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Population structure and group diversity of soil mites (Acari) in pistachio orchards of Kerman Province, Iran

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Abstract

Due to the lack of basic studies, we analyzed the mite fauna of pistachio orchard soils in Kerman Province, the largest pistachio-growing area in Iran. A total of 180 soil samples were collected from the shaded areas beneath pistachio trees across different regions, including Sirjan, Rafsanjan, Zarand, Baghin, and Mahan. The soil samples were collected from three depths (0–15, 15–30, and 30–45 cm) during four seasons, with three replicates each, and then transported to the laboratory. The mites were extracted using a Berlese-Tullgren funnel and cleared using lactic acid, mounted, and identified at family, genus, and species levels. The ten mite families Ascidae, Laelapidae, Phytoseiidae, Rhodacaridae, Neopygmephoridae, Acaridae, Phthiracaridae, Oppiidae, Euphthiracaridae, and Epilohmaniidae were collected. The most frequently found species were *Arctoseius cetratus* (Ascidae), *Gaeolaelaps nolli* and *G. aculeifer* (Laelapidae), *Typhloderomus bakeri* (Phytoseiidae), *Multidentrodacarus denticulatus* (Rhodacaridae), *Pseudopygmephorus tarsalis* and *Kerdabania quadrata* (Neopygmephorididae), *Rhizoglyphus robini*, *Tyrophagus perniciosus*, *Tyrophagus javensis* (Acaridae), and *Metagynella paradoxa* (Metagynuridae). The highest number of mites in all studied areas was found at the first depth (0 to 15 cm), and mites were most abundant in the summer and spring when soil moisture and temperature were appropriate. This is the first study of the mite fauna of soils in pistachio orchards in the world. It provides a more profound understanding of the habitat requirements of soil mites, thereby improving their use as effective bioindicators of soil quality.

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Introduction

Pistachio is one of the most important non-oil export items and strategic product in Iran. This crop is cultivated in arid and semi-arid regions with limited water resources and poor water quality (Sedaghati et al., 2010; Rezvani et al., 2024). Kerman Province is the largest pistachio production area in the country. High evapotranspiration, low rainfall, salinity of irrigation water and soils threaten agricultural sustainability and affect the region's fauna and flora (Bagheri Bodaghabadi et al., 2019). Soil fauna play a vital role in ecosystem functions, especially biogeochemical and nutrient cycling (Fanin et al., 2019; Kudureti et al., 2023). Arthropods are an important component of soil fauna in various seasons and play an important role in the decomposition of plant debris (Vilisics, 2008; Vilisics et al., 2011). These small inhabitants, as a ring of soil food chains will also have an indirect impact on soil organic matter and nutrients (Siepel & Maaskamp, 1994). Among the most important members of soil arthropods, mites are the most diverse in terms of ecological niche and behaviour. Due to the sensitivity of soil mites to soil disturbance, their diversity and numbers can be used as ecological indicators for assessing disturbances in ecosystems (Amani et al., 2020). The population abundance of soil mites varies with various environmental factors like temperature, moisture, soil depth, organic matter, nutrient availibility, etc. (Banerjee et al., 2009). The mites living in soil consist of a wide range of taxa. When soil is disturbed by an ecological factor such as agricultural activity, most mites (Astigmata, Mesostigmata, and Prostigmata) are able to recolonize it within a few months, whereas Oribatida may take several years (Swift, 2004).

