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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 & OConnor 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, 1968 with 31 species (Hajiqanbar & Joharchi 2011); *Orthapolipus* Husband & Li, 1993 with 3 species (Husband *et al.* 2005) and monobasic *Wetapolipus* Husband & Zhang, 2002 (Husband & Zhang 2002). The genus *Podapolipoides* is confined to grasshopper of the families Acrididae (mostly) and Pyrgomorphidae (Husband 1995). So far, *P. grassii* (Berlese, 1897) on *Locusta migratoria* L. and different acridids and *P. anacridii* Hajiqanbar & Joharchi, 2011 on *Anacridium* sp. have been reported from Iran (Ostovan & Saboori 1999; Hajiqanbar & Joharchi 2011). In 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.

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Figure 1 A colony of *Podapolipoides chorthippus* **n. sp.** on pronotum of *Chorthippus* sp.

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 İzzet 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.

Zoobank: 6EC39A40-9645-4C0F-8570-153EFE16AD3F

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); 1*a* m, 2*a* m, 3*b* 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°41′N, 54°24′ 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 presternal apodeme (appr) developed; apodemes II (ap2) not reaching to presternal apodeme; coxal fields I without setae *1a*; coxal fields II with one pair of smooth and pointed setae 2*a* 6; coxal fields III fused and bearing only one pair of smooth and pointed setae 3*b* 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 ω 7, prominent and digitiform, setae *s* and *pv″* spine-like; tibia with one spine-like seta *v′* 9 and 5 setiform setae, eupathidion *k* 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

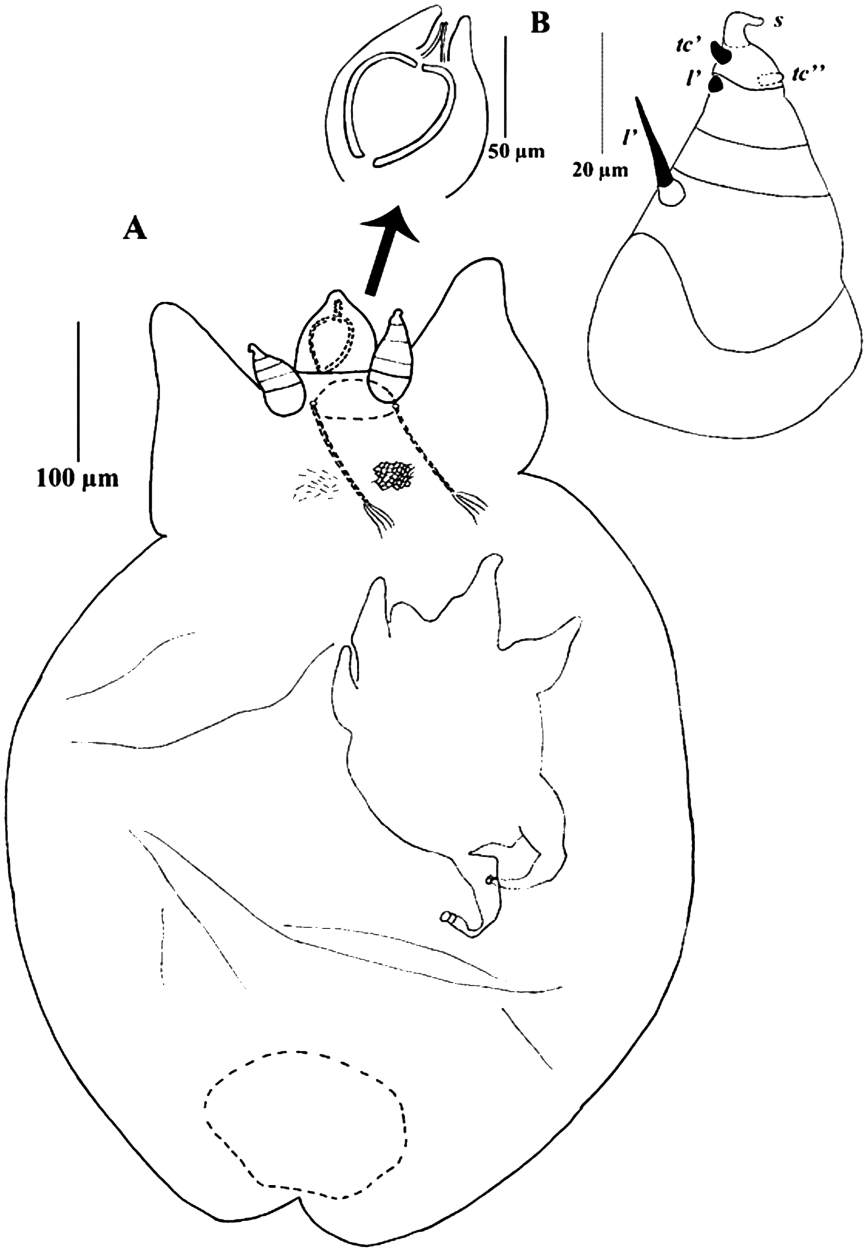

Figure 2 *Podapolipoides chorthippus* **n. sp.**, (adult female). A. Dorsal view, B. Details of leg I (Paratype).

