 (37–45), width 33 (24–34).

*Idiosoma* (Figure 2A) — Idiosoma ovoid and smooth, length 620 (458–670), width 482 (451–517), with bi-lobed protuberances anterolaterally and genital opening posteroventrally; prodorsal shield poorly sclerotised. Stigmata conspicuous and situated at anterior border of prodorsal shield, each with an elongate broad atrium with 4 distal tracheal branches, length of tracheal atrium about 2 times length of pharynx before enlarging and getting off multiple tracheal branches.

*Legs* — (Figure 2B) Only single pair of anterior legs; tarsus with one subunguinal seta \( s \) modified as terminal claw and both spine-like tectal setae \( tc' \) and \( tc'' \) blunt; tibia with 1 spine-like seta \( l' \); genu nude; femur with one prominent seta \( l' \) 18 (18–20).

**Adult Male** — (Figures 3–4)

*Gnathosoma* (Figure 3A) — length 33, width 29, dorsally with one pair of cheliceral seta \( ch \) 3 and ventrally with one pair of subcapitular seta \( su \) 5; cheliceral stylets 14; pharynx length 17, width 13; distances between gnathosomal setae: \( ch-ch \) 19, \( su-su \) 13.

*Idiosomal dorsum* (Figure 3A) — length 180, width 140; prodorsal plate (PrS) subtriangular, with smooth and pointed setae \( v_1 \) 4, \( v_2 \) 5 and attenuated \( sc_2 \) 86. Genital capsule placed in mid-dorsal idiosoma; pointed setae \( c_2 \) 118; distances between dorsal idiosomal setae: \( v_1-v_1 \) 24, \( v_2-v_2 \) 43, \( sc_2-sc_2 \) 56, \( c_2-c_2 \) 102.

*Idiosomal venter* (Figure 3B) — with apodemes I, II and pre sternal apodeme (appr) developed; apodemes II (ap2) not reaching to pre sternal apodeme; coxal fields I without setae \( 1a \); coxal fields II with one pair of smooth and pointed setae \( 2a \) 6; coxal fields III fused and bearing only one pair of smooth and pointed setae \( 3b \) 16.

*Legs* (Figure 4). Leg I (Figure 4A) thicker and shorter than other legs; setal formula (number of solenidia in parentheses): 0-2-0-6-5(1); ambulacrum I with single small claw in sucker-like pad; tarsus with 2 distinctly blunt-ended eupathidial setae \( tc' \) and \( tc'' \), solenidion \( \omega \) 7, prominent and digitiform, setae \( s \) and \( pv'' \) spine-like; tibia with one spine-like seta \( v' \) 9 and 5 setiform setae, eupathidion \( \kappa \) 4; femur with two setae, seta \( l'' \) 5. Leg II (Figure 4B) with setal formula: 0-1-0-4-4; ambulacrum II with no claw but empodium well developed; tarsus with 3
spine-like setae te', u' and pv", seta tc” attenuated, 42 long; tibia with two spine-like setae v' 11 and l' 8, seta d longer than v"; femur with one seta l'. Leg III (Figure 4C) with setal formula: 0-0-0-4-4; ambulacrum III without claw, empodium well developed; tarsus with 3 spine-like setae te', u' and pv", seta tc” attenuate, 103 long; tibia with three spine-like setae v' 14, v" 13 and l' 14, seta d attenuate, 99 long.

Larval female — (Figures 5–6)

Gnathosoma (Figure 5A) — length 48 (58–60), width 70 (60–77); dorsally with one pair of cheliceral seta ch 16 (38–43) and ventrally with one pair of subcapitular seta su 8 (8–9); palpal setae dFe 12 (9–14); dGe 11 (11–16), all setae ch, su, dFe, dFe smooth and pointed;
cheliceral styles 63 (60–86); pharynx oval, length 17 (16–18), width 17 (14–19); distances between gnathosomal setae: ch-ch 34 (37–43), dFe-dFe 17 (17–23), dGe-dGe 8 (8–12), su-su 17 (17–23).

