Acarological Studies

A Part of Acarological Science

Volume: 3
Issue: 2
Year: 2021

OPEN ACCESS

DergiPark AKADEMİK

Designed by Müjdat TÖZ

Acarological Studies
Vol 3 (2): 51-55
doi: 10.47121/acarolstud.973015

REVIEW

The newly formed Mite Specialist Group of the IUCN's Species Survival Commission and the conservation of global mite diversity

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Received: 18 July 2021 Accepted: 30 July 2021 Available online: 31 July 2021

ABSTRACT: The most serious environmental challenge facing humanity is the massive, widespread and continuing loss of biodiversity due to human activities. The commonly reported root causes of the decline and extinction of species are the degradation, destruction and fragmentation of habitat; pollution; pesticide use; invasive species; climate change; and over-exploitation; with co-extinction cascades accelerating the losses. The current alarming rate of loss of species across the biodiversity spectrum has ecological, economic, social, aesthetic, cultural and spiritual impacts that directly undermine the welfare of all humanity. This unprecedented crisis demands an urgent, science-based, comprehensive, coordinated, global response. Among the organizations responding to the multifaceted challenge of biodiversity loss is the International Union for Conservation of Nature (IUCN). Its enormous pool of integrated expertise, technical capacity and policy experience makes the IUCN the global authority on the status of nature and the suite of measures needed to protect it. The largest of the IUCN's six commissions is the Species Survival Commission, a science-based network of over 160 Specialist Groups, including 17 invertebrate groups; Red List Authorities; and Task Forces. Despite there being an estimated 500,000 – 1,500,000 mite species, and their ubiquity in global ecosystems and fundamental role in many ecological processes, mites have received minimal attention on the global conservation agenda. The role of the newly formed Mite Specialist Group, which gained official status in April 2021, is to redress that situation. The mission of the group, which currently includes 65 mite specialists, ecologists, botanists, environmentalists and conservation practitioners from 36 countries on five continents, is to contribute to a collaborative global effort to conserve mite diversity through research, education, advocacy, community engagement and specific conservation initiatives.

Keywords: Acari, biodiversity, co-extinction, endangered species, IUCN Red List.

INTRODUCTION

There is a strong consensus in the scientific community that the decline of insects, other arthropods and all other forms of biodiversity is a serious threat that must be urgently addressed (Harvey et al., 2020). Moreover, Pimm (2021) stated that the on-going massive loss of biodiversity is the most serious environmental challenge facing humanity. Furthermore, Ceballos et al. (2020) stressed the absolute urgency of coordinated, comprehensive worldwide action to save the remaining biodiversity and the ecosystems on which it depends from the current, human-induced, catastrophic global extinction event.

Pimm et al. (2014) asserted that the primary or overarching drivers of the extinction of species are continuing human population growth and the increasing total consumption of natural resources. Habitat destruction, degradation and fragmentation, pollution; pesticides; invasive species, climate change and over-exploitation drive the extinction process (Harvey et al., 2020; Wagner et al., 2021). These drivers individually and collectively contribute to an acceleration of the extinction process through co-extinction cascades (Strona and Bradshaw, 2018).

Terrestrial biodiversity is far from uniformly distributed across the planet. More specifically, a substantial proportion is concentrated in biodiversity hotspots, most of which are located in the tropics and subtropics (Myers, 1988). The astounding levels of biodiversity contained in the hotspots makes them absolutely vital conservation priorities, although by definition they have suffered considerable degradation (Myers, 1988; Myers et al., 2000; Mittermeier et al., 2005). Despite their importance, Hu et al. (2021) reported major, on-going degradation of the biodiversity hotspots that even extended to large areas 'protected' by legislation.

To qualify as a biodiversity hotspot a region must satisfy two criteria, namely (i) the presence of at least 1500 endemic vascular plant species and (ii) have 30% or less of its original natural vegetation remaining. The currently recognized 36 terrestrial biodiversity hotspot areas cover only 2.5% of the earth's land surface but more than 50% of all plant species and nearly 43% of all terrestrial vertebrate species are endemic to them (Conservation International, 2021). In 27 of the biodiversity hotspots, the correlations between plant, vertebrate and phytoseiid mite diversity and endemism, and also the degree of congruence between their respective endemism levels, suggested that the distribution pattern of the phytoseiids closely matched those of the plants and vertebrates (Tixier and Kreiter, 2009).

Among the organizations responding to the challenge of biodiversity loss in terrestrial, freshwater and marine environments across the planet is the International Union for Conservation of Nature (IUCN), which is based in Gland, Switzerland. The IUCN is a membership union comprised of both government and civil society organizations that harnesses the collective experience, resources and networks of more than 1,400 member organisations, including states, government agencies, NGOs, indigenous groups and affiliates, as well as 18,000 voluntary expert members of its commissions. This enormous pool of integrated expertise, technical capacity and policy experience makes the IUCN the global authority on the status of nature and the measures needed to protect it (IUCN, 2021).

The IUCN has official observer status at the UN General Assembly, which explains its strong influence in the shaping of international conservation policy. It has also shaped the major international conservation conventions, such as the Convention on Biodiversity (CBD), the World Heritage Convention (WHC) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Moreover, the IUCN is well known for its flagship knowledge products, such as the Red List of Threatened Species™ (RLTS), the World Database on Protected Areas (WDPA), the Database of Key Biodiversity Areas (KBAs) and the Red List of Ecosystems (RLEs). In addition, it has published numerous international conservation standards and guidelines, such as the global standard for the identification of KBAs, the guidelines for the reintroduction of species and other conservation translocations, and the guidelines for species conservation planning (A. Hochkirch, pers. comm., 2 July 2021).

The IUCN has six interrelated commissions to support its goals, the largest of which is the Species Survival Commission (SSC). The SSC is a science-based network with more than 9,000 volunteer experts working in more than 160 Specialist Groups, Red List Authorities and Task Forces. Some groups address conservation issues related to particular groups of plants, animals and fungi, while others pursue broader objectives such as the reintroduction of species into former habitats, climate change, health of wildlife and sustainable use and trade. Seventeen of the specialist groups and one stand-alone Red List Authority represent the terrestrial, freshwater and marine invertebrates (IUCN, 2021), which until recently did not include a group specifically devoted to the interests of mites (Arachnida: Acari).

FORMATION OF THE MITE SPECIALIST GROUP

Conservative estimates of the total number of mite species range between 500 000 and 1 500 000 (Walter and Proctor, 2013; Stork 2018; Sullivan and Ozman-Sullivan, 2021). There are 528 extant families and 5,629 extant genera, and ~ 63,000 described species (J. Hallan, pers. comm., March 2020 *in* Sullivan and Ozman-Sullivan 2021). Sullivan and Ozman-Sullivan (2021) estimated that ~15% of mite species likely became extinct by 2000, and that extinctions are currently expected to increase by between 0.6% and 6.0% by 2060. The same authors further stated that, based on the work of Fonseca (2009), it is highly likely that at least 150,000 mite species in host-specific relationships with plants and insects in the biodiversity hotspots are committed to extinction but mites have been largely neglected in reports on the global biodiversity situation. The situation of mites (and other organisms) in the vast areas outside the hotspots is understood to generally reflect their precarious situation within the hotspots. In a specific case, Napierala et al. (2018) reported that of the uropodid mites collected over more than 50 years of sampling across Poland, more than 40% of the species pool were classified as either endangered or critically endangered, when modified IUCN criteria were applied. However, only 11 mite species have been assessed for the IUCN Red List of Threatened Species, including the listing of one extinct species (IUCN, 2021).

The SSC of the IUCN has recognized the need to incorporate the broad spectrum of invertebrate diversity more fully into its agenda and is actively pursuing that course. Within that context, shortly after the publication of the paper by Sullivan and Ozman-Sullivan (2021), the authors were contacted by Dr. Axel Hochkirch, Chair of the IUCN's SSC Invertebrate Conservation Committee and Dr. Sergio Henriques, Invertebrate Conservation Coordinator at the Global Center for Species Survival, Indianapolis Zoo, and co-chair of the SSC Spider and Scorpion Specialist Group, who proposed that they establish a Mite Specialist Group (MSG). Drs. Ozman-Sullivan and Sullivan agreed and so began the application process to the SSC which required the meeting of a number of criteria, including those summarized below. After receiving feedback from Drs. Henriques and Hochkirch on a number of drafts, the application was submitted to the SSC for assessment and the MSG was given official status on 23 April of 2021.

A summary of how the criteria for SSC Specialist Group accreditation were met:

1. What are the key conservation issues facing the taxon or group?

Sullivan and Ozman-Sullivan (2021) reported on the specific conservation issues related to mites, including that vast numbers of range and microhabitat restricted species, including host-specific species, are at greater risk of population decline and extinction due to habitat destruction and climate change. The information in the references cited in that paper and herein provides a comprehensive perspective on the nature and distribution of biodiversity, decline of populations and extinctions, and measures which can minimize the rate of loss and in some cases, reverse the declines.

2. Why is this taxonomic level and / or geographic scope considered to be the most appropriate level at which to address these conservation issues?

Mites, which constitute an estimated 20% of all arthropods (Stork, 2018), are an extremely large and highly diverse group that represents a substantial proportion of all the biodiversity that was being underrepresented in SSC activities and reports. Furthermore, the formation of a group advocating specifically for mites complements the activities being conducted on behalf of other arachnid and arthropod groups. It also fills a gap in addressing the global conservation of soil and its fauna, a crucial component of most terrestrial ecosystems, and therefore an important element of the development of the Red List of Ecosystems.

3. Is there a clear gap for the group to fill, and a value-added benefit that the formation of the group would deliver, rather than duplicate efforts of existing Specialist Groups or IUCN partner institutions?

There was a demonstrable void in advocacy and action for the conservation of mites, and because there are many host and range restricted endemic species, countries supporting global Red List Assessment will benefit from the formation of the MSG. In addition, the formation of the MSG, because of the great diversity and ubiquity of mites in terrestrial, freshwater and marine ecosystems, will substantially increase the comprehensiveness, accuracy and credibility of reports on the overall status of biodiversity.

Henriques et al. (2020) stated that current reporting on biodiversity loss may not adequately represent trends across taxa and ecoregions but sampled assessments can accelerate biodiversity monitoring and complement current metrics. Also, Hochkirch et al. (2021) proposed an 8-point strategy for the next decade to address the deficiency of data for neglected taxa. In addition, Harvey et al. (2020) formulated a 'roadmap' for insect conservation and recovery. All three of these approaches are directly applicable to mites, especially given that the ecologies of mites, other arachnids and insects are so intimately interconnected.

4. What are 1) the key activities / outputs that the group would undertake / deliver to better understand and address these issues, and 2) how will these activities / outputs contribute to the SSC Strategic Plan?

In essence, MSG members and its five advisory groups (Acarological Society of America, Acarological Society of Japan, Acarological Society of Iran, Latin American Society of Acarology and Saving Nature) are encouraged to contribute to a global effort to conserve mite diversity through research, education, advocacy, collaboration and conservation initiatives by:

1. proposing species for Red List Assessment (RLA) (the MSG has compiled a list of more than 80 species for assessment by its RLA Coordinator, Dr. Agnieszka Napierala)

2. supporting and engaging in taxonomic and ecological studies that contribute to real conservation gains

3. forming direct links with NGOs (e. g. conservation groups, farmer organizations, reforestation societies), indigenous groups, landholders and government agencies to achieve measurable conservation outcomes; to date, the first steps have been taken in developing productive relationships with MarineBio Conservation Society, Saving Nature, the Turkish Foundation for Combating Soil Erosion and the Wet Tropics Management Authority in Australia

4. supporting and contributing to initiatives that address habitat destruction, climate change, pollution, pesticide use and other drivers of biodiversity loss

5. encouraging the incorporation of mites (and other invertebrates) into the fabric of the biology curriculum in schools and higher education institutions

6. conducting research related to mite conservation issues

7. establishing links with the mass media and a presence in on-line platforms to promote the group and its activities

8. educating/informing government agencies, conservation area managers and the public about the fundamental role that mites and the other invertebrates play in diverse, healthy, productive ecosystems, and

9. engaging in personal behaviors and actions that demonstrate a commitment to the vision of the IUCN, namely, 'a just world that values and conserves nature through positive action to reduce the loss of diversity of life on earth'.

Everyone in the MSG and its advisory groups has been invited to put forward other ideas. The phrase, *'Think globally, act locally'* is highly applicable. All MSG members and advisory group members are encouraged to consider how the MSG can be most effective in conserving mite biodiversity at the local, regional and global levels and act on those suggestions while always remembering that any gains for mites are multiplied as gains for other invertebrates, plants and vertebrates.

5. Is there a core group of relevant experts willing to dedicate energy and time towards furthering a conservation agenda for mites?

To date, a group of 65 acarologists and non-acarologists from 36 countries on 5 continents and with a wide range of expertise have joined the group, although large areas in Africa and South-East Asia appear to be lacking in sufficient local acarological expertise. However, some MSG members are personally familiar with and/or have contacts in those areas. Fifty eight persons in the MSG, to a greater or lesser extent, work directly with mites, and a considerable number were members of the Scientific Committee for the XV International Congress of Acarology in Antalya, Turkey in 2018. The other members of the MSG have expertise in botany, ecology, conservation, environmental activism and protected area management that complements the expertise of the mite specialists. The MSG aims to reduce any gaps in its regional coverage as it becomes more established. The group will communicate via email and on social media platforms to disseminate information within and about the group, and formally through the IUCN SSC. Persons interested in joining the MSG should contact the first author, the chair of the group.

6. Group leadership

The MSG's Chair is Sebahat K. Ozman-Sullivan from Ondokuz Mayıs University in Turkey. The group's Vice Chairs are Ashley Dowling of the University of Arkansas in the USA and Maria Orlova from Tyumen State University in Russia. The Red List Authority Coordinator is Agnieszka Napierala from the Adam Mickiewicz University in Poland and the Conservation Initiatives Coordinator is Gregory T. Sullivan of The University of Queensland in Australia.

7. Reporting to the Species Survival Commission of the IUCN

Reporting processes revolve around quadrennial targets set by the group in consultation with the SSC (the current period is 2021 – 2024). Targets are allocated to the five components of the Species Conservation Cycle (Assess, Plan, Act, Network and Communicate). The current targets include the identification of both general and specific threats to mites across the wide spectrum of ecosystems they inhabit, raising the profile of mites in terms of greater community understanding of their fundamental importance to global ecological functioning and the provision of ecosystem services, development of partnerships to achieve practical conservation outcomes and the assessment of representative mite species according to the IUCN Red List criteria (IUCN, 2021).

CONCLUSIONS

The newly formed Mite Specialist Group of the IUCN's Species Survival Commission cannot alone 'save' the mites in a world becoming increasingly degraded by both human population growth and the increasing demand for natural resources that drive habitat destruction, pollution and climate change. However, by boldly and collaboratively pursuing its research, education, advocacy and conservation goals, the group can put mites and their fundamental role in global ecology directly on the international conservation agenda. Moreover, through cooperation with other Species Survival Commission entities, other IUCN commissions, the IUCN secretariat and IUCN member groups, and non-affiliated groups and individuals pursuing similar objectives, the Mite Specialist Group can make a substantial contribution to reducing the overall loss of mite diversity, with any gains for mites multiplied as gains for other invertebrates, vertebrates and plants.

Authors' contributions

Sebahat K. Ozman-Sullivan: Conceptualization, writing - original draft (equal), writing - review & editing (supporting). **Gregory T. Sullivan:** Writing - original draft (equal), writing - review & editing (lead).

Statement of ethics approval

Not applicable.

Funding

There was no funding received for this study.

Conflict of interest

The authors declare that they have no conflict of interest regarding this paper.

Acknowledgements

The authors thank Dr. Axel Hochkirch, Chair of the IUCN SSC Invertebrate Conservation Committee and Co-Chair of the IUCN SSC Grasshopper Specialist Group, Department of Biogeography, Trier University, Germany for numerous helpful comments on the manuscript, and both Dr. Sergio Henriques, Invertebrate Conservation Coordinator at the Global Center for Species Survival, Indianapolis Zoo, and co-chair of the SSC Spider and Scorpion Specialist Group, and Dr. Hochkirch, for sharing their considerable expertise and also their generous personal support during the process of establishment of the Mite Specialist Group of the IUCN's Species Survival Commission.

REFERENCES

Ceballos, G., Ehrlich, P.R. and Raven, P.H. 2020. Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction. Proceedings of the National Academy of Sciences of the United States of America, 117 (24): 13596-13602. doi: 10.1073/pnas.1922686117

Conservation International. 2021. Biodiversity hotspots: Targeted investment in nature's most important places. Available https://www.conservation.org/priorities/biodiversity-hotspots (Last accessed: 19 May 2021).

Fonseca, C.R. 2009. The silent mass extinction of insect herbivores in biodiversity hotspots. Conservation Biology, 23 (6): 1507-1515. doi: 10.1111/j.1523-1739.2009.01327.x

Harvey, J.A., Heinen, R., Armbrecht, I., Basset, Y., Baxter-Gilbert, J.H. et al. 2020. International scientists formulate a roadmap for insect conservation and recovery. Nature Ecology and Evolution, 4: 174-176. doi: 10.1038/s41559-019-1079-8

Henriques, S., Böhm, M., Collen, B., Luedtke, J., Hoffmann, M. et al. 2020. Accelerating the monitoring of global biodiversity: Revisiting the sampled approach to generating Red List Indices. Conservation Letters, 13 (3): e12703. doi: 10.1111/conl.12703

Hochkirch, A., Samways, M.J., Gerlach, J., Böhm, M., Williams, P. et al. 2021. A strategy for the next decade to address data deficiency in neglected biodiversity. Conservation Biology, 35 (2): 502-509. doi: 10.1111/cobi.13589

Hu, X., Huang, B., Verones, F., Cavalett, O. and Cherubini, F. 2021. Overview of recent land-cover changes in biodiversity hotspots. Frontiers in Ecology and the Environment, 19: 91-97. doi: 10.1002/fee.2276

IUCN, 2021. International Union for Conservation of Nature. Available https://www.iucn.org (Last accessed: 02 July 2021).

Mittermeier, R.A., Robles Gil, P., Hoffman, M., Pilgrim, J., Brooks, T. et al. 2005. Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions. University of Chicago Press, Chicago, USA, 392 pp.

Myers, N. 1988. Threatened biotas: "hot spots" in tropical forests. Environmentalist, 8: 187-208. doi: 10.1007/BF02240252

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature, 403: 853-858. doi: 10.1038/35002501

Napierała, A., Książkiewicz-Parulska, Z. and Błoszyk, J. 2018. A Red List of mites from the suborder Uropodina (Acari: Parasitiformes) in Poland. Experimental and Applied Acarology, 75: 467-490. doi: 10.1007/s10493-018-0284-5

Pimm, S.L. 2021. What is biodiversity conservation? Ambio, 50 (5): 976-980. doi: 10.1007/s13280-020-01399-5

Pimm, S.L., Jenkins, C.N., Abell, R., Brooks, T., Gittleman, J.L. et al. 2014. The biodiversity of species and their rates of extinction, distribution and protection. Science, 344 (6187): 1246752. doi: 10.1126/science.1246752

Stork, N.E. 2018. How many species of insects and other terrestrial arthropods are there on earth? Annual Review of Entomology, 63: 31-45. doi: 10.1146/annurev-ento-020117-043348

Strona, G. and Bradshaw, C.J.A. 2018. Co-extinctions annihilate planetary life during extreme environmental change. Scientific reports, 8 (1): 16724. doi: 10.1038/s41598-018-35068-1

Sullivan, G.T. and Ozman-Sullivan, S.K. 2021. Alarming evidence of widespread mite extinctions in the shadows of plant, insect and vertebrate extinctions. Austral Ecology, 46 (1): 163-176. doi: 10.1111/aec.12932

Tixier, M.-S. and Kreiter, S. 2009. Arthropods in biodiversity hotspots: the case of the Phytoseiidae (Acari: Mesostigmata). Biodiversity and Conservation, 18 (3): 507-527. doi: 10.1007/s10531-008-9517-y

Wagner, D.L., Grames, E.M., Forister, M.L., Berenbaum, M.R. and Stopak, D. 2021. Insect decline in the Anthropocene: Death by a thousand cuts. Proceedings of the National Academy of Sciences of the United States of America, 118 (2): e2023989118. doi: 10.1073/pnas.2023989118

Walter, D.E. and Proctor, H.C. 2013. Mites: Ecology, evolution and behaviour: Life at a microscale. Second Edition. Springer, Dordrecht, The Netherlands, 404 pp. doi: 10.1007/978-94-007-7164-2

Edited by: Salih Doğan
Reviewed by: Four anonymous referees

Citation: Ozman-Sullivan, S.K. and Sullivan, G.T. 2021. The newly formed Mite Specialist Group of the IUCN's Species Survival Commission and the conservation of global mite diversity. Acarological Studies, 3 (2): 51-55.

Acarological Studies
Vol 3 (2): 56-65
doi: 10.47121/acarolstud.865260

RESEARCH ARTICLE

Raphignathoid mites (Acariformes: Raphignathoidea) in parts of the Azerbaijan provinces of Iran

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Received: 20 January 2021 Accepted: 28 March 2021 Available online: 31 July 2021

ABSTRACT: While performing a faunistic study on the superfamily Raphignathoidea of northwestern Iran, north parts of east Azerbaijan and southwest parts of west Azerbaijan provinces during 2016-2018, a total number of 40 species in 13 genera belonging to the superfamily were collected and identified. Among them, four species: *Stigmaeus luxtoni* Wood, 1981; *Ledermuelleriopsis sezeki* Doğan, 2004; *Eustigmaeus gulingensis* Hu and Chen, 1996 and *Molothrognathus kamili* Doğan, 2003 have been recorded for the first time from Iran.

Keywords: Acari, fauna, predatory, new record, Azerbaijan, northwestern Iran.
Zoobank: http://zoobank.org/57B66053-9AD1-4C78-ADA6-83AC029A284A

INTRODUCTION

The predatory mites of the superfamily Raphignathoidea Kramer, 1877 (Acari: Trombidiformes: Prostigmata) are mostly known as biological control agents of small invertebrates such as eriophyid, spider and false spider mites and some small insects. Also, some species of these mites are probably the second most important species of plant mite predators after Phytoseiidae especially when the densities of phytoseiid mites are low (Gerson et al., 2003; Fan and Zhang, 2005; Fan and Flechtmann, 2015).

Currently, raphignathoid mites include about 1087 species of 69 genera in 12 families (Beron, 2020). Until now, seven families, 23 genera and 222 species of this group of mites have been described and reported from Iran, namely: Barbutiidae Robaux (one genus, four species); Caligonellidae Grandjean (five genera, 26 species); Camerobiidae Southcott (two genera, 23 species); Cryptognathidae Oudemans (two genera, 19 species); Eupalopsellidae Willmann (one genus, seven species); Raphignathidae Kramer (one genus, 29 species); Stigmaeidae Oudemans (11 genera, 114 species) (Bagheri and Mohammad-Doustaresharaf, 2020; Mohammad-Doustaresharaf and Bagheri, 2021; Pishehvar and Khanjani, 2021; Rostami and Mohammad-Doustaresharaf, 2021).

In this study, a total number of 40 species in 13 genera within the superfamily Raphignathoidea have been collected; four of them: *Stigmaeus luxtoni* Wood, 1981; *Ledermuelleriopsis sezeki* Doğan, 2004; *Eustigmaeus gulingensis* Hu and Chen, 1996 and *Molothrognathus kamili* Doğan, 2003 are new records for the Iranian fauna.

MATERIALS AND METHODS

Sampling procedure

Many samples collected during 2016-2018, from various habitats such as soil and litter, rotten wood, the aerial parts of the crops, orchards and weeds of different regions of studied area. Mite specimens were extracted using Berlese-Tullgren funnel, preserved in 70% ethanol, cleared in Nesbitt's fluid/lactophenol solution, mounted in Hoyer's medium and studied using BX41 light microscope with phase-contrast device. All examined materials are deposited in the Acarology Laboratory, Plant Protection Department, Agricultural Faculty, University of Maragheh, Iran (UMI).

Study area

The study area is located in north-western Iran and including two provinces: East Azerbaijan and West Azerbaijan. Sampling were taken from different localities in two counties of north parts of East Azerbaijan namely Jolfa and Khoda Afarin and five counties of sothwestern parts of West Azerbaijan namely Urmia, Sardasht, Piranshahr, Mahabad, Oshnaviyeh. The locations of the sampled cities are shown in Figure 1.

RESULTS and DISCUSSION

Superfamily Raphignathoidea
Family Caligonellidae Grandjean, 1944
Genus *Caligonella* Berlese, 1910

Caligonella haddadi Bagheri and Maleki, 2013

This species was originally described from leaf litter under walnut (*Juglans* sp.) from Iran (Bagheri et al., 2013b). It was also recorded from Turkey (Yamaç, 2019; Doğan and Doğan, 2020c).

Material examined: Two females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43′′ E, 1380 m), 27 August 2018; four females, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88′′ E, 1310 m), 4 July 2017; two females, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19′′ E, 1302 m), 24 July 2018; coll. M. Mohammad-Doustaresharaf.

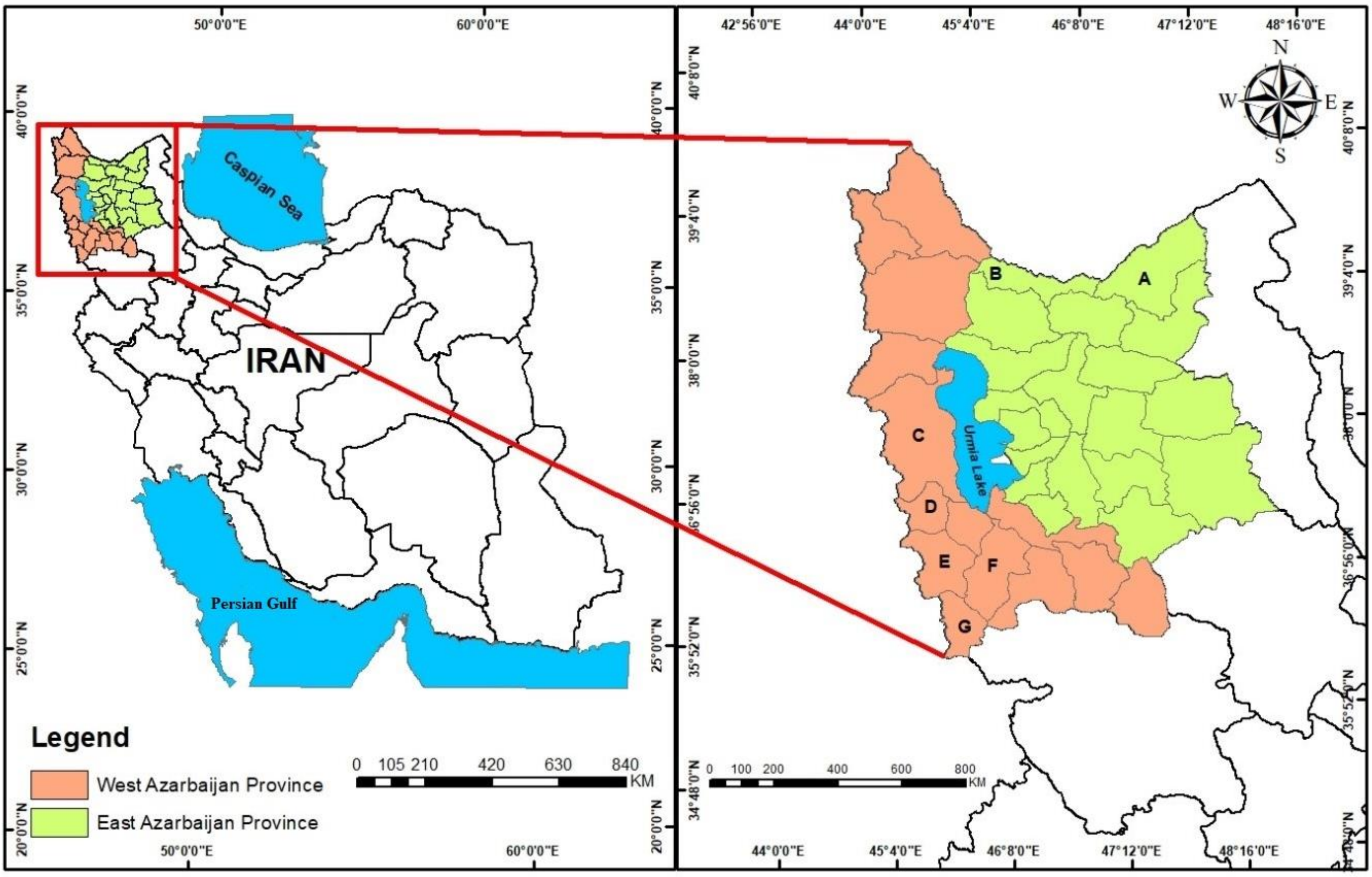

Figure 1. The location of the sampled cities. A: Jolfa, B: Khoda Afarin, C: Urmia, D: Oshnaviyeh, E: Piranshahr, F: Mahabad, G: Sardasht.

