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Article

Relative abundance of oribatid mites (Sarcoptiformes: Oribatida) in two tillage systems of irrigated and rain-fed wheat farms of Khodabandeh County, Iran

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ABSTRACT
Biodiversity is an important factor in soil quality and functionality. Physical and chemical changes during agricultural operations influence on soil biodiversity. Tillage and irrigation significantly change the life of soil microorganisms. The current study was conducted in Khodabandeh County during the wheat growing season. The effect of the first treatment (two tillage systems: conventional and no-tillage systems) and the second treatment (months) in two years on the biodiversity of oribatid mites, were investigated in irrigated and rain-fed wheat farms. Twelve samples were collected randomly per each sampling time during 21 April, 5 June and 30 July 2014 and 10 May, 12 June and 31 July 2015 coinciding with tillering stage, stem elongation and harvesting. Twelve species from eight families and 12 genera were identified. Among them, *Opiella nova* with 24.4% relative abundance was the abundant species in 2014 and *Rhinopia bipectinata* with 27.5% was the abundant species in 2015. The highest value of the Shannon-Wiener diversity index was observed in the irrigated no-tillage (I-NT) system. The statistical results of the ANOVA test showed a significant difference in the Shannon-Wiener diversity index among the four systems. Shannon-Wiener diversity index in the I-NT system had a significant difference with the I-CT system (irrigated-conventional tillage). There were no significant differences between I-CT and I-NT in terms of species richness index while differences between I-NT and R-CT systems and between R-NT and R-CT systems were significant. Also, results showed that species richness index at the time of tillering stage was significantly higher than that of stem elongation. The interaction between two treatments did not show a significant difference. There was no significant difference between the two years, so the results of the two years were merged.

KEY WORDS: Acari; conventional tillage; no-tillage; species richness; Zanjan Province.

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INTRODUCTION

Biodiversity is an important factor in soil quality and its functionality. Physical and chemical changes during agricultural operations influence soil biodiversity. Gulvik (2007) showed that human activities and field and soil management processes affect the population of soil organisms and their balance due to the transformation of soil components and change in soil microhabitats. Tillage and irrigation significantly change the life of soil microorganisms. Agricultural activities influence biodiversity

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through changes of humidity (irrigation),change in vegetation (planting) and physical state of surface layers of soil (tillage). soil organisms, in turn, affect agriculture soil-dwelling mites which play a fundamental role in energy and life cycle and constitute about 7% by weight of soil arthropods (Raoofi *et al*. 2014). Studies have shown the impacts of soil compaction on soil microarthropods (Hendrix *et al*. 1986; Sabatini *et al*. 1997; Neher and Barbercheck 1999). They are often used as bioindicators of agricultural soil quality (Cortet *et al*. 2002; Barbercheck *et al.* 2009).

Mites are of the most prominent terrestrial arthropods which are very sensitive to tillage operations. Therefore, the response of a certain group of mites to soil physical changes can be considered as a bioindicator for agricultural ecosystems (Bedano *et al*. 2005; Booher *et al*. 2012). Oribatid mites among soil-inhabiting arthropods are considered as biological pollution indicators (Rockett 1986; Behan-Pelletier 1999; Gergocs and Hufnagel 2009). They also can be used as indicators of agricultural practices or soil quality (Hulsmann and Woletrs 1998).

Agricultural treatments affect oribatid communities negatively decreasing their abundance and diversity (Coleman *et al.* 2004; Minor and Norton 2004; Gergocs and Hufnagel 2009).

Tillage and irrigation patterns (irrigated or non-irrigated) are of the most important agricultural operations in cereal crops. Both of them have great roles in the presence and activity of various species of soil-inhabiting mites due to severe effect on soil humidity, organic material content as well as on soil erosion and compactness (FAO 2010). Due to the high disturbance of the soil during the process of wheat cultivation, it is obvious that the cultivation process puts the greatest effects on soil biodiversity and particularly, on soil-inhabiting mites.

