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ACAROLOGICAL CHARACTERISATION (ACARI: MESOSTIGMATA) OF AN URBAN GREEN AREA IN BUCHAREST, ROMANIA

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Abstract

The objectives of the study were to assess and compare mite communities from the biggest urban area in Bucharest- Morii Lake, in relation to the soil environmental variables (soil and air temperature; soil pH; soil and air moisture content; soil penetration resistance) and the type of habitats/transects (park area, natural area-island, grassland). The study was made in June 2017. For soil fauna, sixty soil samples were collected, using a MacFadyen core. Seventeen mite species were identified, with 55 individuals. We observed that soil and air temperature, air humidity and soil acidity varied highly significantly between the three transects. Soil temperature, soil moisture content, air humidity influenced significantly the structural composition of the mite populations. Certain parameters were used: numerical abundance, dominance, constancy, species diversity and equitability. Using these indices, we demonstrated that the transect T1-park area offered the most favourable conditions, with the least favourable being T2-island. Acarological characterisation of an urban green area in Bucharest, Romania, revealed that, even at the local scale, the type of habitat and environmental variables influenced significantly the structural composition of the mite populations.

Key words: *environment, habitat, local scale, mite, urban.*

INTRODUCTION

Various ecological studies in Europe have been conducted during the last thirty years, regarding the soil fauna of urban ecosystems. These studies highlighted that soil invertebrates could constitute valuable bioindicators of the environmental conditions that are specific to anthropised ecosystems, and that could be useful in monitoring programmes. Based on their ecological and biological requirements, different soil groups were used as bioindicators i.e.: nematodes, mites, springtails, enchytraeids, earthworms, isopods, beetles, ants, spiders, chilopods, diplopods, etc. Different urban habitats were investigated, i.e.: parks, urban forests, grasslands, industrial areas, cemeteries, transport routes, recreation areas, open lands, domestic gardens, waste grounds, green areas within housing estates, streetside grass verges and green roofs, and studies were conducted in many European countries: Latvia, Denmark, Poland, Romania, Italy, Bulgaria, Poland, Hungary, Germany, Austria, Switzerland, England, Czechia, etc. (Niedbała et al., 1990; Christian & Szeptycki, 2004; Stoev, 2004, Schrader & Boning, 2006; Vilisics et al., 2008; Minova et al., 2015; Manu et al., 2015; Napierała et al., 2015; Santorufo et al., 2015; Giurgincă et al., 2017; Szlavecz et al., 2018; Tóth & Hornung, 2020; Braschler et al., 2020; Manu et al., 2021).
These studied revealed that urbanisation changes the invertebrate fauna, especially reducing the species richness. Extreme urbanisation (from the urban core areas) also reduces this population parameter, through loss of habitable area for invertebrates or degradation of remaining habitat by many anthropogenic activities e.g pollution or traffic. Moderate levels of urbanisation, especially those in suburban areas, do not have such a drastic impact upon invertebrate diversity, and sometimes even increased species richness has been observed (McIntyre, 2000; McKinney, 2008; Nagy et al., 2018). Urban soils differ from those from other managed ecosystems in terms of heterogeneity, unique organic matter inputs and exposure to past and present anthropogenic activities. Pedogenesis in urban ecosystems is