Free soil mites are found in a variety of environments, but they are more common, especially in areas with enough organic matter. Mesostigmata mites are considered bioindicators because of their functional role in the soil ecosystems as predators, large communities, and their relatively high abundances (Koehler, 1999). Predators are more active and respond more sensitively over shorter time to environmental influences in soil ecosystems than other soil arthropods (Călugăr, 2018). Predatory species present on the soil surface are more effective. They feed on small arthropods or their eggs, nematodes, and sometimes each other (Walter & Proctor, 1999). Oribatid mites play an important role in decomposing plant matter, soil formation, material rotation and ultimately soil fertility (Behan-Pelletier, 1999). Some of these mites are highly vulnerable to pesticides and are considered as ecological criteria in environmental toxicology experiments (Akrami & Saboori, 2012). Astigmatic mites are the least common of the soil mites, although they may become abundant in some habitats. The free-living Astigmata prefer moist environments high in organic matter. Mites of the orderTrombidiformes are also found in different soil habitats (Krantz & Walter, 2009). The main objectives of this study are to identify the mite fauna in important pistachio areas of Kerman Province, identifying the dominant mite species in the studied soils, and examine the impact of depth and season on mite populations, to characterise the conservation status of these orchards.

Materials and Methods

During 2018–2019, a total of 180 soil samples were collected from shaded areas beneath pistachio trees at three different depths (0–15, 15–30, and 30–45 cm) in five regions of Kerman Province: Baghin (E 56°46′, N 30°10′), Rafsanjan (E 55°36′, N 30°18′), Sirjan (E 55°36′, N 29°33′), Zarand (E 56°50′, N 30°33′), and Mahan (E 57°10′, N 30°06′). Samples were taken in three replicates per region across four seasons.

After removing a thin layer of topsoil, one kilogram of soil was collected from beneath the canopy (shaded area) of pistachio trees at each depth. The samples were placed in plastic bags, and relevant information, including location and sampling date, was recorded.

The specimens were extracted using Tullgren funnels for 5–7 days (depending on the soil moisture), and the extracted mites were preserved in 75% ethanol. (Mirzaei-Pashami et al., 2020). The mites were cleared in 80% lactic acid mounted in Hoyer's medium and identified using keys constructed for Mesostigmatic and Astigmatic mites (Lindquist et al., 2009). The identification of oribatid mites was carried out to the family level. Analysis of variance and comparison of means for population analysis were performed using SAS software version 9.4 (results were treated as significant when $p < 0.05$). Graphs were drawn in Excel software 2019. All species were deposited in the Acari collection of Shahid Bahonar University of Kerman (SBUK).

Results

Species identification

The identified mite species belonged to three orders: Mesostigmata, Trombidiformes, and Sarcoptiformes (Oribatida, as well as the cohort Astigmatina) (Krantz & Walter, 2009). Ten families of mites with the highest frequency were identified (Table 1). Members of the Oribatid and mesostigmatid were the most abundant.

Relative abundance of mite orders across the study areas

To assess the community composition and relative abundance of mites in the studied regions, the percentage distribution of three dominant orders: Mesostigmata, Trombidiformes, and Sarcoptiformes was calculated and compared across five areas: Rafsanjan, Sirjan, Zarand, Mahan, and Baghin (Fig. 1). In Rafsanjan, the Mesostigmata order was dominant, comprising 55% of the total mite population, followed by Trombidiformes with 35% and Sarcoptiformes with 10%. In Sirjan, Mesostigmata showed a significantly higher dominance, accounting for 95%, while Trombidiformes and Sarcoptiformes represented only 4% and 1%, respectively. In contrast, the distribution of mite orders in Zarand, Mahan, and Baghin was more diverse. In Zarand, Sarcoptiformes had the highest share (55%), with Mesostigmata and Trombidiformes comprising 20% and 25%, respectively. A similar pattern was observed in Mahan, where Sarcoptiformes accounted for 75%, followed by Trombidiformes (15%) and Mesostigmata (10%). In Baghin, Sarcoptiformes remained the most abundant order (70%), while Trombidiformes and Mesostigmata made up 20% and 10%, respectively. These results indicate that Mesostigmata are more prevalent in drier regions such as Sirjan and Rafsanjan, whereas Sarcoptiformes dominate in areas like Baghin and Mahan. Such variations in mite order composition may be associated with local ecological conditions, vegetation types, and soil characteristics, warranting further investigation.

Table1. List of identified species of collected mites.