spine-like setae *tc′*, *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 *tc′*, *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;

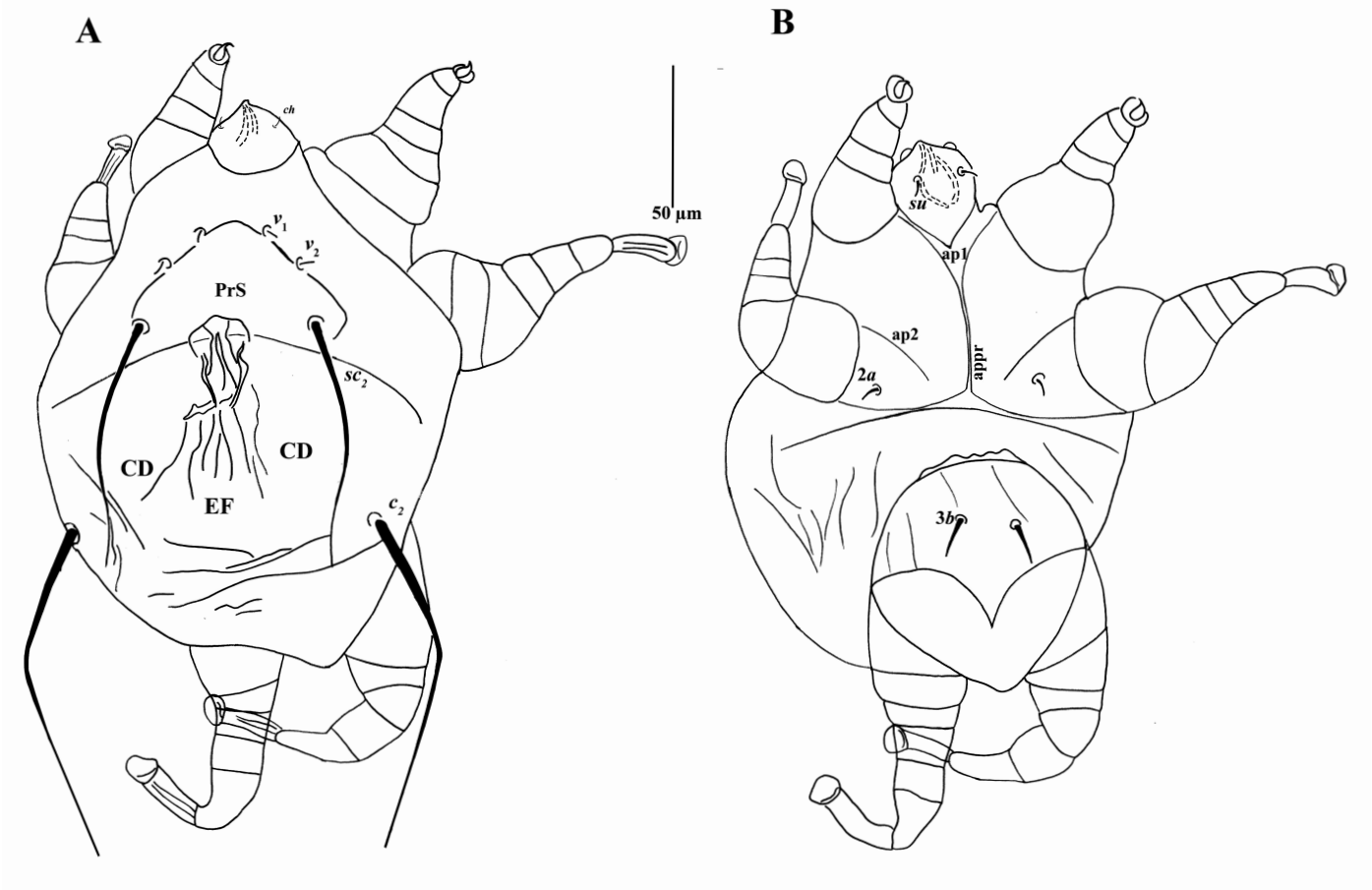

Figure 3 *Podapolipoides chorthippus* **n. sp.**, male. A. Dorsal view. B. Ventral view.