In the conventional method, moldboard plow and disc harrow are used to plug the field. Conservation method (no-tillage) increases soil organic matter content, reduces machinery traffic and costs of tillage and sowing operations, improves soil texture, protects the soil against water and wind erosion and increases water storage capacity (Alimardani 2010), Also it can mitigate greenhouse gas (GHG) emissions in the agricultural sector (Lotz *et al*. 2019). Combustion of fossil fuels and related pollution are reduced too. Despite the relative advantages of conservation tillage, many farmers still use the conventional method due to various reasons. Despite higher average yield of irrigated crops in comparison with non-irrigated crops, some advantages of rain-fed crops such as convenience, lower water consumption and costs, and traditional inclination of farmers to this method besides occurrence of the water crisis in the past years have caused rain-fed crops to be the dominant cultivation pattern having an area under cultivation of 3.4 million hectares compared to 1.9 million hectares area of the irrigated wheat crop in Iran (Ahmadi *et al*. 2019). Hence, it seems necessary to study the effect of both cultivation patterns on the biodiversity of soil-inhabiting mites.

This study aims to investigate simultaneously effects of tillage types and irrigation patterns on biodiversity of soil mites in wheat fields. Wheat as the most important crop in Iran has a special standpoint in food security of the society and always constitutes the highest area under cultivation, e.g. the area was about 5.4 million hectares in the crop year of 2017–2018 (Ahmadi *et al.* 2019). With this in mind, the current study focused on the comparison of effects of conventional tillage (CT) and no-tillage (NT) on oribatid mites as bioindicators in wheat farms during the growing season in Gheydar, Khodabandeh County, in Zanjan Province. Khodabandeh county is located in the southeast of Zanjan (86 km distance), capital of the province. The city is the second city in the province in terms of area and population. The city has an area of 5151 km^2. Beneficiaries in the agriculture sector are 25757 individuals. Khodabandeh County has a temperate mountainous climate. Its annual precipitation is 411 mm and its annual average temperature is 10.3 °C. Wheat is the first crop of Khodabandeh County with an annual production of 180000 tons.

MATERIAL AND METHODS

This research compares the effects of conventional and no-tillage methods on soil-inhabiting mites in wheat fields. The two tillage methods are completely different in terms of the impact on the physical texture of the soil. The conventional method uses a moldboard plow and disc harrow. In a conservative method (no-tillage), no operation is performed to prepare the land. Organic matter and water storage capacity of the soil are increased and soil texture is improved. Given the different moisture changes between rain-fed and irrigated crops, species found in rain-fed and irrigated conditions will be compared in addition to the study of both of tillage methods. For this purpose, after initial studies, four wheat fields with similar conditions in terms of soil texture, temperature, precipitation, relative humidity (Table 1), altitude and slope and geographical location (Table 2) were selected in Gheydar in Khodabandeh County (36° 1′ 47″ N, 48° 59′ 11″ E) as research fields.

Table 1. Relative humidity, pH, and percentage of organic matter in soil of the studied fields.

Soil sample	Irrigated No-Tillage (I-NT)	Irrigated Conventional Tillage (I-CT)	Rain-fed No-Tillage (R-NT)	Rain-fed Conventional Tillage (R-CT)
Relative humidity	2.8	2.2	2.8	2.5
pH	7.51	7.53	7.53	7.60
Organic matter (%)	0.25	0.21	0.18	0.15

Twelve soil samples were collected randomly (Manu 2011; Rahgozar *et al*. 2019) from each field during the seasons in tillering, stemming, and harvesting stages. The samples in each field were collected from zero to 10-cm depth of soil randomly by moving through the diameter of the plot on 21 April, 5 June and 30 July 2014, and 10 May, 12 June and 31 July 2015. Sampling was performed at a certain time of the day (from 8 to 11 a.m.). In total 288 samples were collected (4 sites × 12 samples × 3 months × 2 years). Each sample was about one kilogram. Samples were transported into the laboratory after labeling and recording the time and location. Berlese-Tullgren funnel was used to extract mites from soil (Krantz and Walter 2009). Mites were kept in ethanol 75% after extracting, cleared in Nesbitt's fluid and mounted on microscope slides. Then samples were identified at species level using several keys (e.g. Balogh 1983; Balogh and Balogh 1992; Akrami and Saboori 2012; Keshavarz Jamshidian *et al*. 2016).

Table 2. Geographical coordinates of sampling farms.

Location coordinates	R-CT	I-CT	R-NT	I-NT
Longitude	48° 47′ 46″	48° 48′ 05″	48° 48′ 07″	48° 48′ 00″
Latitude	36° 08′ 44″	36° 07′ 58″	36° 08′ 24″	36° 08′ 28″
Area (hectares)	25	3.5	20	3.5

Accordingly, fauna and biodiversity of each field were determined and the results were interpreted using Ecological Methodology software considering the differences in terms of land preparation system and irrigation method.

