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RESEARCH ARTICLE

Taxonomic investigations into carabodid mites (Acari, Oribatida, Carabodidae) of the Harşit Valley, Türkiye

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ASBTRACT: Oribatid mites are a dominant and biodiversity-rich group of arthropods that primarily inhabit the soil-litter system. In order to contribute to the studies on oribatid mites in Türkiye, the species belonging to the family Carabodidae of oribatid mites extracted from the soil, litter, moss, lichen, and bark collected from the Harşit valley between 2013-2015 were evaluated taxonomically. As a result of the investigations *Carabodes* (*C.*) *labyrinthicus* (Michael), *Carabodes* (*C.*) *pirinensis* Kunst, *Carabodes* (*C.*) *rugosior* Berlese, *Carabodes* (*Flexa*) *dubius* Kulijev and *Carabodes* (*Klapperiches*) *willmanni* Bernini taxa were determined. Of these, *C. willmanni* was identified as a new record for the fauna of Türkiye. The distinguishing features of the identified species were given together with scanning electron microscope photographs. Identified taxa were discussed with previously known ones based on morphological characters, and their geographical distributions are given.

Keywords: Distribution, fauna, new record, oribatid mites, taxonomy
Zoobank: https://zoobank.org/C3A4678B-E182-4092-9FFF-E828004C7241

INTRODUCTION

Oribatid mites constitute one of the arthropod groups that predominate in the organic layers of most soils in the terrestrial environment (Norton, 1990; Norton and Behan-Pelletier, 2009). The body is well sclerotized in adults except in some primitive oribatid mites. They range in size from about 150 to 1500 µm in length. Although they mostly live in the terrestrial environment, a few species live in the aquatic environment and feed on algae, fungi, or decaying materials. Among the soil mites, oribatid mites constitute a rich group of 11628 species belonging to 166 families known and distributed in all zoogeographic regions (Subías, 2004).

The family Carabodidae Koch, which has a cosmopolitan distribution among the known families of oribatid mites, is represented by 35 genera, 18 subgenera, 385 species, and five subspecies worldwide (Subías, 2004). Eight known genera (*Austrocarabodes*, *Bathocepheus*, *Bunabodes*, *Carabodes*, *Cavernocarabodes*, *Gibbicepheus*, *Meriocepheus*, and *Odontocepheus*) are distributed in the Palearctic region, including Türkiye. As a result of the limited number of studies collected and evaluated from various habitats in our country, nine taxa belonging to the genera *Austrocarabodes* and *Carabodes* were recorded from Erzurum, Kayseri, Kastamonu, Mersin, Aksaray, Bolu and Artvin provinces (Ayyıldız, 1988; Per and Ayyıldız, 2005; Yalçın et al., 2013; Murvanidze et al., 2020; Toluk and Ayyıldız, 2021). In our country, which we think is rich in biodiversity, we believe there may be more carabodid taxa than the known ones with more studies and habitat diversity. The aim of this study, based on the material collected from the Harşit Valley, is to identify carabodid mites and to contribute to the oribatid mite fauna of Türkiye.

MATERIALS AND METHODS

Description of the research area

The Harşit Valley (Türkiye) is a region formed by the Harşit Stream, which originates from the Vauk Mountain on the eastern border of Gümüşhane. The stream feeds from the Kalkanlı and Gümüşhane Mountains and flows into the Black Sea in Tirebolu (Fig. 1). This valley has a continental and humid-temperate climate (Ağcakaya and Ayyıldız, 2020).

Collection, extraction, and preparation of carabodid mite specimens

The carabodid mites were evaluated and selected from mite specimens collected between 2013 and 2015 during a faunal study (Project № 113Z094) on the raphignathoid and trombidioid mites of the Harşit Valley. Previously used methods were followed in mite collection, extraction, and preparation (Ağcakaya and Ayyıldız, 2020). Identification of carabodid mites was made using various literature and samples in our collection (Kunst, 1961; Bernini, 1975; Kulijev, 1977; Ayyıldız, 1988; Per and Ayyıldız, 2005; Weigmann, 2006; Mahunka and Mahunka-Papp, 2009; Yalçın et al,. 2013; Murvanidze et al., 2020; Toluk and Ayyıldız, 2021).

Scanning electron microscopy studies were conducted at Erciyes University Nanotechnology Application and Research Center (ERNAM). For microscopic examination, the samples cleaned in tergazyme and bleached using lactic acid were examined on a hollow slide under the light microscope, and the measurements of the body parts of the identified mites were made using an ocular micrometer.

The terminology suggested by Norton and Behan-Pelletier (2009) and Ayyıldız and Taşdemir (2019) was followed.

Information on the habitats of the determined carabodid mites

13T036: 40°32'44''N 31°28'18''E, 1200 m, moss and lichen on stone; 11.10.2013.

13T070: 40°39'58''N 38°59'52''E, 1994 m, fir tree litter; 12.10.2013.

13T572: 40°25'22''N 39°41'37''E, 1538 m, moss under willow; 25.09.2014.

13T578: 40°25'24''N 39°41'57''E, 1589 m, moss under larch; 25.09.2014.

