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Original Paper

Influence of plants on soil mites (Acari, Oribatida) in gardens

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The research of the influence of crops on the species diversity of oribatid mites in garden within the small farmer conditions was carried out in four different microhabitats – carrots, beans (broad beans), onions and tomatoes. Soil samples on each crop were analysed and compared – determined the soil nutrient content and specific elements, continuously recorded the soil temperature, humidity, climate and microclimate relations were also followed within the research, as well as X-ray spectrometric analysis of the soil was done. Chemical elements have no significant impact on soil fauna. Annual average of 563 ind. per square metres and was reported in the microhabitat of beans, while 167 ind. per square metres in carrots, only. Under the broad bean, the highest abundance and species richness and highest species diversity of oribatids was confirmed and seemed to closely connect with the microclimate conditions of this crop. *Tectocepheus velatus sarekensis* Trägårdh, 1910, *Zetomimus furcatus* Pearce and Warburton, 1905, *Steganacarus striculus* C.L.Koch, 1836 and *Protoribates capucinus* Berlese, 1908 seem to be tolerant oribatids, which were confirmed in every microhabitats of the garden. On the contrary, some oribatids occurred in one crop only and specify it. Differences in soil temperature and humidity under plants as well as the type of crops affected occurrence of species spectrum and their abundance. In farm garden, we found two rare species of oribatids; the second records for the fauna of Slovakia – *Corynoppia kosarovi* (Jeleva, 1962) and *Mesoplophora pulchra* Sellnick, 1928.

Keywords: agricultural crops, analysis, oribatids, urban area

1 Introduction

Urban areas are typical with the variety of heterogeneous environment as well a wide range of habitats that have a great impact on the animal species diversity. Gardens represent a type of intensively maintained places, mainly the traditional farm garden with an orchard and crops (Krumpálová et al., 2020). The soil edaphon is an important component of biocoenosis, reflects the burden on biotopes and is an important bio-indicator of environmental quality (Porhajášová-Ivanič et al., 2016). Soil contains, in addition to inanimate ingredients, soil organisms that are essential for most soil functions. Without organisms, soil ceases to be soil and becomes inanimate substrate. Every soil of at least average quality contains a huge number of organisms (Angst et al., 2017). Soil organisms are sensitive to environmental contamination, in which they occur and also called stress as bio-indicators. Their reaction may result to the environmental load in different ways – in a change in behaviour; a change in habitat; a quantitative change and composition of species spectrum; and into physiological or morphological deformation of the individual or of the whole community (Baranová et al., 2015). Human activity alters the physic-chemical properties of the soil, resulting in a negative impact on soil viability, activity and microbial biomass (Zhao et al., 2013).

The soil mites together with springtails are the largest groups of soil arthropods. Soil mites of the Oribatida

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group are the most numerous at depths up to 15 cm from the soil surface (Walter and Proctor, 1999). The importance of saprophagous species is unquestionable in nature – decomposition of organic substances, ensuring the return of nutrients to the soil, which are necessary for growth plants. Their next task is the spread of microorganisms in the soil habitat, which also they affect plant growth either directly or indirectly (Setälä, 1995). Oribatids are rich in terms of species, but are also functionally important soil organisms; therefore often they are bio indicators to indicate the environment (Klimek et al., 2016). Oribatida can be considered a micro fauna sensitive to agricultural activity, such as crop selection, use pesticides and fertilization (Behan-Pelletier, 1999). They can be used in quality assurance, or soil degradation. In demonstrating the quality of soil, we can apply the species alone composition, but also the chemical or physical properties of the soil (Behan-Pelletier, 1999).

The main aim of this research was to find similarity and differences in soil mite assemblages (Acari, Oribatida) under four types of crops. The hypothesis was, based on different type of crops, to detect variance in species diversity, abundance, equitability and predominance some oribatids.

