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Article

Species diversity of soil mites (Acari: Mesostigmata) under different agricultural land use types

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ABSTRACT

Mites are among the most important members of soil arthropod communities, because they are the most diverse in terms of ecological niche and behavior. Due to the sensitivity of soil mites to soil disturbance, their diversity and numbers can be used as ecological indices for assessing disturbances in ecosystems. To determine the effect of land use type on soil mite biodiversity, abundance and biodiversity indices of soil inhabiting mesostigmatic mites were evaluated at eight sites in Saman and Shahrekord, Iran, each site including two adjacent agricultural pieces of land: an orchard and a crop field. The biodiversity of mites was measured by several biodiversity indices and then compared by analysis of variance. The specimens collected belonged to 12 families, 17 genera and 24 species. The biodiversity index values calculated in different months showed that these indices were usually higher in warm months and in orchards than in cold months and crop fields. In the examined crop fields, the diversity index values were lower after harvesting, probably due to soil disturbance by agricultural machinery. There was a significant difference in the Shannon-Wiener's diversity index among different land uses. The maximum and minimum values of this index were recorded at the vine orchard (1.48) and wheat field (0.15) in an elm/wheat site at Shahrekord, respectively. The soil organic matter content was maximum in the vineyard (2.12%) and minimum in the wheat field (0.41%).

KEY WORDS: Abundance; biodiversity; richness; Parasitiformes; Simpson's index.

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INTRODUCTION

Terrestrial communities play significant roles in the ecosystem including decomposition and recycling of organic waste (Wardle *et al*. 2004). In agricultural ecosystems, these communities are influenced by many factors including ploughing, pesticide and fertilizer application, soil compaction during harvest, and removal of herbal biomass. The response of terrestrial communities are represented by changes in abundance, species richness and biodiversity indices (Schulz 1991; Vreeken-Buijs *et al*. 1998; Maraun *et al*. 2003). Less disturbed settlements may be an appropriate

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shelter for some terrestrial species and be richer in varieties (Gulvik *et al*. 2008). Small arthropods constitute an important and significant part of the soil (Walter and Proctor 1999).

Among arthropods, mites are very significant groups in terms of variety richness and abundance and are one of the components of soil biodiversity in terms of behavior and life strategies (Wissuwa *et al*. 2013). Predatory mesostigmatic mites represent a very important part of soil food webs in forest and agricultural soils by feeding on the nematodes, collembolans, as well as insects and mite larvae (Walter and Proctor 1999; Ruf and Beck 2005). Because of their high density, Mesostigmata are effective predators in soil food webs and control prey populations effectively (Schneider *et al*. 2012). However, they are rarely considered in studies on trophic interactions in terrestrial food webs, probably due to their small size (Moore *et al*. 1988).

Natural and uncultivated ecosystems and low-input agroecosystems, such as cropping systems in organic farming are considered to have higher biodiversity than intensively-farmed agroecosystems (Bedano and Ruf 2007). Human disturbance has decreased the abundance and species richness of mites (Gulvik 2007). The effects of plant species on soil food chains has been studied in nematodes (Viketoft *et al*. 2009) and Collembola (Salamon *et al*. 2004). Many studies have been carried out to determine the impact of agricultural practices on the soil fauna, and some have focused on mesostigmatic mites, however, few studies have described the soil mite community of adjacent arable fields with different plant species (Koehler and Born 1989; Kohler 1999; Gulvik 2007; Gulvik *et al.* 2008.).

This study investigates the effect of land use type on the within-habitat diversity of soil mesostigmatic mites using two diversity indices, species richness, and abundance. Adjacent agricultural orchards and crop fields, at different sites with different combinations of plant species, were compared to assess the possible effects of plant species and land use management on the quantitative and qualitative structure of the mesostigmatic mite communities. In addition, in order to determine the effect of soil organic matter content on the biodiversity of mesostigmatic mites, we used canonical correspondence analysis (CCA) (Ter Braak 1988) as one of the most commonly used ordination methods to investigate the relationship of environmental variables to species composition (Lagerlöf and Andrén 1988).

MATERIALS AND METHODS

Study site

The research was conducted in Shahrekord and Saman, two regions of Chaharmahal and Bakhtiari province in southwestern Iran (Fig. 1). Eight pairs of sampling sites in Shahrekord (32.3256° N, 50.8644° E) and Saman (32.27° N, 50.53° E) were chosen to represent various land use types which form a gradient of management intensity: wheat field (W), barley field (B), alfalfa field (Al), saffron field (S), almond orchard (A), elm trees (E), walnut orchard (Wa) and vineyard (V).

Table 1 presents the exact geo-location parameters of the sites using the UTM system as well as a short history of the land use type and management. The selected plots differed in terms of soil moisture, soil organic matter, and type of plant species (Table 1). In some study plots, 20–30-year old trees with a developed canopy led to an increase in litter moisture and a decrease in litter temperature due to lower soil exposure to sunlight. Due to farming operations, the crop fields usually underwent more changes than the orchards. The material for the analysis was collected from fields and orchards that were adjacent to each other. In this study, paired comparisons were used to eliminate variations (Such as the effect of altitude and etc.) between experimental sites. The first comparison was carried out between an almond orchard and wheat field in plot 1. In the same way, in the other plots, orchards and farmlands were compared, except for plot 2 and plot 8 where instead of an orchard, saffron and alfalfa fields were used, respectively. These two crops are perennial plants, usually with lower management and tillage practices than the annuals crops used in this study.