In this study, quantitative indices of species richness, evenness, and heterogeneity were calculated and used to determine biodiversity.

Species richness was estimated with the Jackknife Method (Heltshe and Forrester 1983):

$$\hat{S} = s + \left(\frac{n-1}{n}\right) k$$

where $\hat{S}$ = Jackknife estimate of species richness, s = total number of observed species in n quadrat, *n* = number of all quadrates in sampling, *k* = number of unique species.

Various indices including Camargo, Simpson, Smith and Wilson, and modified Nee were calculated using software and used in order to assess evenness. Smith and Wilson's index is the best to investigate the data (Krebs 1999).

$$E_{var} = 1 - \left[\frac{2}{\pi \arctan\left\{\sum_{j=1}^{s}\left(\log_e(ni) - \sum_{j=1}^{s}\log_e(nj)/s\right)^2 /s\right\}}\right]$$

where E_{var} = Smith and Wilson's evenness index, n_i = number of i species (i=1, 2, 3, ..., s), n_j = number of j species (j = 1, 2, 3, …, s), s = number of all species in samples.

In order to determine the species richness index, Shannon's index was calculated. The index shows the healthiness of populations and varies between zero and about 4.5, the lower the value, the harder the conditions and more polluted the populations will be (Ejtehadi *et al*. 2012).

$$H' = -\sum_{i=1}^{s}(P_i)(LnP_i)$$

where H′ = species diversity index, $P_i = \frac{ni}{N}$, *s* = number of species.

This investigation was performed by using the Ecological Methodology software. Data on species richness, and evenness of oribatid mites in sampling farms were compared using a one-way analysis of variance (ANOVA) using SPSS 25 software. Comparisons of averages and calculations were performed with the SNK test.

RESULTS

In this research, 12 species belonging to 12 genera and eight families of the suborder of Oribatida were identified. Among the collected species, *Opiella nova* with 24.4% relative abundance was the dominant species in 2014 (Table 3) and *Rhinopia bipectinata* with 27.5% was the dominant species in 2015 (Table 4).

Investigating the quantitative indices in the four studied populations according to Jackknife index of species richness showed that the effect of tillage system on species richness index was significant at 99% confidence intervals ($F_{3, 8} = 8.525$; $p \leq 0.01$) and the highest index in both of years was observed in the no-tillage system at tillering stage (ESR = 89 ± 0.92). According to the results, species richness index in the irrigated system was higher than the rain-fed system and in no-tillage was higher than conventional tillage. In addition, in terms of time, the species richness index at the time of the tillering stage was significantly higher than that of the stem elongation stage ($F_{1, 8} = 7.893$; $p \leq 0.05$).

It is also clear that the effect of time on the species richness of oribatid mites is significant (Fig. 1). In July 2015, only two specimens of *Opiella* were found in the I-NT system. The findings were in accordance with the results of Fujita's nine-year study that showed that the best sampling time was in May and April (Fujita 2003). There was a significant difference in the case of species richness index between I-CT and I-NT systems at 95% confidence intervals. The differences of this index between I-NT and R-CT, and between R-NT and R-CT were significant at a 1% significance level (Fig. 2). No significant difference was observed between two years of sampling ($F_{1.14} = 1.072$; $p > 0.05$).

Table 3. The relative abundance of oribatid mites collected from four different wheat farms in 2014.

Species	R-CT		I-CT		R-NT		I-NT		Total	
	Ab	Ab%	Ab	Ab%	Ab	Ab%	Ab	Ab%	Ab	Ab%
Opiella nova			3	27.2	3	25	6	28.6	12	24.4
Ramusella strinnnatii	1	11.1			4	33.3	4	19	9	18.4
Rhinopia bipectinata			3	27.3			2	9.5	5	10.2
Scheloribates fimbriatus			5	45.5	1	8.3	4	19	10	20.4
Microppia minus					2	16.7	2	9.5	4	8.2
Anomaloppia iranica					1	8.3	2	9.5	3	6.1
Sphaerochthonius splendidus							1	4.8	1	2
Hypochthonius luteus										
Parhypochthonius sp.	1	11.1							1	2
Brachychthonius sp.	3	33.3							3	6.1
Nothrus silvestris										
Plesiodamaeus ornatus					1	8.3			1	2

Ab = abundance, Ab% = relative abundance

Table 4. The relative abundance of oribatid mites collected from four different wheat farms in 2015.