13T702: 40°41'53''N 39°11' 05''E, 1200 m, litter and moss under fir tree; 15.11.2014.

13T704: 40°41'30''N 39°10'16''E, 920 m, moss and lichen above ground; 15.11.2014.

13T754: 39°48' 25''N 39°22'49''E, 482 m, litter from hazelnut orchard; 16.04.2015.

13T759: 40°41'44''N 39°10'43''E, 1074 m, rotted log and moss; 16.04.2015.

13T760: 40° 41' 44''N 39v 10' 43''E, 1074 m, mossy and grassy soil from open field; 16.04.2015.

13T777: 40°41'06''N 39°03'07''E, 729 m, grassy soil; 16.14.2015.

13T789: 40°22'01''N 39°49'22''E, 1900 m, debris under larch; 14.05.2015.

13T793: 40°22'06''N 39°49'26''E, 1869 m, mixed spill from roadside; 14.05.2015.

13T797: 40°22'12''N 39°49'32''E, 1860 m, moss and grass from bare area; 14.05.2015.

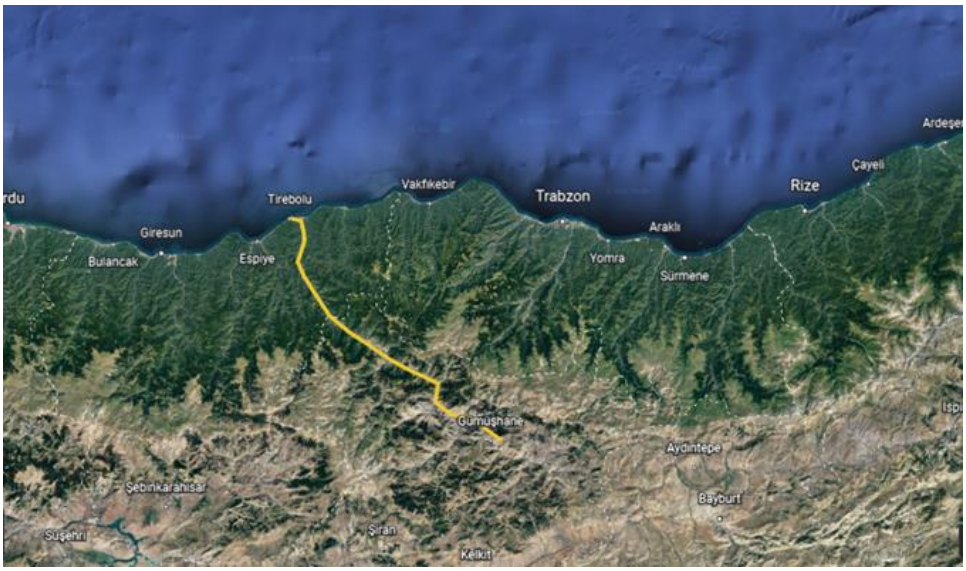

Figure 1. Topographic map of the Harşit Valley.

RESULTS

As a result of the examination of the carabodid mites selected from the material collected in the Harşit Valley in 2013 and 2015, five species, namely *Carabodes* (*C.*) *labyrinthicus* (Michael), *Carabodes* (*C.*) *pirinensis* Kunst, *Carabodes* (*C.*) *rugosior* Berlese, *Carabodes* (*Flexa*) dubius Kulijev and *Carabodes* (*Klapperiches*) *willmanni* Bernini, were determined. Distinctive features of these species are given below, along with scanning electron microscope photographs.

Identification key for subgenera of the genus Carabodes known from Türkiye

1. The ventral region short; genital and anal plates located close to each other; aggenital setae not present..... *Klapperiches* Mahunka

- Ventral region normal length; genital and anal plates separated in the normal position; aggenital setae mostly present.....2

2. The setae c_2 long directed forward, all the other notogastral setae short, leaf-shaped; the lyrifissure *iad* located near the anal opening ..... *Flexa* Kulijev

- The setae c_2 directed outward or backward; no significant difference in length between the setae c_2 and other notogastral setae; the lyrifissure *iad* not present or originates away from the anal opening.....*Carabodes* C.L. Koch

The subgenus *Carabodes* C.L. Koch

Type species: *Carabodes coriaceus* C.L. Koch

Carabodes (*C.*) *labyrinthicus* (Michael)

Body measurements: Length 558 µm, width 350 µm (n=1).