Figure 1. Geographic location of collection sites.

Table 1. Description of experimental plots in Saman and Shahrekord in 2014. Wheatfield (W), barley field (B), alfalfa field (Al), saffron field (S), almond orchard (A), elm trees (E), walnut orchard (Wa), and vine orchard (V).

Site	Location	Plot	History
1	32° 21' 8.11" N, 51° 03" 17.49" E	A	Orchard aged > 7 years
		W	Regular herbicide application (glyphosate), rotated between wheat and barley.
2	32° 17' 42.08" N, 51° 01" 39.51" E	A	Orchard aged > 7 years
		S	Saffron planted in 2009, prior use – almond orchard,
3	32° 20' 39.45" N, 51° 06" 43.30" E	A	Orchard aged > 8 years
		W	Barley/wheat rotation, the last 2 years in wheat, regular herbicide application
4	32° 20' 17.26" N, 50° 49" 33.09" E	E	Trees aged > 18 years, pesticides never used
		W	Annual tillage
5	32° 28' 39.11" N, 50° 54" 17.39" E	A	Orchard aged > 30 years, with high organic content and
		B	regular herbicide application.
6	32° 26' 27.40" N, 50° 52" 55.73" E	V	Orchard aged > 12 years, with leguminous cover crop
		W	Fertilized with manure
			Wheat planted 2012, prior use - viticulture aged > 9 years
7	32° 27' 10.68" N, 50° 53" 59.99" E	Wa	Orchard aged > 20 years
		W	Barley/wheat rotation
8	32° 26' 59.60" N, 50° 55" 49.91" E	A	Regular pesticide application. Different pesticides and herbicides applied as a test
		Al	No tilling for 4 years. Fertilized with liquid manure

Sampling

From March to October 2014, monthly sampling was conducted (25cm × 25 cm × 10 cm depth). Four randomly selected soil samples were taken from each site/plant species (8 sites, 16 plots, 4 replications) and a total of 512 quantitative soil samples and 2838 mite species were taken.

Sample extraction and identification

The specimens were extracted from soil samples by Tullgren funnels for 3–5 days (depending on the sample moisture) and extracted mites were transferred into 75% ethanol. Adults and immature stages of mesostigmatic mites were counted and identified to species level with a differential interference microscope (Leica DLMB). The mites were cleared in 80% lactic acid and mounted in Hoyer's medium on microscope slides. The species were identified using keys constructed for mesostigmatic mites (Lindquist *et al*. 2009; Bregetova 1984).

Determination of soil organic matter

Soil organic carbon was determined by the wet oxidation method (Walkley and Black 1934). For all determinations, three replicates were used. The soil was ground and then passed through a 0.5 mm mesh sieve and placed in a 500 mL Erlenmeyer flask. The amount of soil used in the determination ranged from 0.1 to 0.5 g. Ten milliliters of 0.167 M potassium dichromate and 20 mL of concentrated sulfuric acid were added to the soil. The suspension was swirled and left to stand for 30 min. and then 200 mL of distilled water, 10 mL of concentrated H3PO4, and 1 mL of 0.16 % diphenylamine were added. The excess dichromate was measured by volumetric titration using Mohr's salt (Yeomans and Bremner 1988).

Data analysis

A variety of diversity indices can be used in soil ecology to assess the environmental quality and the disturbance effects on soil communities. In the present study, we used some of these indices (Species richness, Shannon-Wiener's and Simpson's indices) based on Magurran (2003). The numbers of individuals from each taxonomic group per soil core or per sample were determined to calculate the Margalef's index (a number of species per sample), Shannon-Wiener's and Simpson's inverse diversity index, using the formula based on Magurran (2003). Land use type was considered as a fixed effect and other factors, sampling sites (their locations and associated effects of soil type, crop management, etc.) were treated as random factors (Steel *et al*. 1996). For all parameters tested (Margalef's, Shannon-Wiener's and Simpson's inverse), statistical tests were conducted using SAS 9.1 (Schlotzhauer and Littell 1987) and Fisher's protected LSD ($\alpha = 0.05$). The influence of the environmental parameters, such as the organic matter content in the soil, on the mite assemblage, was investigated by canonical correspondence analysis (CCA) using CANOCO software (Ter Braak 1988).

RESULTS

Diversity, species richness, abundance, and organic matter content

After analyzing 512 samples, a total of 2838 mesostigmatic individuals were counted, belonging to 12 families, 17 genera and 24 species. All taxa were identified to species level. Abundance and diversity of mites were found to be higher in orchards than in fields. The diversity indices of soil mites such as Shannon-Wienner's index (1.48 ± 0.01), Margallef's index (1.75 ± 0.11) and Simpson's index (6.39 ± 0.41) were found highest in the sampled vineyard, whereas the lowest mite density was recorded in a wheat field (site 4).