Species	R-CT		I-CT		R-NT		I-NT		Total	
	Ab	Ab%	Ab	Ab%	Ab	Ab%	Ab	Ab%	Ab	Ab%
Opiella nova			4	28.6	5	5.8	15	35.7	24	15
Ramusella strinnnatii	4	17.3	4	28.6	20	23.2	1	2.4	29	18.1
Rhinopia bipectinata	8	34.8			32	37.2	4	9.5	44	27.5
Scheloribates fimbriatus			5	35.7	2	2.3			7	4.4
Microppia minus	5	21.7			3	3.5	5	11.9	13	8.1
Anomaloppia iranica	5	21.7			6	6.9	12	28.6	23	14.3
Sphaerochthonius splendidus										
Hypochthonius luteus	1	4.3			2	2.3			3	1.9
Parhypochthonius sp.										
Brachychthonius sp.										
Nothrus silvestris			1	7.1	11	14.1			12	7.5
Plesiodamaeus ornatus					5	5.9			5	3.1

Ab = abundance, Ab% = relative abundance

According to the results of the Shannon-Wiener index, the highest diversity was equal to 2.121 observed in the I-NT system at the stage of tillering (April 2014). The case repeated at the stage of stem elongation in June 2014 so that the highest amount of Shannon-Wiener's index related to the I-NT system was obtained equal to 1.522. Shannon-Wiener's index at the time of the tillering stage was significantly higher than that of the stem elongation stage (Fig. 3). Comparing the statistical results and one-way ANOVA analysis using SPSS revealed that there is a significant difference between Shannon-Wiener's index between the four systems ($F_{3, 12} = 2.630$; $p \leq 0.05$). Shannon-Wiener's diversity index of I-NT was significantly higher than I-CT at the 95% level. In addition, the mean of this index in the R-NT system was significantly higher than that of the R-CT system at a 95% confidence level. The highest significant difference was observed between R-CT and I-NT and was at the level of 1% (Fig. 4). No significant difference was observed between two years of sampling ($F_{1, 14} = 0.365$; $p > 0.05$).

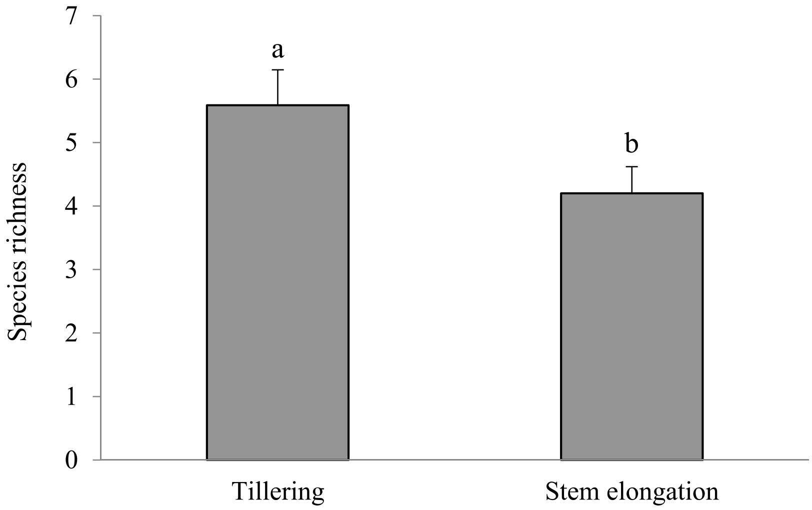

Figure 1. Means comparison of species richness of oribatid mites in sampling times (Different letters on the top of the bars indicate significant difference at P < 0.05 by Student Newman–Keuls test).