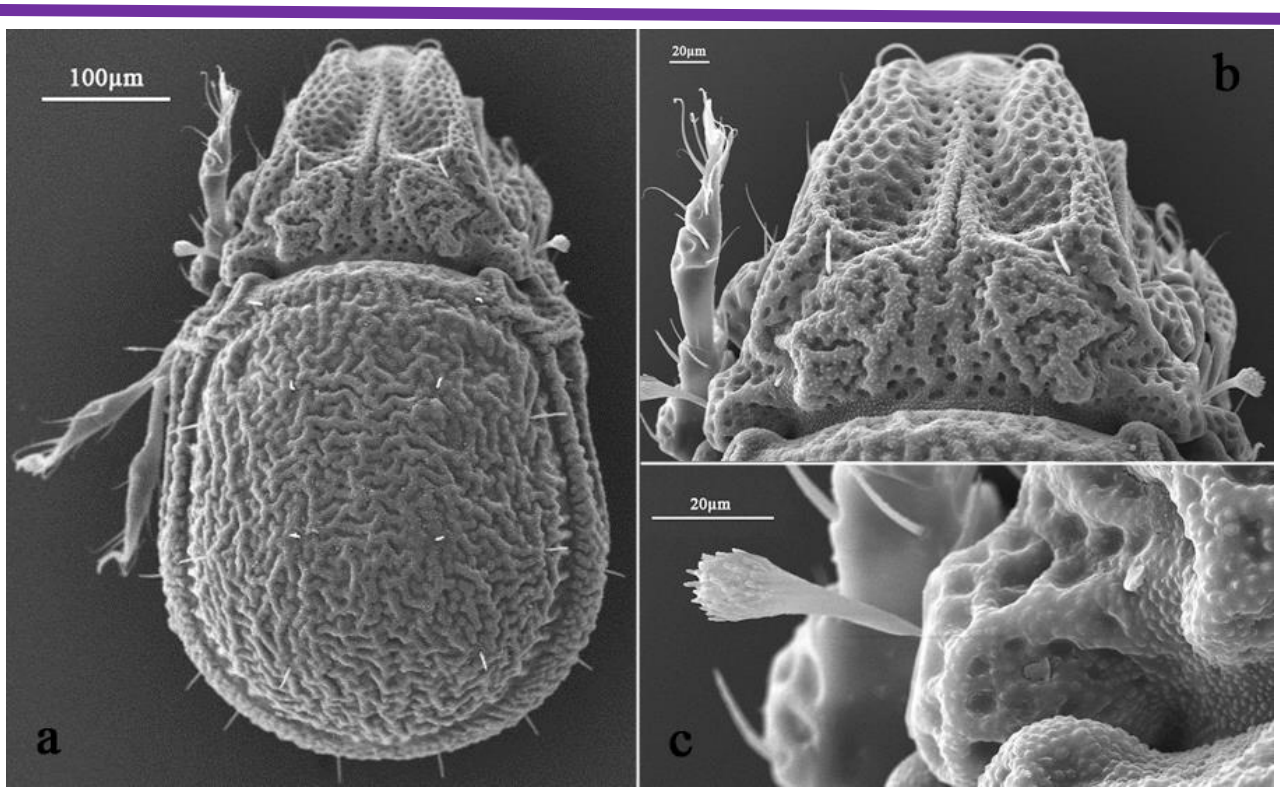

Figure 2. *Carabodes* (*C.*) *labyrinthicus* (Michael): **a.** Dorsal view, **b.** Prodorsum, **c.** Sensillus.

Prodorsum (Figs 2b, c). Length 175 µm, width 159 µm. Rostrum round; lamellae broad, rostral, and lamellar setae thin, straight, and curved inwards; interlamellar setae rod-shaped, erect, and strong; sensillus rod-shaped and barbed head at the tip. The interlamellar region is equipped with labyrinth-shaped irregular ridges, and besides round pores, the ridges are covered with thin small tubercles.

Notogaster (Fig. 2a). Length 383 µm, width 267 µm, oval-shaped, dorsosejugal furrow flat anteriorly; the notogastral region, like the interlamellar region, consists of ridges forming labyrinths and decorated with small tubercles. Dorsosejugal furrow absent. Two prominent humeral projections are directed anteriorly. Notogaster with ten pairs of straight and fine setae. The setae in the middle part are shorter than the setae in the edge.

Ventral region. The subcapitulum diarthric; coxisternal setal formula 3–1–2–3. Four pairs of genital setae, one pair of aggenital setae, two pairs of anal setae, and three pairs of adanal setae. Genital setae are short, fine, and straight.

Material examined: 13T777: 1 adult.

Carabodes (*C.*) *pirinensis* Kunst

Body measurements. Length 420-420 µm, width 240-240 µm (n= 2).