The highest estimated values of Simpson's diversity index were recorded in the vineyard in April (10.73 ± 0.04), in the walnut orchard in May (9.3 ± 0.29), and in the wheat field site 3 in May (10 ± 0.32) (Table 3). *Neoseiulus marginatus* (Wainstein) and *Parasitus fimetorum* (Berlese) were found to constitute the dominant species, nearly 38.6% of total number of individuals observed in all sample sites. Phytoseiid mites were found in all sampling months, but their diversity varied. Differences in soil organic matter content among the eight pairs of sampling dates were more obvious ($p < 0.0001$). Amount of soil organic matter in orchards was found higher than that of farmlands ($p < 0.0001$). The species diversity and density were higher in orchards with higher organic matter than that of fields. The maximum amount of organic matter was present in the grape vineyard (2.12%).

Sample frequencies of *N. marginatus*, *P. fimetorum* and *Parasitus hyalinus* (Willman) were 27.4%, 11.2% and 9.5%, respectively which were classified as dominant. Two other species i.e. *Halolaelaps sexclavatus* (Berlese) and *Onchodellus karawaiewi* (Berlese) ranked as subdominant with 8.5% and 6.9%, respectively.

In all the fields over time before glyphosate application, the index values were high and densities increased. The Shannon-Wienner index of Mesostigmata was the lowest in the agroecosystem and individual soil cores increased in the almond orchard of almond/wheat code. We found significant differences in abundance and species richness, in terms of the Simpson's and Shannon-Wiener's indices of Mesostigmata between the old orchards and perennial and annual fields (Table 4).

Effect of land use type on density

The analysis of the number of species, dominance and average abundance (specimen/m^2) of the species in the examined communities found in the two orchards and fields show the dynamics of the changes over this period. Significantly, the density of Mesostigmata in the orchards was higher than in the fields (Table 2).

The densities of the four most abundant mesostigmatic species - *H. sexclavatus*, *O. karawaiewi*, *P. fimetorum* and *N. marginatus* were significantly higher in orchards than fields except in alfalfa/almond, where the number of *N. marginatus* individuals was higher in *Medicago sativa* than in *Prunus amygdalus*. The densities of *H. sexclavatus*, *O. karawaiewi*, *P. fimeturom* and *N. marginatus* were higher in *Vitis vinifera*, *Amygdalus scoparia, Ulmus carpinifolia,* and *M. sativa* respectively. Interestingly, 20 species occurred both in orchards and in fields. Four species, *Veigaia planicola* (Berlese), *Androlaelaps shealsi* (Costa), *Gaeolaelaps nolli* (Karg) and *Gaeolaelaps queenslandicus* (Womersley) were found only in orchard habitats, while *Arctoseius cetratus* (Sellnick) was associated with the saffron field (Table 5).

DISCUSSION

Effect of land use type on mesostigmata assemblages

Soil biodiversity is commonly used to evaluate land use effects. How to respond to the type of land use changes on soil communities is of great importance (Paoletti *et al*. 1992; Sánchez-Bayo 2011; Pascual *et al.* 2015; Murvanidze *et al.* 2019). Our results showed that a sample size of 32 was sufficient to evaluate the effects of land use on the mesostigmatic mites assemblage in all the examined land use types. Strong relationships between sample size and species richness showed that sample size may be sufficient to capture rare species (Moreno and Halffter 2000). For future studies, the sample size should be optimized by adjusting the sample size to achieve sampling efficiency among all land use types.

As expected, in most of the samplings species diversity was significantly related to land use type and was highest in orchards. Ettema and Wardle (2002) also showed that the abundance and diversity of Oribatida were high in forests and low in corn fields. The indices used in this study are sensitive to the abundance of species per sample and may be influenced by the composition of communities (Magurran 2004). The abundance and diversity at each site may be influenced by environmental factors (Nekola and White 1999). Environmental factors such as high soil organic matter content, suitable soil moisture conditions throughout the year, soil temperatures and low incident radiation due to plant cover are favorable conditions for soil mite development. High organic soil content is usually beneficial for most soil animals and biodiversity is relatively strongly linked to available energy resources and essential nutrients (Pokarzhevskii and Krivolutskii 1997). Schulz (1991) observed that total species richness of oribatid mite increased from corn fields to forests. This is contrary to the intermediate disturbance hypothesis (Connell and Slatyer 1977; Connell 1978) according to which diversity is highest in areas with intermediate disturbance. Maraun *et al.* (2003) showed that the diversity of Oribatida declined when disturbance increased.

Table 2. Diversity of soil mites in different sites/plots under different land uses in Saman and Shahrekord in 2014: Margalef's index, Shannon-Wiener's index, Simpson's index, density (mean ± SE), and ANOVA (GLM, α = 0.05) for the hypothesis of no effect of the land use type.