Idiosomal dorsum (Figure 5A) — oval, length 154 (154–182), width 136 (132–155); prodorsal plate (PrS) subrectangular, wider than long, smooth and pointed setae $v_1$ 4 (2–4), $v_2$ 7 (5–10), and attenuated setae $sc_2$ 93 (85–111); setae $sc_2$, extending beyond posterior margin of tergite D; tergite C surrounding anterior and lateral margins of tergite D, with only one pair of setae $c_2$ 18 (12–22); tergite D almost sub-circular, with one pair of needle-like setae $d_7$ 7 (7–8); tergite EF subtriangular, with one pair of setae $f$ 9 (9–18), indistinctly serrate (left side seta detached); tergite H with two pairs of setae, $h_j$ 207 (207–314) and $h_z$ 10 (10–19); setae $h_j$ whip-like and attenuated, $h_z$ slightly thick; distance between idiosomal setae: $v_1-v_1$ 58 (52–62), $v_2-v_2$ 89 (81–98), $sc_2-sc_2$ 52 (50–63), $c_2-c_2$ 125 (134–148), $d-d$ 23 (22–32), $f-f$ 47 (34–47), $h_2-h_2$ 14 (12–14).

Idiosomal venter (Figure 5B) — apodemes I (ap1) and II (ap2) lightly sclerotized but ap2 not reaching prestermal apodeme (appr); coxal fields I and II each bearing one pair of microsetae $1a$ and $2a$, respectively; coxal fields III separated from each other and from coxal fields II; setae $3b_m$ (m-4), with striation between and around coxal fields III.

Legs — (Figure 6), Leg I (Figure 6A) thicker than other legs; setal formula (number of solenidia in parentheses): 0-3-1-6-7(1); ambulacrum I with bifid small claw in sucker-like pad; tarsus with two distinctly blunt-ended eupathidial setae $tc'$ and $tc''$, solenidion $\omega$ 7 (6–8) prominent and digitiform, seta $s$ spine-like; tibia with eupathidion $k$ 6 (6–9) adjacent to long

Figure 3 Podapolipoides chorthippus n. sp., male. A. Dorsal view. B. Ventral view.
seta $d$ 36 (34–46), setae $v''$ and $l''$ subequal; genu with one seta $v'$; femur with three setae, seta $l'$ needle-like, seta $l''$ 31 (34–46) extending beyond tip of leg and distinctly longer than seta $v''$ 26 (31–35). Leg II (Figure 6B) with setal formula: 0-1-1-4-4; ambulacrum II without claw, empodium well-developed; tarsus with two spine-like setae $t^c$ and $u'$; seta $pv''$ needle-like; tibia with seta $l'$ needle-like, rest of setae of the segment pointed; seta $d$ 28 (27–39) subequal with seta $v''$ 27 (21–27); genu and femur each with one seta $v'$ and $l'$, respectively, $l'$ needle-like. Leg III (Figure 6C) with setal formula: 0-0-1-4-4; ambulacrum III without claw, empodium well-developed; tarsus with two spine-like setae $t^c$ and $u'$, seta $pv''$ needle-like; tibia with seta $d$ 30 (45–50), all setae of segment pointed; genu with one needle-like seta $v'$.