2 Material and methods

Study site represent a typical garden at a family house in Hlohovec town (Western Slovakia, Danube lowland). The area belongs to the Pannonia area (with eu-pannonic xerothermal flora). Soil, which is represented in the monitored area, is cambisol – gleyic cambisols (rich on the minerals). Four garden microhabitats with different crops were selected for soil sampling. Microhabitats were approximately the same size 200 × 600 cm; the first sampling plot was with sown beans (*Vicia faba* L.), root vegetables – carrot (*Daucus carota* L.) was second plot, the third microhabitat was with planted onion (*Allium cepa* L.) and fourth study plot was with tomatoes (*Solanum lycopersicum* L.).

We pick up the samples three times during one growing season – at the beginning of vegetation season (May), in the middle of the season (July) when plants already had fruits, the third collection was carried out after the end of the growing season (October) when plants have already been removed from the soil. From each study site we took six soil samples from a representative part of the crops with soil metal collector with a total volume of 200 cm^3 (measuring 4 × 5 × 10 cm). Totally 72 soil samples were extracted in a high-gradient Tullgren type photo thermal eclector modified according to Crossley and Blair (1991). The soil samples were dried as the temperature gradually increased from 15 to 45 °C continuously for seven days. The oribatids were mounted in temporary preparations filled with 40% lactic acid – translucent medium. To identify individuals into genera we used the determination key (Kunst, 1971), subsequently, we identify specimens into species level following the works of Weigmann and Miko (2006), Olszanowski (1996), Subias and Arillo (2001). The differences between ecological groups were tested by PAST software (Hammer et al., 2001); Kruskal-Wallis nonparametric test to determine if there are statistically significant differences between groups of an independent variable on a continuous dependent variable H (chi squared) = 7.87; $p = 0.048$.

We used the DELTA CLASSIC XRF (U.S.) spectrometer to determine the soil nutrient content and specific elements – Pb, S, Fe, Mn, K, Cu, Cr, Ca, Zn, Mo, Ba, Sr, Rb, Ti, Zr, Cl, I, As, Cd, Zb, Co. For the possibility of comparing the soil moisture on the observed plots was determined soil water content by gravimetric method. We are also continuously every 4 hours (from March to November) record the soil temperature at a depth of approximately 10 cm using miniature samples iButton DS1921G meters with a measuring range of -40 to +85 °C, with a resolution of 0.5 °C, and measuring accuracy ±1 °C.

3 Results and discussion

Soil properties in the garden

We measured the values of chemical elements, for each study site separately. The stationary with the bean crop had higher measured values only for the elements – potassium, calcium and iron. The highest measured values were just calcium, which ranged from approximately 30,000 to 48,000 ppm (note: ppm – parts per million) (Figure 1). Potassium values ranged from approximately 10,000 to 20,000 ppm and iron ranged from 22,000 to 26,000 ppm.

A microhabitat with a tomato had, similar to a stationary with a bean, measured above values only for potassium, calcium (ranged from about 40,000 to 46,000 ppm) and iron elements (below 24,000 ppm) (Figure 1). The study plot with onion reached the lowest measured values of soils elements with higher readings were calcium (from 29,000 to 33,000 ppm), potassium (15,000–17,000 ppm) and iron (26,000–28,000 ppm). In the microhabitat with the carrot crop were similar elements; a higher values – calcium (46,000–50,000 ppm), iron was approximately at 19,000 ppm and potassium had a low values (17,000 ppm). The other elements varied at the zero measurement limits (Figure 2). Based on these measurement results, we assumed the contained chemical elements have no significant impact on soil fauna.

Soil temperature was varied from 16 to 24 °C, while the air temperature was from 10 to 22 °C (monthly average).