Order	Familly	Species
Mesostigmata	Ascidae	*Arctoseius cetratus*
Mesostigmata	Laelapidae	*Gaeolaelaps nolli*
Mesostigmata	Laelapidae	*Gaeolaelaps aculeifer*
Mesostigmata	Phytoseidae	*Typhloderomus bakeri*
Mesostigmata	Rhodacaridae	*Multidentrodacarus denticulatus*
Mesostigmata	Metagynuridae	*Metagynella paradoxa*
Trombidiformes	Neopygmephoridae	*Pseudopygmephorus tarsalis*
Trombidiformes	Neopygmephoridae	*Kerdabania quadrata*
Sarcoptiformes	Acaridae	*Rhizoglyphus robini*
Sarcoptiformes	Acaridae	*Tyrophagus* sp.
Sarcoptiformes	Acaridae	*Tyrophagus perniciosus*
Sarcoptiformes	Acaridae	*Tyrophagus javensis*
Sarcoptiformes	Phthiracaridae (Oribatida)	-
Sarcoptiformes	Oppiidae (Oribatida)	-
Sarcoptiformes	Euphthiracaridae (Oribatida)	-
Sarcoptiformes	Epilohmaniidae (Oribatida)	-

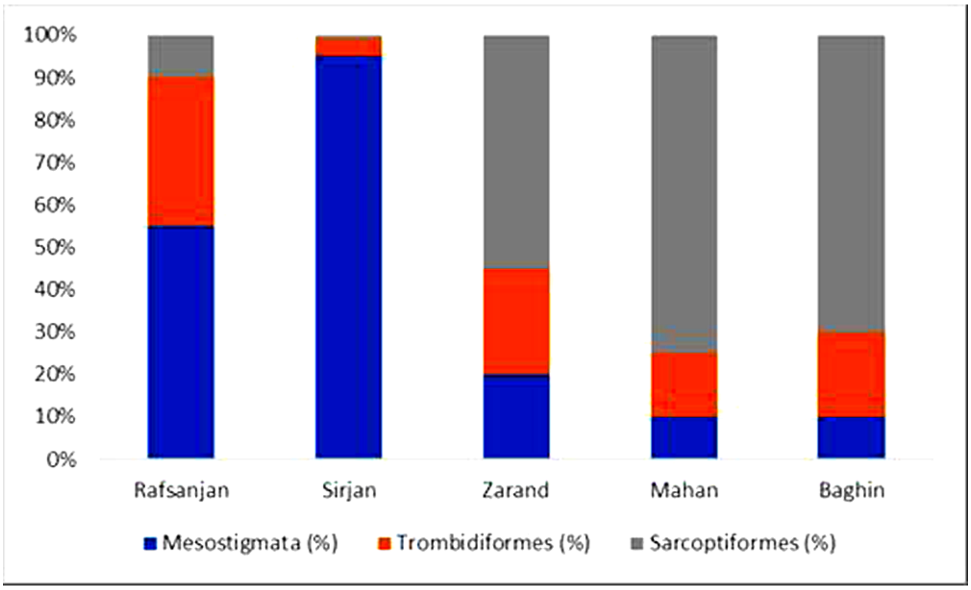

Fig. 1. Community composition and relative abundance of mites in the studied regions.

Analysis of mite family abundance across different orders

In this study, the relative abundance of identified mite families was analysed across three major orders: Mesostigmata, Trombidiformes, and Sarcoptiformes (Fig. 1 and 2). The results demonstrate distinct family compositions within each order, with certain families exhibiting strong dominance in specific groups. Within the Mesostigmata order, the Ascidae family was predominant, accounting for 76% of the total abundance. It was followed by Laelapidae with a combined 11% (including *Gaeolaelaps nolli* and *Gaeolaelaps aculeifer*), Phytoseiidae with 5%, and Metagynuridae with 8%. This pattern indicates a relatively low family diversity and a strong dominance of Ascidae within this order. In the Trombidiformes *Pseudopygmephorus tarsalis* is the key species in this group, representing almost the entire composition of the order. The Sarcoptiformes order showed a more diverse distribution of families. Acaridae was the most abundant family, with a cumulative share of 142% (due to multiple species such as *Tyrophagus spp.* and *Rhizoglyphus robini*). Other significant families included Phthiracaridae (72%), Oribatida (58%), Epilomaniidae (43%), and Euphthiracaridae (20%). This broader distribution reflects a higher ecological diversity and taxonomic complexity within Sarcoptiformes.