Caligonella humilis **(Koch, 1838)**

This species is widely distributed in 14 countries and originally described from Germany (Beron, 2020). It was also previously recorded from different part of Iran (Beyzavi et al., 2013).

Material examined: Two females, soil and litter under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67′′ E, 1297 m), 7 September 2017; six females, soil under apple trees (*Malus* sp.), Urmia (Balanej) (37° 24′ 35″ N, 45° 09′ 11′′ E, 1312 m), 17 September 2018; four females, soil under oak tree (*Quercus* sp.), Mahabad (Kavelan) (36° 23′ 34″ N, 45° 39′ 59′′ E, 1631 m), 19 September 2017; coll. M. Mohammad-Doustaresharaf.

Genus *Molothrognathus* Summers and Schlinger, 1955

Molothrognathus bahariensis **Ueckermann and Khanjani, 2003**

This species was originally described from Iran where it was found from different habitats (Ueckermann and Khanjani, 2003). Recently it was also recorded from Turkey (Doğan and Doğan, 2020a).

Material examined: Two females, soil, Jolfa (Asiyab Kharabeh) (38° 51′ 25″ N, 45° 51′ 21′′ E, 1743 m), 17 July 2018; four females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43′′ E, 1380 m), 27 August 2018; one female, soil under apple trees (*Malus* sp.), Urmia (Balanej) (37° 24′ 35″ N, 45° 09′ 11′′ E, 1312 m), 17 September 2018; five females, soil, Urmia (Ali Beygloo) (37° 74′ 09″ N, 45° 07′ 90′′ E, 1324 m),11 August 2017; coll. M. Mohammad-Doustaresharaf.

Molothrognathus kamili **Doğan, 2003**

This species was originally described from soil under *Astragalus* sp. from Turkey (Doğan, 2003b).

This is a new record for the Iranian fauna.

Material examined: Four females, soil, Urmia (Shalmakan) (37° 27′ 34″ N, 44° 59′ 59′′ E, 1800 m), 16 August 2018; two females, soil, Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37′′ E, 1890 m), 4 August 2016; coll. M. Mohammad-Doustaresharaf.

Molothrognathus mehrnejadi **Liang and Zhang, 1997**

This species is currently known only from Iran where it was found in pistachio (*Pistacia* sp.) collar soil and bark stem (Liang and Zhang, 1997).

Material examined: Seven females, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88′′ E, 1310 m), 4 July 2017; two females, soil under oak tree (*Quercus* sp.), Sardasht (Alvatan) (36° 24′ 22″ N, 45° 21′ 23′′ E, 1526 m), 30 September 2016; five females, soil under oak tree (*Quercus* sp.), Piranshahr (Mirabad) (36° 26′ 08″ N, 45° 21′ 07′′ E, 1294 m), 1 October 2016; coll. M. Mohammad-Doustaresharaf.

Genus *Neognathus* Willmann, 1952

***Neognathus terrestris* (Summers and Schlinger, 1955)**

This species was described from California, USA (Summers and Schlinger, 1955). It was also recorded from Canada, Crimea, Hungary, Turkey and Iran (Beron, 2020).

Material examined: Four females, soil, Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67″ E, 1297 m), 7 September 2017; one female, soil, Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37″ E, 1890 m), 4 August 2016; two females, soil, Urmia (Dolama) (37° 21′ 23″ N, 45° 14′ 51″ E, 1293 m), 16 August 2018; coll. M. Mohammad-Doustaresharaf.

***Neognathus ueckermanni* Bagheri, Doğan and Haddad, 2010**

This species was originally described from soil under *Medicago sativa* L. from Iran (Bagheri et al., 2010a). Recently it was recorded from Turkey (Doğan, 2019).

Material examined: Two females, soil under azarole tree (*Crataegus azarolus*), Piranshahr (Mirabad) (36° 26′ 08″ N, 45° 21′ 07″ E, 1294 m), 1 October 2016; three females, soil and litter under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67″ E, 1297 m), 7 September 2017; four females, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′ 30″ E, 1694 m), 1 July 2017; coll. M. Mohammad-Doustaresharaf.

Family Cryptognathidae Oudemans, 1902

Genus *Cryptognathus* Kramer, 1879

***Cryptognathus lagena* Kramer, 1879**

This species is widely distributed and originally described from Germany (Beron, 2020). It was also previously recorded from Iran (Khanjani et al., 2014).

Material examined: Six females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43″ E, 1380 m), 27 August 2018; one female, soil, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′ 38″ E, 1700 m), 18 July 2018; two females, soil, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19″ E, 1520 m), 4 October 2017; coll. M. Mohammad-Doustaresharaf.

Genus *Favognathus* Luxton, 1973

***Favognathus kamili* Dönel and Doğan, 2011**

This species was originally described from Turkey (Dönel and Doğan, 2011; Doğan, 2019) and it was also recorded from Iran (Bagheri et al., 2015; Doğan and Doğan, 2020b).

Material examined: Two females, soil under oak tree (*Quercus* sp.), Sardasht (Alvatan) (36° 24′ 22″ N, 45° 21′ 23″ E, 1526 m), 30 September 2016; two females, soil, Jolfa (Asiyab Kharabeh) (38° 51′ 25″ N, 45° 51′ 21″ E, 1743 m), 17 July 2018; two females, soil under apple trees (*Malus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67″ E, 1297 m), 7 September 2017; coll. M. Mohammad-Doustaresharaf.

***Favognathus mirazii* Khanjani and Ueckermann, 2008**

This species is currently known only from Iran where it was found from soil under pear tree (*Pyrus* sp.) (Khanjani and Ueckermann, 2008b).

Material examined: One female, soil under apple trees (*Malus* sp.), Urmia (Gasemloo valley) (37° 17′ 58″ N, 45° 07′ 16″ E, 1750 m), 5 July 2017; three females, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19″ E, 1302 m), 24 July 2018; two females, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19″ E, 1302 m), 25 July 2018; coll. M. Mohammad-Doustaresharaf.

Family Eupalopsellidae Willmann, 1952

Genus *Eupalopsellus* Sellnick, 1949

***Eupalopsellus deformatus* Fan, 2004**

This species was originally described from leaves of an unidentified grass, China (Fan, 2004). It was also recorded from Turkey and Iran (Bagheri et al., 2014; Doğan, 2019).

Material examined: One female, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19″ E, 1302 m), 24 July 2018; coll. M. Mohammad-Doustaresharaf.

***Eupalopsellus prasadi* Bagheri and Khanjani, 2009**

This species was described from soil under apple trees (*Malus* sp.) from Iran (Bagheri and Khanjani, 2009). It was also recorded from Turkey (Kasap et al., 2013).

Material examined: Two deutonymphs, Hornbeam tree foliage, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43″ E, 1380 m), 18 July 2017; one female, raspberry foliage (*Rubus* sp.), Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43″ E, 1380 m), 2 September 2017; one female, rose hip foliage (*Rosa* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67″ E, 1297 m), 7 September 2017; coll. M. Mohammad-Doustaresharaf.

Family Raphignathidae Kramer, 1877

Genus *Raphignathus* Dugés, 1834

***Raphignathus azarshahriensis* Ahaniazad and Bagheri, 2012**

This species is currently known only from Iran where it was found from soil of black cherry (*Prunus* sp.), walnut (*Juglans* sp.) and almond orchards (Ahaniazad et al., 2012).

Material examined: Three females, soil under *Astragalus* sp., Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37″ E, 1890 m), 8 July 2018; seven females, soil under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67″ E, 1297 m), 7 September 2017; coll. M. Mohammad-Doustaresharaf.

Raphignathus giselae **Meyer and Ueckermann, 1989**

This species was originally described from Zimbabwe (Meyer and Ueckermann, 1989). It was also recorded from South Africa, Turkey, Yemen and Iran (Beron, 2020).

Material examined: Twelve females, soil under oak tree (*Quercus* sp.), Sardasht (Alvatan) (36° 24′ 22″ N, 45° 21′ 23′′ E, 1526 m), 30 September 2016; three females, soil under azarole tree (*Crataegus azarolus*), Piranshahr (Mirabad) (36° 26′ 08″ N, 45° 21′07′′ E, 1294 m), 1 October 2016; coll. M. Mohammad-Doustaresharaf.

Raphignathus gracilis **(Rack, 1962)**

This species is widely distributed in 17 countries and originally described from Germany (Rack, 1962; Beron, 2020). It was also previously recorded from different part of Iran (Beyzavi et al., 2013; Mohammad-Doustaresharaf and Bagheri, 2018).

Material examined: Three females, soil, Khoda Afarin (Vaygan) (38° 55′ 07″ N, 46° 46′58′′ E, 1350 m), 14 July 2016; four females, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′30′′ E, 1694 m), 1 July 2017; coll. M. Mohammad-Doustaresharaf.

Raphignathus hecmatanaensis **Khanjani and Ueckermann, 2003**

This species originally was described from grass from Iran (Khanjani and Ueckermann, 2003). It was also recorded from different part of Turkey (Doğan, 2019).

Material examined: Five females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 27 August 2018; five females, soil, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′38′′ E, 1700 m), 18 July 2018; four females, soil, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 4 October 2017; coll. M. Mohammad-Doustaresharaf.

Raphignathus khorramabadensis **Bagheri, 2013**

This species was originally described from soil from Iran (Bagheri et al., 2013a). It was also recorded from Turkey (Uluçay et al., 2016).

Material examined: Four females, soil, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 4 October 2017; 12 females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 27 August 2018; four females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 4 August 2018; coll. M. Mohammad-Doustaresharaf.

Raphignathus orientalis **Fan and Li, 1993**

This species was originally described from China (Fan and Li, 1993). It was also recorded from Iran (Mohammad-Doustaresharaf and Bagheri, 2018).

Material examined: Two females, soil, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 27 August 2018; coll. M. Mohammad-Doustaresharaf.

Raphignathus zhaoi **Hu, Jing and Liang, 1995**

This species originally was described from China (Hu et al., 1995). It was also recorded from different part of Turkey and Iran (Beyzavi et al., 2013; Doğan, 2019).

Material examined: Three females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 27 August 2018; two females, soil, Urmia (Ali Beygloo) (37° 74′ 09″ N, 45° 07′90′′ E, 1324 m),11 August 2017; one female, soil, Urmia (Dolama) (37° 21′ 23″ N, 45° 14′ 51′′ E, 1293 m), 16 August 2018; coll. M. Mohammad-Doustaresharaf.

Family Stigmaeidae Oudemans, 1931

Genus *Eustigmaeus* Berlese, 1910

Eustigmaeus anauniensis **(Canestrini, 1889)**

This species is widely distributed in 20 countries and originally described from Italy (Fan et al., 2016; Beron, 2020). It was also previously recorded from different part of Iran (Beyzavi et al., 2013).

Material examined: Five females, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88′′ E, 1310 m), 4 July 2017; three females, soil, Khoda Afarin (Vaygan) (38° 55′ 07″ N, 46° 46′58′′ E, 1350 m), 14 July 2016; two females and one male, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 27 August 2018; four females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′43′′ E, 1380 m), 29 August 2018; coll. M. Mohammad-Doustaresharaf.

Eustigmaeus gulingensis **Hu and Chen, 1996**

This species is currently known only from china where it was found from soil (Hu et al., 1996).

This is a new record for the fauna of Iran.

Material examined: Two females and one deutonymph, soil under *Astragalus* sp., Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37′′ E, 1890 m), 8 July 2018; One female, soil, Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′37′′ E, 1890 m), 4 August 2018; coll. M. Mohammad-Doustaresharaf.

Eustigmaeus pinnatus **(Kuznetsov, 1977)**

This species was originally described from soil from Russia (Kuznetsov, 1977). It was also recorded from Crimea, Greece, Hungary, Moldavia, Russia, Poland, Slovakia, Turkey, Ukraine and Iran (Fan et al., 2016; Beron, 2020).

Material examined: One female, soil, Khoda Afarin (Vaygan) (38° 55′ 07″ N, 46° 46′58′′ E, 1350 m), 14 July 2016; two females, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19′′ E, 1302 m), 24 July 2018; one female, soil under azarole tree (*Crataegus azarolus*), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′ 30′′ E, 1694 m), 1 July 2017; two females, soil under apple trees (*Malus* sp.), Urmia (Balanej) (37° 24′ 35″ N, 45° 09′11′′ E, 1312 m), 17 September 2018; coll. M. Mohammad-Doustaresharaf.

***Eustigmaeus plumifer* (Halbert, 1923)**

This species was originally described from Ireland under a stone (Halbert, 1923). It was also recorded from Austria, Denmark, Greece, Ireland, Russia, Slovakia, Spain, USA and Iran (Fan et al., 2016; Beron, 2020).

Material examined: Four females, soil, Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37′′ E, 1890 m), 4 August 2018; four females, rotten woods, Sardasht (Alvatan) (36° 24′ 22″ N, 45° 21′ 23′′ E, 1526 m), 30 September 2016; two females, soil, Urmia (Shalmakan) (37° 27′ 34″ N, 44° 59′ 59′′ E, 1800 m), 16 August 2018; coll. M. Mohammad-Doustaresharaf.

***Eustigmaeus segnis* (Koch, 1836)**

Cosmopolitan species. This species is widely distributed in 21 countries and originally described from moss from Germany (Fan et al., 2016; Beron, 2020).

Material examined: 15 females, four deutonymphs and two males soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43′′ E, 1380 m), 27 August 2018; three females, soil, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′ 38′′ E, 1700 m), 18 July 2018; 12 females and two deutonymphs, soil, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 4 October 2017; six females, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88′′ E, 1310 m), 4 July 2017; four females, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19′′ E, 1302 m), 24 July 2018; one female, soil under oak tree (*Quercus* sp.), Sardasht (Alvatan) (36° 24′ 22″ N, 45° 21′ 23′′ E, 1526 m), 30 September 2016; one female, soil under azarole tree (*Crataegus azarolus*), Piranshahr (Mirabad) (36° 26′ 08″ N, 45° 21′ 07′′ E, 1294 m), 1 October 2016; two females, soil and litter under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67′′ E, 1297 m), 7 September 2017; two females, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′ 30′′ E, 1694 m), 1 July 2017; five females, three deutonymphs and one larva, soil under *Astragalus* sp., Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37′′ E, 1890 m), 8 July 2018; two females, soil, Jolfa (Asiyab Kharabeh) (38° 51′ 25″ N, 45° 51′ 21′′ E, 1743 m), 17 July 2018; coll. M. Mohammad-Doustaresharaf.

***Eustigmaeus setiferus* Bagheri, Saber, Ueckermann, Ghorbani and Navaei-Bonab, 2011**

This species is currently known only from Iran where it was found from soil in apple trees (*Malus* sp.) orchard (Bagheri et al., 2011b).

Material examined: One female, litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43′′ E, 1380 m), 27 August 2018; four females, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′ 30′′ E, 1694 m), 1 July 2017; six females, soil under apple trees (*Malus* sp.), Urmia (Balanej) (37° 24′ 35″ N, 45° 09′ 11′′ E, 1312 m), 17 September 2018; one female, soil under *Astragalus* sp., Urmia (Soladokal) (37° 10′ 27″ N, 44° 51′ 51′′ E, 2035 m), 5 August 2018; coll. M. Mohammad-Doustaresharaf.

***Eustigmaeus ueckermanni* Bagheri and Beyzavi, 2013**

This species is currently known only from Iran where it was found from humus under oak trees (*Quercus brantii*) (Bagheri and Beyzavi, 2013).

Material examined: Four females, soil and litter under oak tree (*Quercus* sp.), Mahabad (Kavelan) (36° 23′ 34″ N, 45° 39′ 59′′ E, 1631 m), 19 September 2017; one female, rotten wood, Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67′′ E, 1297 m), 7 September 2017; coll. M. Mohammad-Doustaresharaf.

Genus *Ledermuelleriopsis* Willmann, 1953

***Ledermuelleriopsis sezeki* Doğan, 2004**

This species is currently known only from Turkey where it was found from decayed stump and ant (Formicidae) nest (Doğan, 2004).

This is a new record for the Iranian fauna.

Material examined: Two females, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′ 30′′ E, 1694 m), 1 July 2017; coll. M. Mohammad-Doustaresharaf.

***Ledermuelleriopsis zahiri* Khanjani and Ueckermann, 2002**

This species was originally described from soil under *Pyrus communis* from Iran and currently known only from different part of Iran (Khanjani and Ueckermann, 2002; Fan et al., 2016).

Material examined: Three females, soil, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 4 October 2017; 11 females, soil and litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43′′ E, 1380 m), 27 August 2018; seven females and two deutonymphs, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88′′ E, 1310 m), 4 July 2017; four females, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′ 19′′ E, 1302 m), 24 July 2018; two females, soil and litter under oak tree (*Quercus* sp.), Piranshahr (KhidirAabad) (36° 26′ 08″ N, 45° 21′ 07′′ E, 1294 m), 31 July 2017; three females and two males, soil under azarole tree (*Crataegus azarolus*), Piranshahr (Mirabad) (36° 26′ 08″ N, 45° 21′ 07′′ E, 1294 m), 1 October 2016; five females, soil under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67′′ E, 1297 m), 7 September 2017; two females and one deutonymph, soil, Jolfa (Asiyab Kharabeh) (38° 51′ 25″ N, 45° 51′ 21′′ E, 1743 m), 17 July 2018; coll. M. Mohammad-Doustaresharaf.

Genus *Prostigmaeus* Kuznetsov, 1984

***Prostigmaeus khanjanii* Bagheri and Ghorbani, 2010**

This species was originally described from soil from Iran (Bagheri et al., 2010b). Recently it was also recorded from Turkey (Akyol, 2021).

Material examined: Two females and one male, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88′′ E, 1310 m), 4 July 2017; three females, soil, Khoda Afarin (Vaygan) (38° 55′ 07″ N, 46° 46′58′′ E, 1350 m), 14 July 2016; coll. M. Mohammad-Doustaresharaf.

Genus *Stigmaeus* Koch, 1836

***Stigmaeus angustus* Dönel and Doğan, 2011**

This species was described from grassy soil from Turkey (Dönel and Doğan, 2011). It was also recorded from Iran (Bagheri and Mohammad-Doustaresharaf, 2020).

Material examined: Five females and three deutonymphs, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′19′′ E, 1302 m), 24 July 2018; seven females and two males, soil, Urmia (Qare Aqaj) (37° 27′ 53″ N, 45° 09′19′′ E, 1302 m), 12 September 2017; six females, soil, Urmia (Balanej) (37° 24′ 35″ N, 45° 09′11′′ E, 1312 m), 17 September 2018; one female, and one deutonymph soil, Urmia (Dolama) (37° 21′ 23″ N, 45° 14′51′′ E, 1293 m), 16 August 2018; two females, soil and litter under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′67′′ E, 1297 m), 7 September 2017; coll. M. Mohammad-Doustaresharaf.

***Stigmaeus cariae* Khanjani, Pishehvar, Mirmoayedi and Khanjani, 2012**

This species is currently known only from Iran where it was found in soil under walnut trees *Juglans* sp. (Khanjani et al., 2012).

Material examined: Two females, soil under apricot tree (*Prunus armeniaca*), Urmia (Gasemloo valley) (37° 17′ 58″ N, 45° 07′16′′ E, 1750 m), 5 July 2017; three females, soil, Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′ 67′′ E, 1297 m), 7 September 2017; coll. M. Mohammad-Doustaresharaf.

***Stigmaeus elongatus* Berlese, 1886**

This species is widely distributed in 11 countries and originally described from Italy (Fan et al., 2016; Beron, 2020). It was also previously recorded from different part of Iran (Beyzavi et al., 2013).

Material examined: Three females and one male, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′30′′ E, 1694 m), 1 July 2017; five females, soil, Urmia (Balanej) (37° 24′ 35″ N, 45° 09′11′′ E, 1312 m), 17 September 2018; two females and two deutonymphs, soil and litter, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′38′′ E, 1700 m), 18 July 2018; coll. M. Mohammad-Doustaresharaf.

***Stigmaeus glypticus* Summers, 1962**

This species was originally described from stump from USA (Summers, 1962). It was also recorded from Canada, Crimea, Ukraine and Iran (Fan et al., 2016; Mohammad-Doustaresharaf and Bagheri, 2018; Beron, 2020).

Material examined: Twelve females and two males, moss, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 4 October 2017; five females and three deutonymphs, rotten wood, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 11 September 2017; four females, one male and two deutonymphs, litter, Khoda Afarin (Garmanab) (38° 54′ 26″ N, 46° 47′ 19′′ E, 1520 m), 17 September 2017; coll. M. Mohammad-Doustaresharaf.

***Stigmaeus luxtoni* Wood, 1981**

This species was originally described from New Zealand by Wood (1981) and later given from Turkey as *Stigmaeus turcica* by Doğan (2003a), synonymized by Faraji and Ueckermann (2006).

This is a new record for the fauna of Iran.

Material examined: Two females and one deutonymph, soil under *Carpinus* sp., Khoda Afarin (Garmanab) (38° 56′ 42″ N, 46° 45′ 43′′ E, 1302 m), 27 August 2018; coll. M. Mohammad-Doustaresharaf.

***Stigmaeus miandoabiensis* Bagheri and Zarei, 2012**

This species was described from soil in apple trees (*Malus* sp.) from Iran (Bagheri and Zarei, 2012). It was also recorded from Turkey (Bingül et al., 2017).

Material examined: Three females, soil, Urmia (Qarah Hasanlu) (37° 59′ 97″ N, 45° 04′ 67′′ E, 1297 m), 23 August 2016; four females, soil, Urmia (Ali Beygloo) (37° 74′ 09″ N, 45° 07′ 90′′ E, 1324 m),11 August 2017; one female, soil under apricot tree (*Prunus armeniaca*), Urmia (Gasemloo valley) (37° 17′ 58″ N, 45° 07′16′′ E, 1750 m), 5 July 2017; one females, soil under apple trees (*Malus* sp.), Urmia (Balanej) (37° 24′ 35″ N, 45° 09′11′′ E, 1312 m), 17 September 2018; coll. M. Mohammad-Doustaresharaf.

***Stigmaeus pilatus* Kuznetsov, 1978**

This species was described from soil from Crimea (Kuznetsov, 1977). It was also recorded from Azerbaijan, Greece, Latvia, Poland, Slovakia, Spain, Turkey, Ukraine, Asian Russia and Iran (Stathakis et al., 2019; Khaustov, 2020).

Material examined: Four females, soil and litter under oak tree (*Quercus* sp.), Piranshahr (KhidirAabad) (36° 26′ 08″ N, 45° 21′ 07′′ E, 1294 m), 31 July 2017; three females, soil and litter under pear tree (*Pyrus* sp.), Urmia (Marmisho) (37° 59′ 97″ N, 45° 04′67′′ E, 1297 m), 7 September 2017; four females, soil under oak tree (*Quercus* sp.), Oshnaviyeh (Miraveh) (36° 58′ 48″ N, 45° 01′30′′ E, 1694 m), 1 July 2017; coll. M. Mohammad-Doustaresharaf.

Genus *Storchia* Oudemans, 1923

***Storchia robusta* (Berlese, 1885)**

Cosmopolitan species. Recorded from Eurasia, North America, Africa, New Zealand (Dönel and Doğan, 2011; Khaustov and Sergeyenko, 2014; Fan et al., 2016).

Material examined: Five females and two males, soil under oak tree (*Quercus* sp.), Mahabad (Kavelan) (36° 23′ 34″ N, 45° 39′ 59″ E, 1631 m), 19 September 2017; two females and two deutonymphs, soil and litter, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′38″ E, 1700 m), 18 July 2018; one female, soil under oak tree (*Quercus* sp.), Sardasht (Alvatan) (36° 24′ 22″ N, 45° 21′ 23″ E, 1526 m), 30 September 2016; one female, soil, Jolfa (Asiyab Kharabeh) (38° 51′ 25″ N, 45° 51′21″ E, 1743 m), 17 July 2018; two females and one male, soil, Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′ 37″ E, 1890 m), 4 August 2016; one female, soil, Khoda Afarin (Tatar) (39° 03′ 10″ N, 46° 46′34″ E, 308 m), 27 August 2018; one female, soil under *Astragalus* sp., Urmia (Soladokal) (37° 10′ 27″ N, 44° 51′51″ E, 2035 m), 5 August 2018; three females, soil, Urmia (Qarah Hasanlu) (37° 59′ 97″ N, 45° 04′ 67″ E, 1297 m), 23 August 2016; coll. M. Mohammad-Doustaresharaf.

***Storchia yazdaniani* Bagheri, 2011**

This species is currently known only from Iran where it was found on the soil and moss (Bagheri et al., 2011a).

Material examined: Six females, soil and litter, Khoda Afarin (Abbas Abad) (37° 55′ 46″ N, 46° 47′ 88″ E, 1310 m), 5 September 2017; five females, litter, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43″ E, 1380 m), 27 August 2018; one female, soil, Khoda Afarin (Tatar) (39° 03′ 10″ N, 46° 46′ 34″ E, 308 m), 27 August 2018; coll. M. Mohammad-Doustaresharaf.

Genus *Zetzellia* Oudemans, 1927

***Zetzellia mali* (Ewing, 1917)**

Cosmopolitan species. This species is widely distributed in 28 countries and originally described from Hillsboro, Oregon, USA (Fan et al., 2016; Beron, 2020). It was also previously recorded from different part of Iran (Beyzavi et al., 2013; Bagheri and Mohammad-Doustaresharaf, 2020).

Material examined: Two females and two deutonymphs, *Carpinus* sp., foliage, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′ 38″ E, 1700 m), 18 July 2018; one female, *Carpinus* sp., foliage, Khoda Afarin (Kalaleh) (38° 56′ 42″ N, 46° 45′ 43″ E, 1380 m), 27 August 2018; coll. M. Mohammad-Doustaresharaf.

***Zetzellia pourmirzai* Khanjani and Ueckermann, 2008**

This species is currently known only from Iran where it was found on the plum leaves with *Eutetranychus orientalis* (Khanjani and Ueckermann, 2008a).

Material examined: Five females and one deutonymph, *Carpinus* sp., foliage, Khoda Afarin (Aynaloo) (38° 53′ 03″ N, 46° 47′38″ E, 1700 m), 18 July 2018; two females and one deutonymph, azarole foliage (*Crataegus azarolus*), Urmia (Dalamper) (37° 10′ 41″ N, 44° 53′37″ E, 1890 m), 4 August 2016; coll. M. Mohammad-Doustaresharaf.

Authors' contributions

Mojtaba Mohammad-Doustaresharaf: Investigation, resources, collection of the samples, assemble data, writing the original manuscript and identification of specimens. **Mohammad Bagheri:** Supervision, validation, editing, modify and revise.

Statement of ethics approval

Not applicable.

Funding

No funding to declare.

Conflict of interest

All authors have no conflict of interest to report.

Acknowledgements

The present research is a part of the Ph.D. thesis of the first author. We would like to express our sincere gratitude to University of Maragheh. The authors are also would like to extremely thank to Naim Azimi (Ph.D. student of Department of Plant Protection, Faculty of Agriculture, Islamic Azad University, Shiraz, Iran) for his help in creating map of sampling locations and grateful to Prof. Salih Doğan (Department of Biology, Faculty of Sciences and Arts, Erzincan Binali Yıldırım University, Erzincan, Turkey) for his valuable comments on our manuscript.