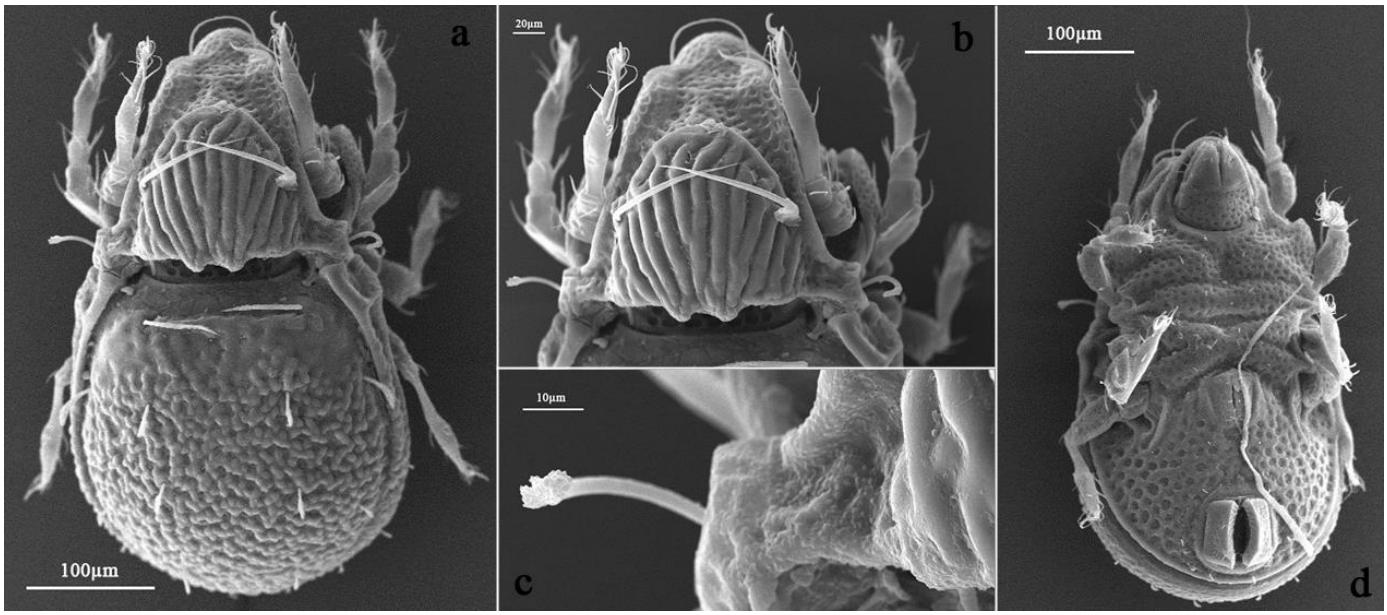

Figure 3. *Carabodes* (*C.*) *pirinensis* Kunst: **a.** Dorsal view, **b.** Prodorsum, **c.** Sensillus, **d.** Ventral view.

Prodorsum (Figs 3b, c). Rostrum round; rostral setae thin and arched, approximately 41 μm long; the lamellar setae about 33 μm long and robust. The interlamellar setae are 81 μm long, directed inwards, tapering from the base to the tip of the sword, and straight. The lamellar and rostral regions are shallowly pitted and reticulate. The interlamellar region separated from the other regions of the prodorsum by forming a mound with 14 longitudinal, ribbed formations. The mound carries two protrusions in the middle posterior part. Sensillus 28 μm long and uniformly thick stem and a finger-shaped protruding head at the tip.

Notogaster (Fig. 3a). Dorsosejugal furrow present. The notogaster has a pair of humeral ridges with small setae and 10 pairs of leaf-shaped ciliated setae. The notogastral cerotegument has a bumpy pattern.

Ventral region (Fig. 3d). The subcapitulum diarthric; the mentum, epimeral and genital regions with a reticulated pattern. Coxisternal setal formula 3–1–3–3. Four pairs of genital setae, one pair of aggenital setae, two pairs of anal setae, and three pairs of adanal setae. Genital plates are approximately 50 μm long and wide; the anal plates are about 67 μm long and wide.

*Material examined.*13T036: 2 adults.

Carabodes (*C.*) *rugosior* Berlese

Body measurements: Range of length 520-530 μm, width 270-280 μm (n=5).