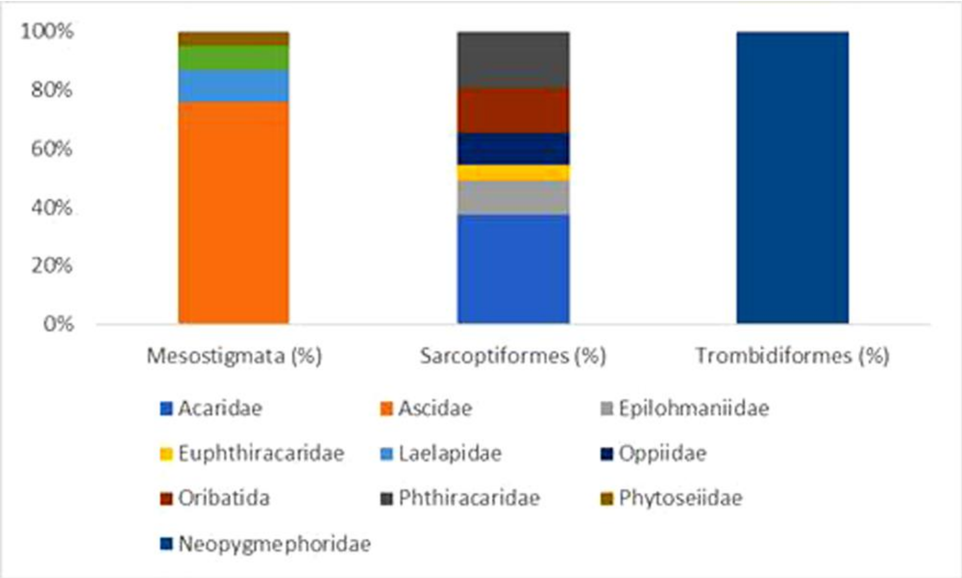

Fig. 2. Relative abundance of identified mites families across three major orders.

According to previous research, the highest abundance of oribatids is usually found in temperate rangelands. Oribatids generally show the highest population levels, followed by mesostigmatid and astigmatid mites (Bedano et al., 2005). The dominance of oribatids is a common feature of natural geographic areas. These mites inhabit stable environments, where they are most abundant in their mature forms, and represent a predominant component of the soil mite fauna in such ecosystems (Behan-Pelletier, 1999; Ermilov & Khaustov, 2021). Mesostigmata mites also occur in relatively high numbers, which aligns with observations showing their abundance in natural soils (Curry & Momen, 1988; Bedano et al., 2005). Mesostigmatid mites form a large group with a worldwide distribution and a wide variety of habitats and lifestyles. Most species are free-living predators, while some are parasitic on mammals, birds, reptiles, or arthropods (Lindquist et al., 2009). The free-living species typically inhabit soil and leaf surfaces, preying on nematodes, arthropods or their eggs, as well as feeding on decaying fungi, bacteria, and organic matter (Walter & Proctor, 1999; Lindquist et al., 2009; Călugăr, 2018).

Some mesostigmatid mites contribute significantly to the biodiversity of soil and greenhouse environments, including species from the families Laelapidae, Macrochelidae, and Ascidae (Krantz, 1998). Their wide dispersal and high adaptability to diverse environmental conditions, along with their predatory efficiency, particularly in the case of *Gaeolaelaps aculeifer*, have proven their potential use as bioindicators (Gillespie & Quiring, 1990; Conijn et al., 1996). Moreover, several studies have shown that an increase in predatory mesostigmata correlates with enhanced biological activity and functioning of the bacterial decomposition pathway, especially the soil food web of treated environments (Urbanowski et al., 2022). As shown in Table 1, several species from the order Mesostigmata (e.g., *Gaeolaelaps aculeifer*) and Oribatida (e.g., *Phthiracarus* sp., *Oppia* sp.) support the observations by Siepel (1996) and others regarding the dominance of these mites in stable, natural environments.