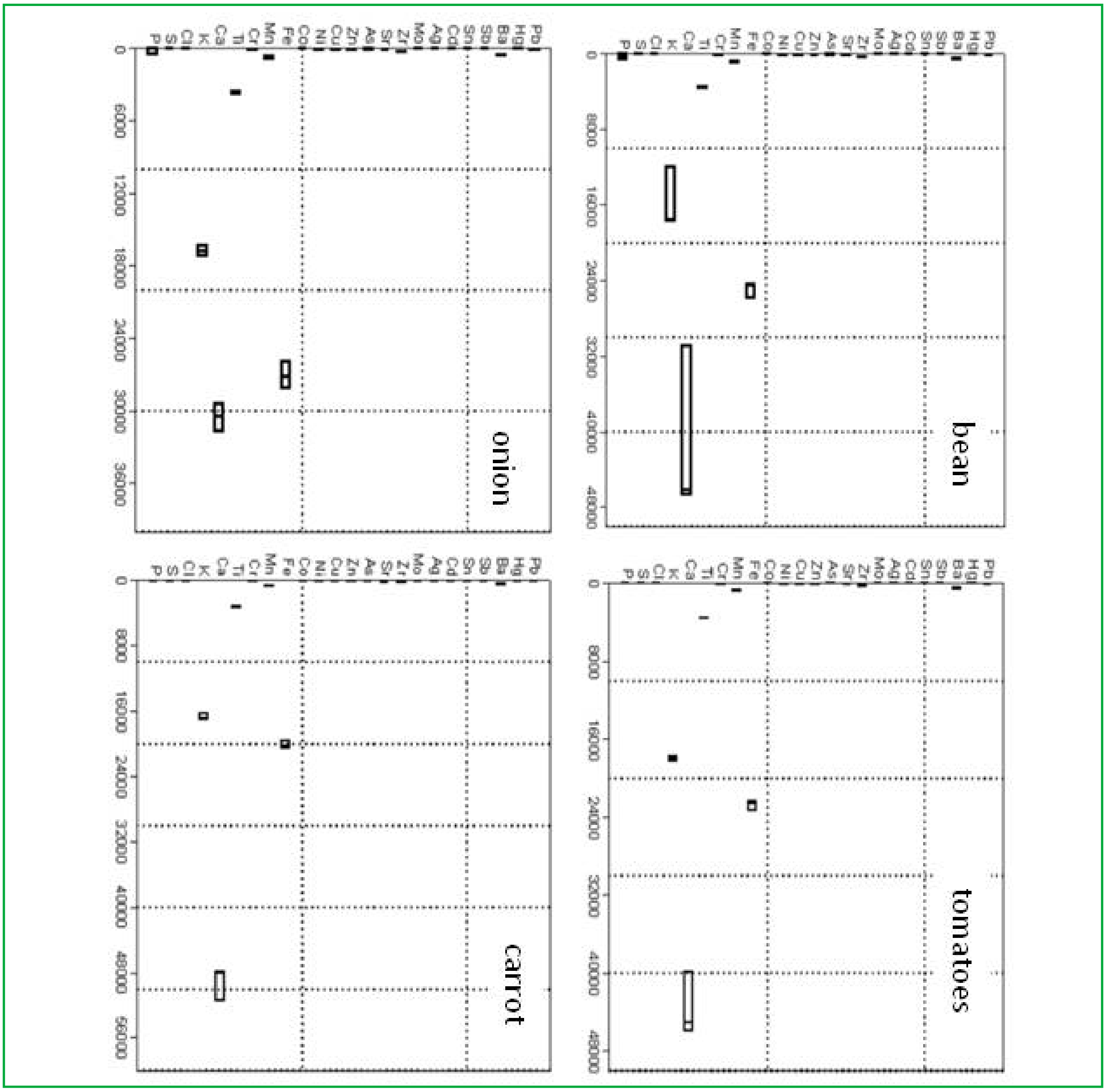

Figure 1 Box plot values of chemical elements (95% data reliability) of study habitats

The most striking temperature difference between two periods was May and June (4 °C). More marked temperature differences of soil between microhabitats can be seen mainly between tomatoes and beans. The stationary with tomatoes had the highest average soil temperatures. On the contrary, beans measured the lowest average soil temperatures (Figure 2) during the whole season.