**Differential diagnosis**

The male of new species belongs to a cluster of species sharing setae $c_2$ 100-125 µm long (see the following key for related these species): *Podapolipoides faini* Husband, 1995, *P. locustanus* Lavoipierre, 1941, *P. alatus* Husband, 1990, *P. cochisensis* Husband, 1993 and *P. anacridii* Hajiqanbar and Joharchi, 2011. According to length of setae $sc_2$ (80-96), *P. chorthippus* (86) is similar to *P. faini* (80) and *P. cochisensis* (96) but differ from from *P. cochisensis* by the length of setae $3b$ 16 (vs vestigial in *P. cochisensis*) and *P. faini* in the length of cheliceral stylets 14 (vs 8 in *P. faini*) and coxal seta $3b$ shorter than gnathosomal width (vs equal to gnathosomal width in *P. faini*) also coxal seta $2a$ shorter than 1/3 gnathosomal width (vs about 1/3 gnathosomal width in *P. faini*), and in *P. chorthippus* larvae setae $c_2$ is longer than $d$ (vs $c_2$ is subequal to $d$ in *P. faini*). Regarding to setae $1a$, *P. chorthippus* n. sp. with no setae $1a$ is similar to *P. alatus* but differs from it by setae $sc_2$ reaching to beyond bases of setae $c_2$ (vs not reaching to bases.
of setae \( c_2 \) in \( P.\) alatus). Based on apodemes II, \( P.\) chorthippus n. sp. resembles \( P.\) anacridii, \( P.\) faini and \( P.\) locustanus but differs from \( P.\) anacridii by ap1 reaching appr (vs not reaching appr in \( P.\) anacridii) and differs from \( P.\) locustanus by setae \( sc_2 \) reaching beyond bases of setae \( c_2 \) (vs not reaching beyond bases of setae \( c_2 \) in \( P.\) locustanus). Among the congeners found in neighboring countries, it is similar to \( P.\) jordani Husband, 1992. However, male of the new species differs from that of \( P.\) jordani by \( sc_2 \) reaching beyond bases of setae \( c_2 \), ap2 not reaching appr, and length of \( tc'' 103 \) (vs \( sc_2 \) not reaching beyond bases of setae \( c_2 \), ap2 reaching appr, \( tc'' 156 \) in \( P.\) jordani). The remainder of the comparative measurements is summarized in Table 1.

Based on length of setae \( v_1 \) and \( v_2 \) (\( v_1 > v_2 \)), larval females of the \( P.\) chorthippus n. sp. can be easily distinguished from all other species of the genus except \( P.\) flechtmanni Husband, 1993. Based on longer setae \( v_2 \) than \( v_1 \), and almost the same length of setae \( h_1 \), \( sc_2 \) and \( f \), larval females of \( P.\) chorthippus are similar to those of \( P.\) flechtmanni. However, they differ in shape of setae \( d, f, h_2 \). In \( P.\) chorthippus, setae \( d \) are thin and pointed, \( f \) serrate, and \( h_2 \) slightly thickened (vs \( d, f, h_2 \) thick and minutely spine-like in \( P.\) flechtmanni); setae \( c_2 \) 12–22 at least two times longer in \( P.\) chorthippus n. sp. (vs 6 in \( P.\) flechtmanni); and coxal setae I and II microsetae (vs 2 in \( P.\) flechtmanni).

**Etymology**

The new species is named based on the genus name of the grasshopper host (\textit{Chorthippus}).
Figure 6 Podapolipoides chorthippus n. sp., (larval female). (A-C). Legs I–III, respectively. Dorsal view, A. right leg, B-C. left legs.

Key to males of Podapolipoides spp. with setae c₂ 100-125 µm

1. Seta 3b vestigial .......................................................... P. cochisensis
   — Seta 3b not vestigial, setiform .............................................. 2

2. Seta sc₂ reaching bases of seta c₂ or beyond .............................................. 3
   — Seta sc₂ never reaching bases of seta c₂ ........................................... 5

3. Coxal fields I without setae 1a ................................................. P. chorthippus n. sp.
   — Coxal fields I with one pair of vestigial setae 1a ................................ 4

4. Femur I seta v” equal to or longer than seta l” ................................. P. locustanus
   — Femur I seta v” about half of the length of seta l” .............................. P. fiani

5. Setae 2a microsetae or vestigial ................................................. P. alatus
   — Setae 2a not microsetae or vestigial, setiform ................................. P. anacridii

Discussion

The genus Chorthippus is a new host record for parasitic mites of the genus Podapolipoides. It is a member of the subfamily Gomphocerinae (Orthoptera: Acrididae). According to the prevalence of Podapolipoides mites on orthopterans provided by Hajiqanbar and Joharchi (2011), 23 genera of Acrididae (22) and Pyrgomorphidae (1) are parasitized by this mite genus. Sarangi et al. (2012) described a new Podapolipoides from Oxya (Acrididae: Oxyinae), a grasshopper genus previously recorded as host of three species of Podapolipoides: P. andrei, P. hopperae
and *P. mohanasundarami* (see Husband 1995; Ramaraju & Mohanasundaram 1996; Ramaraju & Suresh 1999). Hitherto, only one genus of the subfamily Gomphocerinae was recorded as a host of *Podapolipoides*, i.e. *Orphulella* (Feldman-Muhsam and Havivi, 1973). Including the current study, Gomphocerinae includes two host genera (*Orphulella* and *Chorthippus*) of *Podapolipoides*. This extend the number of orthopteran host genera of *Podapolipoides* to 24 (23 belonging to Acrididae). Therefore, the prevalence of *Podapolipoides* mites on acridids