cheliceral stylets 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 (7–8); 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_1 207 (207–314) and h_2 10 (10–19); setae h_1 whip-like and attenuated, h_2 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 presternal 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 3*b* 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 ω 7 (6–8) prominent and digitiform, seta *s* spine-like; tibia with eupathidion *k* 6 (6–9) adjacent to long

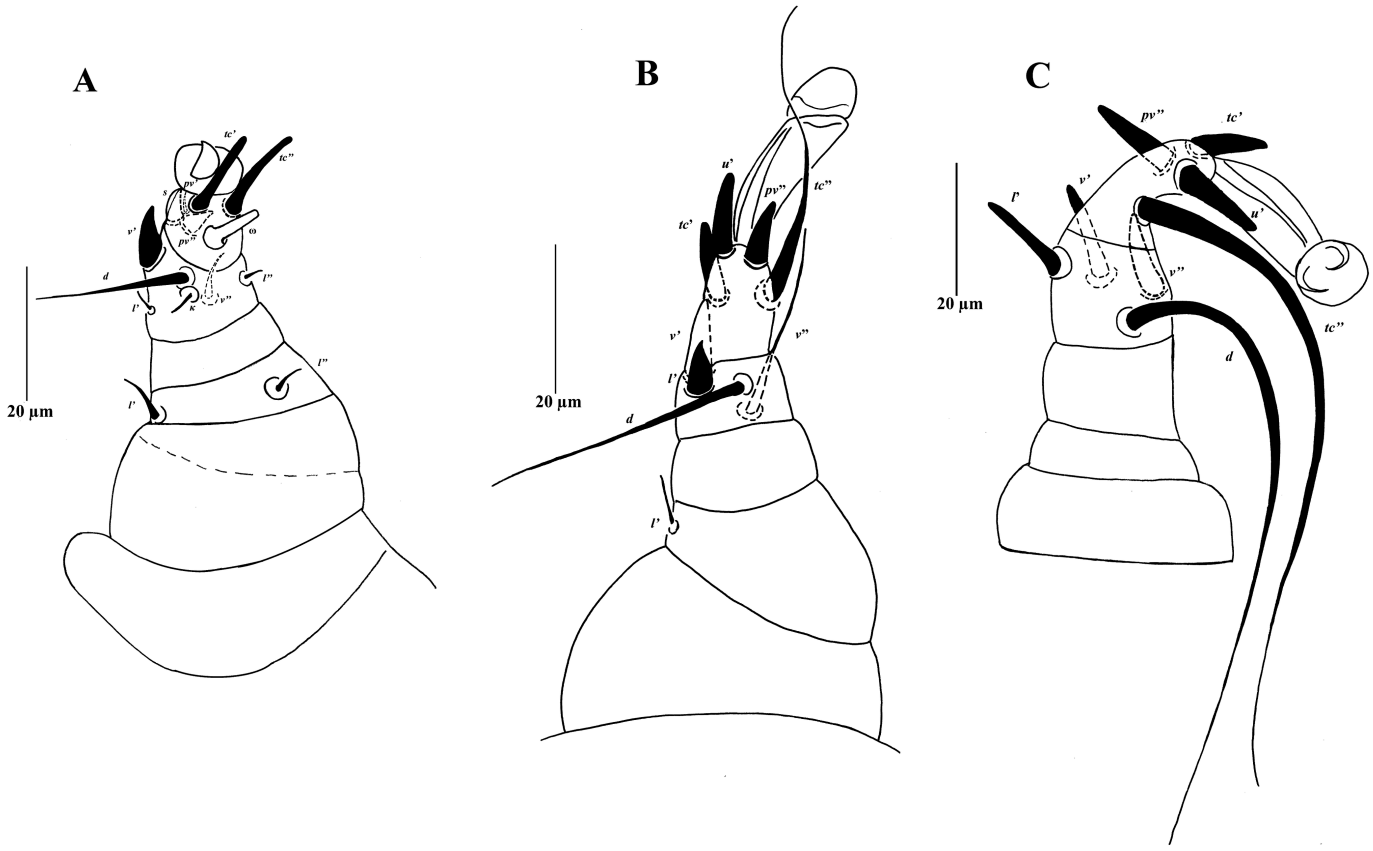

Figure 4 *Podapolipoides chorthippus* **n. sp.**, (male). (A-C). Legs I–III, respectively. Dorsal view, right legs.