The average soil moisture conditions were in the spring for all crops in the interval 11–13%. Significant changes in soil moisture occurred in the second sampling, during summer, when the lowest humidity (4.7%) was recorded under the tomato. On the contrary, the highest humidity

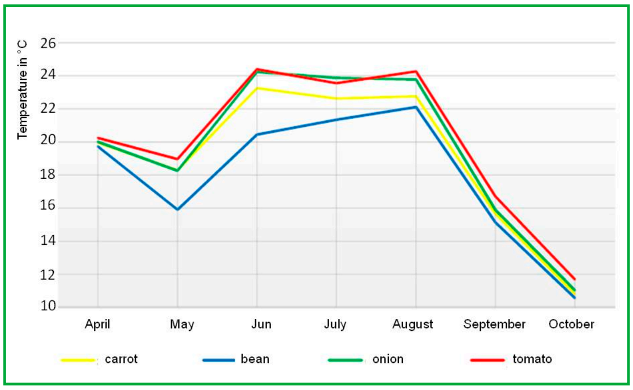

Figure 1 The course of monthly average soil temperatures at individual study plots

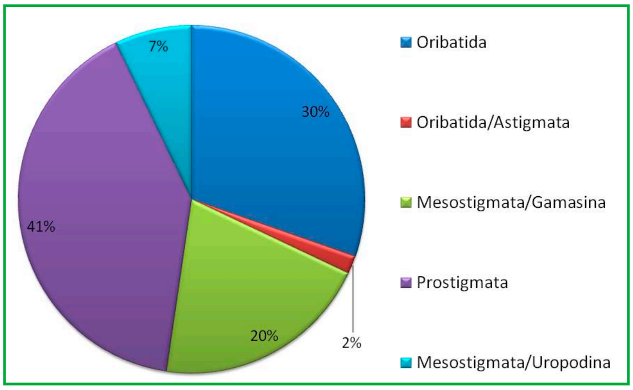

Figure 3 Acari structure in the soil of the garden

in summer was in beans microhabitat (11.8%) and in the onion (11.4%). In the autumn we noticed the highest soil moisture in the whole monitored season. The tomato station has the highest soil moisture overall (21.3%) (Table 1).

Table 1 Soil moisture at individual study plots determined by gravimetric method (%)

	May	July	October
Tomato	11.3	4.72	21.3
Onion	13.2	11.4	19.3
Beans	11.6	11.8	17.7
Carrot	13.1	8.7	18.8

Invertebrate assemblages in the garden

During the research, we picked out the soil samples in four study sites with different crops and collected all together, 1,272 individuals of soil arthropods. In the garden soil predominated Acari cohort, which had a total of 74.21% (944 individuals); the second highest group was of the Collembola – 268 individuals (21.07%). Springtails were most abundant in the summer and autumn collection, especially in July; the low number was recorded in May. The Hymenoptera – Formicoidea was subdominant group having 38 individuals (2.99%). The other groups in garden did not even have one percent representation: Hemiptera – Aphidoidea, Isopoda, Araneae, Chilopoda – *Scolopendra* gen. and Coleoptera – Curculionidae family.

Acari was formed by eudominant groups of Prostigmata, which had 382 individuals (40.7%), Oribatida had 286 individuals (30.3%) and Mesostigmata (Gamasina) with 192 individuals (20.3%). 68 individuals (7.2%) belong to the Mesostigmata (Uropodina) and 16 individuals (1.7%) to the group Oribatida (Astigmata) (Figure 3).

Analysis of Oribatida assemblages in the garden

The priority of our research was to determine the impact of crops on the soil mites (Acari – Oribatida). We collected 193 adult individuals throughout the garden during the monitored season belonging to 24 species (Table 2); nymph-development stadium were not included into evaluation. Most species found in the garden were less than 6% of dominance. Except of two species – *Tectocepheus velatus sarekensis* and *Zetomimus furcatus*, which of all 24 specimens they had eudominant proportion in the garden soil.