REFERENCES

Ahaniazad, M., Bagheri, M., Gharakhani, G. and Zarei, E. 2012. *Raphignathus azarshahriensis* n. sp. (Acari: Trombidiformes: Raphignathidae) from northwest Iran. Acarologia, 52 (4): 367-372. doi: 10.1051/acarologia/20122065

Akyol, M. 2021. Two new records stigmaeid mites (Acari: Stigmaeidae) for the Turkish fauna. KSU Journal of Agriculture and Nature, 24 (2): 430-434. doi: 10.18016/ksutarimdoga.vi.774206

Bagheri, M. and Beyzavi, G. 2013. *Eustigmaeus ueckermanni*, a new species of the genus *Eustigmaeus* Berlese (Acari: Stigmaeidae) from central Iran. Systematic and Applied Acarology, 18 (1): 30-34. doi: 10.11158/saa.18.1.3

Bagheri, M. and Khanjani, M. 2009. A new species of the genus *Eupalopsellus* Sellnick (Acari: Prostigmata, Eupalopsellidae) from West of Iran. International Journal of Acarology, 35 (1): 319-322. doi: 10.1080/01647950902731549

Bagheri, M. and Mohammad-Doustaresharaf, M. 2020. Identification guide for predatory mites of the superfamily Raphignathoidea of Iran. University of Maragheh, 394 pp. [In Persian]

Bagheri, M. and Zarei, E. 2012. *Stigmaeus miandoabiensis* sp. nov. (Acari: Trombidiformes: Stigmaeidae), with redescription of *S. siculus* (Berlese, 1883) from Iran. Systematic and Applied Acarology, 17 (4): 441-447. doi: 10.11158/saa.17.4.13

Bagheri, M., Ahaniazad, M. and Paktinat-Saeej, S. 2014. Predatory prostigmatic mites (Acari: Trombidiformes) fauna in East Azerbaijan province, Iran. In: Proceeding of the 21th Iranian Plant Protection Congress, Urmia, Iran p. 979. [In Persian]

Bagheri, M., Doğan, S., Irani-Nejad, K.H., Kamali, K., Khanjani, M. and Saboori, A. 2010a. A new species of the genus *Neognathus* Willmann (Acari: Prostigmata: Caligonellidae) from Northwestern Iran. Systematic and Applied Acarology, 15 (1): 65-68. doi: 10.11158/saa.15.1.8

Bagheri, M., Ghorbani, H., Navaei Bonab, R., Saber, M., Mehrvar, A. and Ueckermann, E.A. 2010b. *Prostigmaeus khanjanii* (Acari: Stigmaeidae), a new species from Northwest Iran. Systematic and Applied Acarology, 15 (2): 123-128. doi: 10.11158/saa.15.2.6

Bagheri, M., Jafari, S. and Paktinat-Saeej, S. 2013a. A new species of the genus *Raphignathus* (Acari: Raphignathidae) from western Iran. Persian Journal of Acarology, 2 (3): 481-486. doi: 10.22073/pja.v2i3.10044

Bagheri, M., Maleki, N. and Changizi, M. 2013b. On caligonellid mites (Acari: Trombidiformes: Caligonellidae) of Iran: description of two new species. International Journal of Acarology, 39 (8): 632-637. doi: 10.1080/01647954.2013.864331

Bagheri, M., Mohajer, S.S., Saboori, A., Asadeh, G. and Ueckermann, E.A. 2011a. *Storchia yazdaniani* n. sp., a new species of the genus *Storchia* Oudemans, 1923 (Acari: Prostigmata: Stigmaeidae) from Northern Iran. Acarologia, 51 (1): 87-91. doi: 10.1051/acarologia/20111993

Bagheri, M., Saber, M., Ueckermann, E.A., Ghorbani, H. and Navaei-Bonab, R. 2011b. *Eustigmaeus setiferus*, n. sp. (Acari: Stigmaeidae) from Iran. International Journal of Acarology, 37 (1): 212-215. doi: 10.1080/01647954.2011.553201

Bagheri, M., Yousefi, A., Seilsepour, N., Saber, M. and Gharekhani, G. 2015. Redescription of *Neophyllobius astragalusi* and *Favognathus orbiculatus* with *F. acaciae* (Acari: Raphignathoidea) as a new record from Iran. Persian Journal of Acarology, 4 (1): 43-55. doi: 10.22073/pja.v4i1.10186

Beron, P. 2020. Acarorum catalogus VII. Trombidiformes, Prostigmata, Raphignathoidea. Fam. Barbutiidae, Caligonellidae, Camerobiidae, Cryptognathidae, Dasythyreidae, Dytiscacaridae, Eupalopsellidae, Homocaligidae, Mecognathidae, Raphignathidae, Stigmaeidae, Xenocaligonellididae. Pensoft & National Museum of Natural History, Sofia, Bulgaria, 306 pp.

Beyzavi, G., Ueckermann, E.A., Faraji, F. and Ostovan, H. 2013. A catalog of Iranian prostigmatic mites of superfamilies Raphignathoidea & Tetranychoidea (Acari). Persian Journal of Acarology, 2 (3): 389-474. doi: 10.22073/pja.v2i3.10042

Bingül, M., Doğan, S. and Dilkaraoğlu, S. 2017. Contributions to the knowledge of the mite genus *Stigmaeus* Koch, 1836 (Acari, Stigmaeidae) of Turkey. European Journal of Taxonomy, 307: 1-16. doi: 10.5852/ejt.2017.307

Doğan, S. 2003a. A new species and two new records of the genus *Stigmaeus* (Acari: Stigmaeidae) from Turkey. International Journal of Acarology, 29 (4): 381-387. doi: 10.1080/01647950308684355

Doğan, S. 2003b. On caligonellid mites from Turkey (Acari: Caligonellidae). Archives des Sciences, 56 (2): 63-77. doi: 10.5169/seals-740431

Doğan, S. 2004. Three new species and a new record of the genus *Ledermuelleriopsis* (Acari, Stigmaeidae) from Turkey. Biologia, Bratislava, 59 (2): 141-151.

Doğan, S. 2019. Raphignathoidea (Acari: Trombidiformes) of Turkey: A review of progress on the systematics, with an updated checklist. Acarological Studies, 1 (2): 129-151.

Doğan, S. and Doğan, S. 2020a. A new record for the acarofauna of Turkey *Molothrognathus bahariensis* Ueckermann and Khanjani (Acari Caligonellidae). Journal of the Institute of Science and Technology, 10 (3): 1551-1558. [In Turkish] doi: 10.21597/jist.692883

Doğan, S. and Doğan, S. 2020b. A new species of the genus *Favognathus* (Acariformes: Cryptognathidae) from Turkey, with some taxonomic comments on other members of the genus. Acarological Studies, 2 (2): 69-76. [In Turkish] doi: 10.47121/acarolstud.708856

Doğan, S. and Doğan, S. 2020c. First descriptions of the adult male, protonymph and larval stages of the species *Caligonella haddadi* Bagheri & Maleki (Acari: Trombidiformes: Caligonellidae). Erzincan University Journal of Science and Technology, 13 (2): 465-476. [In Turkish] doi: 10.18185/erzifbed.704612

Dönel, G. and Doğan, S. 2011. The stigmaeid mites (Acari: Stigmaeidae) of Kelkit Valley (Turkey). Zootaxa, 2942: 1-56. doi: 10.11646/zootaxa.2942.1.1

Fan, Q.-H. 2004. A catalogue of the genus *Eupalopsellus* Sellnick (Acari: Prostigmata: Eupalopsellidae) with the description of a new species from China. Biologia, Bratislava, 59 (5): 533-546.

Fan, Q.-H. and Li, L. 1993. Descriptions of three new species of superfamily Raphignathoidea (Acari: Actinedida). Journal of Fujian Agricultural University, 22 (3): 321-324. [In Chinese]

Fan, Q.-H. and Zhang, Z.-Q. 2005. Raphignathoidea (Acari: Prostigmata). Fauna of New Zealand, 52. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand, 400 pp.

Fan, Q-H., Flechtmann, C.H. and De Moraes, G.J. 2016. Annotated catalogue of Stigmaeidae (Acari: Prostigmata), with a pictorial key to genera. Zootaxa, 4176: 1-199.
doi:10.11646/zootaxa.4176.1.1

Fan, Q.-H. and Flechtmann, C.H.W. 2015. Chapter 7. Stigmaeidae. In: Prospects for biological control of plant feeding mites and other harmful organisms. Carrillo, D., Moraes, G.J. de and Peña, J. (Eds). Springer, NY, Switzerland, 185-206.
doi: 10.1007/978-3-319-15042-0_7

Faraji, F. and Ueckermann, E.A. 2006. A new species of *Stigmaeus* Koch from Iran (Acari: Stigmaeidae). Systematic and Applied Acarology, 11: 69-72.
doi: 10.11158/saa.11.1.9

Gerson, U., Smiley, R.L. and Ochoa, R. 2003. Mites (Acari) for pest control. Blackwell Science, Oxford, UK, 539 pp.
doi: 10.1002/9780470750995

Halbert, J.N. 1923. Notes on Acari, with descriptions of new species. Zoological Journal of the Linnean Society, London, 35: 363-392.
doi: 10.1111/j.1096-3642.1923.tb01732.x

Hu, C-Y., Jing, Z-Q. and Liang, L-R. 1995. Two new species and one new record of the genus *Raphignathus* Dugés (Acari: Raphignathidae). Journal of Suzhou Railway Teachers College, 12 (3): 21-26.

Hu, S.-Q., Chen, X.-W. and Huang, L. 1996. Mites of the genus *Eustigmaeus* from Jiangxi Province (Acari: Stigmaeidae). Entomologia Sinica, 3 (4): 314-322.

Kasap, İ., Çobanoğlu, S., Pehlivan, S. and Kök, Ş. 2013. *Eupalopsellus prasadi* Bagheri & Khanjani 2009 (Acari: Eupalopsellidae), a new record for the mite fauna of Turkey. Turkish Bulletin of Entomology, 3 (1): 3-6. [In Turkish]

Khanjani, M. and Ueckermann, E.A. 2002. The stigmaeid mites of Iran (Acari: Stigmaeidae). International Journal of Acarology, 28 (4): 317-339.
doi: 10.1080/01647950208684309

Khanjani, M. and Ueckermann, E.A. 2003. Two new species of the genus *Raphignathus* Dugés (Acari: Raphignathidae) from Iran. Acarologia, 43 (3): 299-306.

Khanjani, M. and Ueckermann, E.A. 2008a. A new species of *Zetzellia* Oudemans (Acari: Stigmaeidae) from west Iran. International Journal of Acarology, 34 (3): 237-241.
doi: 10.1080/01647950808684536

Khanjani, M. and Ueckermann, E.A. 2008b. New species of the genus *Favognathus* Luxton (Acari: Cryptognathidae) from Iran. Acarologia, 48 (3-4): 177-186.

Khanjani, M., Khanjani, M., Rafeian Najaf-Abadi, P. and Seeman, O.D. 2014. Three new species of the genus *Favognathus* Luxton (Acari: Cryptognathidae) and redescription of *Cryptognathus lagena* Kramer from Iran. International Journal of Acarology, 40: 370-383.
doi:10.1080/01647954.2014.924993

Khanjani, M., Pishehvar, S., Mirmoayedi, A.N. and Khanjani, M. 2012. Two new eyeless mite species of the genus *Stigmaeus* Koch (Acari: Stigmaeidae) from western provinces of Iran and description of the male *Stigmaeus pilatus* Kuznetsov. International Journal of Acarology, 38 (6): 504-513.
doi: 10.1080/01647954.2012.703690

Khaustov, A.A. 2020. New records of predatory mites of the genus *Stigmaeus* (Acari: Prostigmata: Stigmaeidae) from Western Siberia with the redescriptions of *S. dignus* Kuznetsov and *S. uzunolukensis* Özçelik and Doğan. Acarina, 28 (2): 177-191.
doi: 10.21684/0132-8077-2020-28-2-177-191

Khaustov, A.A. and Sergeyenko, A.L. 2014. Raphignathoid mites (Acari: Raphignathoidea) of the Cape Martyan Nature Reserve, Crimea. Systematic and Applied Acarology, 19 (3): 363-372.
doi: 10.11158/saa.19.3.9

Kuznetsov, N.N. 1977. New species of the family Stigmaeidae from Crimea. Zoologicheskiy Zhurnal, 56: 635-638. [In Russian]

Liang, L. and Zhang, Z.-Q. 1997. Key to species of the genus *Molothrognathus* (Prostigmata: Caligonellidae) with description of a new species from Iran. Systematic and Applied Acarology, Special Publication, 1: 19-24.

Meyer, M.K.P. and Ueckermann, E.A. 1989. African Raphignathoidea. Entomology Memoir Department of Agriculture and Water Supply, Republic of South Africa, 74: 1-58.

Mohammad-Doustaresharaf, M. and Bagheri, M. 2018. Mites fauna of the genera *Stigmaeus* and *Raphignathus* (Acari: Stigmaeidae, Raphignathidae) from Arasbaran forest. In: Proceedings of the 23rd Iranian Plant Protection Congress, 27-30 August, Gorgan University of Agricultural Sciences and Natural Resources, p. 1616. [In Persian]

Mohammad-Doustaresharaf, M. and Bagheri, M. 2021. Description of *Barbutia arasbaraniensis* n. sp. (Acari: Trombidiformes: Barbutiidae) based on the deutonymph and male specimens from Iran. Persian Journal of Acarology, 10 (1): 9-17.
doi: 10.22073/pja.v10i1.64012

Pishehvar, Sh. and Khanjani, M. 2021. Two new species of the genus *Raphignathus* (Acari: Raphignathidae) from Hamedan, Iran, with a key to the known species. Systematic and Applied Acarology, 26(1): 185-198.
doi: 10.11158/saa.26.1.11

Rack, G. 1962. Milben aus Taubennestern mit Beschreibung einer neren Art, *Acheles gracilis* (Acarina, Raphignathidae). Zoologischer Anzeiger, 168 (7-10): 275-292. [In German]

Rostami, A. and Mohammad-Doustaresharaf, M. 2021. Description of *Stigmaeus bagherii* n. sp. (Acari: Stigmaeidae), with a key to the known species of *Stigmaeus* from Iran. International Journal of Acarology, 47(3): 222-232.
doi: 10.1080/01647954.2021.1887933

Stathakis, T.I., Kapaxidi, E.V. and Papadoulis, G.Th. 2019. The genus *Stigmaeus* Koch (Acari: Stigmaeidae) from Greece. Systematic and Applied Acarology, 24 (11): 2010-2093.
doi:10.11158/saa.24.11.4

Summers, F.M. 1962. The genus *Stigmaeus* (Acarina: Stigmaeidae). Hilgardia, 33 (10): 491-537.
doi: 10.3733/hilg.v33n10p491

Summers, F.M. and Schlinger, E.I. 1955. Mites of family Caligonellidae (Acarina). Hilgardia, 23: 539-561.

Ueckermann, E.A. and Khanjani, M. 2003. Iranian Caligonellidae (Acari: Prostigmata), with descriptions of two new species and re-description of *Molothrognathus fulgidus* Summers and Schlinger, with a key to genera and species. Acarologia, 43 (3): 291-298.

Uluçay, İ., Akyol, M. and Koç, K. 2016. Türkiye faunası için yeni bir kayıt: *Raphignathus khorramabadensis* (Acari: Raphignathoidea). 23. National Biology Congress, 5-9 September, 2016, Gaziantep, Turkey, p. 422. [In Turkish]

Wood, T.G. 1981. New species and records of Stigmaeidae (Acari: Prostigmata) from New Zealand. III. Genus *Stigmaeus* Koch. New Zealand Journal of Zoology, 8: 369-377.
doi:10.1080/03014223.1981.10430615

Yamaç, S.Ç., Doğan, S. and Doğan, S. 2019. *Caligonella haddadi* Bagheri and Maleki (Acari, Caligonellidae): A new member of the acarofauna in Turkey. Zeugma II. International Congress on Multidisciplinary Studies, 18-20 January 2019, Gaziantep, Turkey, 256-266.

Edited by: Salih Doğan

Reviewed by: Three anonymous referees

Citation: Mohammad-Doustaresharaf, M. and Bagheri, M. 2021. Raphignathoid mites (Acariformes: Raphignathoidea) in parts of the Azerbaijan provinces of Iran. Acarological Studies, 3 (2): 56-65.

Acarological Studies
Vol 3 (2): 66-72
doi: 10.47121/acarolstud.908554

RESEARCH ARTICLE

Isolation and characterization of 3D chitin from a mite species *Trachytes pauperior* (Parasitiformes: Uropodina)

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Received: 2 April 2021 Accepted: 20 May 2021 Available online: 31 July 2021

ABSTRACT: Chitin is the most abundant structural biopolymer after cellulose in terrestrial ecosystems. Until now, chitin isolation in powder or granule form has been carried out from many macro living groups (Arthropoda, Crustacea, Mollusca etc.). However, studies on chitin characterization of microscopic organisms have remained limited. In this study, three dimensional (3D) chitin extraction was performed for the first time from *Trachytes pauperior* (Berlese), a mite species. The obtained chitin was observed by light microscopy and characterized by FT-IR, and SEM analysis. Our findings suggest that chitin, which was obtained in high purity and constitutes a large part of the organism's body structure, could be a potential source for future studies.

Keywords: Acari, biopolymer, characterization, extraction, *Trachytes pauperior*.
Zoobank: http://zoobank.org/97CD8F14-CF8C-457D-ADB5-85613788CE7E

INTRODUCTION

Chitin is the most abundant biopolymer in nature after cellulose and is found in more than 70% of the living things in the world. Studies have shown that chitin can be isolated from the outer shells of many living organisms (such as crab, shrimp and lobster), from the cell wall of fungi and some algae and from the whole-body structure of coral, sponges and insects (Rudall, 1963; Wu et al., 2004; Ehrlich et al., 2007; Bo et al., 2012; Arbia et al., 2013; Rahman and Halfar, 2014). The study of Kaya et al. (2014a) showed that bat guano is also new chitin sources. Chitin, whose structure consists of β-1,4 linked N-acetyl D-glucosamine, has 3 defined allomorphs; alpha, beta and gamma. When previous studies examined, the most common form of chitin was determined as the alpha form and it has been identified in the branches of Arthropoda, Tardigrada, Bryozoa, Mollusca and the cell walls of Fungi (Brimacombe and Webber, 1964; Ehrlich et al., 2007; Al Sagheer et al., 2009). Considering the literature, it has been seen that there is no enough study on the isolation of the three dimensional (3D) chitin. Moreover, the isolated chitins were mostly obtained either powder or granule form of macro-organisms (Fadlaoui et al., 2019; Kardas et al., 2012).

Chitin is known to be non-toxic, biodegradable, edible, biocompatible, antioxidative, antimicrobial, thermally stable, antioncogenic and has a porous surface. These properties enable chitin and its derivatives to be used in numerous economically important applications in a wide variety of fields such as agriculture, medicine, food industry, textiles, and cosmetics (Jeon et al., 2000; Rinaudo, 2006; Krantz and Walter, 2009; Merzendorfer, 2009; Jayakumar et al., 2011; Anitha et al., 2014; Fernando et al., 2016; Hamed et al., 2016; Petrenko et al., 2017). Although chitin has such a wide area of use, the studies are clearly demonstrated that it is generally obtained from macro-sized organisms and microscopic creatures are neglected.

One of the most abundant invertebrates living in forest ecosystems are mites and more than 50,000 species have been described (Manu et al., 2018). Especially, Uropodina mites are one of the most widespread and diverse groups of mites living in soil (Kontschán, 2010, 2013; Kontschán et al., 2013). Besides, soil mites are known to play an important ecological role in the forest. For instance, they are reported to participate in soil formation processes and affect productivity (Manu et al., 2018). In the genus *Trachytes* Michael within the family Trachytidae, up to 30 species have been identified, 23 of which are from Central European countries such as Germany, the Czech Republic, Austria, Poland, Slovakia, Hungary, Ukraine and Romania (Masan, 2003). *Trachytes pauperior* has a wide ecological tolerance and lives in a variety of habitats (Masan, 2003). This species has been recorded from Europe and Siberia (Masan, 2003), and also reported form Turkey in a PhD dissertation by Bal (2002) and later in MSc dissertation by Özen (2012), but these dissertations have not been published yet. Until now, taxonomic and ecological studies have been conducted on the genus *Trachytes* in general (Pecina, 1970a,b, 1980; Hutu, 1973, 1982; Zirngiebl-Nicol, 1973; Bloszyk, 1980, 1999; Masan, 2003), but no study has been carried out on the content of chitin. In the current study, chitin isolation was performed for the first time from *Trachytes pauperior* (Berlese), which was followed out without damaging the 3D structure.

MATERIALS AND METHODS

Sample Collection

The mite specimens identified as *Trachytes pauperior* were extracted from soil and litter under *Quercus* sp., Pülümür Valley, TURKEY, 39°35'18.72''N 39°51'09.35''E, 1459 m a.s.l., 30 January 2019, using Berlese funnels.

Chitin Extraction

In total, 100 specimens were washed with distilled water for chitin extraction, any remaining particles were removed and dried at 60 °C for 3 days for extraction. It was treated at 60 °C in 2M 250 mL HCl solution for 6 hours to remove the minerals in the structure. At the end of this period, the samples were washed with pure water until they reached neutral pH by keeping their shape. Subsequently, samples were treated with 2M NaOH solution at 85 °C for 8 hours to remove protein residues in their structure. At the end of the treatment, the samples were washed again with pure water until they reached neutral pH and dried for 3 days at 60 °C.

Fourier Transform Infrared Spectroscopy (FT-IR)

The infrared spectra of the chitin isolates obtained from the species *T. pauperior* in 3D were recorded using Perkin Elmer Spectrometer in the range 4000-650 cm^{-1} at 8 cm^{-1} resolution in the wavelength range of 600-4000 cm^{-1}. Besides, the 64 scans were averaged to improve the signal-to-noise ratio.

Scanning Electron Microscopy (SEM) and Light microscopy image

The surface morphology of the isolates of the 3D chitin was demonstrated with the ZEISS LS-10 Life Science Scanning Electron Microscopy device. To get better images, the material was gold-plated before the analysis via Cressington sputter-coated 108 Auto, TED PELLA, INC. The 3D chitin produced from *T. pauperior* was also observed by light microscopy in 5X-60X magnification (Leica DM4000 B LED). The chitin was imaged in ambient conditions using glass slide. Besides, the natural *T. pauperior* structure (without chitin isolation) was examined by light microscopy (Leica Z6 APO).

RESULTS

FTIR

FTIR spectrum of chitin isolates obtained from the species *T. pauperior* in 3D was given in Figure 1 and Table 1. It is clearly observed that the Amide I band is divided into two peaks in the FTIR spectrum of the 3D chitin isolate from *T. pauperior* (Fig. 1 and Table 1), which shows the compatibility of this chitin with α-form. The second important band for the chitin is the Amide II band, which is found around 1552 cm^{-1} for a pure chitin. The recorded Amide II band for the 3D chitin isolate from *T. pauperior* is 1556 cm^{-1}. Thus, the Amide II band was also compatible with the literature and reveals the purity of the 3D chitin obtained from *T. pauperior* as an alpha chitin.

SEM and Light microscopy image

SEM images recorded to illuminate the surface morphology of the chitin isolated from *T. pauperior* in 3D were shown in Figure 2. It was clearly seen in the recorded images that the 3D structure was preserved during the isolation of the chitin and formed a large part of the organism's structure (Figs 2A-C). Looking at the images recorded at different magnifications, it was clearly demonstrated that the structure consists of tubercles with nanofibers and pores, which looks like the pattern of the cuticular cover is the nanoscale images of the chitin inside the cuticle. The same phenomenon can be observed using white light microscopy. The chitin isolated from *T. pauperior* as described above, possess 3D arrangement (Figs 3A, B). It is worth noting that these specific structures of mite chitin are extremely sensitive to drying at room temperature. Thus, to prevent degradation of 3D morphology, the samples were immediately scanned.

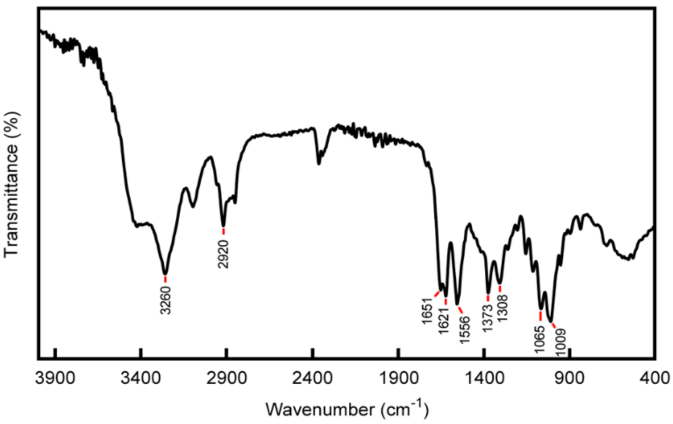

Figure 1. FTIR spectrum of the 3D chitin isolate from *T. pauperior*.

DISCUSSION

For the first time, 3D chitin was successfully isolated from the body structure of the species *T. pauperior* in the current study. As a result, it has been demonstrated that the 3D isolated chitin constitutes a large part of the organism's body structure. The presence of chitin in the peritrophic membrane of *Acarus siro* (Acari: Acaridae) has only been confirmed so far by Sobotnik et al. (2008). However, the study of Sobotnik et al. (2008) was not conducted on the characterization of chitin, only showing that the presence of chitin in the peritrophic membrane provides an opportunity for the application of chitin effectors as acaricides. As it is known, one of the pathways of chitin synthesis in Acari is found in the hypodermis under the cuticle (Mothes and Seitz, 1981). The mite cuticle consists of a wax-containing epicuticle and a thin procuticle (Mothes and Seitz, 1982, 1984). In other words, the nano-sized imaging of the 3D chitin was obtained from the procuticle region of the cuticle layer of the integument.

FTIR spectroscopy is one of the powerful tools for structural analysis of poly-saccharides, including the chitin (Żółtowska-Aksamitowska et al., 2018). Vibration spectra are also sensitive to intramolecular and intermolecular

Table 1. FTIR spectra of the chitin obtained from *Trachytes pauperior*.

Functional groups and vibration modes	Classification	Wavenumber (cm⁻¹) frequency	
		Chitin from *Trachytes pauperior*	Commercial α-chitin (Kaya et al., 2017)
O–H stretching	-	3421	3433
N-H stretching		3260	3104 -3260
CH3 sym. stretch and CH2asym. stretch	Aliphatic compounds	2920	2940
CH3 sym. stretch	Aliphatic compound	2852	2875
C=O secondary amide stretch	Amide I	1651	1652
C=O secondary amide stretch	Amide I	1621	1620
N–H bend, C–N stretch	Amide II	1556	1552
CH2 bending and CH3 deformation	-	1417	1420
CH bend, CH3 sym. deformation	-	1373	1375
CH2 wagging	Amide III, components of protein	1308	1307
Asymmetric bridge oxygen stretching		1154	1154
Asymmetric in-phase ring stretching mode		1112	1112
C–O–C asym. stretch in phase ring	Saccharide rings	1065	1067
C–O asym. stretch in phase ring	-	1009	1008
CH3 wagging	along chain	951	951
CH ring stretching	Saccharide rings	896	892

interactions as well as to the geomolecular molecule. Recently, this method has been successfully applied to identify three known isomorphs of chitin (α, β and γ) (Kaya et al., 2017). There are two characteristic peaks for the chitin. The first one is the Amide I band. Looking at the information in the literature, if this peak is an undivided peak around 1640 cm^{-1}, the chitin is called β-form, however; the two sharp peaks divided around 1660 and 1620 cm^{-1} are called α-form (Jang et al., 2004; Kaya et al., 2017). In the FTIR analysis, it was detected that the isolated chitin both was in α-form and included peaks that were quite compatible with the literature. The Amide I band can be sharply shown at 1651 and 1621 cm^{-1} in the spectrum of the chitin isolate, almost completely consistent with the literature (Table 1).

Generally, the chitin can be grouped in four different ways according to the surface morphology (Kaya et al., 2014b). The first form is a smooth surface morphology without any nanofibers and pores. The second form consists of nanofibers but does not contain pores. The third form has nanofibers and co-pores. The fourth form exhibits two types of pores of different sizes (one large and one small) in combination with nanofibers. In this study, the SEM analysis revealed that the 3D chitin isolated by consists of nanofibers and nanopores, which consistent with the other Arachnida species (Kaya et al., 2016). Similarly, it has been previously stated in the literature that the surface morphology of α-chitin consists of nanofibers and natural pores (Al Sagheer et al., 2009; Ifuku et al., 2011; Kaya et al., 2013; Mushi et al., 2014). In the study of Seyyar and Demir (2020), the chitin from external skeleton of an opilionid species, *Phalangium opilio* (Arachnida: Opiliones) was firstly extracted, and the chitin has been found to have nanofiber and nanoporous surface and alpha form. Additionally, the chitin characterization of two spider specimens demonstrated similar surface morphology (Kaya et al. 2014b). In 2020, Machałowski and coworkers obtained chitin from spider source retaining its unique shapes, including the 3D tubular architecture.

