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Impacts of Tillage on Biodiversity of Microarthropod Communities in Two Different Crop Systems

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***Abstract*—**Different uses of land by humans alter the physico chemical characteristics of the soil and affect the soil microhabitat. The objective of this study was to evaluate the influence of tillage in three different human land uses on microarthropods biodiversity in Khuzestan province, southwest of Iran. Three microhabitats including a permanent grassland with old Date-Palms around and no till system, and two wheat fields, one with conservative agricultural practices and low till system and the other with conventional agricultural practices (deep tillage), were compared for the biodiversity of the two main groups of soil microarthropods (Oribatida and Collembola). Soil samples were collected from the top to a depth of 15 cm bimonthly during a period of two years. Significant differences in the biodiversity index of microarthropods were observed between the different tillage systems ($F = 36.748$, $P = 0.000$). Indeed, analysis of species diversity showed that the diversity index at the conservative field with low till (2.58 ± 0.01) was higher ($p < 0.05$) than the conventional tilled field (2.45 ± 0.08) and the diversity of natural grassland was the highest (2.79 ± 0.19, $p < 0.05$). Indeed, the index of biodiversity and population abundance differed significantly in different seasons ($p < 0.00$).

***Keywords*—**Biodiversity, collembola, microarthropods, oribatida.

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I. Introduction

INTENSIVE human land use and conventional agriculture can influence ecosystems by physical and chemical disturbance and changes in soil state and functioning through compaction [3], [6], [16], [26], [28]. Conventional tillage usually causes a reduction in the number of soil microarthropod and their distribution, and increase the incidence of soil erosion [8]. Instead, conservation tillage such as low tillage generally reduces soil compaction and erosion by water and wind and leaves crop residues from the previous years at the soil surface [4]. Microarthropods are an important group of the soil biomass and have an essential role in soil food webs. They have positive effects on decomposition and “soil respiration” through their feeding on the soil [10]. They are abundant in most agricultural soils and are often used as bioindicators of agricultural soil quality [8], [13]-[15], [17], [20], [22], [25], [30]. Acari and Collembola are two main groups of microarthropods and often account for 90-95% of the living creatures in the soil [28]. Conservation tillage practices make beneficial changes in the soil environment and overall health of the systems. Also there are some studies about the impact of specific management practices on soil fauna and microarthropods communities around the world [3], [5], [7], [12], [18], [19], [21], [22], [26], [27], [29], but studies on the effect of different land uses and agricultural management on the soil fauna in Iran are very few. Thus, the objective of this study is to evaluate the effect of tillage on the soil microarthropods biodiversity and density including Oribatida and Collembola in Khuzestan province, southwest of Iran.

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II. Material and Methods

The study was carried out at three different microhabitats in Ramhormoz county, Khuzestan province, southwest of Iran. One site was a winter wheat with conventional tillage system and without any crop residues and soil crust in summer (Conv.T.), and the other was a field with low-till system (conservative) with plant residues all the year (Cons.T.) and the third was a permanent natural grassland (N. grass.) with old date palms around and no-till system as a control. The climate in this region is typically warm and dry and the mean annual temperature is 27˚C with minimum temperature in late December to late January (with a mean of 12.6˚C) and the maximum in late June to early August (with a mean of 39.14˚C) and the mean annual precipitation is 340 mm with minimum precipitation in early June to early August (with 0 mm in Jun) and relatively high in winter (with 89 mm in December). Soil samples were collected monthly from each site during two years. In each sampling date, five soil samples of 10 cm diameter were taken from the surface to the depth of 15 cm. The microarthropod specimens (Oribatida and Collembola) were extracted by Berlese-Tullgrun extractors. The specimens were preserved in 75% ethanol and Lactophenol and Hoyer’s medium were utilized for bleaching, and then fixing the specimens on the microscopic slides, respectively. Specimens were then identified to the species level and counted. Characteristics of Oribatida and Collembola communities such as diversity, equitability and dominant species were determined by the use of SDR software, version 4 [24], and one tailed t-test were used to determine the differences between the diversity and density of microarthropods in different sampling sites and during different seasons.

III. Results and Discussion

A total of 3363 Collembolan specimens including 14 species and 2575 Oribatida specimens including 18 species were collected. All species and their individuals' densities (expressed as numbers per m^2 soil) are given in Figs. 1 and 2.

The monthly microarthropod abundance was similar in N. grass and Cons.T. during the year and the greatest average population abundance was in winter, particularly in January and March for Cons.T. (150.25 and 145.5, respectively) and in March for N. grass. (146.5) and the lowest abundance was in the summer for both microhabitats (66.5 in August for N. grass and 75.5 in July for Cons.T.). The abundance of microarthropods in Conv.T. was significantly lower (F=73.425, P=0.000) than in the two other microhabitats. The highest and the lowest microarthropod population abundance were seen in January (34.5) and July (6), respectively (Table I).