Table 1 Comparison of selected maximum measurements of *P. chorthippus* n. sp. (*Pch*), *P. anacridii* (*Pan*), *P. faini* (*Pf*), *P. locustanus* (*Pl*), *P. alatus* (*Pal*) and *P. cochisensis* (*Pc*).

| Character                      | Pch  | Pan  | Pf   | Pl   | Pal  | Pc   |
|-------------------------------|------|------|------|------|------|------|
| **Adult female**              |      |      |      |      |      |      |
| Idiosomal length              | 670  | 432  | 460  | 490  | 530  | 662  |
| Idiosomal width               | 517  | 368  | 340  | 410  | 546  | 556  |
| Gnathosomal width             | 62   | 70   | 40   | 48   | 56   | 47   |
| Cheliceral stylet             | 27   | 33   | 18   | 22   | 29   | 27   |
| Pharynx width                 | 34   | 36   | 28   | 33   | 32   | 33   |
| Femur I seta l'               | 20   | 20   | 14   | 19   | 15   | 15   |
| Tarsus I seta tc'             | 4    | 7    | 5    | 5    | 5    | 5    |
| **Male**                      |      |      |      |      |      |      |
| Idiosoma length               | 180  | 205  | 147  | 158  | 158  | 133  |
| Idiosomal width               | 140  | 152  | 113  | 133  | 137  | 120  |
| Gnathosomal width             | 29   | 29   | 23   | 28   | 29   | 27   |
| Cheliceral stylet             | 14   | 13   | 8    | 8    | 10   | 13   |
| Subcapitular seta su v        | 5    | 5    | 5    | 5    | 4    | 2    |
| v                            | 118  | 125  | 104  | 123  | 113  | 123  |
| sc 2                         | 86   | 65   | 80   | 105  | 74   | 96   |
| 3b                           | 16   | 27   | 23   | 37   | 29   | v    |
| Tibia I seta k                | 4    | 5    | 7    | 8    | 5    | 5    |
| Tibia I seta v'               | 9    | 10   | 9    | 11   | 8    | 26   |
| Tibia III seta d              | 99   | 125  | 96   | 118  | 133  | 107  |
| Tibia III seta v'             | 14   | 15   | 13   | 17   | 18   | 13   |
| Tarsus III seta tc''          | 103  | 128  | 104  | 152  | 142  | 125  |
| **Larval female**             |      |      |      |      |      |      |
| Idiosomal length              | 182  | 235  | 146  | 179  | 176  | 143  |
| Idiosomal width               | 155  | 201  | 122  | 173  | 143  | 129  |
| Gnathosomal width             | 77   | 77   | 52   | 62   | 52   | 48   |
| Cheliceral stylet             | 86   | 99   | 60   | 66   | 68   | 52   |
| Cheliceral seta ch dFe v i v2 | 43   | 42   | 28   | 34   | 25   | 28   |
| v                            | 14   | 18   | 13   | 12   | 10   | 5    |
| dFe                          | 18   | 24   | 15   | 16   | 24   | 14   |
| h1                          | 314  | 400  | 415  | 428  | 497  | 385  |
| h2                          | 19   | 25   | 18   | 15   | 20   | 12   |
| Femur I seta l"              | 46   | 51   | 39   | 42   | 49   | 38   |
| Tibia I seta k                | 9    | 8    | 5    | 9    | 8    | 7    |
| Tibia III seta d              | 50   | 70   | 51   | 51   | 57   | 29   |
and pyrgomorphids subfamilies is updated as follows: Oedipodinae (38.6%), Cyrtacanthacridinae (27.2%), Acridinae (11.4%), Oxyinae (9.1%), and Melanoplinae, Gomphocerinae, and Pyrgomorphinae each with 4.5%.

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