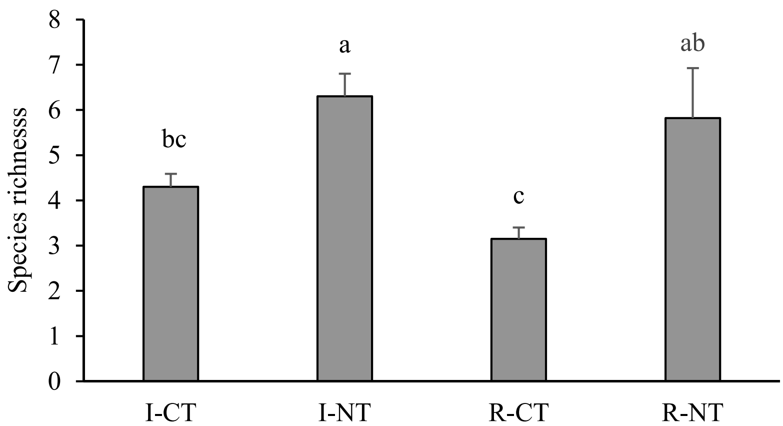

Figure 2. Means comparison of species richness of oribatid mites in four systems (Different letters on the top of the bars indicate significant difference at P < 0.05 by Student Newman.

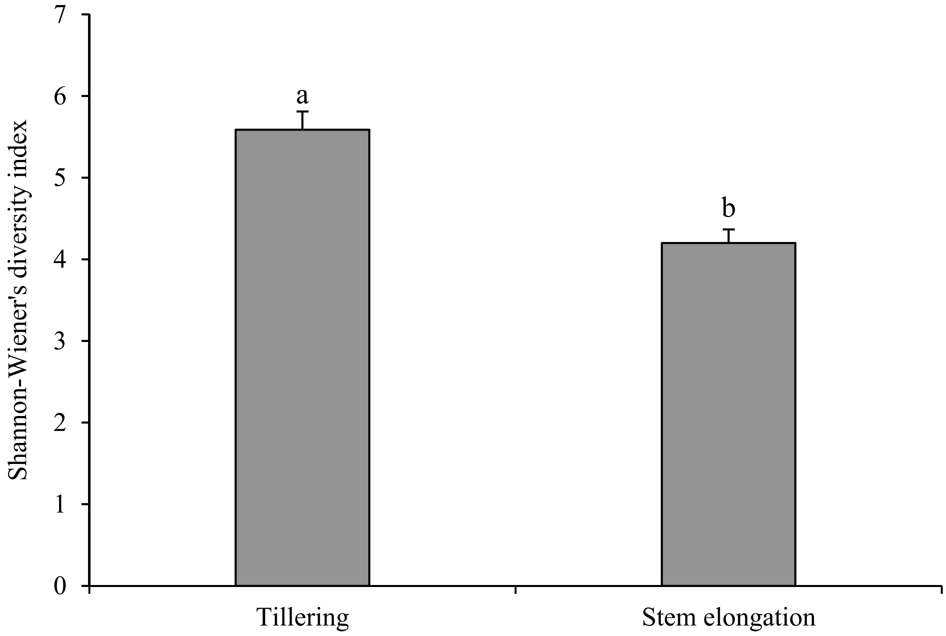

Figure 3. Means comparison of diversity of oribatid mites in sampling times (Different letters on the top of the bars indicate significant difference at $P < 0.05$ by Student Newman-Keuls test).