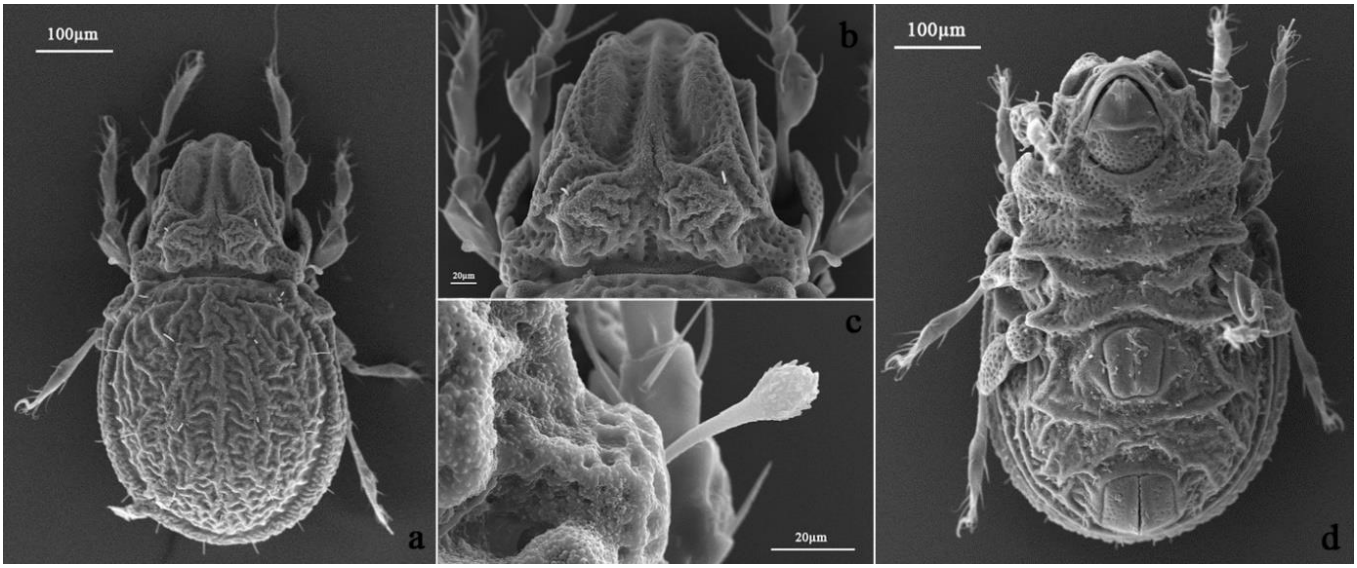

Figure 4. *Carabodes* (*C.*) *rugosior* Berlese: **a.** Dorsal view, **b.** Prodorsum, **c.** Sensillus, **d.** Ventral view.

Prodorsum (Figs 4b, c). Rostrum round; rostral setae thin and arched inward; interlamellar setae 11 μm long and straight; lamellar setae 35 μm long, curved inwards, straight shaped. Two tubercles in the posterior part of the prodorsum are raised and covered with small mounds; the lamellae are covered with small mounds on chitin ridges and round pits. Sensillus 25 μm long, rod-shaped head with tubercles.

Notogaster (Fig. 4a). Ridges are in irregular shapes, one in the middle and one on the sides, and the entire surface is covered with very thin and small tubercles. Notogastral setae thin and straight baciliform, the setae c_2 15 μm, and the other setae a length ranging from 30-35 μm. The dorsosejugal suture is straight and carries anterior humeral prominence on both sides.

Ventral region (Fig. 4d). The subcapitulum and epimeral region have a circular porous pattern. The subcapitulum diarthric. The epimeral setae formula 3–1–3–3. The genital plate is 91 μm long and 77 μm wide, with four short and straight setae pairs. The anal plate is 86 μm long and 97 μm wide and carries two pairs of setae.

Material examined. 13T754: 5 adults; 13T759: 267 adults (two of them were used in the scanning electron microscopy examination).

The subgenus *Flexa* Kulijev

Carabodes (*Flexa*) *dubius* Kulijev

Body measurements. Range of length 460-530 μm, width 210-280 μm (n=8).

Prodorsum (Figs 5b, c). Rostrum round; rostral setae 40 μm long, slightly curved inward and straight. Lamellar setae short ciliated, interlamellar setae inwardly curved, 113 μm long, and sparsely ciliated. The rostral and lamellar regions are shallow pits, and the interlamellar region is a shallow pit structure with longitudinal and transverse labyrinth-shaped ridges in front. Sensilli a finger-shaped cap at the tip.

Notogaster (Fig. 5a). Notogaster surface raised pattern of ridges to form a rosette flower structure. Notogaster setae narrow, leaf-shaped, and spiny in the enlarged part; the setae c_2 100 μm long, anteriorly directed and strong; all other notogastral setae are similar to each other. The dorsosejugal furrow present and about 20 μm wide.