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 *tc′* 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 *tc′* 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 3*b* 16 (*vs* vestigial in *P. cochisensis*) and *P. faini* in the length of cheliceral stylets 14 (*vs* 8 in *P. faini*) and coxal seta 3*b* shorter than gnathosomal width (*vs* equal to gnathosomal width in *P. faini*) also coxal seta 2*a* 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 1*a*, *P. chorthippus* **n. sp.** with no setae 1*a* 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

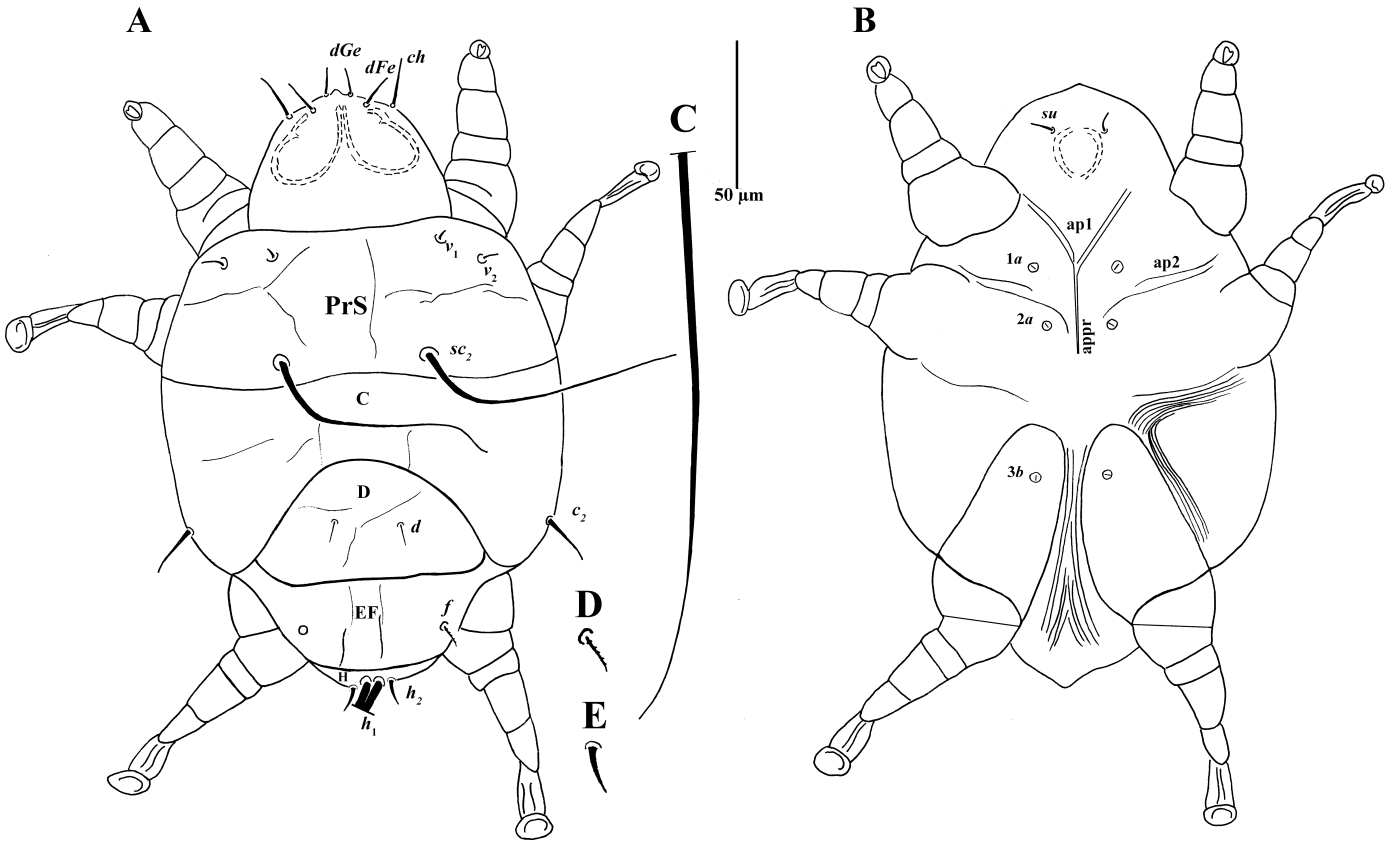

Figure 5 *Podapolipoides chorthippus* **n. sp.**, (larval female). A. Dorsal view. B. Ventral view. C. Seta h_1 enlarged. D. Seta *f* enlarged. E. Seta h_2 enlarged.

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 (*Chorthippus*).