Site	Crop	Shannon-Wiener's index	Margalef's index	Simpson's index	Density	Organic matter (Percent)
1	Almond	0.99 ± 0.06	1.07 ± 0.09	4.47 ± 0.26	5.9 ± 0.54	1.2 ± 0.02
	Wheat	0.64 ± 0.01	0.74 ± 0.06	3.62 ± 0.25	2.43 ± 0.35	0.62 ± 0.00
	$F_{(1, 30)}$	2.17	15.65	3.96	25.4	301.79
	P	0.01	0.007	0.09	0.002	< 0.0001
2	Almond	1.01 ± 0.04	1.15 ± 0.03	4.05 ± 0.18	7.21 ± 0.52	1.25 ± 0.00
	Saffron	0.66 ± 0.07	0.93 ± 0.09	3.55 ± 0.3	4.71 ± 0.5	1.04 ± 0.02
	$F_{(1, 30)}$	15.69	2.05	1.32	11.33	82.79
	P	0.007	0.2	0.2	0.01	< 0.0001
3	Almond	1.26 ± 0.08	1.35 ± 0.07	5 ± 0.46	6.37 ± 0.26	1.92 ± 0.00
	Wheat	0.46 ± 0.07	1.23 ± 0.08	4.81 ± 0.5	1.37 ± 0.32	0.53 ± 0.00
	$F_{(1, 30)}$	13.01	1.2	0	218.18	155.2
	P	< 0.0001	0.3	0.92	< 0.0001	< 0.0001
4	Elm	1.16 ± 0.09	1.57 ± 0.13	3.44 ± 0.19	17.15 ± 1.7	1.730 ± 0.01
	Wheat	0.15 ± 0.04	0.22 ± 0.06	1.81 ± 0.23	1.15 ± 0.17	0.41 ± 0.00
	$F_{(1, 30)}$	336.1	138.02	347.11	92.07	109.4
	P	< 0.0001	< 0.0001	0.0002	< 0.0001	< 0.0001
5	Almond	1.4 ± 0.05	1.70 ± 0.07	6.17 ± 0.33	16 ± 1.63	1.75 ± 0.01
	Barley	0.19 ± 0.05	0.31 ± 0.06	2.4 ± 0.17	1.84 ± 0.23	0.54 ± 0.01
	$F_{(1, 30)}$	165.1	347.5	32.44	116.18	325.5
	P	< 0.0001	< 0.0001	0.0001	< 0.0001	< 0.0001
6	Vine	1.48 ± 0.01	1.75 ± 0.11	6.39 ± 0.41	18.06 ± 2.06	2.12 ± 0.03
	Wheat	0.99 ± 0.02	1.21 ± 0.12	6.35 ± 0.46	6.37 ± 0.98	0.93 ± 0.01
	$F_{(1, 30)}$	36.12	62.25	3.46	13.69	113.61
	P	0.001	< 0.002	0.1	0.001	< 0.0001
7	Walnut	1.1 ± 0.03	1.21 ± 0.09	5.2 ± 0.46	8.28 ± 0.53	1.51 ± 0.03
	Wheat	0.2 ± 0.02	0.25 ± 0.03	2.06 ± 0.18	2.84 ± 0.76	0.72 ± 0.01
	$F_{(1, 30)}$	169.66	192.62	33.06	27.11	362.4
	P	< 0.0001	< 0.0001	0.001	0.002	< 0.0001
8	Almond	0.82 ± 0.08	1.02 ± 0.11	6.02 ± 0.43	3.96 ± 0.3	1.1 ± 0.02
	Alfaalfa	0.76 ± 0.03	0.83 ± 0.04	2.3 ± 0.16	15.53 ± 1.42	1.17 ± 0.02
	$F_{(1, 30)}$	0.29	5.25	57.98	56	5.18
	P	0.6	0.06	0.0008	< 0.0003	0.06

Our results showed that as land management intensity increased, the diversity of Mesostigmata declined. The density of Mesostigmata varied in arable land and high densities were found in Lucerne ley (Andrén and Largerlöf 1983). Wardle *et al.* (2004) found a high density of mites in former agricultural land caused by a higher survival rate resulting from the former agricultural use. Plant species may be effective in soil biota because they make a difference in the quantity and quality of resources that are returned to the soil (Walter and Proctor 2004). According to Maraun *et al.* (2003), the intermediate disturbance hypothesis does not apply to the ecological dynamics of soil microarthropods. A balance between the sequence of disturbance and recolonization time, for different populations of microarthropods, is essential for the formation of societies in managed or disturbed habitats (Siepel 1996).

Table 3. Simpson's diversity index from March to October 2014.