Abundance, species spectrum and diversity of some oribatids coenoses in garden differed. A total of 81 adults (18 species) were sampled at the soil under beans. The highest species spectrum was recorded in summer and autumn; in the summer we recorded the highest

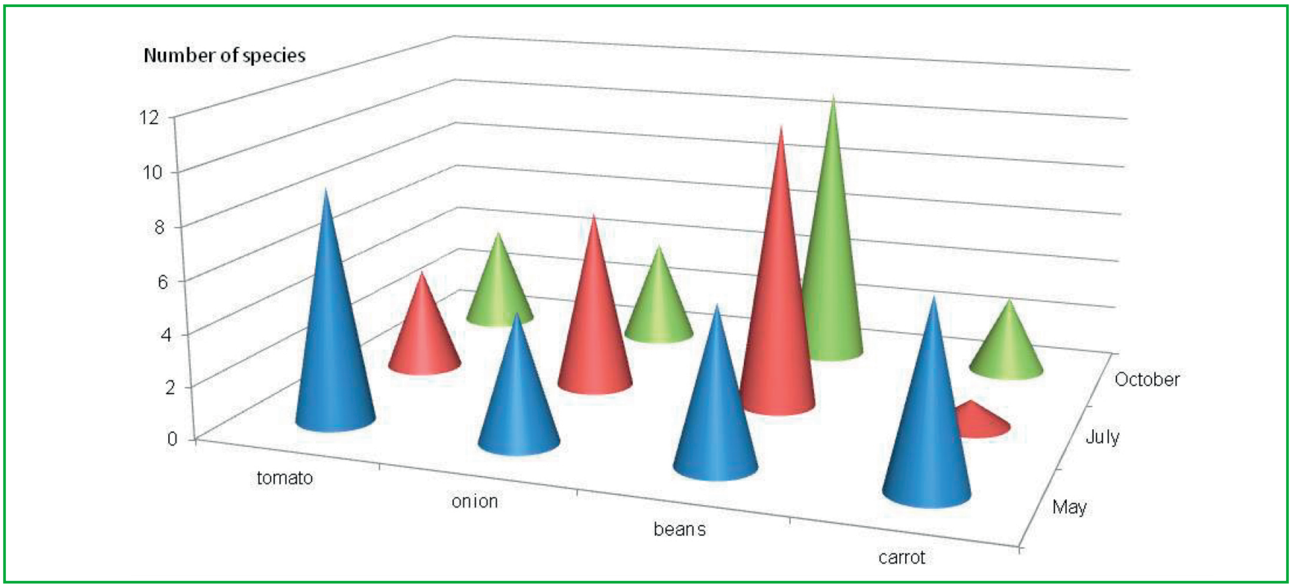

Figure 4 Seasonal differences in the abundance of oribatids found in different crops in the garden

Table 2 Abundance of Oribatida mites in the soil of some crops, indices diversity and total dominance of oribatids in the garden

Species	Abundance on separate study sites				Oribatida´s dominance (%)
	tomato	beans	carrot	onion	
Achipteria coleoptrata (Linné, 1758)	1	3		1	2.59
Achipteria nitens (Nicolet, 1855)	1				0.52
Corynoppia kosarovi (Jeleva, 1962)		1			0.52
Cosmochthonius lanatus (Michael, 1885)	1				0.52
Ctenobelba pectinigera (Berlese, 1908)	1	2			1.55
Epilohmannia cylindrica (Berlese, 1904)				1	0.52
Epilohmannia minima Schuster, 1960	2		3	1	3.11
Galumna lanceata (Oudemans, 1900)		2			1.4
Mesoplophora pulchra Sellnick, 1928		1			0.52
Metabelba pulverosa Strenzke, 1953		3			1.55
Microppia minus (Paoli, 1908)		1			0.52
Nothrus anauniensis Canestrini & Fanzago, 1876		3		1	2.7
Protoribates capucinus Berlese, 1908	3	3	3	1	5.18
Ramusella cf. *elliptica* (Berlese, 1908)		4			2.7
Ramusella furcata (Willmann, 1928)				2	1.4
Ramusella insculpta (Paoli, 1908)		7			3.63
Rhysotritia ardua (C.L. Koch, 1841)		1	2	1	2.7
Scheloribates laevigatus (C.L. Koch, 1835)		2			1.4
Scutovertex sp.	7		3	1	5.70
Sphaerochthonius splendidus (Berlese, 1904)		1			0.52
Steganacarus carinatus f. *pulcherrima* (Berlese, 1887)		1			0.52
Steganacarus (Atropacarus) *striculus* (C.L.Koch, 1835)	3	2	2	1	4.15
Tectocepheus velatus sarekensis Trägardh, 1910	23	33	5	10	36.79
Zetomimus furcatus (Pearce & Warburton, 1906)	16	11	6	10	22.28
Species diversity (Shannon´s index)	1.68	2.18	1.87	1.82	
Species richness (Margalef´s index)	2.22	3.87	1.89	2.94	
Species equitability (Pielou´s index)	0.72	0.75	0.96	0.76	