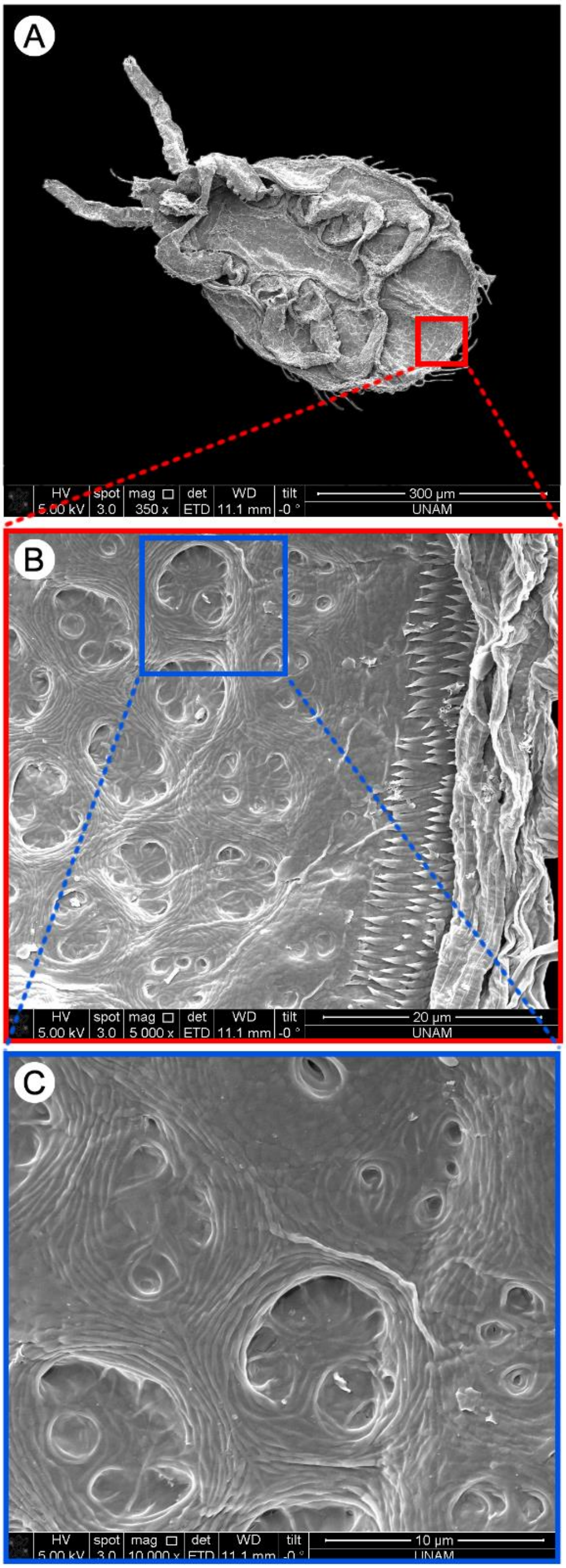

Figure 2. SEM images of chitin isolates from *T. pauperior* in 3D.

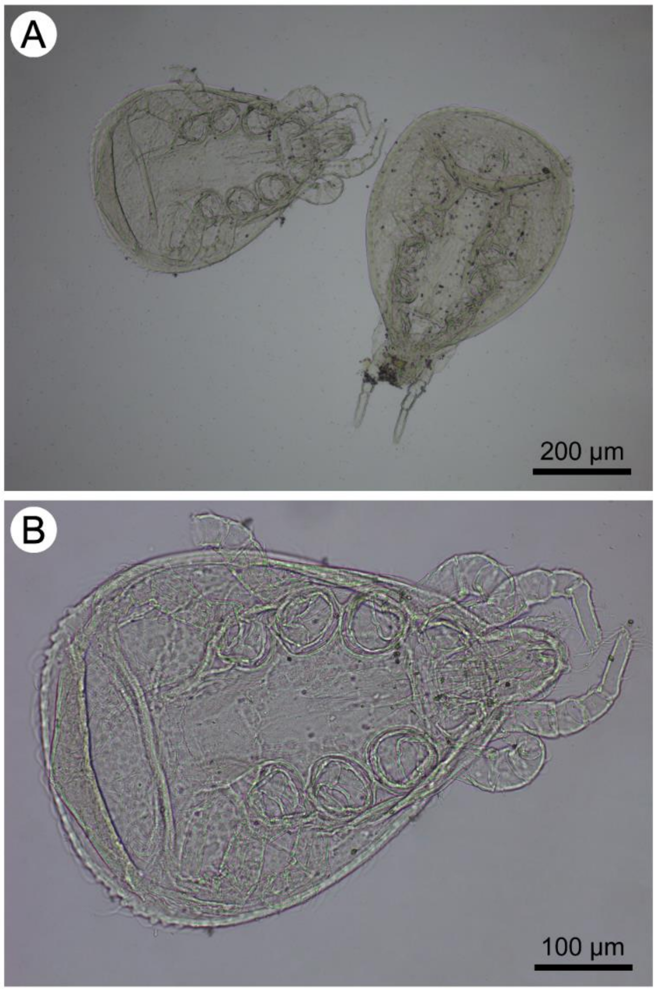

Figure 3. Purified chitin of *T. pauperior* of light microscopy modus (0-60X).

In addition to SEM images, the light microscopy clearly showed that the 3D structure was preserved without damaging. These part that looks like the pattern of the cuticular cover is the nanoscale images of the chitin inside the cuticle. Although we could not give the ratio of the chitin because it is very small organism, we predict that the content of the chitin is close to the Arthropoda, since we can isolate the 3D structure without deterioration. Thus, the results of the current study demonstrated that as a microscopic organism, *T. pauperior*, could be an alternative source of chitin for future applications. We suggest that the discovery of chitin within other representatives of the mite species is the next step.

Authors' contributions

Emel Çakmak: Investigation (equal), formal analysis (equal), methodology (equal), visualization (lead), writing - original draft (supporting), writing - review & editing (lead). **Behlül Koç-Bilican**: Investigation (equal), formal analysis (equal), methodology (equal), visualization (supporting), writing - original draft (lead), writing - review & editing (supporting).

Statement of ethics approval

Not applicable.

Funding

There is no fund for the present study.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

We would like to thank Prof. Dr. Salih DOĞAN (Erzincan Binali Yıldırım University, Turkey) for supporting over this manuscript.

REFERENCES

Al Sagheer, F., Al-Sughayer, M., Muslim, S. and Elsabee, M. 2009. Extraction and characterization of chitin and chitosan from marine sources in Arabian Gulf. Carbohydrate Polymers, 77 (2): 410-419. doi: 10.1016/j.carbpol.2009.01.032

Anitha, A., Sowmya, S., Kumar, P.S., Deepthi, S., Chennazhi, K. et al. 2014. Chitin and chitosan in selected biomedical applications. Progress in Polymer Science, 39 (9): 1644-1667. doi: 10.1016/j.progpolymsci.2014.02.008

Arbia, W., Arbia, L., Adour, L. and Amrane, A. 2013. Chitin extraction from crustacean shells using biological methods–a review. Food Technology and Biotechnology, 51 (1): 12-25.

Bal, D.A. 2002. Uropodid (Acari, Gamasida, Uropodina) fauna of Erzincan and Erzurum provinces. PhD Dissertation. Graduate School of Natural and Applied Sciences, Atatürk University, Erzurum, Turkey, 328 pp. [In Turkish]

Bloszyk, J. 1980. Mites of the genus *Trachytes* Michael, 1894 (Acari, Mesostigmata) in Poland. Prace Komisji Biologicznej, Poznan, 54: 1-51.

Bloszyk, J. 1999. Geographical and ecological variability of mites of the kohort Uropodina (Acari: Mesostigmata) in Poland. I. Uropodine mites of oak-hornbeam forests (*Carpinion betuli*). Kontekst, Poznan, Poland, 245 pp. [In Polish]

Bo, M., Bavestrello, G., Kurek, D., Paasch, S., Brunner, E. et al. 2012. Isolation and identification of chitin in the black coral *Parantipathes larix* (Anthozoa: Cnidaria). International Journal of Biological Macromolecules, 51 (1-2): 129-137. doi: 10.1016/j.ijbiomac.2012.04.016

Brimacombe, J.S. and Webber, J.M. 1964. Mucopolysaccharides: chemical structure, distribution and isolation. Elsevier, Amsterdam, The Netherlands, 181 pp.

Ehrlich, H., Maldonado, M., Spindler, K., Eckert, C., Hanke, T. et al. 2007. Evidence of chitin as a component of the skeletal fibers of marine sponges. Part I. Verongidae (Demospongia: Porifera). Journal of Experimental Zoology-B: Molecular and Developmental Evolution, 308 (4): 347-356. doi: 10.1002/jez.b.21156

Fadlaoui, S., El Asri, O., Mohammed, L., Sihame, A., Omari, A. and Melhaoui, M. 2019. Isolation and characterization of chitin from shells of the freshwater crab *Potamon algeriense*. Progress on Chemistry and Application of Chitin and its Derivatives, 24: 23-35. doi: 10.15259/PCACD.24.002

Fernando, L.A.T., Poblete, M.R.S., Ongkiko, A.G.M. and Diaz, L.J.L. 2016. Chitin extraction and synthesis of chitin-based polymer films from Philippine blue swimming crab (*Portunus pelagicus*) shells. Procedia Chemistry, 19: 462-468. doi: 10.1016/j.proche.2016.03.039

Hamed, I., Özogul, F. and Regenstein, J.M. 2016. Industrial applications of crustacean by-products (chitin, chitosan, and chitooligosaccharides): A review. Trends in Food Science & Technology, 48: 40-50. doi: 10.1016/j.tifs.2015.11.007

Hutu, M. 1973. Gangsystematik der Parasitiformes. Teil 145. Zur Kenntnis der Uropodiden-Fauna Rumäniens. Neue Uropodiden-Arten der Gattungen *Trachytes* Michael, 1894, *Dinychus* Kramer, 1886 und *Trachyuropoda* (Berlese, 1888) Hirschmann u. Zirngiebl-Nicol, 1961 nov. comb. Acarologie, Schriftenreihe für Vergleichende Milbenkunde, 19: 45-51.

Hutu, M. 1982. Strukturelle Eigenschaften Von Uropodiden-Zoenosen In Der Streuschicht Verschiedener Walottypen Laengs Eines Hoehengradienten. Pedobiologia, 23 (1): 68-89.

Ifuku, S., Nomura, R., Morimoto, M. and Saimoto, H. 2011. Preparation of chitin nanofibers from mushrooms. Materials, 4 (8): 1417-1425. doi: 10.3390/ma4081417

Jang, M.K., Kong, B.G., Jeong, Y.I., Lee, C.H. and Nah, J.W. 2004. Physicochemical characterization of α-chitin, β-chitin, and γ-chitin separated from natural resources. Journal of Polymer Science Part A: Polymer Chemistry, 42 (14): 3423-3432. doi: 10.1002/pola.20176

Jayakumar, R., Prabaharan, M., Kumar, P.S., Nair, S. and Tamura, H. 2011. Biomaterials based on chitin and chitosan in wound dressing applications. Biotechnology Advances, 29 (3): 322-337. doi: 10.1016/j.biotechadv.2011.01.005

Jeon, Y.-J., Shahidi, F. and Kim, S.-K. 2000. Preparation of chitin and chitosan oligomers and their applications in physiological functional foods. Food Reviews International, 16 (2): 159-176. doi: 10.1081/FRI-100100286

Kardas, I., Struszczyk, M.H., Kucharska, M., van den Broek, L.A., van Dam, J.E. and Ciechańska, D. 2012. Chitin and chitosan as functional biopolymers for industrial ap-

plications. In: The European Polysaccharide Network of Excellence (EPNOE). Navard, P. (Ed.), Springer, Vienna, Austria, 329-373.
doi: 10.1007/978-3-7091-0421-7_11

Kaya, M., Tozak, K. Ö., Baran, T., Sezen, G. and Sargin, I. 2013. Natural porous and nano fiber chitin structure from *Gammarus argaeus* (Gammaridae Crustacea). Excli Journal, 12: 503-510.

Kaya, M., Seyyar, O., Baran, T. and Turkes, T. 2014a. Bat guano as new and attractive chitin and chitosan source. Frontiers in Zoology, 11 (1): 1-10.

Kaya, M., Seyyar, O., Baran, T., Erdoğan, S. and Kar, M. 2014b. A physicochemical characterization of fully acetylated chitin structure isolated from two spider species: With new surface morphology. International Journal of Biological Macromolecules, 65: 553-558.
doi.org/10.1016/j.ijbiomac.2014.02.010

Kaya, M., Baublys, V., Sargin, I., Šatkauskienė, I., Paulauskas, A. et al. How taxonomic relations affect the physicochemical properties of chitin. Food Biophysics, 11 (1): 10-19.
doi: 10.1007/s11483-015-9404-5

Kaya, M., Mujtaba, M., Ehrlich, H., Salaberria, A.M., Baran, T. et al. 2017. On Chemistry of γ-chitin. Carbohydrate Polymers, 176: 177-186.
doi: 10.1016/j.carbpol.2017.08.076

Kontschán, J. 2010. Taxonomical and faunistical studies on the Uropodina mites of Greece (Acari: Mesostigmata). Opuscula Zoologica Budapest, 41 (1): 29-38.

Kontschán, J. 2013. Species of the genus *Trachytes* Michael, 1894 (Acari: Uropodina: Trachytidae) of Romania. Acta Zoologica Academiae Scientiarum Hungaricae, 59 (4): 321-336.

Kontschán, J., Park, S.J., Yoon, T.J. and Choi, W.Y. 2013. Uropodina mites from Korean Peninsula (Acari: Mesostigmata). Ad Librum, Budapest, Hungary, 70 pp.

Krantz, G.W. and Walter, D.E. 2009. A manual of Acarology. Third Edition. Texas Tech University Press, Lubbock, Texas, USA, 807 pp.

Machałowski, T., Amemiya, C. and Jesionowski, T. (2020). Chitin of Araneae origin: Structural features and biomimetic applications: A review. Applied Physics A, 126 (9): 1-17.
doi: 10.1007/s00339-020-03867-x

Manu, M., Bancila, R.I. and Onete, M. 2018. Importance of moss habitats for mesostigmatid mites (Acari: Mesostigmata) in Romania. Turkish Journal of Zoology, 42 (6): 673-683.
doi: 10.3906/zoo-1712-6

Masan, P. 2003. Identification key to Central European species of *Trachytes* (Acari: Uropodina) with redescriptions, ecology and distribution of Slovak species. European Journal of Entomology, 100 (3): 435-448.
doi: 10.14411/eje.2003.066

Merzendorfer, H. 2009. Chitin: structure, function, and metabolism. In: The Sugar Code: Fundamentals of Glycosciences. Gabius, H.-J. (Ed.), Wiley, VCH, Weinheim, Germany, 217-229.

Mothes, U. and Seitz, K.A. 1981. A possible pathway of chitin synthesis as revealed by electron microscopy in *Tetranychus urticae* (Acari, Tetranychidae). Cell and Tissue Research, 214 (2): 443-448.

Mothes, U. and Seitz, K.A. 1982. Action of the microbial metabolite and chitin synthesis inhibitor nikkomycin on the mite *Tetranychus urticae*; an electron microscope study. Pesticide Science, 13 (4): 426-441.

Mothes, U. and Seitz, K.A. 1984. Fine structure of the cuticle and structural changes occurring during moulting in the mite *Tetranychus urticae*. I. Fine structure of the cuticle. Acarologia, 25 (3): 253-258.

Mushi, N.E., Butchosa, N., Salajkova, M., Zhou, Q. and Berglund, L.A. 2014. Nanostructured membranes based on native chitin nanofibers prepared by mild process. Carbohydrate Polymers, 112: 255-263.
doi: 10.1016/j.carbpol.2014.05.038

Özen, E. 2012. Uropodid (Acari: Mesostigmata: Uropodina) fauna of Kelkit Valley. MSc Dissertation. Graduate School of Natural and Applied Sciences, Erzincan University, Erzincan, Turkey, 128 pp. [In Turkish]

Pecina, P. 1970a. Contribution to the knowledge of Uropodidae (Berlese, 1892) sensu Hirschmann et Zirngiebl-Nicol, 1964, of the environs of Prague (Acari, Mesostigmata). Acta Universitatis Carolinae. Biologica, 1968: 417-434.

Pecina, P. 1970b. Czechoslovak uropodid mites of the genus *Trachytes* Michael, 1894 (Acari, Mesostigmata). Acta Universitatis Carolinae. Biologica, 1969: 39-59.

Pecina, P. 1980. Additional knowledge of members of the genus *Trachytes* Michael, 1894 (Acari, Mesostigmata) from Czechoslovakia. Acta Universitatis Carolinae. Biologica, 1978: 389-407.

Petrenko, I., Bazhenov, V.V., Galli, R., Wysokowski, M., Fromont, J. et al. 2017. Chitin of poriferan origin and the bioelectrometallurgy of copper/copper oxide. International Journal of Biological Macromolecules, 104: 1626-1632.
doi: 10.1016/j.ijbiomac.2017.01.084

Rahman, M.A. and Halfar, J. 2014. First evidence of chitin in calcified coralline algae: new insights into the calcification process of *Clathromorphum compactum*. Scientific Reports, 4: 6162.
doi: 10.1038/srep06162

Rinaudo, M. 2006. Chitin and chitosan: Properties and applications. Progress in Polymer Science, 31 (7): 603-632.
doi: 10.1016/j.progpolymsci.2006.06.001

Rudall, K. 1963. The chitin/protein complexes of insect cuticles. Advances in Insect Physiology, 1: 257-313.
doi: 10.1016/S0065-2806(08)60177-0

Seyyar, F. and Demir, H. 2020. Extraction and physico-chemical characterization of chitin from *Phalangium opilio* Linnaeus, 1758 (Arachnida: Opiliones). Acta Biologica Turcica, 33 (4): 258-263.

Sobotnik, J., Kudlikova-Krizkova, I., Vancova, M., Munzbergova, Z. and Hubert, J. 2008. Chitin in the peritrophic membrane of *Acarus siro* (Acari: Acaridae) as a target for novel acaricides. Journal of Economic Entomology, 101 (3): 1028-1033.
doi: 10.1093/jee/101.3.1028

Wu, T., Zivanovic, S., Draughon, F.A. and Sams, C.E. 2004. Chitin and chitosan value-added products from mushroom waste. Journal of Agricultural and Food Chemistry, 52 (26): 7905-7910.
doi: 10.1021/jf0492565

Zirngiebl-Nicol, I. 1973. Gangsystematik der Parasitiformes. Teil 134. Wiederbeschreibung von 7 bekannten Uroseius-Arten (Uropodini, Uropodinae). Acarologie, 19: 5-10.

Żółtowska-Aksamitowska, S., Tsurkan, M.V., Lim, S.C., Meissner, H., Tabachnick, K. et al. 2018. The demosponge *Pseudoceratina purpurea* as a new source of fibrous chitin. International Journal of Biological Macromolecules, 112: 1021-1028.
doi: 10.1016/j.ijbiomac.2018.02.071

Edited by: Salih Doğan
Reviewed by: Two anonymous referees

Citation: Çakmak, E. and Koç Bilican, B. 2021. Isolation and characterization of 3D chitin from a mite species *Trachytes pauperior* (Parasitiformes: Uropodina). Acarological Studies, 3 (2): 66-72.

Acarological Studies
Vol 3 (2): 73-81
doi: 10.47121/acarolstud.911415

RESEARCH ARTICLE

Zerconid mites (Acari, Zerconidae) from eastern parts of Aydın Province (Turkey), with description of *Zercon karacasuensis* sp. nov.

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Received: 7 April 2021 Accepted: 3 June 2021 Available online: 31 July 2021

ABSTRACT: Species diversity of zerconid mites was investigated in Buharkent, Karacasu and Kuyucak counties of Aydın province during February 2019 until February 2020. Seven species of the family Zerconidae were found in the research area, two of which belong to the genus *Prozercon* and remaining five species belong to the genus *Zercon*. A new species, *Z. karacasuensis* **sp. nov.**, was collected from pine habitats (*Pinus* sp.) and described. In addition, altitute and habitat preferences of all zerconid mites collected from the research area, were given.

Keywords: Mesostigmata, new species, preference, Buharkent, Karacasu, Kuyucak.
Zoobank: http://zoobank.org/267CE1FD-CA43-4482-A06B-AC1C2BEA1316

INTRODUCTION

Members of the family Zerconidae constitute a large group of soil-inhabiting mites in the order Mesostigmata. However, all records of genera and species of zerconids have been only known from the Holarctic region. In terms of the species richness of zerconid mites, Turkey is one of the well studied countries. Although, two genera (*Prozercon* and *Zercon*) and 130 species from the country have been recorded, there are many areas that have not been studied hitherto (Urhan and Karaca, 2019, 2020; Urhan et al., 2020a,b; Karaca, 2021; Keçeci et al., 2021). Systematics and ecological researches are still ongoing on this family both in Turkey and the other countries in Northern hemisphere. Therefore, new occurrences of zerconid mites are being increased day by day, especially with local systematic studies in these areas (Marchenko, 2018, 2019, 2021; Kaczmarek et al., 2020; Moghimi et al., 2021).

Aydın, one of the provinces in the Aegean region, includes 17 counties. Conditions of the Mediterranean climate and topographical structure caused the development of two separate plant communities (maquis and forest) in Aydın and its surroundings. In the present study, three counties (Buharkent, Karacasu and Kuyucak) of Aydın Province were selected for the reveal of species diversity of zerconid mites. According to literature records, no studies about zerconid mites have been performed in these counties so far. Also, it is aimed that to research about altitudinal and habitat preferences of zerconids as well as the species diversity.

For these purposes, species diversity of zerconid mites in Buharkent, Karacasu and Kuyucak counties were investigated. A species list for the family found in the research area were presented, their previous records were noted, and altitudinal and habitat preferences of the species were revealed. In addition, description of a new species, *Zercon karacasuensis* **sp. nov.** was given.

MATERIALS AND METHODS

Mite specimens were collected from different localities (especially from forestland areas) in Buharkent, Karacasu and Kuyucak counties, Aydın Province, between February 2019 and February 2020. Soil, litter and moss samples were taken from 98 sites, and totally 407 samplings were made in the research area. The Garmin GPSmap 62s was used for taking information of sampling sites (coordinates and altitudes). All collected materials were carried to the laboratory and later processed using Berlese-Tullgren funnel with 25 Watt fluorescent bulb for one week.

Zerconid mites were extracted using a stereo microscope (Nikon SMZ 745T), then cleared in 60% lactic acid and transferred to glycerine medium. A light microscope (Olympus CX41) was used for identification of zerconids. The Olympus DP25 camera integrated into light microscope was used to transfer living images to the computer system. Illustrations of specimens of *Zercon karacasuensis* **sp. nov.** were made by pencil drawing. The DP2-BSW (ver.2.1) software was used for measurement of various body parts and setae of the species. The holotype and paratypes of the new species, as well as the other zerconid specimens were deposited in the Acarology Laboratory of the Department of Biology, Faculty of Science and Arts, Pamukkale University, Denizli, Turkey.

Terminology of idiosomal setation follows Lindquist and Evans (1965), with modifications for the caudal region as given by Lindquist and Moraza (1998). Terminology of idiosomal adenotaxy and poroidotaxy follows that of Johnston and Moraza (1991). All measurements were given as micrometers (μm). Abbreviations of DN and PN were used for deutonymph and protonymph specimens, respectively.

RESULTS

After examination of zerconid mites collected from the research area, two *Prozercon* and five *Zercon* species were identified. All the species were listed below, and some information about each species, e.g. numbers and localities of examined specimens, distributions of the species in Turkey and the world, altitude and habitat preferences of the specimens were given in alphabetical order herein. With the new species, the number of zerconid mites known from Turkey has increased to 131.

Family Zerconidae Canestrini, 1891

Genus *Prozercon* Sellnick, 1943

Type species: *Zercon fimbriatus* C. L. Koch, 1839

Prozercon demirsoyi Urhan and Ayyıldız, 1996

Materials examined: One male: soil and litter samples under common fig tree (*Ficus carica*), 37°54'10.68'' N, 28°32'37.50'' E, 94 m a.s.l., Obam roadhouse, vicinity of Pamukören neighborhood (Kuyucak), 3 February 2019. Three females: soil and litter samples under rockrose (*Cistus* sp.), 38°2'53.76'' N, 28°38'25.68'' E, 860 m a.s.l., vicinity of Taşoluk neighborhood (Kuyucak), 6 October 2019. Seven females and four males: soil and litter samples under black pine tree (*Pinus nigra*), 37°59'16.62'' N, 28°41'1.08'' E, 450 m a.s.l., Karacaören graveyard (Karacasu), 7 October 2019. Four females and two males: soil and litter samples under kermes oak tree (*Quercus coccifera*), 37°48'52.26'' N, 28°39'17.16'' E, 755 m a.s.l., vicinity of Karacaören neighborhood (Karacasu), 7 October 2019. Four females and two males: moss samples, 37°59'16.62'' N, 28°41'1.08'' E, 450 m a.s.l., Gelenbe neighborhood (Buharkent), 22 January 2020. Five females: soil and litter samples under kermes oak tree (*Quercus coccifera*), 37°58'39.96'' N, 28°36'56.04'' E, 701 m a.s.l., Dereköy neighborhood (Kuyucak), 22 January 2020. Three females and four males: soil and litter samples under Mount Tabor oak tree (*Quercus ithaburensis*), 37°58'45.96'' N, 28°36'46.38'' E, 771 m a.s.l., Dereköy neighborhood (Kuyucak), 22 January 2020. Five females and one male: soil and litter samples under Mount Tabor oak tree (*Quercus ithaburensis*), 37°58'25.62'' N, 28°40'31.14'' E, 377 m a.s.l., Feslek neighborhood (Buharkent), 22 January 2020.

Turkish distribution: Artvin (Urhan and Ayyıldız, 1996), Giresun (Karaca and Urhan, 2015), İstanbul (Duran and Urhan, 2017) and Aydın (present study).

Known distribution: Turkey (Urhan and Ayyıldız, 1996).

Prozercon yavuzi Urhan, 1998

Materials examined: Two females: soil and litter samples under olive tree (*Olea europaea*), 37°54'45.84'' N, 28°34'46.26'' E, 103 m a.s.l., vicinity of Horsunlu neighborhood (Kuyucak), 3 February 2019. Four females: soil and litter samples under kermes oak tree (*Quercus coccifera*) and Turkish pine tree (*Pinus brutia*), 37°54'20.22'' N, 28°29'40.50'' E, 83 m a.s.l., Buharkent-Karacasu-Kuyucak road junction (Kuyucak), 3 February 2019. Three females: soil and litter samples under Aleppo oak tree (*Quercus infectoria*), 37°41'20.46'' N, 28°37'9.90'' E, 667 m a.s.l., Yazır neighborhood (Karacasu), 7 October 2019. One female: moss samples, 37°40'31.14'' N, 28°38'32.64'' E, 638 m a.s.l., vicinity of Yazır neighborhood (Karacasu), 7 October 2019.

Turkish distribution: Muğla (Urhan, 1998), Denizli, Aydın (Karaca, 2015), İstanbul (Duran and Urhan, 2017) and Balıkesir (Karaca, 2021).

Known distribution: Turkey (Urhan, 1998) and Greece (Ujvári, 2008, 2011).

Genus *Zercon* C. L. Koch, 1836

Type species: *Zercon triangularis* C. L. Koch, 1836

Zercon colligans Berlese, 1920

This species was the most abundant zerconid species in terms of number of individuals in the study area.