Site	Crop	March	April	May	June	July	August	September	October
1	Almond	1.13 ± 0.02	5.6 ± 0.53	5.6 ± 0.11	5.1 ± 0.05	3.5 ± 0.21	4.3 ± 0.08	3.9 ± 0.08	5.2 ± 0.05
	Wheat	*NA*	4.30 ± 0.15	4.8 ± 0.26	3.03 ± 0.00	0.99 ± 0.08	3.02 ± 0.00	5 ± 0.1	2.6 ± 0.00
	$F_{(1,6)}$	*NA*	0.33	2.02	5.2	6.15	3.27	3.4	2.9
	P	*NA*	0.59	0.2	0.0007	0.06	0.1	0.1	0.1
2	Almond	3.2 ± 0.2	1.7 ± 0.13	4.3 ± 0.24	5.3 ± 0.15	3.7 ± 0.28	3.7 ± 0.08	4.3 ± 0.11	4.4 ± 0.09
	Saffron	1.2 ± 0.05	5.7 ± 0.15	6.05 ± 0.29	4.9 ± 0.18	2.7 ± 0.04	2.66 ± 0.08	2.5 ± 0.05	0.5 ± 0.00
	$F_{(1,6)}$	6.5	17.9	0.86	0.11	0.37	3.34	12.9	15.2
	P	0.04	0.01	0.38	0.74	0.57	0.09	0.01	0.01
3	Almond	2.47 ± 0.01	2.18 ±0.12	5.9 ± 0.13	6.4 ± 0.3	6.07 ± 0.09	8.78 ± 0.29	4.9± 0.12	4.6 ± 0.1
	Wheat	0.99 ± 0.00	3.3 ± 0.13	10 ± 0.32	3.2 ± 0.21	3.02 ± 0.00	3.02 ± 0.00	5 ± 0.14	5 ± 0.13
	$F_{(1,6)}$	1.95	1.18	12.5	3.1	9.74	3.07	0.03	0.14
	P	0.02	0.35	0.02	0.1	0.05	0.1	0.8	0.7
4	Elm	4.3 ± 0.00	3.03 ± 0.00	3.61 ± 0.13	5.38 ± 0.14	3.1 ± 0.11	3.81 ± 0.08	2.9 ± 0.01	16.2 ± 0.23
	Wheat	*NA*	3.03 ± 0.00	3.02 ± 0.00	3.02 ± 0.00	0.99 ± 0.00	0.99 ± 0.00	0	*NA*
	$F_{(1,6)}$	*NA*	0	0.83	15	15.3	18.7	811.2	*NA*
	P	*NA*	0	0.4	0.008	0.01	0.02	0.0001	*NA*
5	Almond	2.28 ± 0.12	7.5 ± 00	5.58 ± 0.16	6.72 ± 0.07	6.24 ± 0.09	9.2 ± 0.25	7.01 ± 0.11	4.17 ± 0.02
	Barley	3.32 ± 0.11	2.3 ± 0.3	3.07 ± 0.07	1.58 ± 0.18	*NA*	0.99 ± 0.00	*NA*	*NA*
	$F_{(1,6)}$	0.95	1.62	12.9	37.4	*NA*	11.04	*NA*	*NA*
	P	0.4	0.3	0.01	0.01	*NA*	0.04	*NA*	*NA*
6	Vine	2.43 ± 0.21	10.73 ± 0.04	5.6 ± 0.17	6.2 ± 0.18	6.5 ± 0.08	7.81 ± 0.13	7.8 ± 0.11	5 ± 0.08
	Wheat	*NA*	0.99 ± 0.00	8.8 ± 0.17	4.5 ± 0.2	6.8 ± 0.18	6.15 ± 0.1	6.4 ± 0.13	4 ± 0.05
	$F_{(1,6)}$	*NA*	365.8	5.3	1.6	0.1	3.07	1.7	0.6
	P	*NA*	0.002	0.05	0.2	0.7	0.1	0.2	0.4
7	Walnut	3.7 ± 0.36	6.4 ± 0.11	9.3 ± 0.29	8.03 ± 0.26	3.62 ± 0.09	4.25 ± 0.09	0.38 ± 0.01	2.09 ± 0.02
	Wheat	*NA*	3.5 ± 0.08	1.86 ± 0.08	2.2 ± 0.13	0.99 ± 0.00	0.99 ± 0.00	*NA*	*NA*
	$F_{(1,6)}$	*NA*	12.3	19.5	18.7	34.5	20.74	*NA*	*NA*
	P	*NA*	0.02	0.006	0.005	0.004	0.01	*NA*	*NA*
8	Almond	3.38 ± 0.31	6.25 ± 0.00	7.34 ± 0.38	5.98 ± 0.12	5.5 ± 0.19	7.01 ± 0.16	2.3 ± 0.05	*NA*
	Alfaalfa	1.79 ± 0.17	3.74 ± 0.25	2.06 ± 0.09	2.25 ± 0.05	1.8 ± 0.05	1.24 ± 0.11	5.6 ± 0.12	1.98
	$F_{(1,6)}$	1.51	0.85	9.7	41.4	20.3	27.8	45.59	*NA*
	P	0.2	0.4	0.02	0.001	0.004	0.001	0.001	*NA*

NA = not applicable (Species richness = 0)

The main characteristic of farming systems is repeated disturbances and the rapid growth cycle under conditions of tillage and fertilization which help organisms with short generation time and rapid dispersal (Cambardella and Elliott 1994). In 1994, Sgardelis and Usher (1994) concluded that a sharp decline is common in the species richness of oribatids mite in arable fields.

In our study, the diversity and abundance of Mesostigmata were related to land use type. Mesostigmata can temporarily exploit restricted habitats and one important life strategy of their species is the recolonization in different sources of soil (Siepel and Maaskamp 1994; Walter and Lindquist 1995). Some families of Mesostigmata have a short life cycle, for example, Ascidae from 1.5 to 2 weeks, and Laelapidae from 3 to 4 weeks (Hartenstein 1962; Binns 1975).