abundance (32 individuals), in the end of the season this number decreased (to two individuals). Microhabitat with tomatoes throughout the season obtained 58 adults. The highest species spectrum was in spring (36 individuals, nine species). Subsequent samplings showed not only a lower number of species (only four species were found), but also the abundance dropped to 11 individuals (both summer and autumn) (Figure 4, Table 2). At the soil under carrot, we found seven species (only 24 individuals) for the whole season; the highest number of individuals was in the spring (18 individuals), in summer the abundance dropped (one specimen), in autumn slightly increased to five individuals (3 species). The microhabitat with the onion had a total of 11 species (30 individuals) in the whole season. The number of individuals in this site was during the year relatively balanced; the richest species spectrum we found in summer (Figure 4, Table 2).

The highest species diversity (Shannon index) was recorded in soil below a bean crop of 2.18, lowest under the tomato (H' = 1.68). On the contrary, the highest species equitability (Pielou index) achieved the oribatids in carrot (E = 0.96); the species richness (Margalef index) varied from 1.89 to 3.87; highest value was on the stationary with onions (Table 2).

The number of individuals ranged from zero to approximately five individuals. In the first sampling

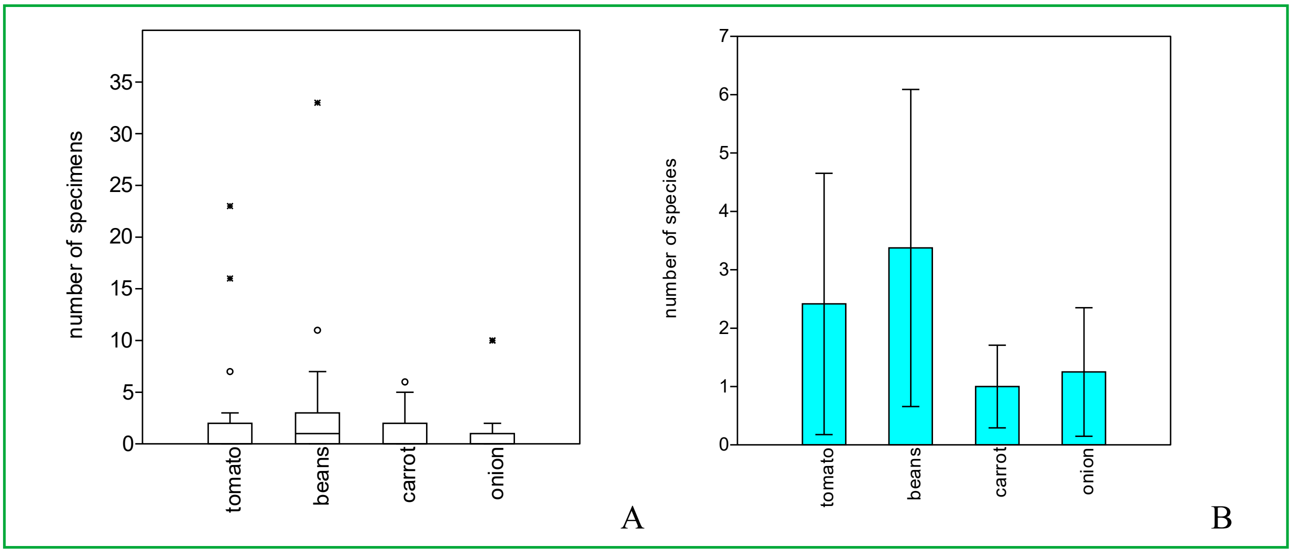

Figure 5 A – box plot of the number of oribatid individuals in samplings during season; B – box chart of the number of oribatids in the whole season (max., min., median; 95 percent data confidence)