Materials examined: 187 females, 146 males, 79 DN and 40 PN: soil, litter and moss samples under various plants (see Table 4), 37°57'20.70'' N, 28°45'38.52'' E, 151 m a.s.l., Savcıllı neighorbood (Buharkent), 2 February 2019. 140 females, 82 males, 45 DN and 24 PN: soil, litter and moss samples under various plants (see Table 4), 37°56'18.66'' N, 28°48'21.72'' E, 203 m a.s.l., Kızıldere neighorbood (Buharkent), 2 February 2019. 156 females, 112 males, 56 DN and 21 PN: soil, litter and moss samples under various plants (see Table 4), 37°58'35.94'' N, 28°48'24.66'' E, 361 m a.s.l., vicinity of Kızıldere neighorbood (Buharkent), 2 February 2019. 61 females, 30 males and 13 DN: soil, litter and moss samples under various plants (see Table 4), 38°0'10.02'' N, 28°43'2.10'' E, 839 m a.s.l., Muratdağı neighorbood (Buharkent), 5 October 2019. 63 females, 23 males, 16 DN and four PN: soil, litter and moss samples under various plants (see Table 4), 38°58'25.62'' N, 28°40'31.14'' E, 377 m a.s.l., Feslek neighorbood (Buharkent), 22 January 2020. 408 females, 233 males, 123 DN and 75 PN: soil, litter and moss samples under various plants (see Table 4), 37°49'40.86'' N, 28°33'59.58'' E, 206 m a.s.l., vicinity of Bahçeköy neighorbood (Karacasu), 4 February 2019. 129 females, 74 males, 68 DN and 35 PN: soil, litter and moss samples under various plants (see Table 4), 37°44'58.50'' N, 28°37'6.36'' E, 366 m a.s.l., Kuyucak-Karacasu road junction (Karacasu), 4 February 2019. 249 females, 183 males, 110 DN and 53 PN: soil, litter and moss samples under various plants (see Table 4), 37°42'41.64'' N, 28°43'48.78'' E, 536 m a.s.l., vicinity of Aphrodisias Ancient City, Geyre graveyard (Karacasu), 4 February 2019. 161 females, 184 males, 92 DN and 53 PN: soil, litter and moss samples under various plants (see Table 4), 37°51'25.92'' N, 28°39'33.42'' E, 464 m a.s.l., vicinity of Aksaz neighorbood (Karacasu), 27 June 2019. 180 females, 95 males, 75 DN and 27 PN: soil, litter and moss samples under various plants (see Table 4), 37°49'38.82'' N, 28°34'23.22'' E, 205 m a.s.l., vicinity of Bahçeköy neighorbood (Karacasu), 22 January 2020. 249 females, 179 males, 118 DN and 70 PN: soil, litter and moss samples under various plants (see Table 4), 37°54'10.68'' N, 28°32'37.50'' E, 94 m a.s.l., Obam roadhouse, vicinity of Pamukören neighborhood (Kuyucak), 3 February 2019. 521 females, 289 males, 75 DN and 41 PN: soil, litter and moss samples under various plants (see Table 4), 37°53'19.02'' N, 28°38'53.64'' E, 170 m a.s.l., Yamalak neighborhood (Kuyucak), 3 February 2019. 161 females, 133 males, 76 DN and 51 PN: soil, litter and moss samples under various plants (see Table 4), 37°52'15.96'' N, 28°39'27.48'' E, 254 m a.s.l., vicinity of Yamalak and Aksaz neighborhoods (Kuyucak), 3 February 2019. 101 females, 32 males, 17 DN and two PN: soil, litter and moss samples under various plants (see Table 4), 38°57'4.20'' N, 28°36'46.92'' E, 424 m a.s.l., Kurtuluş neighborhood (Kuyucak), 22 January 2020.

Turkish distribution: Afyonkarahisar, Artvin, Aydın, Balıkesir, Çanakkale, Denizli, Edirne, Erzurum, Giresun, İstanbul, Kırklareli, Kütahya, Tekirdağ and Uşak (Karaca, 2015, 2021; Karaca and Urhan, 2016; Urhan and Duran, 2019).

Known distribution: Austria, France, Iran, Ireland, Italy, Russia, Sweden, Swiss and Turkey (Karaca and Urhan 2016; Karaca et al., 2017; Karaca, 2021).

Zercon cretensis Ujvári, 2008

Materials examined: 36 females, 21 males and 30 DN: soil and litter samples under Turkey oak tree (*Quercus cerris*), olea tree (*Olea europaea*), garland thorn (*Paliurus spina-christi*) and rockrose (*Cistus* sp.), 37°44'58.50'' N, 28°37'6.36'' E, 366 m a.s.l., Kuyucak-Karacasu road junction (Karacasu), 4 February 2019. Five females, two males and three DN: soil and litter samples under juniper tree (*Juniperus* sp.), 37°45'18.06'' N, 28°37'23.40'' E, 355 m a.s.l., Göçükbaşı neighorbood (Karacasu), 4 February 2019. One male: soil and litter samples under Turkish pine tree (*Pinus brutia*), 37°42'27.24'' N, 28°36'40.98'' E, 628 m a.s.l., vicinity of Yazır neighorbood (Karacasu), 4 February 2019. Four females and three males: moss sample, 37°51'34.44'' N, 28°40'0.72'' E, 383 m a.s.l., vicinity of Aksaz and Kayabaşı neighorboods (Kuyucak), 6 October 2019.

Turkish distribution: İstanbul (Duran and Urhan, 2017) and Aydın (present study).

Known distribution: Greece (Ujvári, 2008) and Turkey (Duran and Urhan, 2017).

Zercon denizliensis Urhan, 2011

Materials examined: 12 females, five males and seven DN: soil and litter samples under rockrose (*Cistus* sp.) and garland thorn (*Paliurus spina-christi*), 37°44'58.50'' N, 28°37'6.36'' E, 366 m a.s.l., Kuyucak-Karacasu road junction (Karacasu), 4 February 2019. Five females, two males and three DN: soil and litter samples under juniper tree (*Juniperus* sp.), 37°45'18.06'' N, 28°37'23.40'' E, 355 m a.s.l., vicinity of Göçükbaşı neighorbood (Karacasu), 4 February 2019. Four females and three males: moss samples, 37°51'34.44'' N, 28°40'0.72'' E, 383 m a.s.l., vicinity of Aksaz neighorbood (Kuyucak), 6 October 2019. One male: soil and litter samples under Turkish pine tree (*Pinus brutia*), 37°42'27.24'' N, 28°36'40.98'' E, 628 m a.s.l., vicinity of Yazır neighorbood (Karacasu), 7 October 2019. Three males: soil and litter samples under Aleppo oak tree (*Quercus infectoria*), 37°41'20.46'' N, 28°37'9.90'' E, 667 m a.s.l., Yazır neighorbood (Karacasu), 7 October 2019. 10 females, five males and six DN: moss samples, 37°40'31.14'' N, 28°38'32.64'' E, 638 m a.s.l., vicinity of Yazır neighorbood (Karacasu), 7 October 2019. Nine females and one male: soil and litter samples under rockrose (*Cistus* sp.) and Mount Tabor oak tree (*Quercus ithaburensis*), 37°58'25.62'' N, 28°40'31.14'' E, 377 m a.s.l., Feslek neighorbood (Buharkent), 22 January 2020. Six females and three males: soil and litter samples under Turkish pine tree (*Pinus brutia*), 37°50'17.28'' N, 28°34'34.74'' E, 193 m a.s.l., Yenice neighorbood (Karacasu), 22 January 2020. Two males: soil and litter samples under kermes oak tree (*Quercus coccifera*), 37°49'18.36'' N, 28°34'33.00'' E, 203 m a.s.l., Çamköy neighorbood (Karacasu), 22 January 2020.

Turkish distribution: Denizli (Urhan, 2011), Afyonkarahisar, Kütahya, Uşak (Urhan and Duran, 2019), Balıkesir (Karaca, 2021) and Aydın (present study).

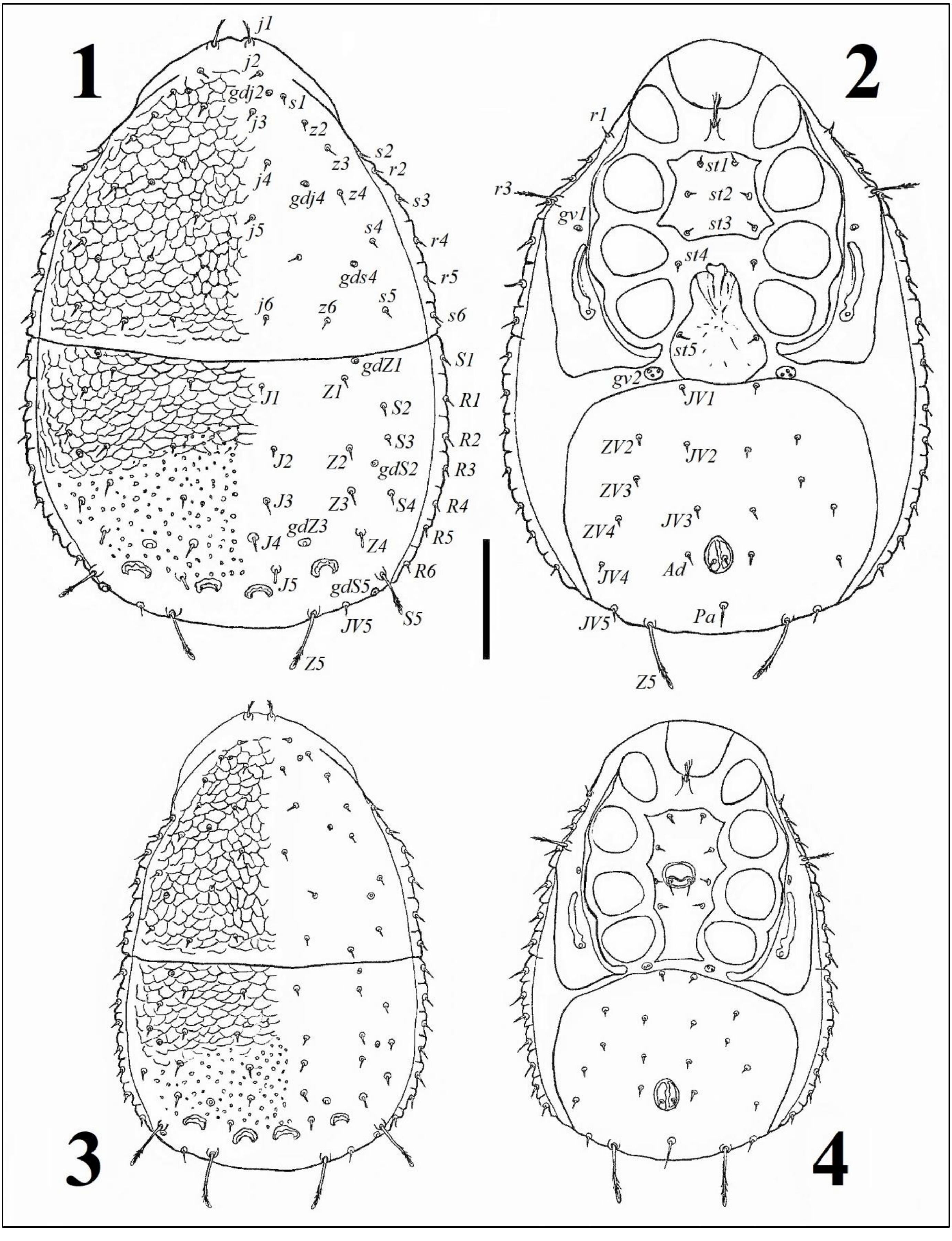
Known distribution: Turkey (Urhan, 2011).

Zercon huseyini Urhan, 2008

Materials examined: Four females, three males and one DN: soil and litter samples under kermes oak tree (*Quercus coccifera*), 37°58'35.94'' N, 28°48'24.66'' E, 361 m a.s.l., vicinity of Kızıldere neighorbood (Buharkent), 2 February 2019. One female: soil and litter samples under olive tree (*Olea europaea*), 37°57'47.64'' N, 28°48'36.84'' E, 256 m a.s.l., vicinity of Kızıldere neighorbood (Buharkent), 2 February 2019. Seven females and one male: soil and litter samples under sage-leaved rockrose (*Cistus salviifolius*), 37°58'27.18'' N, 28°48'8.16'' E, 415 m a.s.l., vicinity of Kızıldere neighorbood (Buharkent), 2 February 2019. Eight females, three males and two DN: soil and litter samples under Turkish pine tree (*Pinus brutia*) and rockrose (*Cistus* sp.), 37°46'24.54'' N, 28°37'5.04'' E, 350 m a.s.l., Güzelköy neighorbood (Karacasu), 7 October 2019. Two females: soil and litter samples under oleaster-leafed pear tree (*Pyrus elaeagrifolia*), 37°51'11.52'' N, 28°34'45.24'' E, 219 m a.s.l., Başaran neighorbood (Karacasu), 22 January 2020. Three females and two males: soil and litter samples under black pine tree (*Pinus nigra*), 38°3'20.52'' N, 28°37'25.26'' E, 894 m a.s.l., Musakolu neighorbood (Kuyucak), 22 January 2020.

Turkish distribution: Denizli (Urhan, 2008), Afyonkarahisar, Kütahya, Uşak (Urhan and Duran, 2019) and Aydın (present study).

Known distribution: Turkey (Urhan, 2008).



Figures 1-4. *Zercon karacasuensis* **sp. nov.** **1.** Dorsal view of holotype female, **2.** Ventral view of holotype female, **3.** Dorsal view of male, **4.** Ventral view of male. Scale bar 100.

***Zercon karacasuensis* sp. nov.** (Figures 1-4)

Zoobank: http:/zoobank.org/361001AE-0C37-4BB0-8A61-ECEB1B52D081

Type material. Holotype (female), soil and litter samples under Turkish pine tree (*Pinus brutia*), 37°47'15.90'' N, 28°37'39.30'' E, 459 m a.s.l., vicinity of Dereköy and Güzelköy neighorboods, Karacasu County, Aydın Province, 7 October 2020. Paratypes: One female, one male, same data as holotype.

Diagnosis. Anterior margin of ventrianal shield with one pair of setae (*JV1*). All podonotal setae short, smooth and needle-like (except seta *j1*). Seta *j1* slightly elongated, finely barbed apically. Great majority of opisthonotal setae short, smooth and needle-like. Setae *Z5* and *S5* longer than other opisthonotal setae, finely barbed with hyaline endings. Pores *gdS2* located between setae *Z2* and *S3*, *gdZ3* located between setae *J4* and *Z4*. Dorsal cavities distinct and strongly developed. Podonotum and anterior margin of opisthonotum covered with tile-like pattern, mid-area to posterior margin of opisthonotum covered by irregular punctate pattern.

Female (Figs 1, 2) (n= 2). Lenghts (without gnathosoma) 437–460 and widths 310–330.

Dorsal side (Fig. 1). Twenty pairs of setae present on podonotum: setae in *j* series with six pairs, *z* series with five pairs, *s* series with six pairs and *r* series with three pairs. All of them short, equal in size, smooth and needle-like (except seta *j1*). Setae *j1* slightly elongated, finely barbed apically. Twenty one pairs of setae present on opisthonotum: setae in *J* series with five pairs, *Z* series with five pairs, *S* series with five pairs and *R* series with six pairs. Most of opisthonotal setae short, smooth and needle-like (except setae *J5*, *Z4–5* and *S5*). Setae *J5* and *Z4* short, but hyaline endings without finely barbed. Setae *Z5* and *S5* longer than others, finely barbed with hyaline endings and reaching to beyond of opisthonotum. None of setae in *J*, *Z* and *S* series reaching the bases of the following seta. Seta *JV5* similar in length and shape to marginal *R* setae. All marginal setae (*S1* + *R1–R6*) situated as vertically to lateral margin of opisthonotum. The intervals between setae *Z5* and *Z5* 101–107, setae *Z5* and *JV5* 26–29, respectively. Lengths of the opisthonotal setae and distances between setal bases within longitudinal *J*, *Z* and *S* rows are given in Table 1 for female and male specimens.

Pores (Fig. 1). On podonotum, pores *gdj2* located on the line connecting setae *j3–s1*, closer to *s1*. Pores *gdj4* located on the line connecting setae *j4–z4*, closer to *z4*. Pores *gds4* located on the line connecting setae *s4–s5*, closer to *s4*. On opisthonotum, pores *gdZ1* located above the insertions of setae *Z1*. Pores *gdS2* located on the line connecting setae *Z2–S3*. Pores *gdZ3* located on the line connecting setae *J4–Z4*, closer to *J4*. Pores *gdS5* located below to the insertions of setae *S5*.

Ventral side (Fig. 2). Chaetotaxy and shape of the peritrematal shields normal for the genus *Zercon*. Posterolateral tips of peritrematal shield reaching the level of setae *S1–R1*. Peritrematal shield with two pairs of setae (*r1* and *r3*), seta *r1* short, smooth and needle-like, seta *r3* elongated and finely barbed apically. Peritremes similar to reverse comma. Sternal shield with three pairs of setae (*st1–st3*), epigynal shield with one pair of setae (*st5*), and one seta (*st4*) located between sternal and epigynal shields; all of them (*st1–st5*) short, smooth and needle-like. Glands *gv2* present between posterior section of epigynal shield and anterior section of ventrianal shield. Ventrianal shield with nine pairs of setae (*JV1–JV5*, *ZV2–ZV4* and *Ad*) and one single postanal seta (*Pa*); all of them short, smooth and needle-like. Seta *ZV1* absent. Postanal seta as the longest on the ventrianal shield. Anterior margin of ventrianal shield with one pair of setae (*JV1*).

Male (Figs 3, 4) (n= 1). Lenght (without gnathosoma) 334 and width 228. Chaetotaxy of idiosoma, location of pores on idiosoma and ornamentation of dorsal shields similar to the females (except opisthonotal setae *J5* and *Z4*). Although these setae are hyaline endings without finely barbed in female specimens, they are smooth and needle-like in male specimen. The intervals between setae Z5 and Z5 88, setae *Z5* and *JV5* 20, respectively.

Immature stages. Not found.

Etymology. The specific epithet '*karacasuensis*' refers to the Karacasu County (Aydın Province) where the new species was collected.

Remarks. *Zercon karacasuensis* **sp. nov.** is quite similar to *Z. hispanicus* Sellnick, 1958, *Z. kastamonuensis* Urhan and Karaca, 2019 and *Z. lepurus* Błazsak, 1979. The morphological distinguishing characters of these four species were given in Table 2.

Altitude preferences of zerconid mites in the research area

All materials of zerconid mites were collected from suitable forestland areas at the altitude from 0 to 1200 m a.s.l. All sampling areas were divided according to 100 meters elevation ranges. After identification processes in the laboratory, the altitudinal distribution results of the *Prozercon* and *Zercon* species were marked in Table 3.

According to Table 3, *Z. karacasuensis* **sp. nov.** was only found at 400–500 m a.s.l. *Zercon colligans* was found at all altitudinal zones, from 0 to 1200 m a.s.l. Remaining species have no clear preference in terms of altitudinal ranges.

Habitat preferences of zerconid mites in the research area

All materials of zerconid species were collected from 98 sites in the research area and the following 41 habitat types, mostly tree species, were noted: alder (*Alnus* sp.), almond (*Prunus* sp.), broom (*Genista* sp.), chestnut (*Castanea sativa*), citrus (*Citrus* sp.), dog rose (*Rosa canina*), elm (*Ulmus* sp.), eucalypt (*Eucalyptus* sp.), fig (*Ficus carica*), grape (*Vitis vinifera*), hawthorn (*Crataegus* sp.), ivy (*Hedera* sp.), juniper (*Juniperus* sp.), mastic (*Pistacia* sp.), milkvetch (*Astragalus* sp.), moss (unspecified), mullein (*Verbascum* sp.), oaks: Aleppo oak (*Quercus infectoria*), evergreen oak (*Q. ilex*), kermes oak (*Q. coccifera*), Macedonian oak (*Q. trojana*), Mount Tabor oak (*Q. ithaburensis*), Turkey oak (*Q. cerris*), oleander (*Nerium oleander*), olive (*Olea europaea*), pear (*Pyrus* sp.), pines: black pine (*Pinus nigra*), stone pine (*Pinus pinea*), Turkish pine (*Pinus brutia*), pomegranate (*Punica granatum*), poplar (*Populus* sp.), raspberry (*Rubus* sp.), rockrose (*Cistus* sp.), shrub (*Sytrax officinalis*), spurge (*Euphorbia* sp.), sycamore (*Platanus* sp.), tamarisk (*Tamarix* sp.), thorn (*Paliurus spina-christi*), vitex (*Vitex agnus-castus*), walnut (*Juglans regia*) and willow (*Salix* sp.). Habitat preferences of the *Prozercon* and *Zercon* species were marked in Table 4.

According to Table 4, *Zercon colligans* was found in samples taken from 36 different habitat types. On the other hand, *Z. karacasuensis* **sp. nov.** was found only in Turkish pine (*Pinus brutia*) habitat. In addition, the most richness habitats in terms of species diversity of zerconids are follow: kermes oak, moss, rockrose and Turkisk pine. Specimens belonging to five zerconid species were found in all of these habitats. In contrary of these richness habitats, no specimens of zerconid mites were found in the following habitats: citrus, dog rose, hawthorn, mullein and spurge.

Table 1. Lengths of opisthonotal setae and the distances between their insertions in *J*, *Z*, and *S* rows of *Zercon karacasuensis* **sp. nov.**

Setae	♀	♂	Setae	♀	♂	Setae	♀	♂
J1	10-12	6	***Z1***	15-18	6	***S1***	17-20	9
J1–J2	51-54	34	***Z1–Z2***	60-62	35	***S1–S2***	65-72	51
J2	10-13	6	***Z2***	15-19	6	***S2***	10-14	5
J2–J3	39-41	20	***Z2–Z3***	29-33	14	***S2–S3***	38-41	20
J3	19-22	9	***Z3***	18-24	18	***S3***	10-16	5
J3–J4	29-30	18	***Z3–Z4***	36-38	23	***S3–S4***	42-47	28
J4	18-19	8	***Z4***	11-12	13	***S4***	12-19	5
J4–J5	28-33	26	***Z4–Z5***	59-63	37	***S4–S5***	56-57	33
J5	10-16	9	***Z5***	12-19	12	***S5***	44-48	44

Table 2. Morphological distinctive characters among *Z. karacasuensis* **sp. nov.**, *Z. hispanicus*, *Z. kastamonuensis* and *Z. lepurus*.

Characters	***Z. karacasuensis*** sp. nov.	***Z. hispanicus*** Sellnick, 1958	***Z. kastamonuensis*** Urhan and Karaca, 2019	***Z. lepurus*** Błazsak., 1979
Setae *r4–r5*, *s6*	short, smooth, needle like	short, smooth, needle like	short, finely barbed without hyaline ending	elongated, finely barbed without hyaline ending
Seta *J3*	short, smooth, needle like	elongated, finely barbed without hyaline ending	short, finely barbed without hyaline ending	short, smooth, needle like
Setae *J4–J5*	short, smooth, needle like	elongated, finely barbed without hyaline ending	short, finely barbed with hyaline ending	short, smooth, needle like
Seta *Z3*	short, smooth, needle like, not reaching the base of seta *Z4*	elongated, finely barbed without hyaline ending, reaching the base of seta *Z4*	short, finely barbed without hyaline ending, not reaching the base of seta *Z4*	short, smooth, needle-like, reaching the base of seta *Z4*
Seta *Z4*	short, smooth, needle like, not reaching the base of seta *S5*	elongated, finely barbed without hyaline ending, reaching the base of seta *S5*	elongated, finely barbed with hyaline ending, reaching the base of seta *S5*	elongated, finely barbed with hyaline ending, reaching the base of seta *S5*
Seta *S4*	not reaching the margin of opisthonotum	not reaching the margin of opisthonotum	not reaching the margin of opisthonotum	reaching the margin of opisthonotum
Setae *S1*, *R1–R2*	short, smooth, needle like	short, smooth, needle like	short, finely barbed without hyaline ending	short, smooth, needle like
Seta *JV5*	short, smooth, needle like	short, smooth, needle like	short, finely barbed without hyaline ending	elongated, smooth, needle like

Table 3. Altitude preferences of zerconid mites in Buharkent, Karacasu and Kuyucak counties (Aydın).

	0–100[1]	100–200	200–300	300–400	400–500	500–600	600–700	700–800	800–900	900–1000	1000–1100	1100–1200
P. demirsoyi	+			+	+			+	+			
P. yavuzi	+	+					+					
Z. colligans	+	+	+	+	+	+	+	+	+	+	+	+
Z. cretensis				+			+					
Z. denizliensis		+	+	+			+					
Z. huseyini			+	+	+				+			
***Z. karacasuensis* sp. nov.**					+							

[1]. Altitudes in m a.s.l.

Table 4. Habitat preferences of zerconid mites in Buharkent, Karacasu and Kuyucak counties (Aydın).

	P. demirsoyi	***P. yavuzi***	***Z. colligans***	***Z. cretensis***	***Z. denizliensis***	***Z. huseyini***	***Z. karacasuensis* sp. nov.**
***Alnus* sp.**			+				
***Astragalus* sp.**			+				
Castanea sativa			+				
***Cistus* sp.**	+		+	+	+	+	
***Citrus* sp.**							
***Crataegus* sp.**							
***Eucaliptus* sp.**			+				
***Euphorbia* sp.**							
Ficus carica	+		+				
***Genista* sp.**			+				
***Hedera* sp.**			+				
Juglans regia			+				
***Juniperus* sp.**			+	+	+		
Moss (unspecified)	+	+	+	+	+		
Nerium oleander			+				
Olea europaea		+	+	+		+	
Paliurus spina-christi			+	+	+		
Pinus brutia			+	+	+	+	+
P. nigra	+	+	+			+	
P. pinea			+				
***Pistacia* sp.**			+				
***Platanus* sp.**			+				
***Populus* sp.**			+				
***Prunus* sp.**			+				
Punica granatum			+				
***Pyrus* sp.**			+			+	
Quercus cerris			+	+			
Q. coccifera	+	+	+		+	+	
Q. ilex			+				
Q. infectoria		+	+		+		
Q. ithaburensis	+		+		+		
Q. trojana			+				
Rosa canina							
***Rubus* sp.**			+				
***Salix* sp.**			+				
Sytrax officinalis			+				
***Tamarix* sp.**			+				
***Ulmus* sp.**			+				
***Verbascum* sp.**							
Vitex agnus-castus			+				
Vitis vinifera			+				

Authors' contributions

Davut Rıza Bulut: Investigation, collection of specimens (lead), methodology (equal), writing- original draft (supporting), preservation. **Raşit Urhan:** Funding acquisition, methodology (equal), project administration, supervision (lead), collection of specimens (supporting), identification, illustration. **Mehmet Karaca:** Data curation, formal analysis, methodology (equal), supervision (supporting), writing - original draft (lead), writing - review & editing, collection of specimens (supporting).

Statement of ethics approval

Not applicable.

Funding

This study was financially supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK) with 118Z101 project number.

Conflict of interest

No potential conflict of interest was reported by the authors.

Acknowledgments

We would like to express our sincere gratitude to TÜBİTAK for their financial support to this study. Also, we are grateful to the "Republic of Turkey Ministry of Agriculture and Forestry General Directorate of Nature Conservation and National Parks" that provided the necessary permissions for field surveys. This paper was prepared based on first author's M.Sc. thesis and summary of this study was presented as oral presentation and published as an abstract at the 2nd Annual International Turkic World Congress on Science and Engineering (TURK-COSE 2020), which was held on 14-15 November 2020 at the L.N. Gumilyov Eurasian National University, Nur-Sultan (Kazakhstan).

REFERENCES

Duran, E.H. and Urhan, R. 2017. Zerconid mites (Acari: Zerconidae) in İstanbul with four new records for the Turkish fauna. Turkish Journal of Zoology, 41 (5): 931-939.

Johnston, D.E. and Moraza, M.L. 1991. The idiosomal adenotaxy and poroidotaxy of Zerconidae (Mesostigmata: Zerconina). In: Dusbábek, F. and Bukva, V. (Eds). Modern Acarology. Academia, Prague, Czech Republic, 2: 346-356.

Kaczmarek, S., Marquardt, T. and Jangazieva, B. 2020. *Zercon utemisovi* sp. n. – a new species of Zerconidae (Parasitiformes, Mesostigmata) from Kazakhstan with notes on *Zercon karadaghiensis* Balan, 1992. International Journal of Acarology, 46 (1): 52-59.
doi: 10.1080/01647954.2019.1704867

Karaca, M. 2015. Systematic studies on zerconid mites (Acari, Mesostigmata, Zerconidae) of Thrace Region (Turkey). PhD Dissertation. Department of Biology, Institute of Sciences, Pamukkale University, Denizli, Turkey, 288 pp. [In Turkish]

Karaca, M. 2021. Zerconid mites (Acari: Mesostigmata: Zerconidae) of the Kazdağı National Park, Turkey, with altitude and habitat preferences of the species. Biharean Biologist, 15(1): 6-13.