Comparative analysis of soil Mite abundance across different depths and regions

Fig. 3 shows variation of the number of soil mites across different depths and regions. The highest number of mites was observed in Rafsanjan at the surface depth (0–15 cm), followed by Mahan and Sirjan. Across all studied areas, mite abundance consistently decreased with depth. This pattern may be due to higher organic matter availability and habitat stability in surface layers. The significantly higher mite population in Rafsanjan could be attributed to a longer history of agricultural activity and manure application in pistachio orchards. These practices enrich the upper soil layers with nutrients and organic matter, creating favorable conditions for mite development (Badejo, 1995). Mesostigmatid mites, which are often predatory, are commonly found in soil and litter layers (Karg, 1965). The composition of soil habitat, organic inputs, and agricultural practices such as tillage can significantly affect mite populations (Pérez-Velázquez et al., 2011). Reduced mite abundance in autumn may result from soil disturbance due to plowing and planting activities (Loring et al., 1981; Perdue & Crossley, 1989).

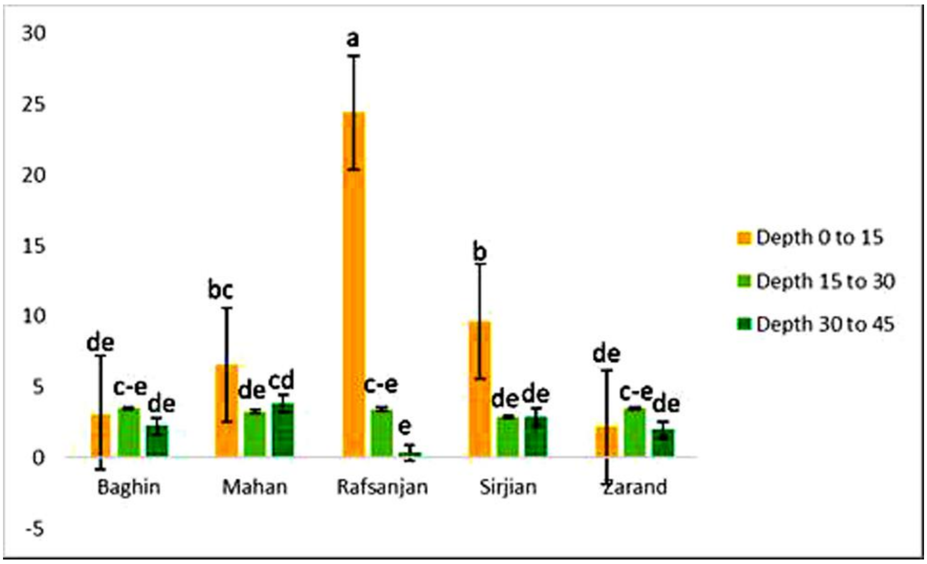

Fig. 3. The effect of depth and area on the number of soil mites.

Changes in the composition of the habitat of mites have significant effects on their population, so that if animal manure and organic matter such as plant residues are added, they provide a suitable growth medium for the growth and increase of the population. The chemical composition of the substrate can also affect the abundance and diversity of soil mites (Badejo, 1995). One of the most important factors in changing the relative abundance of mites is habitat vegetation and type of agricultural activity (King & Hutchinson, 1976; Bardgett & Cook, 1998). The abundance and diversity of mites in higher vegetation habitats are significantly greater due to reduced use of chemicals such as pesticides and fertilizers, along with less tillage operations (Pérez-Velázquez et al., 2011). Tillage operations can cause a decline in the microarthropod population, which can also be attributed to habitat degradation, temperature changes, moisture and pore size distribution, and reduced organic matter content (Loring *et al*., 1981; Perdue & Crossley, 1989). The sharp decline in mites in the fall can also be partly due to the start of the new crop season and the start of the plowing season in pistachio orachards and also a decrease in irrigarion in this area.