under the tomato crop, 16 individuals (outlier) of species *Tectocepheus velatus sarekensis* reached, in the third sampling under the bean crop we registered higher occurrence of the same species (13 individuals). Other crops had significant richness only one sampling per season (Figure 5A). The greatest number of oribatid species within the garden we found under the bean crop that reached its maximum of six species. A higher number of species was also recorded under the beans (Figure 5B).

Four species occurred in all four habitats of garden – *Tectocepheus velatus sarekensis*, *Zetomimus furcatus*, *Steganacarus striculus* and *Protoribates capucinus*. *Tectocepheus velatus sarekensis* and *Zetomimus furcatus* achieved the highest frequency of occurrence in individual crops overall and were also the eudominant species in each collection (except for the spring field collection in carrots, where we didn't even notice it). On the contrary, during the research we found the oribatids

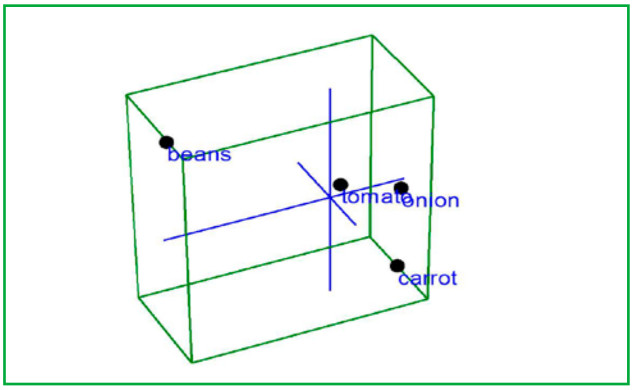

Figure 6 Landmark chart specifying the oribatid assemblages according the type of crops

that occurred in soil under only one crop and specify the assemblages (Figure 6, Table 2). Species *Achipteria nitens* and *Cosmochthonius lanatus* occurred under tomatoes only; soil microhabitat with onion also had two specific species – *Ramusella furcata* and *Epilohmannia cylindrica*. No specific species under the carrot were recorded that would was unique to this crop. On the contrary, the soil under bean had several specific species including – *Corynoppia kosarovi*, *Galumna lanceata*, *Mesoplophora pulchra*, *Metabelba pulverosa*, *Microppia minus*, *Ramusella* cf. *elliptica*, *Ramusella insculpta*, *Scheloribates laevigatus*, *Sphaerochthonius splendidus* and *Steganacarus carinatus* f. *pulcherrima*.

Among the oribatids in garden we also noted exceptional findings of species that were not until recently confirmed in our country, respectively, they are not typical for central European territory. The species *Corynoppia kosarovi* (family Oppiidae) is the second confirmed finding for Slovakia. It is a very interesting species that has been recorded only once during the entire research period. Its occurrence was recorded in summer in the bean crop (July 18, 2017). The first finding was recorded in the same year in Bratislava at the cemetery (Mangová et Krumpál, 2017). Another extremely interesting finding is the species *Mesoplophora pulchra*, the third finding for Slovakia. We found it in the autumn sampling in bean crop (October 27, 2017). It is a subtropical – tropical species that prefers the south of European and the Mediterranean environment (Starý, 2008; Miko, 1987; Miko, 1995).