Karaca, M. and Urhan, R. 2015. The diversity of zerconid mites (Acari, Zerconidae) in Giresun province, with a new record for the Turkish fauna. Opuscula Zoologica Budapest, 46 (2): 199-209.
doi: 10.18348/opzool.2015.2.199

Karaca, M. and Urhan, R. 2016. Five new species of *Zercon* C. L. Koch, 1836 (Acari: Zerconidae) from northwestern Turkey. Zootaxa, 4127 (1): 31-59.
doi: 10.11646/zootaxa.4127.1.2

Karaca, M., Ordoukhanian, C., Ahadiyat, A. and Urhan, R. 2017. New occurrences of zerconid mites (Acari: Zerconidae) from Iran, with checklist and a key to the Iranian species. International Journal of Acarology, 43 (8): 603-611.
doi: 10.1080/01647954.2017.1373857

Keçeci, B., Urhan, R. and Karaca, M. 2021. Mites of the genus *Prozercon* (Acari, Zerconidae) in Dilek Peninsula-Büyük Menderes Delta National Park (Turkey), with desription of a new species. Acarological Studies, 3 (1): 37-42.
doi: 10.47121/acarolstud.837286

Lindquist, E.E. and Evans, G.O. 1965. Taxonomic concepts in the Ascidae, with a modified setal nomenclature for the idiosoma of the Gamasina (Acarina: Mesostigmata). Memoirs of the Entomological Society of Canada, 47: 1-64.

Lindquist, E.E. and Moraza, M.L. 1998. Observations on homologies of idiosomal setae in Zerconidae (Acari: Mesostigmata), with modified notation for some posterior body setae. Acarologia, 39: 203-226.

Marchenko, I.I. 2018. A new species of *Halozercon* (Acari: Zerconidae) from South Siberia (Russia) with additional information on *Halozercon karacholana* Wiśniewski *et al*., 1992. Zootaxa, 4394 (3): 347-370.
doi: 10.11646/zootaxa.4394.3.2

Marchenko, I.I. 2019. Three new species of *Halozercon* (Acari: Mesostigmata: Zerconidae) from Altai Mountains in South Siberia (Russia). Zootaxa, 4568 (3): 401-434.
doi: 10.11646/zootaxa.4568.3.1

Marchenko, I.I. 2021. Four new species of *Halozercon* (Acari: Mesostigmata: Zerconidae) from South Siberia Mountains (Russia) with a key to all known species. Zootaxa, 4941 (2): 151-185.
doi: 10.11646/zootaxa.4941.2.1

Moghimi, F., Ahadiyat, A., Karaca, M., Kiadaliri, H. and Urhan, R. 2021. Description of *Prozercon caspiansis* sp. nov. (Acari: Mesostigmata: Zerconidae) from Iran, with descriptions of male and larva of *P. dominiaki* Błaszak, 1979. Systematic and Applied Acarology, in press.

Ujvári, Z. 2008. Zerconid mites (Acari: Mesostigmata: Zerconidae) from Crete, Greece, with description of two new species. Opuscula Zoologica Budapest, 39: 99-108.

Ujvári, Z. 2011. Six new species of *Prozercon* Sellnick, 1943 (Acari, Mesostigmata, Zerconidae) from Greece, with remarks on the genus. Zootaxa, 2785: 1-31.
doi: 10.11646/zootaxa.2785.1.1

Urhan, R. 1998. Some new species of the family Zerconidae (Acari: Mesostigmata) from Turkey. Journal of Natural History, 32 (4): 533-543.
doi: 10.1080/00222939800770291

Urhan, R. 2008. Two new species of *Zercon* (Acari: Zerconidae) from Turkey. Biologia, 63 (3): 395-401.
doi: 10.2478/s11756-008-0057-4

Urhan, R. 2011. Two new species of zerconid mites (Acari, Mesostigmata) from Honaz Mountain National Park (Turkey). Turkish Journal of Zoology, 35 (2): 163-174.

Urhan, R. and Ayyıldız, N. 1996. Two new species of genus *Prozercon* Sellnick from Turkey (Acari: Zerconidae). Genus, 7 (3): 569-580.

Urhan, R. and Duran, E.H. 2019. Zerconid mites (Acari, Zerconidae) in Inner Aegean Region, with a new record for the Turkish fauna. Zootaxa, 4568 (2): 323-336.
doi: 10.11646/zootaxa.4568.2.7

Urhan, R. and Karaca, M. 2019. A new species of the genus *Zercon* (Acari, Mesostigmata, Zerconidae) from Kastamonu, Turkey. Acarological Studies, 1 (1): 3-10.

Urhan, R. and Karaca, M. 2020. First finding of *Prozercon bulgariensis* Ujvári, 2013 (Acari, Zerconidae) from Turkey. International Journal of Scientific and Technological Research, 6 (7): 91-97.
doi: 10.7176/JSTR/6-07-10

Urhan, R., Duran, E.H. and Karaca, M. 2020a. Three new species of *Zercon* C. L. Koch, 1836 (Acari: Zerconidae) from Coastal Aegean Section of Turkey. Journal of Natural History, 54 (35-36): 2323-2341.
doi: 10.1080/00222933.2020.1844328

Urhan, R., Karaca, M. and Duran, E.H. 2020b. Description of *Prozercon miraci* sp. nov. (Acari: Mesostigmata: Zerconidae) from Coastal Aegean Section in Turkey, with a key to the Turkish species. Acarological Studies, 2 (1): 18-23.

Edited by: Salih Doğan

Reviewed by: Three anonymous referees

Citation: Bulut, D.R., Urhan, R. and Karaca, M. 2021. Zerconid mites (Acari, Zerconidae) from eastern parts of Aydın Province (Turkey), with description of *Zercon karacasuensis* **sp. nov**. Acarological Studies, 3 (2): 73-81.

Acarological Studies
Vol 3 (2): 82-88
doi: 10.47121/acarolstud.915447

RESEARCH ARTICLE

First record of the genus *Leonardiella* in China, with the description of the *Leonardiella pappi* sp. nov. from Hong Kong (Acari: Mesostigmata: Trachyuropodidae)

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Received: 14 April 2021 Accepted: 4 June 2021 Available online: 31 July 2021

ASBTRACT: *Leonardiella pappi* **sp. nov.** is described based on six females and two males collected from soil under *Machilus* sp., in Tai Po Kau Nature Reserve, in Hong Kong. The new species differs from the other species from the congeners in the shape of dorsal and ventral setae and dorsal and ventral sculptural pattern. A new diagnosis to the genus *Leonardiella* and a new catalog to all known species are given.

Keywords: Mite, new species, South-East Asia.
Zoobank: http://zoobank.org/B02CF959-16EB-47B3-855A-2223DA11D129

INTRODUCTION

The family Trachyuropodidae (Acari: Mesostigmata) is one of the well-recognized groups of the suborder Uropodina. Their body is usually large, strongly sclerotized, and covered by depressions and ridges in dorsal and ventral sides. Internal malae on gnathosoma are divided into numerous, apically pilose or smooth branches (like a mustache), characteristic T-shaped setae with a short stem and long cross-bar can be observed on the body of majority of the known species (Kontschán, 2007; Lindquist et al., 2009).

The genus *Leonardiella* Berlese, 1904 is a very characteristic group within this family by having a triangular or pentagular shape of the idiosoma and the presence of a pair of ventral depression posterior to coxae IV (Kontschán, 2011b). The genus contains thirteen species described from the Holactis and tropical realms (Kontschán, 2011a).

During the last visit of the author to Geneva's Natural History Museum some soil samples from Hong Kong were investigated. One of the samples contained several specimens of a new *Leonardiella* species described herein as first report of this genus from Hong Kong and from China.

MATERIALS AND METHODS

The female and male specimens were cleared in lactic acid for a week and later, they were investigated on half-covered deep slides with a Leica 1000 microscope. Drawings were made with the aid of a drawing tube on a Leica 1000 microscope. All specimens are stored in 75% ethanol and deposited in the Natural History Museum in Geneva. Abbreviation: *h* = hypostomal setae. All measurements and the scale bars in the figures are given in micrometres (μm).

RESULTS

Leonardiella Berlese, 1904

Trachyuropoda (*Leonardiella*) Berlese, 1904: 367.

Diagnosis. Shape of idiosoma triangular or pentagonal. Dorsal shield with lateral decision at level of coxae IV. Dorsal shield with strongly sclerotized straight, undulate or ring-like grooves. One pair of transversal furrows bordered by setae situated posterior to coxae IV on ventral idiosoma. Genital shield of female scuti- or linguliform. Leg I with claws.

Type species: *Uropoda canestriniana* Berlese, 1891: 4, by original designation.

List of the known *Leonardiella* species

Leonardiella athiasae (Hirschmann, 1975)
Trachyuropoda athiasae Hirschmann, 1975: 103.

Occurrence and habitat: Chad, from gallery forest (Hirschmann, 1975).

Leonardiella canestriniana (Berlese, 1891)
Uropoda canestriniana Berlese, 1891: (without page number).

Occurrences and habitat: Italia, French, Great-Britannia, from nests of ants (Wiśniewski and Hirschmann, 1993).

Leonardiella cistulata (Hirschmann, 1975)
Trachyuropoda cistulata Hirschmann, 1975: 103-104.

Occurrence and habitat: Sri Lanka, without information about the habitat (Hirschmann, 1975).

Leonardiella constricta (Banks, 1916)
Trachyuropoda constricta Banks, 1916: 231.

Occurrence and habitat: Australia, together with ants (Wiśniewski and Hirschmann, 1993).

Leonardiella cubana Kontschán, 2011
Leonardiella cubana Kontschán, 2011b: 211-213.

Occurrence and habitat: Cuba, from leaf litter of a coffee plantation (Kontschán, 2011b).

Leonardiella harteni Kontschán, 2011
Leonardiella harteni Kontschán, 2011a: 29-31.

Occurrence and habitat: United Arab Emirates, from leaf litter of a garden (Kontschán, 2011a).

Leonardiella koreana Kontschán, Park, Yoon and Choi, 2012
Leonardiella koreana Kontschán, Park, Yoon and Choi, 2012: 173-175.

Occurrence and habitat: North-Korea, from soil (Kontschán et al., 2012).

Leonardiella machadoi Kontschán, 2006
Leonardiella machadoi Kontschán, 2006: 4-7.

Occurrence and habitat: Angola, without information about the habitat (Kontschán, 2006).

Leonardiella matsuurai (Hiramatsu, 1980)
Trachyuropoda matsuurai Hiramatsu, 1980: 25.

Occurrence and habitat: Japan, from forest soil (Hiramatsu, 1980).

Leonardiella riccardiana (Leonardi, 1895)
Uropoda riccardiana Leonardi, 1895: 318.

Occurrence and habitat: Austria, Romania, Czech Republic, Slovakia, Italia, Hungary, Iran, from nests of ants (Wiśniewski and Hirschmann, 1993, Arjomandi and Kazemi, 2014).

Leonardiella septentrionalis (Berlese, 1904)
Trachyuropoda (*Leonardiella*) *canestriniana* (Berlese, 1891) var. *septentrionalis* Berlese, 1904: 369.

Occurence and habitat: Russia, from nests of ants (Wiśniewski and Hirschmann, 1993).

Leonardiella similiathiasae (Hiramatsu, 1979)
Trachyuropoda similiathiasae Hiramatsu, 1979: 106.

Occurrence and habitat: Japan, from forest soil (Hiramatsu, 1979).

Leonardiella whitkombi (Hirschmann, 1975)
Trachyuropoda whitkombi Hirschmann, 1975: 103.

Occurrence and habitat: Brazil, from nests of ants (Hirschmann, 1975).

Leonardiella pappi **sp. nov.**

Zoobank: http://zoobank.org/02B52A0E-478F-414F-AC04-D3AEF6F0609F

(Figures 1-10)

Diagnosis. Dorsal shield with one pair of U-shaped, strongly sclerotized lateral incision at level of coxae IV on dorsal shield, and a strongly sclerotized ring-like groove situated between two lateral incisions. Dorsal shield covered by oval pits but reticular sculptural pattern situated anterior and posterior to ring-like groove. Female genital shield linguliform covered by oval pits. One pair of deep and lateral furrow with smooth and needle-like setae on their margins situated posterior to coxae IV on ventral idiosoma.

Material examined. *Holotype.* Female. Hong Kong, New Territories, Tai Po Kau Nature Reserve, forest along "Tai Po Kau Trail", soil sample under *Machilus* sp., 160 m; 14.III.2000; leg. B. Hauser (Berlese extraction in Geneva). *Paratypes.* Five females and two males, collection data as in holotype.

Description

Female (n=6).

Description. Length of idiosoma 650–690, width 380–440. Shape pentagonal, posterior margin rounded, colour reddish brown.

Dorsal idiosoma (Fig. 1). Marginal and dorsal shields completely separated. Majority of dorsal setae T-shaped with a short stem and long cross-bar (ca 14–17), some long, wide and marginally pilose setae (ca 23–33 long) placed around lateral incision of dorsal shield. One pair of U-shaped, strongly sclerotized, 71–80 long and 44–52 wide lateral incision situated at level of coxae IV on dorsal shield. A strongly sclerotized, 43–47 long and 78–85 wide ring-like groove situated between two lateral incisions. Dorsal shield covered by oval pits (ca 4–5×3–6), but reticular sculptural pattern situated anterior and posterior to ring-like groove. Two pairs of pores placed posterior to lateral incisions. Marginal shield wide, without sculptural pattern and setation.

Ventral idiosoma (Fig. 2). Sternal shield covered by some oval pits (ca 2–4×2–5) close to apical margin, other parts smooth. Ten pairs of sternal setae T-shaped, their crossbar ca 10–11 long. Seven sternal setae situated close to anterior and lateral margin of genital opening, three pairs between coxae III and IV. One pair of deep and lateral furrow (46–50 long and 110–120 wide) with smooth and needle-like (ca 23–27 long) setae on their margins situated posterior to coxae IV. Surface of ventral shield smooth. First pair of ventral setae wide and pilose (ca 27–30 long), other ventral setae T-shaped, their crossbar ca 20–23 long. Setae around anal opening similar in shape to ventral setae, but shorter (their crossbar ca 10–13).

One pair of large (85–90×80–90) rounded holes situated at caudal edges on ventral idiosoma, surface of holes covered by reticulate sculptural pattern. Anal opening small, ca 15–18 long and ca 4–5 wide. One pair of large pores situated anterior to anal opening and one pair of small pores lateral to anal opening. Peritremes (Fig. 3) without poststigmatid part and with a long and hairpin-like prestigmatid part. Stigmata situated between coxae II and III. Genital shield wide, linguliform (206–210 long and 105–109 wide), without apical process. Surface of genital shield covered by oval pits (ca 4–6×3–5).

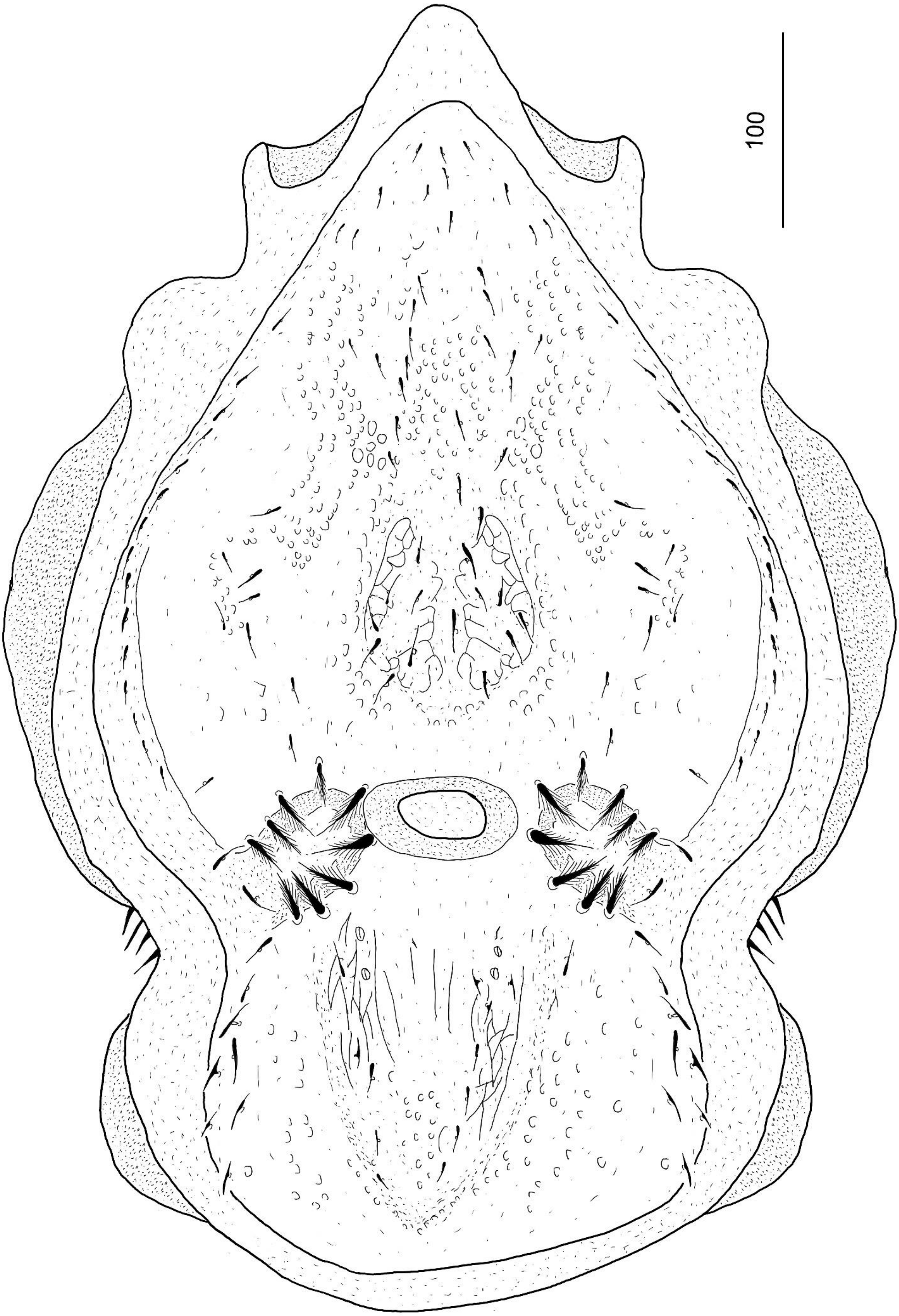


Figure 1. Dorsal view of *Leonardiella pappi* **sp. nov.** female, holotype.

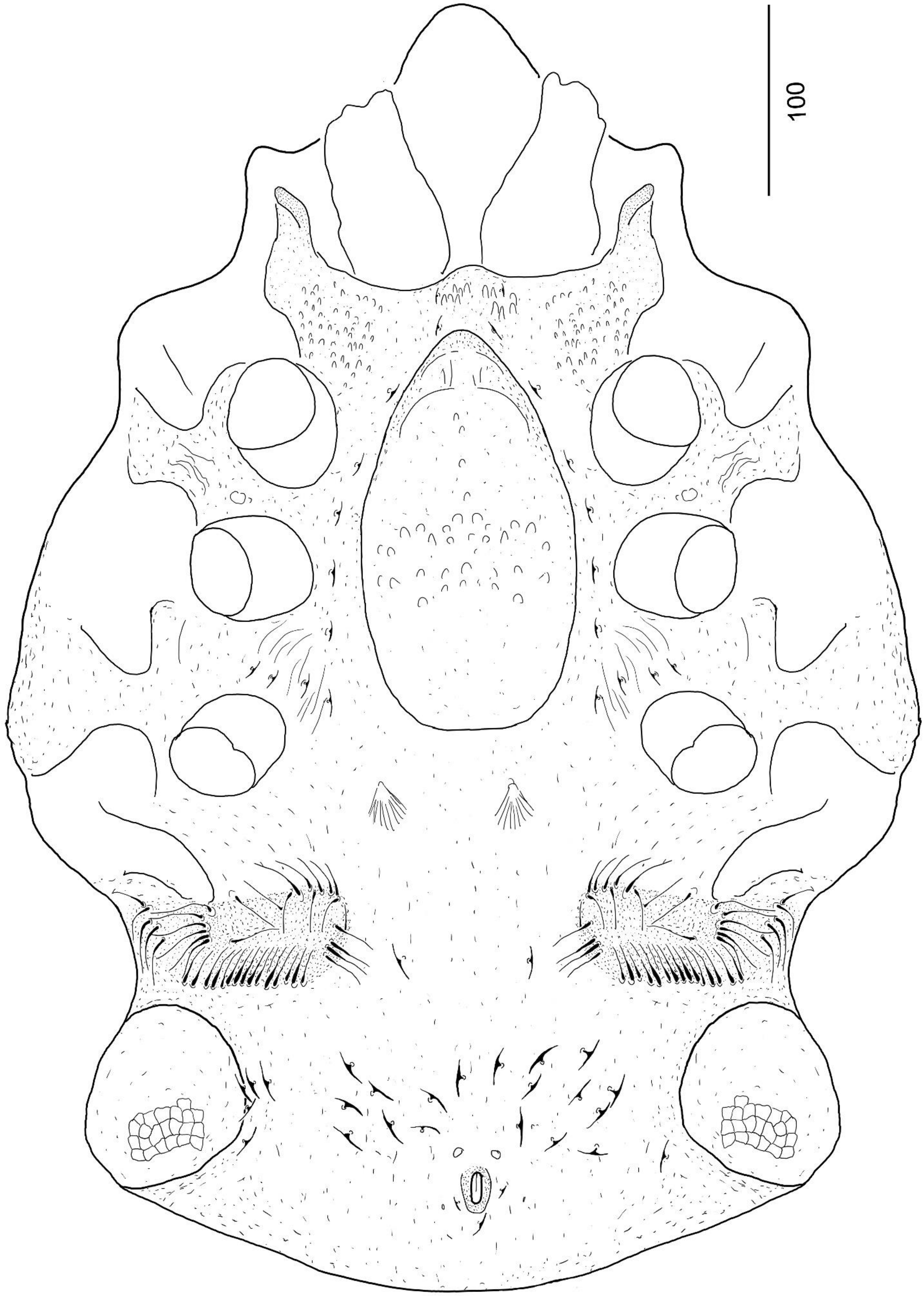
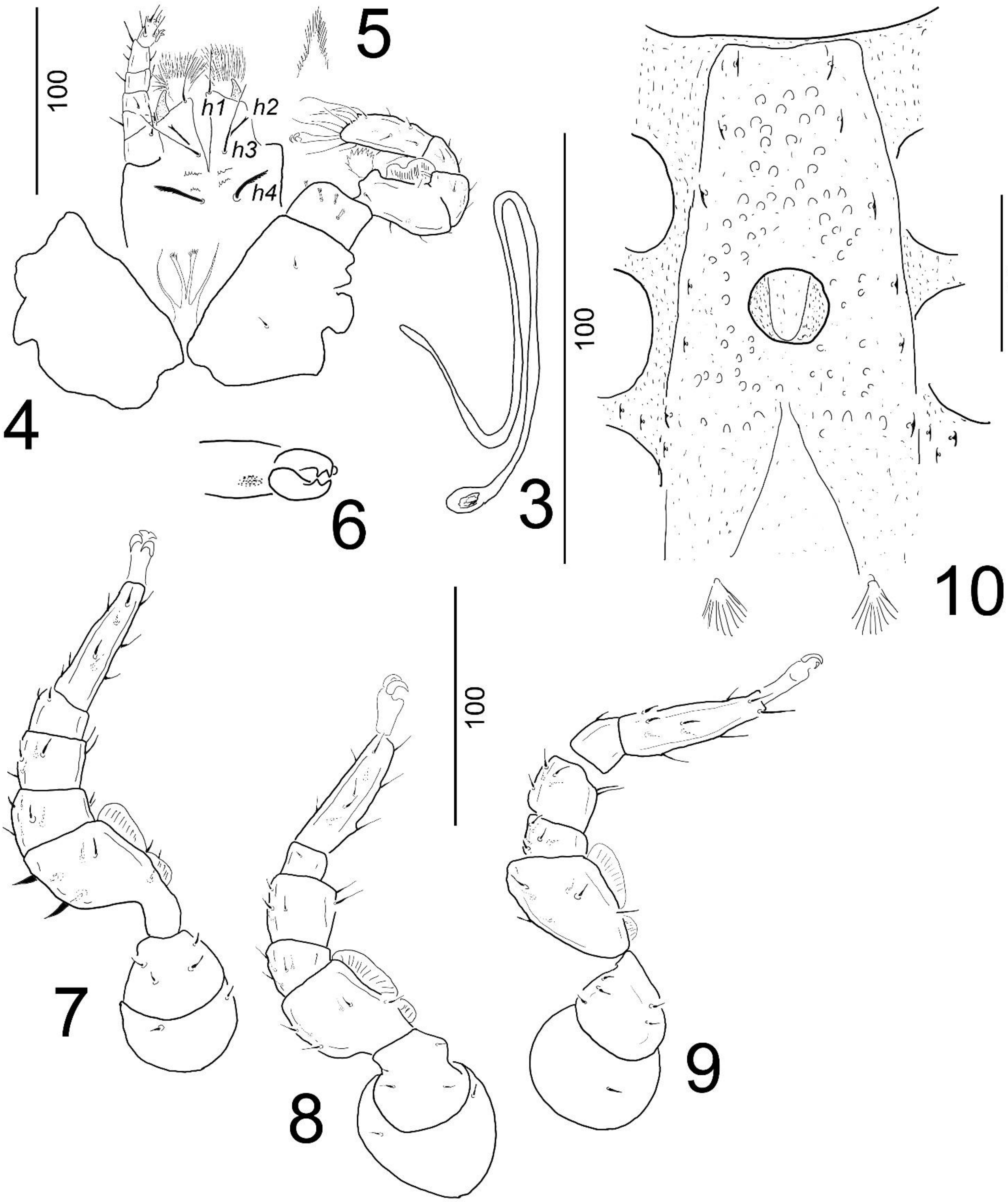


Figure 2. Ventral view of *Leonardiella pappi* **sp. nov.** female, holotype.



Figures 3-10. *Leonardiella pappi* **sp. nov.** female, holotype. 3. Peritreme. 4. Gnathosoma, tritosternum, palp and leg I in ventral view. 5. Apical part of epistome. 6. Lateral view of chelicera. 7. Leg II in ventral view. 8. Leg III in ventral view. 9. Leg IV in ventral view. 10. Intercoxal area of male paratype.

Pedofossae deep, their surface smooth, separate furrows for tarsi IV present. Base of tritosternum narrow, vase-like, tritosternal laciniae divided into two smooth lateral and two apically pilose central branches (Fig. 4).

Gnathosoma (Fig. 4). Corniculi horn-like, internal malae longer than corniculi and divided into numerous smooth branches. Hypostomal setae *h1* situated on apical margin of gnathosoma, ca 19–23 long, smooth and needle-like, *h2* apically bifurcated and ca 15-17 long, *h3* very long (ca 37–40) smooth and needle-like, *h4* ca 17–18 long and marginally pilose. Two rows of denticles between *h3* and *h4* present. Palp setae smooth and needle-like. Episome apically pilose (Fig. 5). Fixed digit of chelicerae as long as movable digit with one-one central tooth on both digits. Internal sclerotized nodes present (Fig. 6).

Legs (Figs 7-9). Majority of setae on legs smooth and needle-like, except four pilose setae trochanter of leg I and one large serrate ventral seta on femur of leg I. Claws on first leg smaller than on other legs. All femora bearing flap-like ventral processes. Leg I 230–240, leg II 215–220, leg III 205–210, leg IV 230–240.

Male (n=2).

Length of idiosoma 650–690, width 380–440.

Dorsal idiosoma. Ornamentation and chaetotaxy of dorsal shield as for female.

Ventral idiosoma (Fig. 10). Sternal shield with nine pairs of T-shaped setae, their crossbar ca 12–15 long. Sternal shield covered by oval pits (ca 4–5×4–5). Genital shield oval (45–47×50–52) and situated between coxae II. Other characters as in female.

Larva and nymphs. Unknown.

Etymology. The new species is dedicated to the excellent Hungarian fly specialist and zootaxonomist, Prof. Dr. László Papp (1946-2021), who passed away this year.