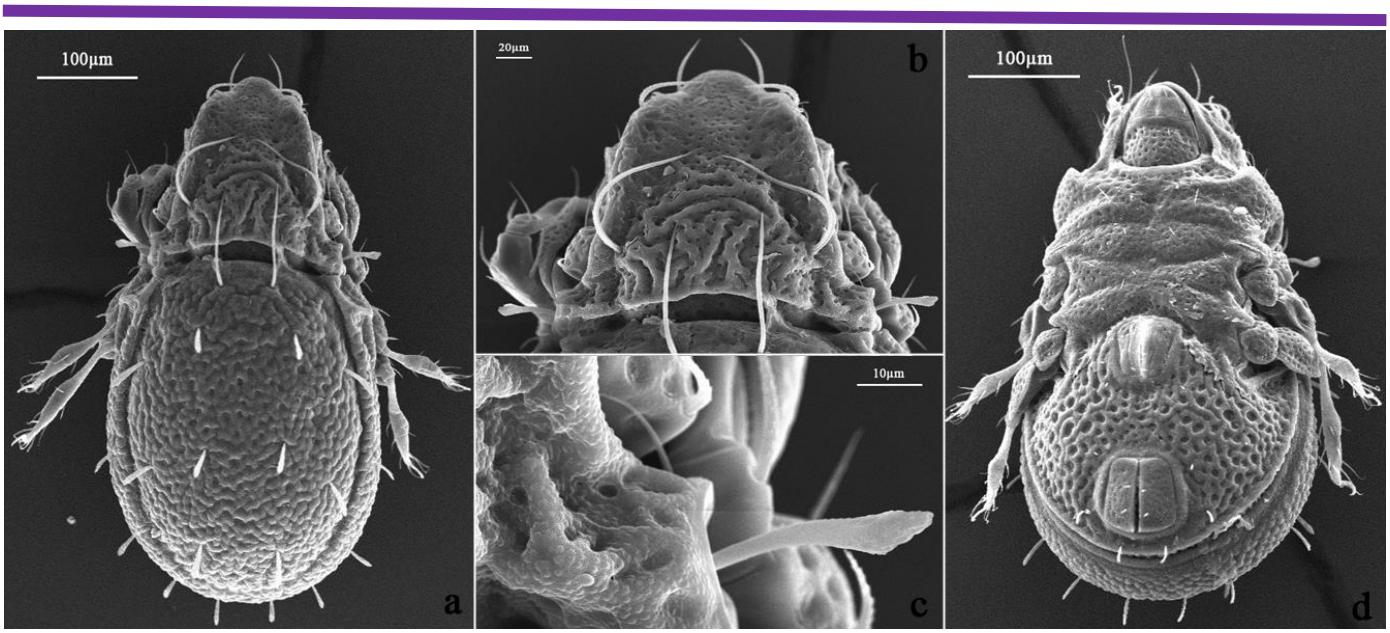

Figure 5. *Carabodes* (*Flexa*) *dubius* Kulijev: **a.** Dorsal view, **b.** Prodorsum, **c.** Sensillus, **d.** Ventral view.

Ventral region (Fig. 5d). The subcapitulum is diarthric; the mentum region small pits and a reticulate pattern. The epimeral and genito-anal regions also a similar structural pattern. The epimeral setae 3–1–3–3. The genito-anal region setal formulae 4–1–2–3. The genital plate a length of 56 µm and a width of 44 µm. The length and width of the anal plate are about 67 µm.

Material examined. 13T070: 2 adults; 13T702: 3 adults; 13T704: 27 adults (three were used in the scanning electron microscopy examination).

The subgenus *Klapperiches* Mahunka

Carabodes (*Klapperiches*) *willmanni* Bernini

Body measurements. Range of length 350-470 µm, width 220-270 µm (n=8).

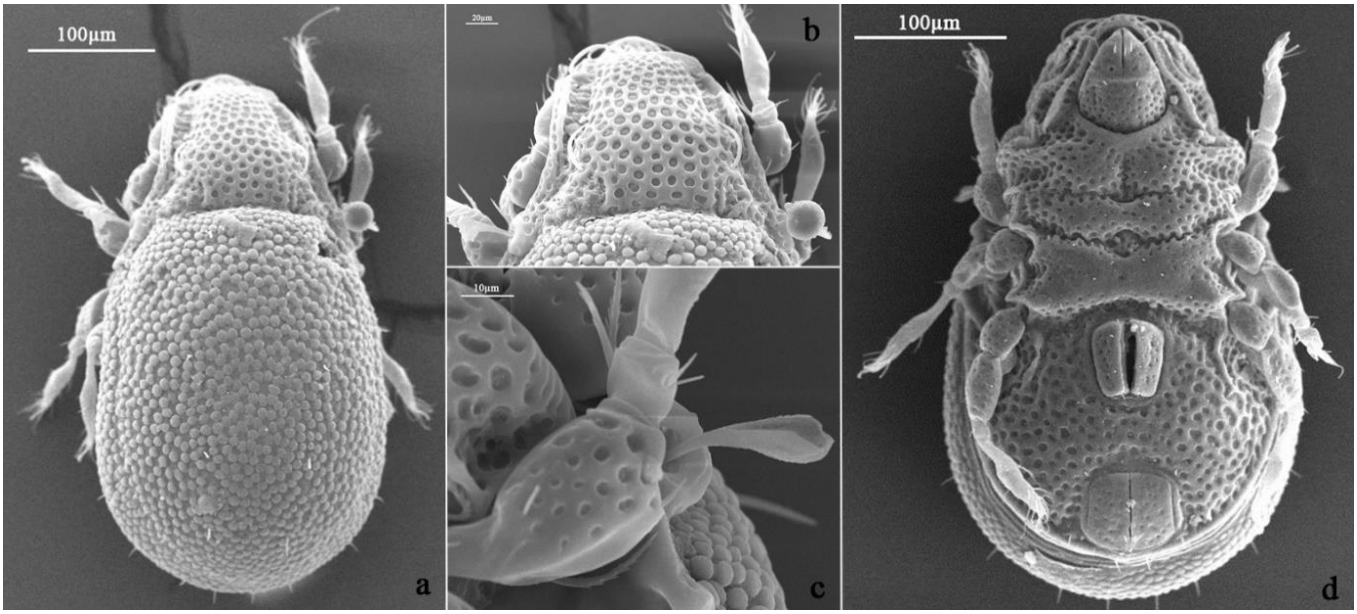

Figure 6. *Carabodes* (*Klapperiches*) *willmanni* Bernini: **a.** Dorsal view, **b.** Prodorsum, **c.** Sensillus, **d.** Ventral view.

Prodorsum (Figs 6b, c). Rostrum round; rostral and lamellar setae broad and curved inward; interlamellar setae 30 µm long, arcuate, tapering to the tip, rod-shaped and straight; the interlamellar region a network structure consisting of small spaces (pores); sensillus short-stalked (10 µm), club-shaped (25 µm) at the tip, broadly slit in the middle of the head region.