Oribatida (Astigmatina), Mesostigmata (Gamasina), Prostigmata, Mesostigmata (Uropodina) and Acari (Oribatida) were represented in all chosen study sites. Two groups of arthropods, which occurred in all four habitats, were Collembola and Hymenoptera. Collembola was most abundant in the summer and autumn collection, especially in July; the smallest number was recorded in May. These results also partially correspond to paper of Bandyopadhya et al. (2002), which recorded the highest frequency in spring and autumn. The reduction in the abundance of Collembola was recorded immediately after soil cultivation. In our case it was in the spring, when the soil was prepared for planting. In autumn, after the crops have been removed from the soil, the soil was not being so disturbed that it would be caused the fall of springtails.

The nitrogen and carbon content of the soil positively affect the abundance of individuals; these elements create suitable living conditions in the soil (Horwood and Butt, 2000; Maraun and Scheu, 2000; Petersen and Luxton, 1982). Therefore, we assumed that under beans would be higher species diversity most diverse as leguminous plants using symbiotic bacteria bind atmospheric nitrogen. Obtained results of oribato-coenosis confirm this assumption (diversity index, species spectrum). Equally, differences in soil temperature and humidity may have affected occurrence of species and their abundance in monitored habitats (Štipčáková, 2018; Krumpálová et al., 2020).

The cosmopolitan species of *Tectocepheus velatus sarekensis* was observed in every soil sampling from selected microhabitats, but also in each collection (except for one summer under the carrot crop). The occurrence of this species was to be expected during our research, as *T. velatus* often dominates on cultivated soils (Ľuptáčik et al., 2012; Maribie et al., 2011).

The dominant species in all habitats was also *Zetomimus furcatus*, its dominance was quite unexpected. So far it has only been known from three locations in Slovakia (Starý, 2008). According to Weigmann and Miko (2006), its occurrence is focused on oligotrophic peat lands and forests; this species seems to tolerate a low proportion of nutrients in the soil than other species. *Microppia minus* was also found in oribatocoenoses during our study. It is a species with small body dimensions of 170–215 µm (Weigmann and Miko 2006), which is also abundant in agrosystems, preferring habitats with increased humidity (Ľuptáčik et al., 2012). The preference of humid habitats explains its low abundance in dry habitats. Most of the species that we found have occurred in very low abundance. Probably the cause of this state was the habitat requirements of species, which according to the garden failed, as well the garden disturbance.

Starý (2008) declares that the number of individuals is affected by several factors and changes in Oribatida communities can be observed from several aspects. First there are periodic variations in coenoses, which are affected by environmental changes caused by anthropogenic activity and natural changes. Fertility, mortality, length life cycle, number of generations per year and migratory capacity of dominant species affect the seasonal dynamics of oribatids the most. Agro ecosystem soils have the lowest species diversity and mite equitability compared to forests and soils used as pastures (Arroyo and Iturrondobeitia, 2006). To increase community richness and abundance not only soil mites but overall edaphone, it would be advisable to replace crops within the garden. This agricultural practice has confirmed stimulating mite regeneration (Neher, 1999).

Results of this research, exactly the research of the oribatids in the garden of the family house under different crops are unique and first of its kind not only in Slovakia but also in Central Europe.

4 Conclusions

The abundance of individuals under crops varied. Highest abundance, similarly and species diversity was under the bean crop, a yearly average of 563 ind m^{-2} and lowest one was noticed in micro habitat with carrot, only 167 ind m^{-2}. By comparison, forest soil habitats achieve abundance as well several 100,000 individuals per square meter (Norton, 1994). We have confirmed the assumption that under the beans was the abundance and species diversity of oribatids highest, which can also be closely connected with the microclimatic conditions of the crop. Species richness and abundance of oribatids in the soil of different crops closely related to the microclimatic conditions of the crop. The temperature of the soil under the bean was significantly lower (Figure 2) than below other crops; as well as the markedly higher soil moisture was there. The leguminous plants create a compact vegetation cover that provides shading, reduce the effects of extreme temperatures and water vaporisation from soil; and this can positively affect soil mites (Figure 2, Table 1) – more stable microclimate conditions could be the cause of minor fluctuations of species at the oribatid assemblages.

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