Remark. Till today only four species are reported from East- and South-East Asia, namely *Leonardiella cistulata*, *L. koreana*, *L. matsuurai* and *L. similiathiasae.*. The new species differs from these four ones in the presence of the strongly sclerotized ring-like dorsal groove, which is absent in these four species. One pair of U-shaped, strongly sclerotized lateral incision at the level of coxae IV on dorsal shield are visible only on the new species and on the *L. similiathiasae,* but the reticulate sculptural pattern on dorsal shield absent on *L. similiathiasae* (this character is visible on the new species) and setae around horizontal furrow on ventral idiosoma are pilose on *L. similiathiasae*, contrary they are smooth on the new species.

Statement of ethics approval

Not applicable.

Funding

There is no fund for the present study.

Conflict of interest

No potential conflict of interest was reported by the author.

Acknowledgement

I am very grateful to Dr. Peter Schwendinger (Natural History Museum of Geneva) for his kind hospitality during my stay in Geneva.

REFERENCES

Arjomandi, E. and Kazemi, S. 2014. Edaphic mesostigmatic mites (Acari: Mesostigmata) fauna in parks and landscapes of Kerman City. The Third Insect Pest Management Conference, Kerman, Shahid Bahonar University of Kerman, Kerman, Iran, 243-251.

Banks, N. 1916. Acarians from Australian and Tasmanian ants and ant nests. Transactions, Proceedings and Report, Royal Society of South Australia, 40: 224-240.

Berlese, A. 1891. Acari, Myriopoda et Scorpiones hucusque in Italia reperta, 58, 18 text pages + plates 1-10. Reprint by Junk, The Hague, 1979. [In Italian]

Berlese, A. 1904. Illustrazione iconografica degli Acari mirmecofili. Redia, 1: 299-474. [In Italian]

Hiramatsu, N. 1979. Gangsystematik der Parasitiformes. Teil 332. Teilgang, Stadium von 2 neuen *Trachyuropoda*-Arten aus Japan (Trachyuropodini, Oplitinae). Acarologie, Schriftenreihe für Vergleichende Milbenkunde, 25: 105-107. [In German]

Hiramatsu, N. 1980. Gangsystematik der Parasitiformes. Teil 359. Stadium einer neuen *Trachyuropoda*-Art der *Canestriniana*-Gruppe aus Japan (Trachyuropodini, Oplitinae). Acarologie, Schriftenreihe für Vergleichende Milbenkunde, 27: 25-26. [In German]

Hirschmann, W. 1975. Gangsystematik der Parasitiformes. Teil 214. Stadien von 8 neuen *Trachyuropoda*-Arten (Trachyuropodini, Oplitinae). Acarologie, Schriftenreihe für Vergleichende Milbenkunde, 21: 101-105. [In German]

Kontschán, J. 2006. Uropodina (Acari: Mesostigmata) species from Angola. Acta Zoologica Academiae Scientiarum Hungaricae, 52 (1): 1-20.

Kontschán, J. 2007. Trachyuropodid mites of the Carpathian Basin (Acari: Uropodina: Trachyuropodidae). Opuscula Zoologica Budapest, 36: 43-56.

Kontschán, J. 2011a. Order Mesostigmata, family Trachyuropodidae. In: Arthropod fauna of the UAE Volume 4. van Harten, A. (Ed.). Dar Al Ummah Printing, Publishing and Advertising, Abu Dhabi, UAE, 29-32.

Kontschán, J. 2011b. Six new species of family Trachyuropodidae from the Neotropical region (Acari: Mesostigmata: Uropodina). Studies on Neotropical Fauna and Environment, 46 (3): 211-223. doi: 10.1080/01650521.2011.618034

Kontschán, J., Park, S.J., Yoon, T.J. and Choi, W.Y. 2012. New Uropodina records and species from the Korean Peninsula (Acari: Mesostigmata). Opuscula Zoologica Budapest, 43 (2): 169-177.

Leonardi, G. 1895. Intorno ad alcune nuove specie di Acari italiani ecc. Atti della Societá Veneto Trentina di Scienze Naturali, 2: 318. [In Italian]

Lindquist, E.E., Krantz, G.W. and Walter, D.E. 2009 Order Mesostigmata. In: A manual of acarology. 3rd Edition. Krantz, G.W. and Walter, D.E. (Eds). Texas University Press, Lubbock, Texas, USA, 124-232.

Wiśniewski, J. and Hirschmann, W. 1993. Gangsystematik der Parasitiformes. Teil 548. Katalog der Ganggattungen, Untergattungen, Gruppen und Arten der Uropodiden der Erde (Taxonomie, Literatur, Grösse, Verbreitung, Vorkommen). Acarologie. Schriftenreihe für Vergleichende Milbenkunde, 40: 1-220. [In German]

Edited by: Raşit Urhan
Reviewed by: Two anonymous referees

Citation: Kontschán, J. 2021. First record of the genus *Leonardiella* in China, with the description of the *Leonardiella pappi* sp. nov. from Hong Kong (Acari: Mesostigmata: Trachyuropodidae). Acarological Studies, 3 (2): 82-88.

Acarological Studies
Vol 3 (2): 89-95
doi: 10.47121/acarolstud.907114

RESEARCH ARTICLE

Occurrence of *Ophionyssus natricis* (Acari: Macronyssidae) on the captive corn snake, *Pantherophis guttatus*, (Squamata: Colubridae) in Turkey

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Received: 31 March 2021 Accepted: 20 May 2021 Available online: 31 July 2021

ABSTRACT: Exotic snakes may harbour numerous parasites and play an important role in the spreading of parasites. *Ophionyssus natricis* (Gervais) (Acari: Macronyssidae) has been found in natural conditions on a wide variety of snakes in Africa, but this mite has been distributed by exotic pet trade in various parts of the world. In the present study, *O. natricis* was reported on the captive corn snake, *Pantherophis guttatus* (L.) (Squamata: Colubridae), in Turkey, for the first time. Male and protonymph stage of *O. natricis* were also first time reported in Turkey. In addition, some setal variations in the pygidial shield of protonymphs were documented.

Keywords: Infestation, parasitic mites, pest animal, Reptilia.
Zoobank: http://zoobank.org/CC0C89B0-3B83-4FA1-A373-79519ED9CE66

INTRODUCTION

Both legal and illegal trade of numerous exotic species is constantly increasing throughout the world. This can be a serious global problem in biodiversity conservation and affecting entire ecosystems out of balance (Petrossian et al., 2016; Setiyani and Ahmadi, 2020). Also, the trade of exotic pets is responsible for the invasion of non-native species that are harming native species and ecosystems around the world. Reptiles have a big percentage in the exotic pet trade and over 35% of reptile species are traded on numerous online platforms (Marshall et al., 2020). Exotic snakes may harbor numerous ecto- and endoparasite and play an important role in the spreading of parasites (Pérez, 2009; Mendoza-Roldan et al., 2020).

The genus *Ophionyssus* Mégnin (Mesostigmata: Macronyssidae) is represented currently by 17 species in the world (Moraza et al., 2009). One of them, *Ophionyssus natricis* (Gervais) is naturally lizard and snake hosts in Africa (Till, 1957; Evans and Till, 1966), but it has been distributed by pet trade in various parts of the world (Miranda et al. 2017; Norval et al., 2020). Individual herpetocultures, especially, have a big risk due to the ability to spread fast of this mite from a single infested animal to others.

Ophionyssus natricis can cause several disorders like anemia, dehydration, and dermatitis (Wozniak and DeNardo, 2000). Several blood-borne infectious diseases in reptiles have been related to this mite and it is a mechanical vector of *Aeromonas hydrophila*, the causative agent of hemorrhagic disease in reptiles (Mitchell, 2007; Mendoza-Roldan et al., 2020). In addition, the presence of *Anaplasma* sp. and *Rickettsia* sp. in *O. natricis* has been documented (Reeves et al., 2006; Mendoza-Roldan et al., 2021). This mesostigmatid mite may also accidentally infest humans and even also can cause severe mite-associated dermatitis (Schultz, 1975; Amanatfard et al., 2014).

In this study, the presence of *O. natricis* on the captive corn snake, *Pantherophis guttatus* (L.), additionally male and protonymph stage of *O. natricis* were first time reported in Turkey. Besides, setal variations in the pygidial shield of protonymphs were documented.

MATERIALS AND METHODS

Mites were collected from the body surface of a captive corn snake by its owner in Tokat province and sent to the Parasitology Laboratory, Department of Biology, Tokat Gaziosmanpaşa University, Tokat, Turkey for species identification. Mites were cleared in 70% lactic acid and mounted on microscopic slides in the Hoyer medium. Mites were examined and photographed with microscopes (Olympus CX41, Leica DM4000), and they were identified based on keys and descriptions given by Evans and Till (1966) and Moraza et al. (2009). All specimens were deposited in the Parasitological Collection of the Parasitology Laboratory, Department of Biology, Tokat Gaziosmanpaşa University, Tokat, Turkey.

RESULTS

A total of 134 mite specimens were collected from a captive female corn snake (Fig. 1). All mites were identified as *O. natricis* (115 females 1 male and 18 protonymphs). The female of *O. natricis* can be separated by the following combination of characters: (1) dorsal shield divided into a large anterior and minute pygidial shields (Fig. 2A), (2) podonotal shield with 10 pairs of setae, (3) two pairs of minute mesonotal scutellae, (4) pygidial shield without setae, (5) sternal shield ratio width/length: 2.5 (Fig. 2B), (6) anal shield pear-shaped with three setae (Fig. 2C), (7) peritreme extending to posterior margin of coxa II (Fig. 2D), (8) tritosternum with hyaline membrane; laciniae two times nearly longer than the base (Fig. 2E). The male of *O. natricis* can be separated by the following combination of characters: (1) holoventral shield absent, (2) ventral spur on femur III absent, (3) sternogenital shield with

Figure 1. The corn snake, *Pantherophis guttatus* (L.), female.

2 pairs of setae (*st1*, *st2*), (4) femora III and IV without modified ventral setae, (5) dorsal shield with 17 pairs of setae. Unfortunately, the male specimen could not be photographed because the specimen folded during the mounting process. The protonymph of *O. natricis* can be separated by the following combination of characters: (1) podonotal shield bearing 11 pairs of setae (Fig. 3A); (2) two pairs of minute mesonotal scutellae; (3) pygidial shield with 3 pairs of setae (*J4*, *Z4*, *Z5*) (Fig. 3B), (4) setae *Z5* three times longer than of *J4*, (5) setae *Z4* two times longer than of *J4*, (6) setae *z2* on podonotal shield, (7) anal shield pear-shaped with three setae.

DISCUSSION

Acariasis, an infestation of ticks and mites, is a great and nuisance problem for both wild and captive reptiles. When ticks and mites were detected on a snake, these parasites should be promptly eradicated. Several tick species and more than 250 mite species were naturally parasitized on reptiles (Fitzgerald and Vera, 2006; Guglielmone et al., 2014). The ticks can be manually removed from snakes using tweezers or forceps; however, other parasitic mites should be treated with several chemical agents by veterinarians. To remove mites from the reptiles, topical ivermectin (0.2 mg/kg) was recommended three times at two-week intervals (Wozniak and DeNardo, 2000). Permethrin spray (0.5%) was advised to elimination of mites from the cage (Mitchell, 2007). After permethrin application, we recommended that the peat should be changed and the cage should be washed with lukewarm water to remove possible toxic effects of permethrin.

Acariasis cases in both wild and captive reptiles are rarely reported in Turkey. Three tick species (Ixodida, Ixodidae), *Haemaphysalis sulcata* Canestrini and Fanzago, *Hyalomma aegyptium* (L.), *Ixodes ricinus* (L.), infesting some wild reptiles have been only documented in Turkey (Bursali et al., 2012; Keskin et al., 2013), whereas several chigger mite species were reported from some wild reptiles (Kepka, 1962, 1966; Kalúz, 2011; Stekolnikov and Daniel, 2012). In addition, *Hirstiella* sp. (Prostigmata, Pterygosomatidae), was reported from green iguanas (*Iguana iguana* (L.)) in Turkey (Gazyağcı et al., 2011; Altınok-Yipel, 2014).

In the present study, *O. natricis* on the captive corn snake, *P. guttatus,* were reported in Turkey for the first time. In addition, male and protonymph stage of *O. natricis* were first time reported in Turkey. The corn snake, *P. guttatus*, is a non-venomous and unaggressive snake species native to the south-eastern United States. Many of its bites occur when the snake is intentionally molested. The corn snakes are highly adaptive, living in the forest, semi-desert, and grassland habitats, and even populating urban areas. They have also widely different color morphs such as orangish-brown with black-bordered orange, red, or brownish blotches. Therefore, *P. guttatus* is a very popular pet and has been distributed to many parts of the world for the pet trade (Fisher and Csurhes, 2009; Fonseca et al., 2014; McFadden et al., 2017; Alves et al., 2019; Kubiak, 2020).

Ophionyssus natricis is one of the most problematic parasites infested captive snakes and has been reported from numerous native and captive reptiles and lizards in many countries of the world (Yunker, 1956; Till, 1957; Miranda et al., 2017; Norval et al., 2020). However, we have

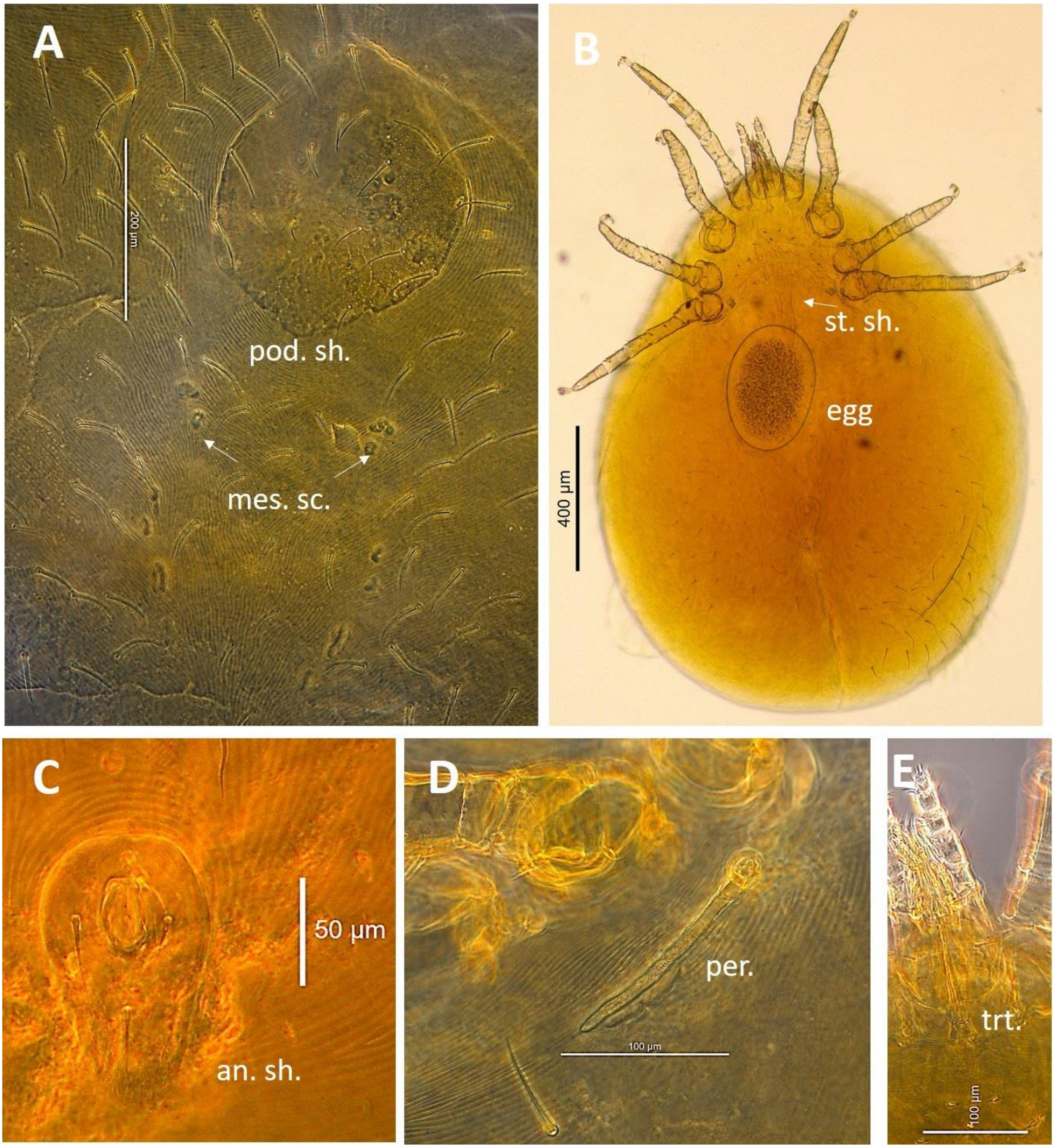

Figure 2. *Ophionyssus natricis* (female) **A.** Podonotal shield (pod. sh.) and mesonotal scutellae (mes. sc.), **B.** Sternal shield (st. sh.), **C.** Anal shield (an. sh.), **D.** Peritreme (per.), **E.** Tritosternum (trt).

currently very limited information on the presence and the prevalence of *O. natricis* infestations on the native and captive snakes and lizards in Turkey. To date, there are only two reports on the presence of *O. natricis* from captive snakes. The first report of *O. natricis* in Turkey was given by Kurtdede et al., (2009). They collected more than a hundred female specimens of *O. natricis* from *Boa constrictor* L. Afterward, Dik (2012) documented presence of *O. natricis* in a captive dice snake, *Natrix tessellata* (Laurenti) based on six female specimens. Apart from these studies, a Ph.D. dissertation about the ectoparasitic mites on some wild lizards of Turkey was compiled by Jabbarpour (2016), and three *Ophionyssus* species (*Ophionyssus saurarum* (Oudemans), *O. natricis*, and *Ophionyssus* sp.) were reported in this study; but, this dissertation, unfortunately, has not been published in a journal, yet.

On the other hand, the patterns of chaetotaxy are typically considered constant within a species, but intraspecific variation in chaetotaxy have been reported in some mites (Głowska and Skoracki, 2009; Seniczak et al., 2012; Bingül et al., 2017, 2018). The variations may lead to some

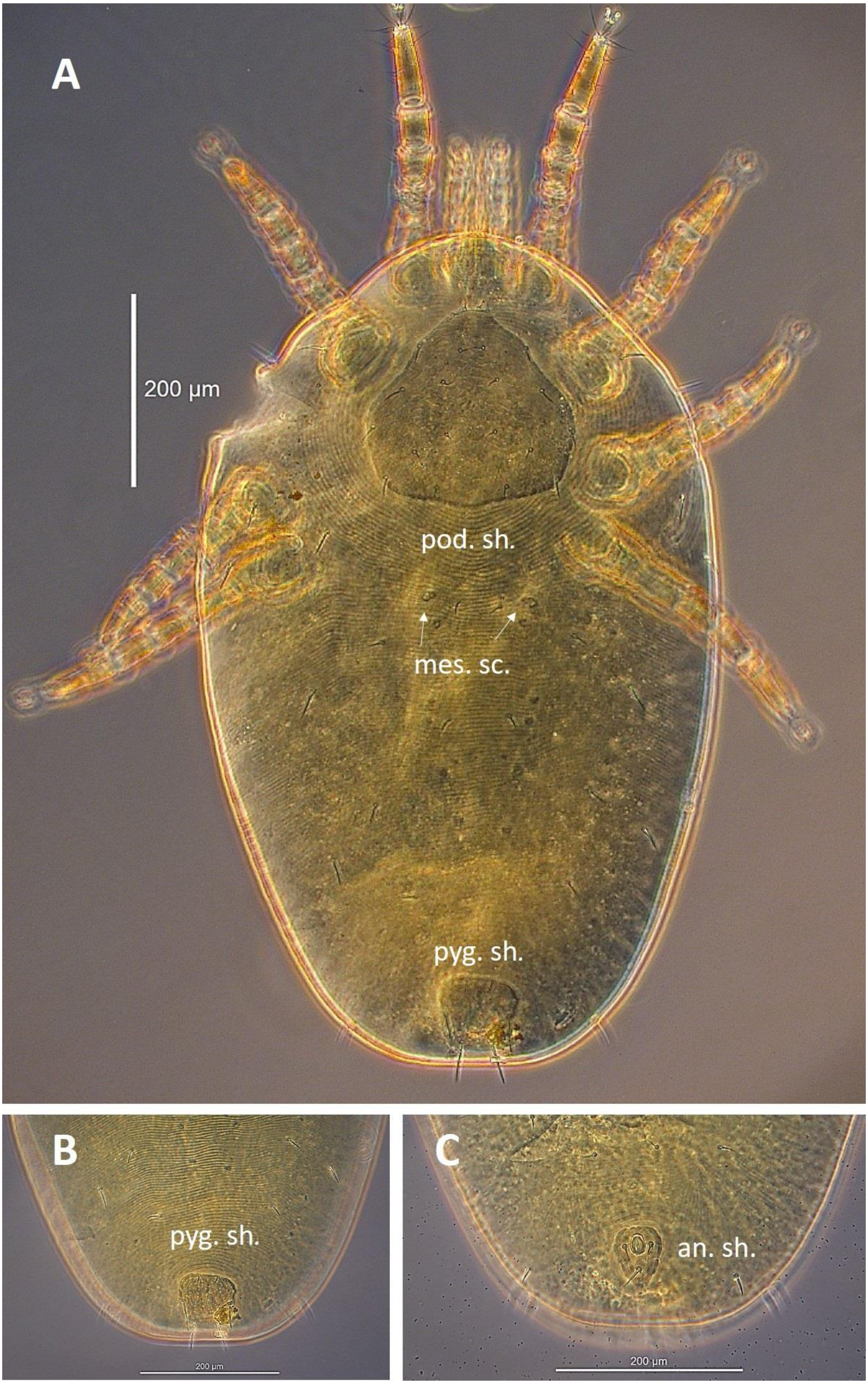

Figure 3. *Ophionyssus natricis* (protonymph) **A.** Podonotal shield (pod. sh.) and mesonotal scutellae (mes. sc.), **B.** Pygidial shield (pyg. sh.), **C.** Anal shield (an. sh.).

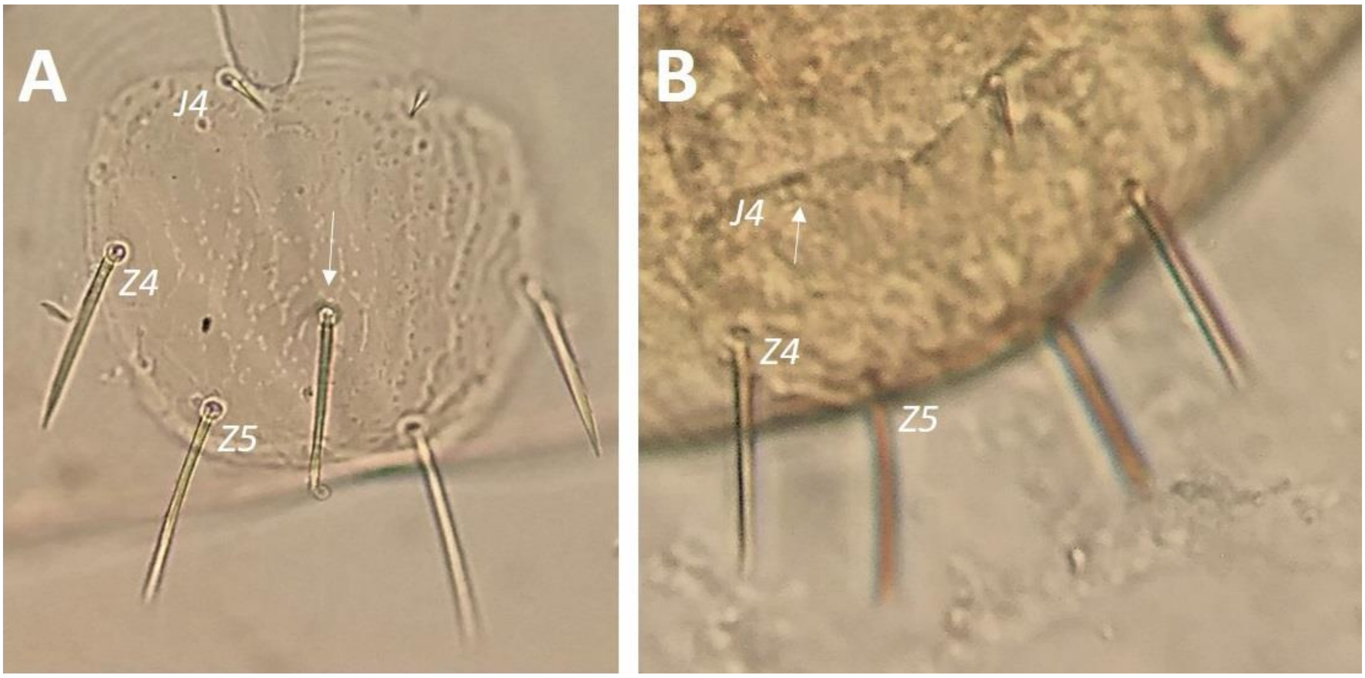

Figure 4. *Ophionyssus natricis* (protonymh), numerical variations in the pygidial setae **A.** Additional seta, **B.** Absence of left seta *J4*.

problems with species identification, and even cause taxonomic mistakes. In the present study, setal variations in the pygidial shield of two protonymphs were detected. An addition seta is found in one specimen in its pygidial shield (Fig. 4A), while left seta *J4* was absent in the pygidial shield of the other specimen (Fig. 4B). To the best of our knowledge, such a variation was detected in the protonymphs of *O. natricis* for the first time.

Consequently, ectoparasitic mites associations of both captive and wild reptiles have been poorly studied and studied and understood in Turkey. Therefore, future studies should be focused on the ectoparasitic mites associations of both captive and wild reptiles in Turkey.

Statement of ethics approval

Not applicable.

Funding

There is no fund for the present study.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

REFERENCES

Altınok-Yipel, F. 2014. The infestation of ectoparasites (*Hirstiella* spp.) treatment with ivermectin solition in a green iguana: case report. Kocatepe Veterinary Journal, 7: 85-87. doi: 10.5578/kvj.7349

Alves, R.R.N., de Araújo, B.M.C., da Silva Policarpo, I., Pereira, H.M., Borges, A.K.M., da Silva Vieira, W.L. and Vasconcellos, A. 2019. Keeping reptiles as pets in Brazil: Ethnozoological and conservation aspects. Journal for Nature Conservation, 49: 9-21. doi: 10.1016/j.jnc.2019.02.002

Amanatfard, E., Youssefi, M.R. and Barimani, A. 2014. Human dermatitis caused by *Ophionyssus natricis*, a snake mite. Iranian Journal of Parasitology, 9: 594-596.

Bingül, M., Doğan, S. and Doğan, S. 2017. Morphological abnormalities in some stigmaeid species of *Eustigmaeus*, *Stigmaeus* and *Storchia* (Acari: Raphignathoidea: Stigmaeidae). Systematic and Applied Acarology, 22: 2119-2126. doi: 10.11158/saa.22.12.7

Bingül, M., Doğan, S. and Doğan, S. 2018. Asymmetric variations in some species of the genus *Raphignathus* Dugès (Acari: Raphignathidae). Trakya University Journal of Natural Sciences, 19: 55-58. doi: 10.23902/trkjnat.334190

Bursali, A., Keskin, A. and Tekin, S. 2012. A review of the ticks (Acari: Ixodida) of Turkey: Species diversity, hosts and geographical distribution. Experimental and Applied Acarology, 57: 91-104. doi: 10.1007/s10493-012-9530-4

Dik, B. 2012. The first case of *Ophionyssus natricis* (Gervais, 1844) on a sea snake (*Natrix tessellata*, Laurente 1768) (Reptilia: Squamata: Colubridae) in Turkey. Türkiye Parazitoloji Dergisi, 36: 112-115. doi: 10.5152/tpd.2012.27

Evans, G.O. and Till, W.M. 1966. Studies on the British Dermanyssidae (Acari: Mesostigmata). Part II Classification. Bulletin of the British Museum (Natural History) Zoology, 14: 107-370.

Fisher, P. and Csurhes, S. 2009. Pest animal risk assessment American corn snake *Elaphe guttata*. Queensland Primary Industries and Fisheries, Brisbane, Australia, 15 pp.