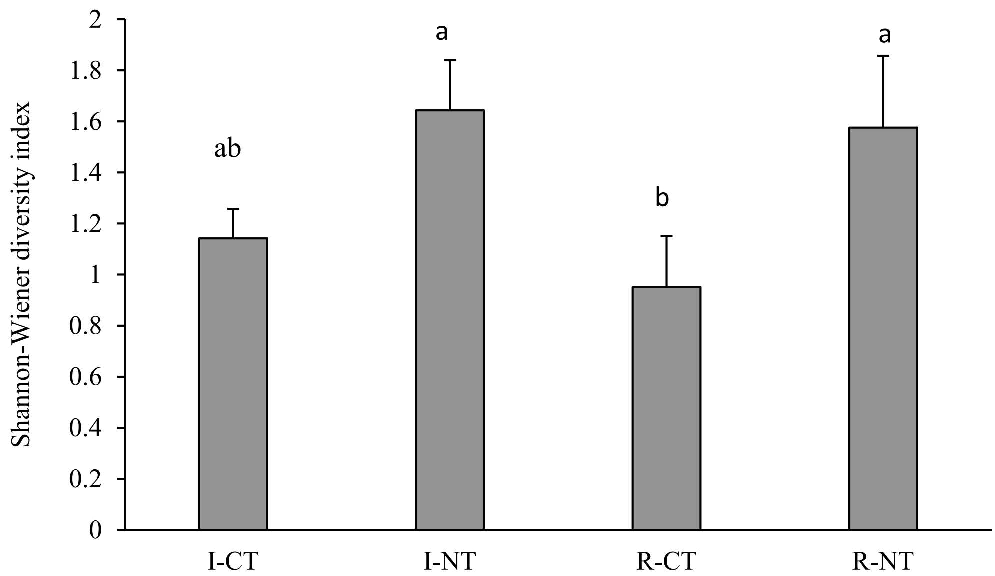

Figure 4. Means comparison of shannon-wiener index of oribatid mites in four systems (Different letters on the top of the bars indicate significant difference at $P < 0.05$ by Student Newman-Keuls test).

In terms of sampling time, Shannon-Wiener's index was significantly higher at the tillering stage (the first sampling) than the stem elongation stage (the second sampling) at a 99% confidence level ($F_{1, 8} = 14.340$, $p \leq 0.01$). However, there was no significant difference with Smith and Wilson's index.

DISCUSSION

A significant difference in species richness index between I-CT and I-NT systems at a 95% confidence level shows that although these systems are equal in terms of irrigation type, different tillage methods result in significant difference in terms of species richness of oribatid mites as bioindicators. Bedano *et al.* (2005) suggested that low radiation intensity due to the existence of plant residuals on the soil, higher organic matter and water content in the soil of these farms causing this difference. This can be attributed to higher organic matter, higher water capacity, an increase in water penetration speed, higher ventilation, and lower compression in the no-tillage system (Singh *et al.* 2018). Differences in this index between I-NT and R-CT and between R-NT and R-CT were significant at 1% level. Higher relative humidity in the soil of irrigated farms is an appropriate factor to increase their diversity and population (Gergocs and Hufnagel 2009; Sharma and Parwez 2017). Klimek *et al.* (2013) showed that irrigation is a determinant factor in the population of oribatid mites in artificial forests in Poland. According to the results, different species richness indices show the effect of cropping method and tillage method on species richness of oribatid mites as a biological indicator. The results agree with those of Rodriguez *et al.* (2006) who reported a higher relative density of arthropods in the no-tillage system compared to the conventional tillage system. Non-difference in species richness index between two years of sampling means in case of relative similarity of climatic conditions in consecutive years, no significant change will occur in species richness of Oribatida. Considering the variation range of the Shannon-Wiener's index can be concluded that the biodiversity of oribatid mites is low in wheat farms (the least and the highest amounts were 0.722 and 2.121, respectively). Various studies confirm that diversity of soil inhabitant populations in low level input systems is greater than in high level input systems (Fuller *et al.* 2005). This can be the result of agricultural operations, applying chemical pesticides and fertilizers, and severe physical and chemical changes in the soil (Arroyo and Iturrondobeitia 2006; Booher *et al.* 2012).

Rockett (1986) investigated long-term effects of intensive and concentrated agricultural operations on scattering and biodiversity of oribatid mites as the best-known terrestrial mites that live in upper layers of soil and observed that oribatid heterogeneity was significantly reduced in the total cultivated plots as compared to the total wood plot sections. Ramezani and Mossadegh (2014) found that biodiversity of oribatid mites in date-palm microhabitats was higher than cropped fields, and sampling time during the year had not any significant effects on biodiversity. Amani *et al.* (2015) observed a significant difference in the Shannon-Weiner species diversity index of Laelapid mites among different land uses. The maximum value of this index was recorded in soil of elm trees while the lowest was documented in wheat and barley farms. This can be due to application of pesticides, fungicides, herbicides and chemical fertilizers, and physical and chemical changes in the soil of wheat farms because of heavy machinery traffic during the growing season (Perez-Vlaquez *et al.* 2011; Amani *et al.* 2015). In addition, higher biodiversity in I-NT shows how no-tillage positively affects the biodiversity of Oribatida (Rodriguez *et al.* 2006; Gergócs and Hufnagel 2009; Sharma and Parwez 2017). Zhan *et al.* (2013) studied effect of various tillage operations on frequency, number of families, population structure, and surface scattering of soil-inhabiting mites and determined that farms with rotary plowing had the highest abundance but the highest number of families was related to low-till treatment. Also, results show that higher amount of soil moisture in irrigated fields increases diversity and population of Oribatda. Previous research show that humidity of microhabitats is an important factor that influences the abundance, distribution, and diversity of oribatid mites (Seyd and Seaward 1984; Siepel 1996; Smrž & Kocourková 1999; Maturna 2000; Rahgozar *et al.* 2019). Moisture changes may have indirect effects on fungivorous fauna and oviposition of oribatid mites with affecting the fungal community (Hågvar 1998). In terms of sampling time, Shannon-Wiener's index was significantly higher at tillering stage (the first sampling) than stem elongation stage (the second sampling) at 99% confidence level (Fig. 3). It shows that changes in temperature and rainfall effected on diversity of soil oribatid mites in four systems. These results are in accordance with those of previous studies (Arroyo and Iturrondobeitia 2006; Booher *et al*. 2012).