The diversity and abundance of Mesostigmata decrease in agroecosystems but in ruderal sites and undisturbed landscapes, they can be very high (Koehler 1991; Schulz 1991). The effect of land use type was significant for the community composition of Mesostigmata. All species of

Meosostigmata with different life history tactics were filtered from soil communities by attentions of land management which was confirmed with the effect of land use type (Aoki 1979; Siepel 1994, 1996; Maraun and Scheu 2000). Some families of Mesostigmata such as Veigaiidae and Parholaspidae are k-selected given that their development is slow and their dispersal is low, while some of them such as Ascidae, Laelapidae and Phytoseiidae are r-selected. In this study, k-selected species were associated with orchards, and r-selected species were associated with fields (Petrova 1977; Athias-Binche 1989; Ruf 1998; Koehler 1999). Our results showed that the diversity and abundance of mesostigmatic populations correlated with land use type and response to land management.

Table 4. Richness diversity index from March to October 2014.

Site	Crop	March	April	May	June	July	August	September	October
1	Almond	0	1.35 ± 0.02	1.2 ± 0.07	1.28 ± 0.01	0.95 ± 0.08	1.12 ± 0.03	1.3 ± 0.03	0.8 ± 0.02
	Wheat	0	1.17 ± 0.01	1.18 ± 0.02	0.91 ± 0.00	0	0	1.09 ± 0.00	1.27 ± 0.06
	$F_{(1,6)}$	0	7.68	0.02	151.74	91.16	252.3	3.96	1.29
	P	0	0.03	0.89	< 0.0001	< 0.0001	< 0.0001	0.09	0.2
2	Almond	1.033 ± 0.02	0.69 ± 0.01	1.12 ± 0.05	1.46 ± 0.03	1.08 ± 0.07	1.28 ± 0.00	1.23 ± 0.04	1.2 ± 0.04
	Saffron	0.24 ± 0.03	1.71 ± 0.04	1.49 ± 0.1	1.28 ± 0.03	0.37 ± 0.03	0.8 ± 0.02	0.68 ± 0.01	0.7 ± 0.01
	$F_{(1,6)}$P	151.79	112.49	1.78	2.41	23.17	56.16	5.93	1.37
		< 0.0001	< 0.0001	0.2	0.1	0.0003	0.0003	0.05	0.2
3	Almond	1.41 ± 0.08	0.74 ± 0.01	1.73 ± 0.05	1.69 ± 0.08	1.59 ± 0.03	1.87 ± 0.03	1.36 ± 0.09	1.3 ± 0.03
	Wheat	0	0.58 ± 0.03	0.92 ± 0.00	1.49 ± 0.04	0.57 ± 0.05	0.57 ± 0.04	1.23 ± 0.07	0
	$F_{(1,6)}$	390.75	5.12	45.64	0.63	60.1	107.86	3.25	1.2
	P	< 0.0001	0.06	0.0005	0.4	0.0002	< 0.0001	0.1	0.5
4	Elm	0	1.25 ± 0.06	1.97 ± 0.05	2.54 ± 0.03	1.75 ± 0.04	2.04 ± 0.03	1.95 ± 0.03	0.82 ± 0.02
	Wheat	0	0.22 ± 0.01	0.91 ± 0.00	0.91 ± 0.00	0	0	0	0
	$F_{(1,6)}$	0	91.71	75.49	388.3	652.7	271.2	307.33	13.91
	P	0	< 0.0001	< .0001	< 0.0001	< 0.0001	< 0.0001	0.0001	0.009
5	Almond	1.26 ± 0.03	1.28 ± 0.08	1.96 ± 0.09	3.32 ± 0.02	1.78 ± 0.1	2.27 ± 0.04	2.05 ± 0.02	1.24 ± 0.04
	Barly	0.57 ± 0.02	0.8 ± 0.03	0.85 ± 0.06	0	0	0	0	0
	$F_{(1,6)}$	64.63	7.06	16.20	199.3	121.5	758.8	158.8	222.3
	P	0.0002	0.03	0.006	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001
6	Vine	0.34 ± 0.03	1.86 ± 0.04	1.67 ± 0.07	2.43 ± 0.03	2.1 ± 0.05	2.1 ± 0.07	1.71 ± 0.04	1.43 ± 0.06
	Wheat	0	0	219 ± 0.07	1.19 ± 0.06	1.5 ± 0.05	1.56 ± 0.04	2.01 ± 0.01	1.41 ± 0.07
	$F_{(1,6)}$	317.7	719.5	2.9	2.98	5.6	5.3	7.99	0
	P	< 0.0001	< 0.0001	0.13	0.13	0.05	0.05	0.03	0.9
7	Walnut	0.66 ± 0.02	1.2 ± 0.08	1.91 ± 0.06	1.88 ± 0.04	1.14 ± 0.04	1.24 ± 0.02	0.85 ± 0.05	0.53 ± 0.01
	Wheat	0	0.32 ± 0.1	0.55 ± 0.06	1.26 ± 0.09	0	0	0	0
	$F_{(1,6)}$	115.7	8.99	51.54	5.25	373.88	161.32	631.1	295.6
	P	< 0.0001	0.02	0.0004	0.06	< 0.0001	< 0.0001	0.0001	< 0.0001
8	Almond	0.53 ± 0.01	0	1.66 ± 0.03	1.46 ± 0.01	1.32 ± 0.06	1.5 ± 0.04	0.83 ± 0.02	0
	Alfaalfa	0.37 ± 0.05	1.21 ± 0.05	0.87 ± 0.06	1.01 ± 0.06	0.37 ± 0.04	0.83 ± 0.05	1.31 ± 0.06	0.76 ± 0.02
	$F_{(1,6)}$	6.9	233.6	19.59	9.7	12.56	17.08	14.79	109.69
	P	0.03	< 0.0001	0.004	0.02	0.01	0.006	0.008	< .0001