Notogaster (Figs 6a, 7a, b). Dorsosejugal furrow absent. The surface of the notogaster is covered with rounded bumps (tubercles) varying between 7-10 µm. Seven pairs of notogaster setae lanceolate and the setae p_{1-3} short and thin. The length of notogastral setae varies between 15-20 µm.

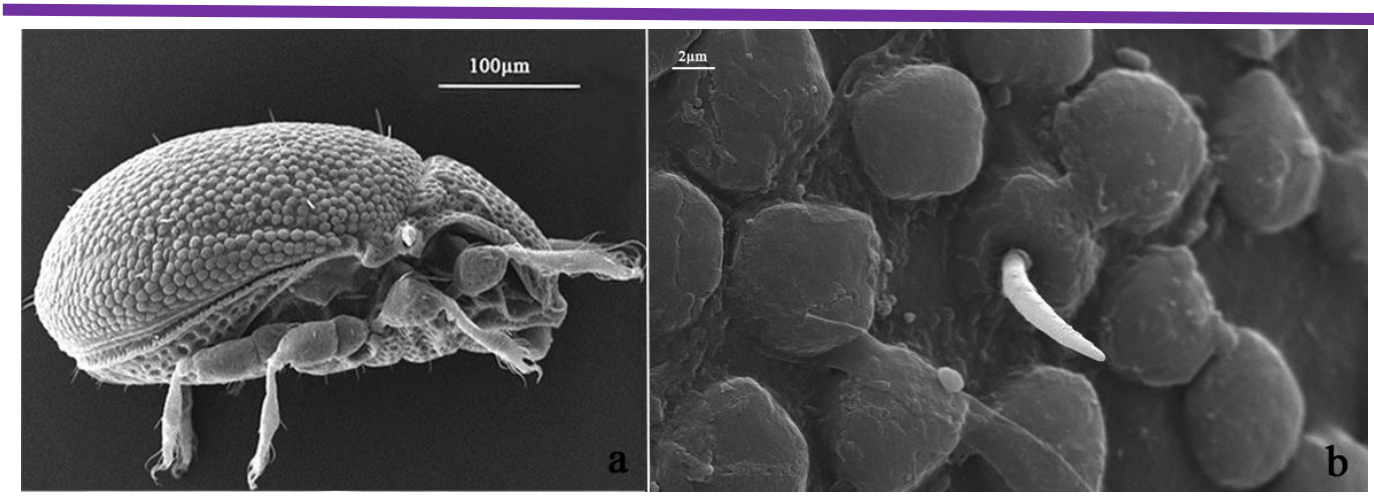

Figure 7. *Carabodes* (*Klapperiches*) *willmanni* Bernini: **a.** Lateral view, **b.** Notogastral seta.

Ventral region (Fig. 6d). The subcapitulum diarthric and the mentum region have a small porous pattern. Like the mentum region, the epimeral region has a small porous pattern. The distribution of the setae in the epimeral region 3–1–3–3. The genital plate is 53 µm long and 47 µm wide and bears four pairs of setae. The anal plate is 53 µm long, 66 µm wide and has two pairs of setae. The genito-anal area is covered with a circular pitted pattern.

Material examined. 13T036: 78 adults; 13T572: 1 adult; 13T578: 2 adults; 13T702: 5 adults; 13T704: 7 adults; 13T760: 3 adults; 13T777: 1 adult; 13T789: 1 adult; 13T793: 5 adults; 13T797: 3 adults (three of them were used in the scanning electron microscopy examination).

DISCUSSION

The five carabodid mite species mentioned here are discussed below, considering their zoogeographic distribution and taxonomic features.

Carabodes (*C.*) *labyrinthicus* (Michael). It is commonly distributed in the Holarctic region and Mexico (Bulanova-Zakhvatkina, 1975; Subías, 2004). It was previously recorded in Bolu province in Türkiye (Toluk and Ayyıldız, 2021).

This species can be distinguished by its irregularly raised prodorsal structure, spiny-rod-shaped sensillus, the absence of dorsosejugal furrow, the notogaster pattern equipped with articulated tubercles, and the short genital setae (Weigmann, 2006; Murvanidze, 2008).

The body length for this species varies between 430-608 µm. In this respect, it was determined as 558 µm in the samples examined, and it is understood that it is within the known range. It has been determined that the features given by various researchers for this species are generally in concordance with the features of our specimens (Weigmann, 2006; Murvanidze, 2008; Toluk and Ayyıldız, 2021).

Carabodes (*C.*) *pirinensis* Kunst. It spreads in Bulgaria and Türkiye in the Palearctic region (Kunst, 1961; Subías, 2004; Toluk and Ayyıldız, 2021). It was previously recorded from Bolu province in Türkiye (Toluk and Ayyıldız, 2021). Harşit Valley is the second locality record in our country.

Its long, strong, straight interlamellar setae can easily distinguish this species. It is separated from the other parts of the prodorsum by the mound formed by the ridges arranged to form a longitudinal groove, varying between 8-14.