influenced by the activity of bacteria and fungi, but also strongly correlated with invertebrate activity, due especially to their importance in soil organic matter dynamics (Bray & Wickings, 2019). In this context, mites (Acari) represent one of the most important and abundant invertebrate groups. They play an important role in the complex soil ecological systems, being actively involved in the flow of energy, matter and information. Mite research could enrich many different approaches, from zoogeography to ecology, taxonomy and parasitology or even palaeontology (Gwiazdowicz, 2021). Specific habitat and environmental variables will influence the composition of mite communities, being a valuable tool for monitoring environmental quality, including in urban soils, where one particular order has been highlighted as important i.e. predatory mites (Mesostigmata). Focussing only on habitats in urban ecosystems, faunistic and taxonomic studies have occurred in Italy, Hungary, Slovakia, Latvia, Poland, as well as in Romania (Bucharest city), but with little information regarding the ecology of soil mite communities in relation to urban environmental factors (Niedbała et al., 1990; Kontschán et al., 2015; Santorufo et al., 2015; Fendá & Hruzova, 2016; Salmane, 2018; Manu et al., 2021). Detailed studies from Bucharest (Manu et al., 2021) revealed the presence of specific mesostigmatid mite communities (together with differing numerical abundance and species richness) in managed green areas and in unmanaged green areas. In comparison with managed green areas, unmanaged urban habitats were characterised by higher values of community parameters (i.e. Shannon diversity, dominance and equitability), as well as by the highest values of the soil maturity index. Making a comparative analysis of different managed green areas (metropolitan, municipal and district urban parks), the study revealed that the species communities from metropolitan parks were richer than those from district parks. This study demonstrated the important links between mite communities in specifically urban ecosystems that are under anthropogenic pressure, also highlighting that unmanaged urban green areas were "hotspots" of Mesostigmata diversity (Manu et al., 2021). These studies analysed the specificity of mite communities from urban green areas in Bucharest to different management practices. However, the study did not examine what happened at the small scale, focussing on one green area in Bucharest i.e. Morii Lake.

The aims of the present study are: (1) to assess and compare mite communities on three separate areas (transects) from Morii Lake, divided by the lake dam as a barrier; (2) to identify the major soil environmental variables shaping the structure of mite communities; (3) to investigate the taxonomic and compositional response of mites to urban management scenarios and environmental variables.

MATERIALS AND METHODS

Study area

The research was conducted in June 2017 in the green area close to Morii Lake, Bucharest (44°27'20"N; 26°01'31"E). Morii Lake is the largest lake in Bucharest, with an area of 246 hectares. After floods in 1972, 1975 and 1979, local administrators from that period decided to build a reservoir, with the purpose of protection against damage from extreme climatic events. Thus, in 1986 Morii Lake appeared on the map of Bucharest city, protecting the capital against floods, and also becoming an important recreation area. Morii Lake provides a constant flow to the Dâmboviţa River in the city. The lake is protected by a dam of 15 m height, situated approximately six kilometres from the centre of Bucharest (Piața Unirii) and located between the Polytechnic University of Bucharest neighbourhood to the east, the Crângași and Giulești districts to the north, and the Militari district to the south (Figure 1) (Nae & Turnock, 2011).

In order to investigate the project objectives, three transects were analysed (T1, T2 and T3), which were well-spaced (approximately 1500 metres) and under different management types (T1= park area; T2= natural area-island; T3= overgrazed grassland). Transect 1 was located at 44°27'14.9"N; 26°02'38.6"E, and 79 metres altitude, on sandy soil. Transect 2 was located at 44°27'59.5"N; 26°01'77.9"E, at 87 metres altitude and with alluvial soil. Transect 3 had an alluvial soil, located at 44°27'35.1"N; 26°01'00.2"E, and at 83 metres altitude. None of the transects were on a slope (Figure 1).

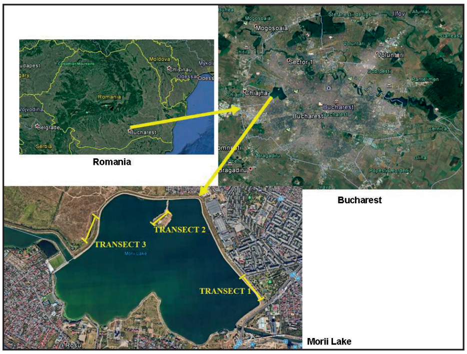

Figure 1. Geographical characterisation of the investigated area at Morii Lake, Bucharest-Romania, in 2017

Characterisation of vegetation type revealed the presence of the following dominant species:

- in T1 (park area): *Platanus x hispanica, Rumex* sp.*, Capsella bursa-pastoris, Dactylis glomerata, Trifolium repens, Urtica dioica, Silene latifolia* subsp. *alba*.
- in T2 (island): *Salix babylonica, Lolium perenne, Poa* spp.*, Taraxacum* sp.*, Cardaria draba, Heracleum sphondylium, Prunus* sp.*, Trifolium repens*.
- in T3 (grassland): *Salix babylonica, Prunus* sp.*, Capsella bursa-pastoris, Lolium perenne, Poa* spp.*, Taraxacum* sp.*, Cardaria draba, Heracleum sphondylium, Trifolium repens.*