Effect of environmental parameters on Mesostigmata assemblage

CCA showed that environmental parameters significantly impact the social structure of Mesostigmata (Fig. 2). The most significant effect has been linked to organic carbon as well as Collembola communities were influenced by soil organic matter (Salamon *et al*. 2011). Koehler and Born (1989) found that among several parameters, such as soil moisture and pH, organic carbon is more correlated with mite assemblages. Andrén and Lagerlöf (1983) reported a relationship between soil organic matter and Gamasina in agricultural systems. High levels of organic matter promote the growth of bacteria and fungi, and attract predators such as collembola, nematode, and oribatida, and thus influence higher trophic levels such as mites. Soil organic matter is a direct food resource of Collembola (Scheu and Falca 2000) and Mesostigmata feed on collembolans (Karg 1993). Some species of the Ascidae family feed on collembola and nematodes and juvenile oribatida (Karg 1993). Feeding habits show a relationship between Mesostigmata and Collembola, Nematoda and Oribatida.

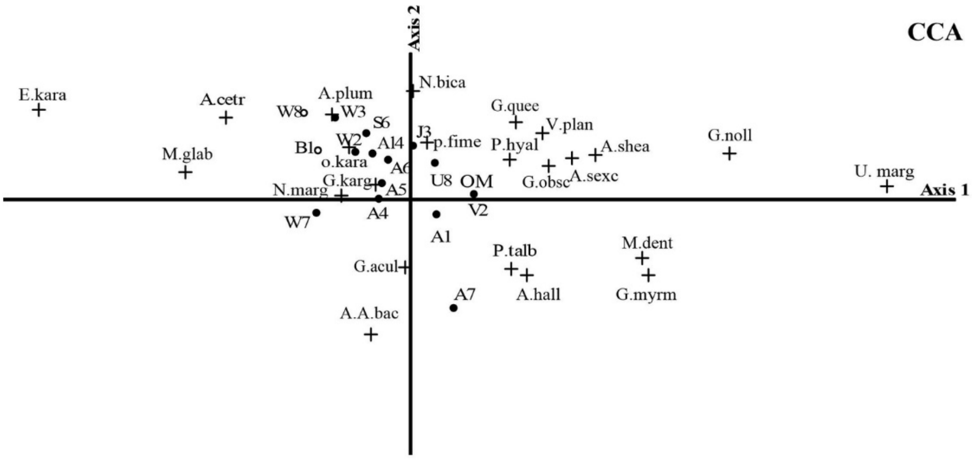

Figure 2. Ordination bi-plot of the canonical correspondence analysis (CCA) for Mesostigmata. Environmental variable organic matter (OM). For abbreviations of mite species see Table 5.

Table 5. Number of individuals of Mesostigmata species in different land use types in Saman and Shahrekord region (S = Saman, Sh = Shahrekord). For other abbreviations see Table 1.

Species	S		S		S		S		Sh		Sh		Sh		Sh	
	A	B	W	V	W	J	A	Al	A	W	A	S	A	W	W	U
***Ameroseius plumosus* (Oudemans)**	-	-	19	-	-	-	-	-	-	-	29	34	-	-	3	-
***Antennoseius bacatus* (Athias-Henriot)**	-	-	-	-	-	-	54	-	5	11	-	-	18	79	-	-
***Arctoseius cetratus* (Sellnick)**	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
***Alliphis halleri* (G. & R. Canestrini)**	18	-	2	- -	10	6	6	-	-	-	-	-	34	-	-	-
***Halolaelaps sexclavatus* (Berlese)**	2	-	120	18	18	2	11	-	-	-	29	4	6	7	22	2
***Euandrolaelaps karawaiewi* (Berlese)**	1	-	20 -	-	-	-	-	-	-	-	-	3	-	-	-	-
***Gymnolaelaps obscuroides* (Costa)**	21	-	26	7	-	-	8	5	-	-	5	-	-	-	22	-
***Gaeolaelaps queenslandicus* (Womersley)**	-	-	-	-	-	-	-	-	-	-	-	6	-	-	23	-
***Gaeolaelaps asperatus* (Costa)**	-	-	3	-	-	-	-	-	39	-	-	-	7	-	-	-
***Gaeolaelaps aculeifer* (Canestrini)**	19	2	-	-	-	-	-	-	2	-	-	6	-	-	-	-
***Gaeolaelaps kargi* (Costa)**	-	-	8	-	8	2	11	9	-	-	-	-	9	5	8	-
***Gaeolaelaps nolli* (Karg)**	-	-	8	-	-	-	-	-	-	-	-	-	-	-	9	-
***Onchodells karawaiewi* (Berlese)**	63	13	31	28	4	18	5	-	-	-	-	-	-	-	25	9
***Parasitus fimetorum* (Berlese)**	24	9	102	41	49	46	-	-	3	16	35	17	14	-	112	2
***Parasitus hyalinus* (Willmann)**	-	-	-	-	-	-	-	-	3	17	-	-	-	-	96	-
***Neoseiulus marginatus* (Wainstein)**	126	10	102	41	-	-	242	28	34	9	32	83	8	36	22	6