Significant differences in abundance of microarthropods were observed between the systems concerning Oribatida (F=86.057, P=0.000) which was more abundant in N. grass with no till system compared with the Conv.T. and Cons.T. (Fig. 1) and Collembola (F=211.98, p=0.000), which were more abundant in Cons.T. compared with the Conv.T. and N. grass. (Fig. 2).

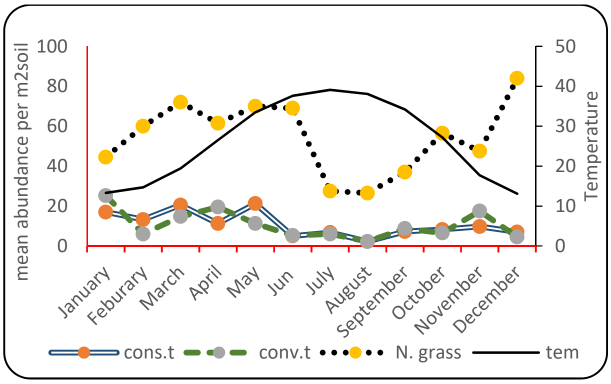

Fig. 1 Mean abundance of Oribatida per m^2 soil in different sampling sites during two years sampling

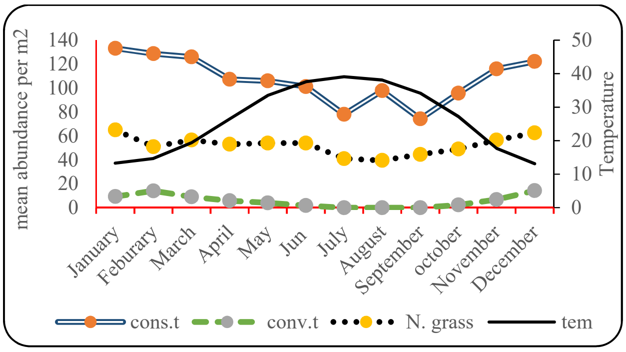

Fig. 2 Mean abundance of Collembola per m^2 soil in different sampling sites during two years sampling

In general, Collembola and mites were less abundant in the Conv. T. than in Cons.T. and N. grass. As it shown in Fig. 2, significantly (F=0.737, P<0.01) more Collembola (1286 individuals in two years of sampling) were found in Cons.T. and then in N. grass (626 individuals in two years of sampling), while the mean abundance of this microarthropod group was less than Oribatida in Conv.T. (191 individuals in two years of sampling). One explanation for the lower abundance of Collembola in N. grass compare to the Cons.T. could be attributed to higher organic content from plant residues and moisture from irrigation during the year in Cons. T. and the lower abundance in Conv. T. compare to the Cons. T. could be explained by that some individuals of Collembola are more sensitive to disturbance such as tillage and compaction during the growth season and dry condition in summer in Conv.T. Reference [12] concluded that the influence of land-use differed across taxonomic groups of microarthropods and farmlands have the greatest positive effects on the abundance and species richness of Collembola than in natural steppe.

The mean total abundance of two groups of microarthropods (Oribatida and Collembolan) was significantly greater in Cons.T. than in Conv.T. field. Reference [5] reported that microarthropods abundance is significantly greater in no till soil than in conventionally tilled soil. The difference between biodiversity index in different months was not significant (f= 0.666, p=0.764) in N. grass and Cons.T. but it was significant (p< 0.05) in Conv.T. and it was the highest in autumn (2.12 in November) and the lowest in summer (0.833 in August) (Table I). The biodiversity index in N. grass and Cons.T. was high all over the year and it was the highest in April (2.79) and March (2.43) and the lowest in February (2.39) and August (1.68) for both sites, respectively.

The index of Shannon wiener indicated significant (F=0.826, p<0.01) greater microarthropods biodiversity in N. grass. (2.87±0.02) and in Cons.T. (2.57±0.06) than in the Conv.T. (2.45±0.09). The most marked difference in biodiversity between three microhabitats occurred in warm months during a year, especially in summer for both years of sampling (Table II); it is because there were not any plant residues in the Conv.T. from mid-spring to late summer and the soil was so dry and hot.

Although agricultural or land-use intensity may have a negative effect on soil micro arthropods biodiversity, similar to reference [1], [2], [9], [12], [19], our findings showed that conservative agriculture had the positive effect on Collembola and Oribatida but the highest average density of microarthropods were observed in the permanent N. grass. These results were similar to the results were observed by reference [11].