Comparative analysis of soil mite abundance across different depths and seasons

Fig. 4 illustrates the seasonal variation in soil mite abundance across three soil depths. The highest number of mites was recorded in spring, followed by summer and winter, with the lowest abundance observed in autumn. This seasonal pattern was consistent across all depths, with the greatest populations always found in the 0–15 cm layer. This may be attributed to the use of livestock and poultry manure in pistachio orchards, which enriches the surface soil with organic matter and creates favorable microhabitats for mite development (Banerjee et al., 2009).

The chemical composition of the substrate is another important factor influencing the abundance and diversity of soil mites (Badejo, 1995).

Soil temperature is also known to affect mite population dynamics. Experimental studies have shown that temperature may have a stronger regulatory role than soil moisture in determining seasonal abundance trends. This may explain the decline in mite numbers during autumn, which could be associated with lower biological activity and environmental stress and a decrease in irrigarion during this period in this area.

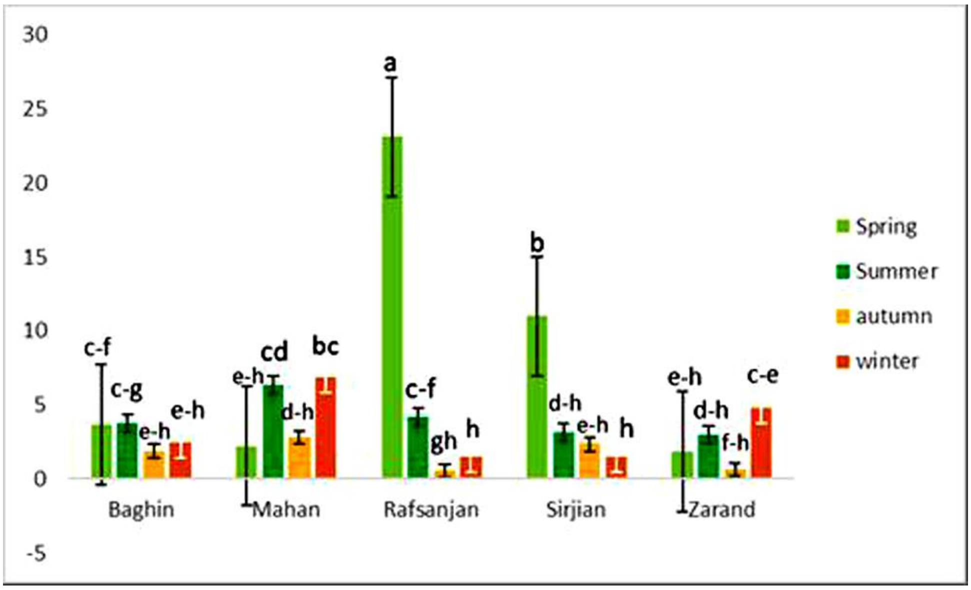

Fig. 4. Seasonal and depth-wise variation in soil mite abundance.

Conclusion

The results of this study show that the mites in pistachio orchards do not have significant species diversity. In this study, the largest number belonged to the families Ascidae, Neopygmephoridae, Laelapidae, Phytoseiidae, Rhodacaridae, Acaridae and four families of Oribatida. This study confirms that the highest mite densities occur in the upper 0-15 soil layer and that during summer and spring in Kerman pistachio orchards.

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Conflict of interest

The authors declare that there are no conflicts of interest present.

CRediT author statement

S. D. Ziarazavi: Obtaining resources, & conducting the project. **M. Sarcheshmehpour, M. Asadi & M. Moradi faradonbeh:** Methodology, Data curation, Review, & Editing.

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