Fitzgerald, K.T. and Vera, R. 2006. Acariasis. In: Reptile medicine and surgery. Mader, D.R. (Ed). Elsevier, Saint Louis, USA, 720-738.

Fonseca, É., Marques, R. and Tinôco, M.S. 2014. New records of *Pantherophis guttatus* (Squamata: Colubridae) in the state of Bahia, an alien species to Brazil. Salamandra, 50: 241-244.

Gazyağcı, S., Aktaş, M.S. and Sarı, B. 2011. The first record of the mite (*Hirstiella* sp.) on a green iguana from Turkey and its therapy with fipronil-a case report. Veterinarski Arhiv, 81: 793-797.

Głowska, E. and Skoracki, M. 2009. Anomalous chaetotaxy in the quill mites *Torotrogla merulae* Skoracki et al., 2000 (Acari, Prostigmata, Syringophilidae). Acta Parasitologica, 54: 364-367.
doi: 10.2478/s11686-009-0046-y

Guglielmone, A.A., Apanaskevich, D.A., Estrada-Peña, A., Robbins, R.G., Petney, T.N. and Horak, I.G. 2014. The hard ticks of the world: (Acari: Ixodida: Ixodidae). Springer, Dordrecht, The Netherlands, 738 pp.

Jabbarpour, S. 2016. Ectoparasit living mites on some lizard which distributed in Turkey (Arachnida: Acarina). PhD Dissertation. Department of Biology, Graduate School of Natural and Applied Science, Ege University, İzmir, Turkey, 158 pp. (In Turkish)

Kalúz, S. 2011. Two new chigger mites of the genus *Lacertacarus* (Acari: Prostigmata, Trombiculidae). Zootaxa, 2922: 15-26.
doi: 10.11646/zootaxa.2922.1.2

Kepka, O. 1962. Trombiculidae (Acari) aus der Türkei. Zeitschrift für Parasitenkunde, 21: 273-289.
doi: 10.1007/BF00261369

Kepka, O. 1966. Trombiculidae (Acari) aus der Türkei. II. Zeitschrift für Parasitenkunde, 27: 43-63.
doi: 10.1007/BF00261217

Keskin, A., Bursali, A., Kumlutas, Y., Ilgaz, C. and Tekin, S. 2013. Parasitism of immature stages of *Haemaphysalis sulcata* (Acari: Ixodidae) on some reptiles in Turkey. Journal of Parasitology, 99: 752-755.
doi: 10.1645/13-187.1

Kubiak, M. 2020. Corn Snakes. In: Handbook of exotic pet medicine. Kubiak, M. (Ed.). John Wiley and Sons Ltd, New Jersey, USA, 283-304.

Kurtdede, A., Haydardedeoğlu, A.E. and Kar, S. 2009. Bir *Boa constrictur* [sic]'da *Ophionyssus natricis* enfeksiyonu ve sağaltımı. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 15: 323.
doi: 10.9775/kvfd.2008.98-E

Marshall, B.M., Strine, C. and Hughes, A.C. 2020. Thousands of reptile species threatened by under-regulated global trade. Nature Communications, 11: 4738.
doi: 10.1038/s41467-020-18523-4

McFadden, M.S., Topham, P. and Harlow, P.S. 2017. A ticking time bomb: Is the illegal pet trade a pathway for the establishment of corn snake (*Elaphe guttata*) populations in Australia? Australian Zoologist, 38: 499-504.
doi: 10.7882/AZ.2017.006

Mendoza-Roldan, J.A., Modry, D. and Otranto, D. 2020. Zoonotic parasites of reptiles: a crawling threat. Trends in Parasitology, 36: 677-687.
doi: 10.1016/j.pt.2020.04.014

Mendoza-Roldan, J.A., Ribeiro, S.R., Castilho-Onofrio, V., Marcili, A., Simonato, B.B., Latrofa, M.S., Benelli, G., Otranto, D., and Barros-Battesti, D.M. 2021. Molecular detection of vector-borne agents in ectoparasites and reptiles from Brazil. Ticks and Tick-borne Diseases, 12: 101585.
doi: 10.1016/j.ttbdis.2020.101585

Miranda, R.J., Cleghorn, J.E., Bermúdez, S.E. and Perotti, M.A. 2017. Occurrence of the mite *Ophionyssus natricis* (Acari: Macronyssidae) on captive snakes from Panama. Acarologia, 57: 365-368.
doi: 10.1051/acarologia/20164161

Mitchell, M.A. 2007. Parasites of reptiles. In: Flynn's parasites of laboratory animals. Baker, D.G. (Ed). Blackwell Publishing, Iowa, USA, 177-216.

Moraza, M.L., Irwin, N.R., Godinho, R., Baird, S.J.E. and Bellocq, J.G. 2009. A new species of *Ophionyssus* Mégnin (Acari: Mesostigmata: Macronyssidae) parasitic on *Lacerta schreiberi* Bedriaga (Reptilia: Lacertidae) from the Iberian Peninsula, and a world key to species. Zootaxa, 2007: 58-68.
doi: 10.11646/zootaxa.2007.1.3

Norval, G., Halliday, B., Sih, A., Sharrad, R.D. and Gardner, M.G. 2020. Occurrence of the introduced snake mite, *Ophionyssus natricis* (Gervais, 1844), in the wild in Australia. Acarologia, 60: 559-565.
doi: 10.24349/acarologia/20204385

Pérez, J.M. 2009. Parasites, pests, and pets in a global world: new perspectives and challenges. Journal of Exotic Pet Medicine, 18: 248-253.
doi: 10.1053/j.jepm.2009.09.003

Petrossian, G.A., Pires, S.F. and van Uhm, D.P. 2016. An overview of seized illegal wildlife entering the United States. Global Crime, 17: 181-201.
doi: 10.1080/17440572.2016.1152548

Reeves, W.K., Dowling, A.P. and Dasch, G.A. 2006. Rickettsial agents from parasitic Dermanyssoidea (Acari: Mesostigmata). Experimental snd Applied Acarology, 38: 181-188.

doi:10.1007/s10493-006-0007-1

Schultz, H. 1975. Human infestation by *Ophionyssus natricis* snake mite. British Journal of Dermatology, 93: 695-697.
doi: 10.1111/j.1365-2133.1975.tb05120.x

Seniczak, S., Ayyıldız, N. and Seniczak, A. 2012. Setal losses in the dorsal hysterosoma of Plateremaeoidea (Acari: Oribatida) in the light of ontogenetic studies. Journal of Natural History, 46: 411-451.
doi: 10.1080/00222933.2011.640464

Setiyani, A.D. and Ahmadi, M.A. 2020. An overview of illegal parrot trade in Maluku and North Maluku Provinces. Forest and Society, 4: 48-60.
doi: 10.24259/fs.v4i1.7316

Stekolnikov, A. and Daniel, M. 2012. Chigger mites (Acari: Trombiculidae) of Turkey. Zootaxa, 3216: 1-104.
doi: 10.11646/zootaxa.3216.1.1

Till, W.M. 1957. Mesostigmatic mites living as parasites of reptiles in the Ethiopian region (Acarina: Laelaptidae). Journal of the Entomological Society of Southern Africa, 20: 120-143.

Wozniak, E.J. and DeNardo, D.F. 2000. The biology, clinical significance and control of the common snake mite, *Ophionyssus natricis*, in captive reptiles. Journal of Herpetological Medicine and Surgery, 10: 4-10.
doi: 10.5818/1529-9651-10.3.4

Yunker, C.E. 1956. Studies on the snake mite, *Ophionyssus natricis*, in Nature. Science, 124: 979-980.
doi: 10.1126/science.124.3229.979

Edited by: Salih Doğan

Reviewed by: Four anonymous referees

Citation: Keskin, A. 2021. Occurrence of *Ophionyssus natricis* (Acari: Macronyssidae) on the captive corn snake, *Pantherophis guttatus*, (Squamata: Colubridae) in Turkey. Acarological Studies, 3 (2): 89-95.

Acarological Studies
Vol 3 (2): 96-100
doi: 10.47121/acarolstud.911455

RESEARCH ARTICLE

First record of *Poecilochirus necrophori* (Acari: Mesostigmata: Parasitidae) from Turkey and its importance in forensic acarology

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Received: 9 April 2021 Accepted: 18 July 2021 Available online: 31 July 2021

ABSTRACT: *Poecilochirus necrophori* Vitzthum, 1930 is a Palearctic distributed species, which deutonymphs are phoretic on some burying beetles (Coleoptera: Silphidae). The mites use adult beetles for transport to carcasses where the deutonymphs moult into adults and both mites and beetles feed and reproduce. A life cycle of *Poecilochirus* species is synchronized with their phoronts and they can be used in a forensic acarology as indicators of post mortem interval. We present the first record of *P. necrophori* from Turkey. Phoretic deutonymphs of *P. necrophori* were found on the beetle *Nicrophorus vespillo* (L.) (Coleoptera: Silphidae) in Sakarya province. The deutonymphs were also found on carcasses of marten (*Marten* sp.) and mole (*Talpa* sp.) from Sakarya, Turkey. Moreover, a significance of *Poecilochirus* species in forensic acarology is briefly discussed.

Keywords: Parasitidae, *Poecilochirus necrophori*, phoretic mites, carcasses, Turkey
Zoobank: http://zoobank.org/B0359A97-7806-4A39-889B-4540972977F6

INTRODUCTION

Poecilochirus necrophori Vitzthum, 1930 is a phoretic mite species living in association with carrion and burying beetles (Baker and Schwarz, 1997). Adults can be found on animal and human carcasses, while deutonymphs are phoretic on adult beetles. Deutonymphs can also be found on the carcasses, until they attach to their phoront (Schwarz and Walzl, 1996). The deutonymphs of this species prefer a beetle *Nicrophorus vespillo* (L.) as a host, however, they can use different beetle species if their preliminary host is not available (Nehring et al., 2017). The nature of a relationship between *Poecilochirus* mites and their host beetles depends on a number of conditions and can vary from parasitic or competitive through commensal to mutualistic (Nehring et al., 2017; Sun et al., 2019).

Due to their specificity, abundance, diversity, and frequent occurrence on carcasses, *Poecilochirus* species are of great importance to be used as indicator species in forensic acarology (Perotti et al., 2009, Pérez-Martínez et al., 2019). Despite the knowledge regarding the presence of mites in corpses, and their role in the decomposition of carcasses for a long period of time, their importance in forensic research has only been recognized in recent decades (Braig and Perotti, 2009; Medina et al., 2013, Saloña-Bordas and Perotti, 2014; Saloña-Bordas and Perotti, 2019). The only way for *Poecilochirus* species to get to the carcass is a phoresy (Perotti et al., 2009). They can change hosts on the carcass and even feed and reproduce on the carcass when there is no host present. However, as the mites cannot move to new carrion on their own, the offspring must reach the phoretic stage before the corpse rots and must attach to new host insects (Schwarz and Koulianos, 1998). Therefore, mites reproduce much faster than their carriers which makes them better timeline markers than insects in forensic research (Perotti et al., 2009).

Hyatt (1980) synonymized this species with *Poecilochirus carabi* G. et R. Canestrini, 1882 due to variability of characters (e.g. shape of a transverse sclerotized sternal band, size of dorsal shields, length of setae) used for identification of these species. However, subsequent studies (Müller and Schwarz, 1990, Schwarz et al., 1991, Schwarz and Walzl, 1996) have shown, that both species are behaviorally and reproductive isolated and Baker and Schwarz (1997) reviewed the taxonomic status of both species.

Poecilochirus necrophori is known from Europe and Asia (Karg, 1993), it is probably a Palearctic species with the same distribution as its main host *N. vespillo*, although it may accidentally be found on other silphid beetles (Springett, 1968). Canitz et al. (2021) found this species in Europe and Kazakhstan.

The aim of the current study is to report *P. necrophori* based on the materials collected on animal carcasses of *Martes* sp. (Carnivora: Mustelidae) and *Talpa* sp. (Eulipotyphla: Talpidae) and beetle (*N. vespillo*) for the first time in Turkey.

MATERIALS AND METHODS

Mites were collected from animal carcasses (*Martes* sp. and *Talpa* sp.) and from host beetle (*N. vespillo*). The mites and phoretic carrier were photographed on the spot with a camera (Nikon P610). Subsequently, the samples were preserved in 70% ethanol. The mite samples were kept in formaldehyde for 24 hours to be translucent, then identified under a Fluorescence Upright Microscope (Nikon Eclipse 80i). Photographs were taken with the Mdx4-t model microscope camera. The measurements of setae, podonotum and opisthonotum were taken by the MShot Image Analysis System program.

Identifications of beetle and mites were done according to the keys published by Ciftci et al. (2018) and Mašán (1999), respectively. The specimens are deposited in the Parasitology Laboratory of Department of Parasitology, Faculty of Veterinary Medicine of Ondokuz Mayıs University (Samsun, Turkey).

Material examined: *Poecilochirus necrophori,* 25 deutonymphs phoretic on *N. vespillo,* 13.07.2019, Sakarya, 41°3'54.06"N, 30°39'19.00" E, altitude 60 m, leg. G. Eren; 11 deutonymphs on carcasses, ibidem, collected on animal carcasses (*Martes* sp. and *Talpa* sp.) and on beetle (*N. vespillo* that was feeding on carcass).

RESULTS

The phoretic deutonymphs of *P. necrophori* were found attached to the host beetle *N. vespillo* (Figs 1, 2). Deutonymphs of *P. necrophori* differ from other *Poecilochirus* species by having a dark sclerotized transverse band located in the area between setae st1 and st2 in the sternal shield (Fig. 1C). In addition, they also differ by the presence of a membranous process at the tip of cheliceral fixed digit (Fig. 1D) (Mašán, 1999). *P. necrophori* can be separated from its sibling species *P. carabi*, based on the length of dorsal setae and the opisthonotal shield (Fig. 1A) (Baker and Schwarz, 1997).

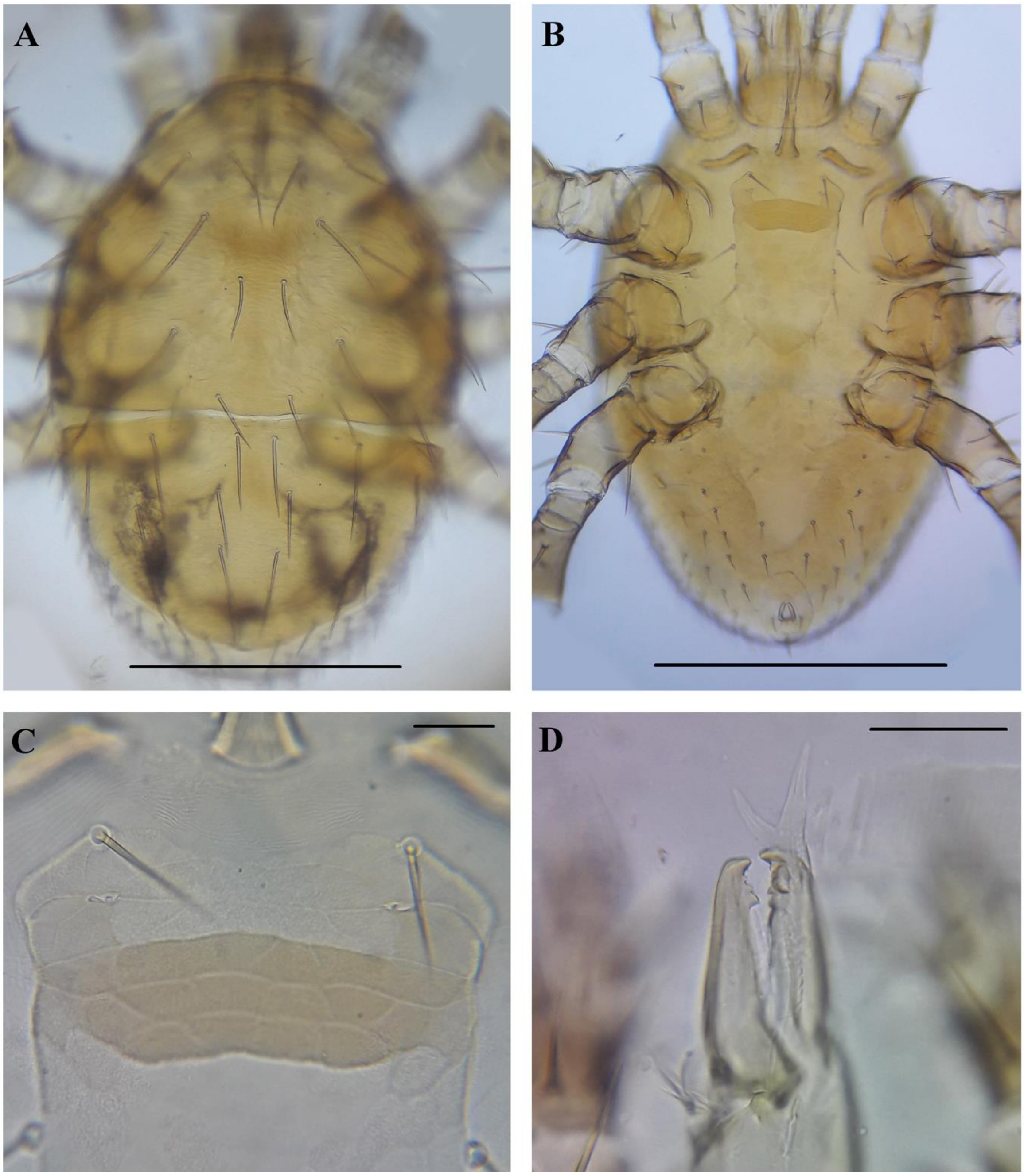

Figure 1. *Poecilochirus necrophori* (Deutonymph) **A.** Dorsal viewl, **B.** Ventral view (scale bars = 500 µm), **C.** Sclerotized transverse sternal bands (scale bar = 50 µm), **D.** Cheliceral digitus fixus (scale bar = 40 µm).

Figure 2. *Poecilochirus necrophori* (Deutonymph) on its phoront *Nicrophorus vespillo* (from the marten (*Martes* sp.) carcass).

DISCUSSION

Carcasses are dynamic and temporary ecosystems with a relatively short duration, which are attractive for different trophic groups of mites. All those mites had to develop strategies to migrate to new carcasses after the first one is reduced and the phoresy is one of these strategies. Most of the mites regularly found on carcasses belong to families Ascidae, Laelapidae, Macrochelidae, Parasitidae and Uropodidae and they can be used as indicator species in forensic studies (Pérez-Martínez et al., 2019). Over 100 species of mites associated with human and animal carcasses have been reported so far (Perotti et al., 2009). *Poecilochirus* species are one of the most abundant gamasid mites found in carcasses, however, different species may occur at the different stages of the decomposition (Pérez-Martínez et al., 2019, Saloña-Bordas and Perotti, 2019). Several *Poecilochirus* species (*P. austroasiaticus*, *P. carabi*, *P. davydovae* and *P. subterraneus*) have been already reported on human carcasses, *P. mrciaki* on a pig carcass, *P. necrophori* on a mouse carcass and *Poecilochirus* sp. on seal, rat and rabbit carcasses (Lord and Burger, 1984; De Jong and Chadwick, 1999; Braig and Perotti, 2009; Medina et al., 2013; Saloña-Bordas and Perotti, 2014; Saloña-Bordas and Perotti, 2019).

In this study, the mites were collected together with *N. vespillo* feeding from marten (*Martes* sp.) and mole (*Talpa* sp.) carcasses, as well as mites walking directly on the carcass.

The observations and measurements of collected specimens are in agreement with those reported by Baker and Schwarz (1997) (Table 1). In addition to morphological and molecular methods (which couldn't be used in this case due to the fact that our material was processed in formaldehyde), behavioral methods can be used to identify this species among others *Poecilochirus* species. Many studies (Müller and Schwarz, 1990, Schwarz et al., 1991, Nehring et al., 2017, Canitz et al., 2021) have confirmed that the species *P. necrophori* is specialized to the beetle species *N. vespillo*, on which our individuals were found.

Table 1. Length of dorsal setae and dorsal shields of *Poecilochirus necrophori* (Deutonymph)

Seta / shield	Range (µm)	Mean
Z1	150-150	150
s4	160-180	167.5
J1	110-135	134.5
s5	150-165	152.7
z5	260-280	272
r3	350-365	353
opisthonotum	420-475	449.5
podonotum	575-600	595

Till now, only four *Poecilochirus* species were known and described from Turkey (Ramaraju and Madanlar, 1998). None of them was found on the carcass and none of these species possesses apomorphies, which are characteristic for *Poecilochirus* deutonymphs. These characters include the sternal shield with the sclerotized transverse sternal band and the membranous process at the tip of the fixed digit of chelicerae (Hyatt, 1980).

In the present study, *Poecilochirus* mites are evaluated in terms of forensic acarology in Turkey and *P. necrophori* is reported from Turkey for the first time. Additionally, further studies are essential in order to obtain more detailed knowledge for the use of these mites in forensic acarology in Turkey.

Authors' contributions

Kamila Ondrejková: Conceptualization (equal), data curation, formal analysis (equal), resources (equal), visualization (equal), writing - original draft (supporting), writing - review & editing (lead). **Gökhan Eren:** Conceptualization (equal), investigation, formal analysis (equal), methodology (equal), resources (equal), visualization (equal), writing - original draft (lead), writing - review & editing (supporting). **Mustafa Açıcı:** Conceptualization (equal), methodology (equal), supervision, visualization (equal), writing - original draft (supporting), writing - review & editing (supporting).

Statement of ethics approval

Not applicable.

Funding

There is no fund for the present study.

Conflict of interest

The authors do not have conflict of interest.

REFERENCES

Baker, A.S. and Schwarz, H.H. 1997. Morphological differences between sympatric populations of the *Poecilochirus carabi* complex (Acari: Mesostigmata: Parasitidae) associated with burying beetles (Silphidae: Nicrophorus). Systematic Parasitology, 37: 179-185. doi: 10.1023/A:1005822702267

Braig, H.R. and Perotti, M.A. 2009. Carcases and mites. Experimental and Applied Acarology, 49 (1): 45-84. doi: 10.1007/s10493-009-9287-6

Canitz, J., Sikes, D.S., Knee, W., Baumann, J., Haftaro, P., Steinmetz, N., Nave, M., Eggert, A.-K., Hwang, W. and Nehring, V. 2021. Cryptic diversity within the *Poecilochirus carabi* mite species complex phoretic on *Nicrophorus* burying beetles: phylogeny, biogeography, and host specificity. bioRxiv. doi:10.1101/2021.05.20.443311

Ciftci, D., Ruzicka, J., Hasbenli, A. and Sahin, Ü. 2018. The large carrion beetles (Coleoptera: Silphidae) of Turkey: a review with a new species record. Zootaxa, 4441 (3): 555-591. doi:10.11646/zootaxa.4441.3.10

De Jong, G.D. and Chadwick, J.W. 1999. Decomposition and arthropod succession on exposed rabbit carrion during summer at high altitudes in Colorado, USA. Journal of Medical Entomology, 36 (6): 833-845. doi:10.1093/jmedent/36.6.833

Hyatt, K.H. 1980. Mites of the subfamily Parasitinae (Mesostigmata: Parasitidae) in the British Isles. Bulletin of the British Museum (Natural History), Zoology series, 38 (5): 237-378.

Karg, W. 1993. Acari (Acarina), Milben. Parasitiformes (Anactinochaeta) Cohors Gamasina, Leach, Raubmilben. 2. Überarbeitete Auflage. Die Tierwelt Deutschlands, 59. Gustav Fischer Verlag, Jena-Stuttgart, Germany and New York, USA 523 pp. [In German]

Lord, W.D. and Burger, J.F. 1984. Arthropods associated with harbor seal (*Phoca vitulina*) carcasses stranded on islands along the New England Coast. International Journal of Entomology, 26: 282-285.

Mašán, P. 1999. Mites (Acarina) associated with burying and carrion beetles (Coleoptera, Silphidae) and description of *Poecilochirus mrciaki* sp. n. (Mesostigmata, Gamasina). Biologia, Bratislava, 54: 515-524.

Medina, A.G., Herrera, L.G., Perotti, M.A. and Ríos, G.J. 2013. Occurrence of *Poecilochirus austroasiaticus* (Acari: Parasitidae) in forensic autopsies and its application on postmortem interval estimation. Experimental and Applied Acarology, 59 (3): 297-305. doi: 10.1007/s10493-012-9606-1

Müller, J.K. and Schwarz, H.H. 1990. Differences in carrier-preference and evidence of reproductive isolation between mites of *Poecilochirus carabi* (Acari, Parasitidae) living phoretically on two sympatric *Necrophorus* species (Coleoptera, Silphidae). Zoologische Jahrbücher, Abteilung für Systematik, Ökologie und Geographie der Tiere, 117: 23-30.

Nehring, V. Müller, J.K. and Steinmetz, N. 2017. Phoretic *Poecilochirus* mites specialize on their burying beetle hosts. Ecology and Evolution, 7 (24): 10743-10751. doi: 10.1002/ece3.3591

Pérez-Martínez, S., Moraza, M.L. and Saloña-Bordas, M.I. 2019. Gamasina mites (Acari: Mesostigmata) associated with animal remains in the mediterranean region of Navarra (Northern Spain). Insects, 10 (1): 5. doi: 10.3390/insects10010005

Perotti, M.A., Braig, H.R. and Goff, M.L. 2009. Phoretic mites and carcasses: Acari transported by organisms associated with animal and human decomposition. In: Current concepts in forensic entomology. Amendt, J., Goff, M.L., Campobasso, C.P. and Grassberger, M. (Eds). Springer, Dordrecht, The Netherlands, 69-91.

doi: 10.1007/978-1-4020-9684-6_5

Prevett, P. 1953. Notes on the feeding habits and life history of *Galeruca tanaceti* L. (Col., Chrysomelidae). Entomologist's Monthly Magazine, 89: 292-293.

Ramaraju, K. and Madanlar, N. 1998. Four new *Poecilochirus* G. & R. Canestrini (Acarina: Parasitidae) species from Turkey. Turkish Journal of Entomology, 22 (1): 3-17.

Saloña-Bordas, M.I. and Perotti, M.A. 2014. First contribution of mites (Acari) to the forensic analysis of hanged corpses: A case study from Spain. Forensic Science International, 244: e6-e11.
doi: 10.1016/j.forsciint.2014.08.005

Saloña-Bordas, M.I. and Perotti, M.A. 2019. First record of *Poecilochirus mrciaki* Mašán, 1999 (Acari, Parasitidae) and its phoretic carriers in the Iberian Peninsula. Acarologia, 59 (2): 242-252.
doi: 10.24349/acarologia/20194328

Schwarz, H.H. and Koulianos, S. 1998. When to leave the brood chamber? Routes of dispersal in mites associated with burying beetles. Experimental and Applied Acarology, 22 (11): 621-631.
doi: 10.1023/A:1006054604520

Schwarz, H.H. and Walzl, M.G. 1996. Pairing, oviposition and development in two sibling species of phoretic mites (Acari: Mesostigmata: Parasitidae: *Poecilochirus* spp.) associated with burying beetles (Coleoptera: Silphidae: *Nicrophorus* spp.). Journal of Natural History, 30 (9): 1337-1348.
doi: 10.1080/00222939600771251

Schwarz, H.H., Müller, J.K. and Baker, A. 1991. Genetic differentiation between deuteronymphs of *Poecilochirus carabi* (Mesostigmata, Parasitidae) living on sympatric *Necrophorus* species (Coleoptera, Silphidae). In: Modern Acarology (Vol. 2) Dusbábek, F. and Bukva, V. (Eds). Academia, Prague, Check Republic and SPB Academic Publishing, The Hague, the Netherlans, 431-436.

Springett, B.P. 1968. Aspects of the relationship between burying beetles, *Necrophorus* spp. and the mite, *Poecilochirus necrophori* Vitz. The Journal of Animal Ecology, 37 (2): 417-424.
doi: 10.2307/2957

Sun, S.J., Horrocks, N.P.C. and Kilner, R.M. 2019. Conflict within species determines the value of a mutualism between species. Evolution Letters, 3 (2): 185-197.
doi: 10.1002/evl3.109

Edited by: Sebahat K. Ozman-Sullivan

Reviewed by: Four anonymous referees

Citation: Ondrejková, K., Eren, G. and Açıcı, M. 2021. First record of *Poecilochirus necrophori* (Acari: Mesostigmata: Parasitidae) from Turkey and its importance in forensic acarology. Acarological Studies, 3 (2): 96-100.