Soil fauna

In April 2017, sixty soil samples were collected, using a MacFadyen soil core (5 cm diameter) to 10 cm depth. The samples were collected randomly (20 samples/transect). For each investigated transect, the sampled area was 200 m^2. Mites were extracted with a Berlese-Tullgren funnel, in ethyl alcohol, clarified in lactic acid and identified to species level, using published identification keys (Ghilyarov & Bregetova 1977; Hyatt, 1980; Karg, 1993; Mašán, 2003; Mašán & Fendá, 2004; Mašán, 2007; Mašán et al., 2008; Mašán & Halliday, 2010, 2013; Özbek & Halliday, 2015). Some specimens were mounted on permanent slides. All species were deposited in the collection of the Institute of Biology-Bucharest, Romanian Academy- Research Station Posada. No immature stages were identified, since these were missing from the soil samples.

Environmental variables

In total, six environmental variables were quantified: a) within the soil (temperature –T_{soil}; acidity-pH; moisture content- H_{soil}; penetration resistance- RP); and b) 5 cm above the soil level (temperature - T_{air}; air moisture content- H_{air}). In total, 60 soil samples were analysed (20 samples/transect) in order to measure these abiotic factors. A digital thermo-hygrometer PCE-310 was used to measure air and soil moisture and temperature. Penetration resistance was determined with a soil penetrometer, Step System GmbH, 41010. The pH was measured with a C532 Jasco Consort pH-meter. Due to the homogeneity of the vegetation cover (especially between samples of each transect), this parameter was not considered further (Figure 2 a, b, c). The average values of environmental variables are presented in table 1.

a. b. c.

Figure 2. The vegetation aspect of each investigated transect, in Morii Lake-Bucharest (a = transect T1-park area; b = transect T2- island; c = transects T3-grassland)

Data analysis

The population parameters used in the statistical analysis were: the numerical abundance (number of individuals), dominance (D%), constancy (C%), species diversity (Shannon-Wiener index) and equitability (J index).

The dominance index (D %) was obtained using the formula: D = nA / N x 100, where: nA – number of individuals of species "A" and N – total number of individuals. In terms of this index, the mite communities were grouped as follows: eudominant with D over 10% (D5);

dominant with D between 5.1 and 10% (D4); subdominant with D between 2.1 and 5% (D3); recedent with D between 1.1-2% (D2) and subrecedent with D under 1.1% (D1) (Engelmann, 1978).

The constancy index (C %) was obtained using the formula: C = 100% * pA/P, where: pA = number of samples with species A; P = total number of samples. The mite species were classified in 4 constancy classes: euconstant species with C of 75.1–100% (C4); constant species with C of 50.1–75% (C3); accessory species with C of 25.1–50% (C2); and accidental species with C of 1–25% (C1) (Selvin & Vacca, 2004).

The relationship between the environmental parameters and the number of species was established using canonical correspondence analysis (CCA). CCA is the analysis of the correspondence of a site / species matrix, in which each site gave values for one or more environmental variables. Sorting axes are linear combinations of environmental variables. CCA is thus an example of direct gradient analysis, where the gradient of environmental variables is known a priori and species abundances are considered to be a response to this gradient (Legendre & Legendre, 1998). Eigenvalues for the first two ordination axes are given, indicating their relative importance in explaining the spread in the data. For the environmental parameters, the mean values were evaluated, including the standard error (± SE).

The software also includes standard statistical tests for univariate data, such as the ANOVA test. This analysis of variance is a statistical procedure for testing the null hypothesis, for several univariate samples that are taken from within mite communities that have the same average. The samples are assumed to have a normal distribution and a similar variance (df = degrees of freedom, F = statistical test, p = is the probability of obtaining a result at least as extreme as the one actually observed, given that the null hypothesis is true).

The Jaccard-j (based on presence/absence data) and Bray-Curtis-bc (based on abundance data) similarity indices were used to indicate the association of species. The statistical software package PAST was used (Hammer et al., 2001)

RESULTS AND DISCUSSIONS

Among the six measured environmental variables from the three studied transects, we observed that the soil and air temperatures, air humidity and soil acidity varied highly significantly between T1, T2 and T3 ($p<0.001$; df = 2). The highest average values for soil temperature, soil moisture content and soil resistance at penetration and pH were obtained in T3, with the lowest values being from T1. Air temperature had its highest recorded value in T2 and in air humidity in T1 (Table 1).