IV. Discussion

Physical modifications caused by soil cultivations particularly tillage are often considered as the more intensive factor of reduction of microarthropod biodiversity and population abundance. Our results showed that the overall density and diversity of Collembola was higher in the Cons.T. as compared to the Conv.T. The absence of plant residue from late spring to early autumn and the high temperature during the summer in Conv.T caused soil drought. Also, deep tillage may lead the higher intensity of disturbance in Conv.T. as compared to Cons.T. and alter the soil structure. Higher species diversity and density was recorded during the winter and spring months when the soil temperature is moderate and moisture was on the higher range than in summer months.

The abundance and diversity of soil microarthropods are directly related to quantity of litter accumulations and soil organic matter [31]. In our study, the vegetation cover for N. grass over the soil surface maintains soil moisture and prepares food sources for soil organisms, and therefore, increases the soil biodiversity. Similar to our findings, [23] found that the variation in seasonal composition, abundance and diversity of the soil microarthropod community in different habitats is significant. Although their results demonstrated that soil microarthropods are more sensitive to temporal changes than to habitat changes, our results showed that habitat changes have more significant effects on the biodiversity and population abundance of microarthropods than seasonal changes. Indeed, [13] showed that the abundance of microarthropods was positively correlated to soil moisture and organic carbon and had negative correlation to soil temperature and soil pH.

TABLE I
TWO-WAY ANALYSIS OF VARIANCE OF ABUNDANCE AND BIODIVERSITY INDEX RESPECT TO SAMPLING SITES AND SEASONS

	Abundance			Biodiversity index		
	Collembola	Oribatida	Total microarthropods	Collembola	Oribatida	Total microarthropods
Sampling sites	3.496 ^{ns}	83.069**	73.425**	38.373**	81.61**	149.874**
season	0.619 *	0.837 *	1.738 *	0.121 *	0.12 *	0.34 *
Sampling sites & season	2.059^{ns}	42.94**	39.88**	19.056**	40.25**	74.032**

*, **, ns. indicate significant at p<0.05, p<0.01 and non-significant respectively.

Also, [12] found that conversion of native steppes to farmland soil has positive effects on biodiversity and microarthropod communities; however, the results of our study showed that these indices were high significantly in N. grass in comparison to the farmlands, although that was different in farmlands due to their different kind of tillage systems and was higher in Cons.T. than in Conv. T.

TABLE II
MICROARTHROPODS INDEX OF BIODIVERSITY IN THREE DIFFERENT MICROHABITATS

Sampling date	N.grass	Conv.t	Cons.t
January	2.685	1.442	2.182
February	2.39	1.99	2.387
March	2.449	2.048	2.432
April	2.792	0.833	2.061
May	2.662	1.49	2.317
June	2.719	1.561	2.07
July	2.399	0.9503	2.089
August	2.337	1.332	1.68
September	2.569	1.523	2.032
October	2.756	0.9507	2.337
November	2.602	2.12	2.293
December	2.653	1.752	1.948

TABLE III
MICROARTHROPODS INDEX OF BIODIVERSITY IN DIFFERENT SEASONS

Seasons	Shannon index		
	Cons.t	Conv.t	N. grass
winter	2.516±0.003 ^{a}	1.796±0.014^{c}	2.677±0.002^{c}
spring	2.277±0.002 ^{b}	1.511±0.017^{a}	2.801±0.002^{c}
summer	2.483±0.01 ^{a}	1.479±0.031^{a}	2.521±0.004^{a}
autumn	2.299±0.007 ^{b}	1.621±0.007^{c}	2.749±0.002^{c}

Different letters in each column means significant difference at 95% confidence level.

Reference [2] concluded that the no till system is not an environmentally friendly practice for agricultural lands because it reduces the pH and organic matter, and increases soil impaction compared with N. grass. However, our study showed that both seasons and land use have significant effect on the biodiversity and population densities of microarthropods. Similar to our results, [11] in their assessment on the influence of different land uses and seasons on soil microarthropod communities, found that different seasons have a significant effect on biodiversity and the microarthropods population, while changes in the density of the Collembola and Shannon index were weakly significant.

V. CONCLUSION

The density and biodiversity index of microarthropods were low in the Conv. T. but they were significantly high in Cons.T. and N. grass. This result may be explained by tillage, which is known to decrease microarthropod abundance. Soil cultivation, particularly tillage, was more intense in the Conv.T. than in the Cons.T and furthermore tillage is known to increase soil compaction and have negative effect on micro arthropod population. Although, tillage negatively affects the soil microarthropod population, climatic factors such as temperature and precipitation, which can vary with time and space, affect it, too. Abundance variations of microarthropods occurred over time with the significant increase in population densities during winter when precipitation was high (53.1%) and temperature was moderate (13.8°C) and was favorable for greater biodiversity.

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