Table 5. Continued.

Species	S		S		S		S		Sh		Sh		Sh		Sh	
	A	B	W	V	W	J	A	Al	A	W	A	S	A	W	W	U
***Paraseiulus talbii* (Athias-Henriot)**	54	12	2	-	-	-	-	-	-	-	-	15	45	2	-	-
***Neoseiulus bicaudus* (Wainstein)**	-	-	-	-	31	3	-	-	-	-	-	-	-	-	8	-
***Multidentorhodacarus denticulates* (Berlese)**	6	-	2	1	-	-	-	-	-	-	-	-	7	-	5	-
***Uroobovella marginata* (Koch)**	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
***Veigaia planicola* (Berlese)**	-	-	21	-	11	-	13	-	-	-	-	5	-	-	27	-
***Gymnolaelaps myrmecophilus* (Berlese)**	8	-	12	6	-	-	-	-	-	-	-	-	17	-	-	-
***Macrocheles glaber* (Müller)**	-	-	-	-	-	-	43	-	-	-	21	-	-	-	-	-
***Androlaelaps shealsi* (Costa)**	6	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-

In conclusion, the results of the current study clearly show that the Mesostigmata communities were unstructured, and with their short generation cycles, many Mesostigmata species seem to exist on temporal scales that are too short to be affected by human land use practices. It may, therefore, be difficult to relate their local species richness to landscape factors. On the other hand, the diversity of Mesostigmata at both the site and soil core-levels correlated with the land use type, suggesting that mesostigmatic mites respond to land management at a variety of scales. For Mesostigmata, the life history traits of individual species can be used to predict the effect of land management on species assemblages.

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تنوع گونه‌ای کنه‌های خاکزی (Acari: Mesostigmata) در زمین‌های کشاورزی با کاربری متفاوت

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چکیده

کنه‌ها بهترین نمایندهٔ بندپایان خاکزی‌اند، زیرا از نظر اکولوژیک و رفتارهای محیطی متنوع‌ترین‌اند. با توجه به حساسیت کنه‌های خاک به آشفتگی خاک، از تنوع و تعداد آنها می‌توان به عنوان شاخص‌های اکولوژیک برای ارزیابی آشفتگی در اکوسیستم‌ها استفاده کرد. برای تعیین تأثیر نوع کاربری زمین بر تنوع زیستی کنه‌های خاکزی، شاخص‌های فراوانی و تنوع زیستی میان‌استیگمایان خاکزی در هشت ایستگاه در شهرستان‌های سامان و شهرکرد در کشور ایران مورد بررسی قرار گرفت. هر ایستگاه شامل دو قطعهٔ کشاورزی باغ و کشتزار در کنار هم بود که مورد ارزیابی قرار گرفتند. تنوع زیستی کنه‌های خاکزی با چند شاخص اندازه گیری شد و سپس با تجزیه و تحلیل واریانس مقایسه شد. نمونه‌های جمع‌آوری شده متعلق به ۱۲ خانواده، ۱۷ جنس و ۲٤ گونه بود. مقادیر شاخص تنوع زیستی محاسبه شده در ماه‌های مختلف نشان داد که این شاخص‌ها به طور معمول در ماه‌های گرم و باغ‌ها بیشتر از ماه‌های سرد و کشتزارها است. در کشتزارهای مورد بررسی، مقدار شاخص‌های تنوع پس از برداشت، به احتمال به دلیل تاثیر ماشین‌های کشاورزی در خاک کشتزارها کمتر بود. تفاوت معنی‌داری در شاخص شانون–وینر در مورد تنوع کنه‌های خاکزی در زمین‌هایی با کاربری متفاوت وجود داشت. بیشترین و کمترین مقادیر این شاخص به ترتیب در باغ انگور (۱/٤۸) و کشتزارهای گندم (۰/۱۵) و در کشتزار گندم کنار درختان نارون در شهرکرد ثبت شد. محتوای مادهٔ آلی خاک در تاکستان بیشینه (۲/۱۲ درصد) و کمترین میزان آن در کشتزار گندم (۰/٤۱) بود.

واژگان کلیدی: فراوانی؛ تنوع زیستی؛ غنا؛ Parasitiformes؛ شاخص سیمپسون.

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