We identified 17 species of mite (Acari: Mesostigmata) fauna with 55 individuals and no immature stages. Transect T1 was characterised by the highest numerical abundance and number of species, as well as the Shannon-Wiener diversity index. The lowest values were found in the communities of mites from T2. The most abundant species were *Hypoaspis aculeifer* and *Rhodacarellus silesiacus*, which were also eudominant (Table 2). Transect T1 is defined by the highest number of characteristic species (9), T2 by one species and T 3 by five species.

Examining results for the dominance index, from the total number of species, in T1 22.27% are eudominant and 72.72% are subdominant ones. In transect T2, the eudominant mites represent 66.66% of the total number of mites and 33.33% dominants. In transect T3, the invertebrates were grouped as in T2, but in different percentages: 42.85% eudominant and 57.14% dominant. For the constancy index, we observed that in all transects the species were classified as accessory and accidental ones (Table 2). Analysing the equitability index for all three investigated transects, we observed that it has the same value in T1 and T2, meaning that the species were represented by a similar number of individuals.

Table 1. Average values of environmental variables from the investigated transects at Morii Lake- Bucharest, 2017 (± SE)

Variables	T1	T2	T3	p	F
Tsoil (^{0}C)	12.90 (± 0.21)	16.07 (± 0.48)	17.72 (± 0.31)	<0.0001	46.72
RP (Mpa)	173.5 (± 6.03)	181.2 (± 5.98)	185 (± 9.83)	0.545	0.61
Hsoil (%)	10.65 (± 1.16)	10.68 (± 1.04)	13.36 (± 0.60)	0.084	2.58
Tair (^{0}C)	24.1 (± 0.44)	28.66 (± 0.23)	26.66 (± 0.20)	<0.0001	53.77
Hair (%)	63.8 (± 0.87)	55.8 (± 1.73)	56.8 (± 1.45)	0.000237	9.69
pH	8.58 (± 0.04)	8.33 (± 0.06)	8.59 (± 0.05)	0.001687	7.16

Table 2. The population parameters of the mites (Acari: Mesostigmata) identified in three transects (T1, T2, T3) in soil at Morii Lake urban area, Bucharest 2017

		T1			T2			T3		
Species	Code	No. ind	D%	C%	No.ind	D%	C%	No.ind	D%	C%
Alliphis halleri	*Al ha*	4	15	20						
Ameroseius sp.	*Am sp*	1	3.8	5						
Dendrolaelaps sp.	*De sp*	1	3.8	5						
Dinychus sp.	*Di sp*	1	3.8	5						
Glyptholaspis americana	*Gl am*	1	3.8	5						
Hypoaspis aculeifer	*Hy ac*	7	27	35	6	55	25	2	11	5
Hypoaspis karawaiewi	*Hy ka*	1	3.8	5						
Lasioseius sp.	*La sp*	1	3.8	5						
Onchodellus karawaiewi	*On ka*	1	3.8	5						
Parasitus fimetorum	*Pa fi*	1	3.8	5						
Rhodacarellus silesiacus	*Rh si*	7	27	25	4	36	20	10	56	35
Veigaia planicola	*Ve pl*				1	9.1	5			
Proctolaelaps sp.	*Pr sp*							1	5.6	5
Pergamasus crassipes	*Pe cr*							1	5.6	5
Parasitus beta	*Pa be*							1	5.6	5
Pergamasus laetus	*Pe la*							1	5.6	5
Lysigamaus sp.	*Ly sp*							2	11	5
Total number of individuals		26			11			18		
Total number species		11			3			7		
Dominance_D		0.18			0.44			0.35		
Shannon_H		2.00			0.92			1.46		
Equitability_J		0.83			0.83			0.75		

Applying the similarity indices in order to highlight the affinity between mite communities from the three transects, we observed that, based on the presence/absence data, the Jaccard index of similarity recorded highest values between invertebrate communities from T2 and T3 (j=0.25) and the lowest between T1 and T 2 (j= 0.16) (Figure 3a). If we take into consideration the abundance data, the Bray-Curtis index of similarity recorded the highest value between mite communities from T1 and T 2 (bc=0.54) and the lowest between T1 and T3 (bc=0.40) (Figure 3b).