Body measurements (length x width) for type specimens are 570-604 x 330-370 µm (Kunst, 1961). For previously recorded samples from Türkiye, body measurements were given as 504-560 x 272-320 µm and reported to be smaller (Toluk and Ayyıldız, 2021). In the samples we examined, the body length was measured as 420 µm and the width as 240 µm, the smallest recorded size. The setae $ps_{1\text{-}3}$ and r_3 were reported to be rod-shaped with denticles for Bolu samples (Toluk and Ayyıldız, 2021), whereas it was reported to be leaf-shaped in the original shape and description given by Kunst (1961). In the examined samples, these setae appear to be similar to those described by Kunst (1961). Apart from this, it has been determined that it is in accordance with the previous definitions regarding other characteristics.

Carabodes (*C.*) *rugosior* Berlese. It spreads in the Holarctic region (Bulanova-Zakhvatkina, 1975; Reeves and Behan-Pelletier, 1998; Subías, 2004; Murvanidze, 2008; Kagainis, 2010; Hågvar et al., 2014). It was previously recorded from Bolu province in Türkiye (Toluk and Ayyıldız, 2021).

This species is distinguished by having two tubercle patterns on the posterior part of the prodorsum, the sensillus being in the shape of a flat finger, the absence of dorsosejugal furrow, one long and the other covered with an irregularly raised pattern in the notogaster, normal setae c_2, and short and thin genital setae.

The body length varies between 480-650 µm (Weigmann, 2006; Murvanidze, 2008; Toluk and Ayyıldız, 2021). Our sample measured the body length as 520-530 µm and the width as 270-280 µm, which was compatible with known studies. In terms of other features, it generally agrees with the previously reported features of the species (Reeves and Behan-Pelletier, 1998; Weigmann, 2006; Murvanidze, 2008; Toluk and Ayyıldız, 2021).

Table 1. The main distinguishing features of *Carabodes minusculus* and *C. wilmanni*.

Features	*Carabodes wilmanni*	*Carabodes minusculus*
Body length (µm)	310–450	340–385
Prodorsum pattern	Areolate	Tuberculate
Setae length (µm)	30	45
in setae shape	Straight, tapered bar	Straight, rod-shaped
Sensillus shape	Short shank end stick	Rod-shaped
Dorsosejugal furrow	Not available	Not available
Notogaster pattern	Tuberculate	Tuberculate
ng setae length (µm)	15-20	15-25
ng setae shape c_2	Lanceolate	Phylliform
c_2 setae	Normal	Normal
Genital setae	Short	Short
p_{1-3} setae	Short and thin	Short and thick

Carabodes (*Flexa*) *dubius* Kulijev. This species is distributed in the Caucasus in the Palearctic region (Kulijev, 1977; Subías, 2004; Murvanidze, 2008). It was previously recorded from Bolu province in Türkiye (Toluk and Ayyıldız, 2021).

Several longitudinal grooves distinguish this species in the interlamellar region, the setae c_2 being anteriorly directed and strong and the other nine pairs of notogaster setae being leaf-shaped and spiny. This species' body length was 420-517 µm by Murvanidze (2008) and 422-474 µm by Kulijev (1977). Toluk and Ayyıldız (2021) reported that the body size of the samples they collected from Bolu province was 396 x 225 µm and reported that they were small. In our samples, the body length was measured as 460-530 µm and the width as 210-280 µm, and it is understood to be slightly larger than the known ones. In terms of other features, it has been determined that our samples are generally compatible with the features in the definitions given by various researchers before (Kulijev, 1977; Murvanidze, 2008; Toluk and Ayyıldız, 2021).

Carabodes (*Klapperiches*) *willmanni* Bernini. This species is distributed in the Holarctic region (Bernini, 1975; Pérez-Íñigo, 1997; Subías, 2004). It was determined as a new record for the fauna of Türkiye.

This species is distinguished by the small pore pattern of the prodorsum region, rod-shaped and flat interlamellar setae, club-shaped sensillus, absence of dorsosejugal furrow, notogaster pattern with rounded tubercles, notogaster setae in lanceolate form, normal c_2 setae and short genital setae (Murvanidze, 2008). Body length for this species varies between 310-450 µm (Bernini, 1975; Murvanidze, 2008). In our samples, the body length was measured as 350-470 µm and the width as 220-270 µm, and it is understood that it is within the range of variation generally known for this species. Our samples are in perfect harmony with the characteristics of the species given by Bernini (1975) and Pérez-Íñigo (1997).

C. minusculus and *C. wilmanni* are two closely related species. The distinguishing features of these two species are given in the Table 1 by comparing them.

As can be seen from the table, the most distinctive feature is the prodorsum pattern and the shapes of the notogastral setae.

Authors' contributions

Büşra Arık: Investigation, validation, visualization, writing-original draft, writing-review and editing. **Nusret Ayyıldız:** Conceptualization, supervision, validation, writing-original draft, writing-review and editing.

This study is a part of the primary author's MSc thesis.

Statement of ethics approval

Not applicable.

Conflict of interest

The authors declare that there are no conflicts of interest.

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