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فراوانی نسبی کنه‌های اریباتید (Sarcoptiformes: Oribatida) در دو سامانهٔ خاک‌ورزی کشتزارهای گندم آبی و دیم در شهرستان خدابنده، ایران

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چکیده

تنوع زیستی عامل مهمی در کیفیت خاک و عملکرد آن به شمار می‌آید. بروز تغییرات فیزیکی و شیمیایی در طول عملیات کشاورزی در خاک، سبب دگرگونی تنوع زیستی خاک می‌شود. خاک‌ورزی و آبیاری تاثیرات چشمگیری در زندگی میکروارگانیسم‌های خاک دارند. بررسی حاضر در طول فصل رشد گندم و در شهرستان خدابنده انجام شده است. تاثیر تیمار نخست (دو سامانه‌ی خاک‌ورزی: مرسوم و بی‌خاک‌ورزی) و تیمار دوم (ماه‌ها) در دو سال بر تنوع زیستی کنه‌های اریباتید خاکزی در مزارع گندم دیم و آبی بررسی شد. دوازده نمونه به صورت تصادفی در هر نوبت نمونه‌برداری و در تاریخ یکم اردیبهشت، ۱۵ خرداد و ۸ مرداد سال ۱۳۹۳ و ۲۰ اردیبهشت، ۲۲ خرداد و نهم مرداد سال ۱۳۹٤ همزمان با دوره‌های پنجه زنی، ساقه‌روی و برداشت گندم از خاک کشتزارها جمع‌آوری شد. دوازده گونه از هشت خانواده و ۱۲ جنس شناسایی شدند. گونهٔ *Opiella nova* با فراوانی نسبی ۲٤/٤٪ به عنوان گونهٔ فراوان در سال ۹۳ و گونهٔ *Rhinopia bipectinata* با فراوانی نسبی ۲۷/۵٪ گونهٔ فراوان در سال ۹٤ مشخص شد. بیشترین مقدار شاخص تنوع زیستی شانون–واینر در سامانه بی‌خاک‌ورزی–آبی (I-NT) مشاهده شد. با مقایسه نتایج آماری و انجام آزمون تجزیهٔ واریانس، تفاوت معنی‌داری بین شاخص تنوع شانن–واینر در چهار سامانه مشاهده شد. شاخص تنوع شانون–واینر درسامانهٔ I-NT با اختلاف معنی‌دار بیشتر از سامانهٔ I-CT (خاک‌ورزی مرسوم–دیم) بود. شاخص غنای گونه‌ای درسامانهٔ I-CT و سامانهٔ I-NT تفاوت معنی‌داری نشان نداد. در حالی‌که اختلاف این شاخص در سامانهٔ I-NT و R-CT و همچنین R-NT و R-CT معنی‌دار مشاهده شد. افزون بر این، نتایج مشخص کرد که شاخص غنای گونه‌ای در مرحلهٔ پنجه‌زنی، به شکل معنی‌داری بیشتر از مرحله‌ی ساقه‌روی است. اثر متقابل میان دو تیمار تفاوت معنی‌داری نشان نداد. اختلاف معنی‌داری بین دو سال دیده نشد بنابراین نتایج دوسال ادغام شد.

واژگان کلیدی: زیردهٔ کنه‌ها؛ خاک‌ورزی مرسوم؛ بی‌خاک‌ورزی؛ غنای گونه‌ای؛ استان زنجان.

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