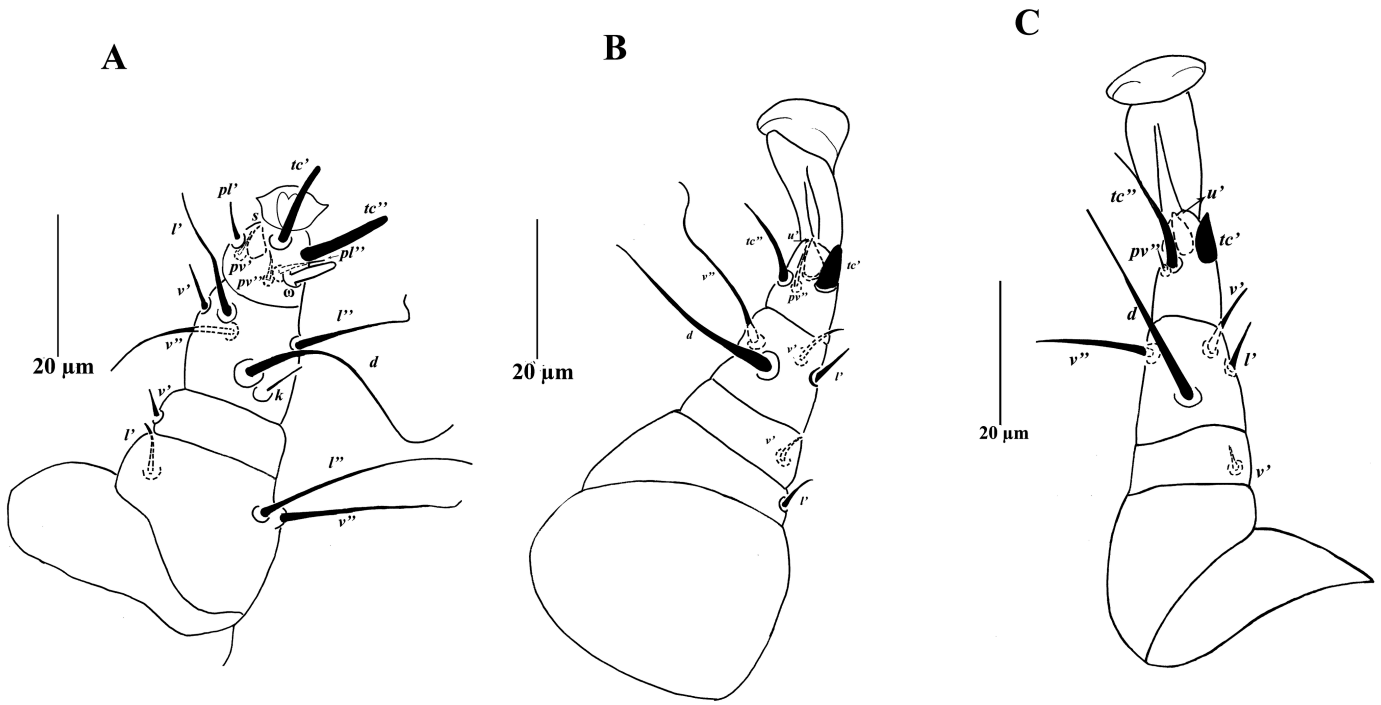

Figure 6 *Podapolipoides chorthippus* **n. sp.**, (larval female). (A-C). Legs I–III, respectively. Dorsal view, A. right leg, B-C. left legs.

Key to males of *Podapolipoides* spp. with setae c_2 100-125 µm

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

2. Seta sc_2 reaching bases of seta c_2 or beyond 3
— Seta sc_2 never reaching bases of seta c_2 5

3. Coxal fields I without setae 1*a* ..... *P. chorthippus* **n. sp.**
— Coxal fields I with one pair of vestigial setae 1*a* 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 2*a* microsetae or vestigial ..... *P. alatus*
— Setae 2*a* not microseta or vestigial, setiform ..... *P. anacridii*

Discussion

The genus C*horthippus* 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).*

	Species					
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
Idiosoma 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*	5	6	5	5	4	2
v_2	5	8	5	7	3	5
c_2	118	125	104	123	113	123
sc_2	86	65	80	105	74	96
3*b*	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*	43	42	28	34	25	28
dFe	14	18	13	12	10	5
v_1	4	20	12	15	17	10
v_2	10	11	10	10	7	7
d	8	24	15	18	22	15
Distance *d*-*d*	32	54	39	40	35	37
f	18	24	15	16	24	14
h_1	314	400	415	428	497	385
h_2	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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