Analysing the relationship between environmental variables and numerical abundance of mite species, canonical correspondence analysis demonstrated that soil temperature influenced *Pergamasus laetus* and the soil moisture content affected *Parasitus beta*, from T3 samples. Air humidity was another factor that influenced *Alliphis halleri*, from T1 (Figure 4).

Each transect was characterised by specific microclimatic conditions: T1 had the lowest average values of soil and air temperature, soil moisture content, soil resistance at penetration and the highest average value of air humidity;

T2 had the highest average values air temperature and the lowest average values of air moisture content and soil acidity; in T3 some environmental parameters had their highest average values i.e. soil temperature and air moisture content, soil resistance at penetration and soil pH. The habitat of T1 was described as park, being managed as a green urban green area with mowing of the grass, and inputs of allochthonous soil through tree-planting, meaning external inputs of organic matter. Transect T2 had an aspect of island, close to the water of Morii lake (explaining the highest average value of soil moisture content), and the habitat of T3 was a grazed grassland (with the driest soil and more compacted) (Grădinaru et al., 2018).

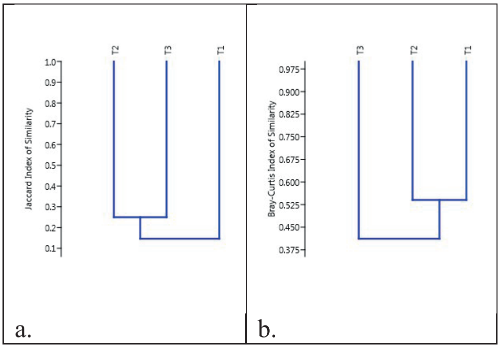

Figure 3. Indices of similarity (a- Jaccard; b- Bray-Curtis) between mite communities from the three transects on Morii Lake, Bucharest 2017

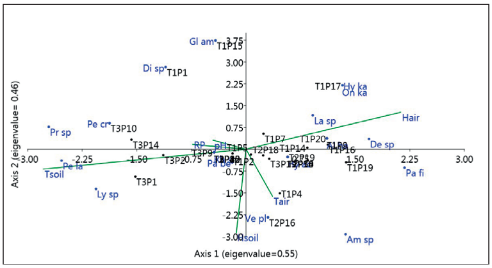

Figure 4. Canonical correspondence analysis between soil mite communities and environmental variables in Morii Lake urban area, Bucharest 2017. The short names of species are listed in Table 2

Comparing the Morii Lake results with those from elsewhere in Romania, the total number of species and individuals are closest to those obtained in some unmanaged urban green areas of Bucharest (e.g. Pantelimon, Băneasa, Griviţa with 12-22 species and 48-49 individuals) or much higher than some managed urban parks (e.g. Cişmigiu, Unirea, Izvor, Carol, Plumbuita, Floreasca, Văcăreşti with 3-10 species and with 25-43 individuals) or lower than those from Tineretului and Fundeni areas (17-18 species with 110-157 individuals) (Manu et al., 2018, 2021).

Comparing the number of Mesostigmata species from urban habitats at European level, the value at Morii Lake is comparable with that obtained in housing estates in Warsaw (18 species), higher than that in urban bamboo plantations from urban green areas in Szada, Gödöllő, Szeged and Budapest, Hungary (1-8 species) and lower than either parks and the city centre in Warsaw (22 and 39 species) or urban forest (28 species), greenery (32 species) and roadsides (33 species) from Riga, Latvia (Niedbała et al., 1982; Kontschán et al., 2015; Salmane, 2018).

Examining the number of species and the numerical abundance within the three investigated transects, we observed that T1 was characterised by the highest value of species diversity and number of individuals, whilst T2 had the lowest values of the two parameters. This result was further confirmed by the values of the Shannon index of diversity. Although the soil moisture content in T1 had the lowest average values, it is possible that it was still suitable for development of mite communities due to the reduced soil resistance at penetration, to the highest average value of air moisture content and to the reduced average value of air temperature. Lower soil resistance at penetration is correlated with larger values of organic matter, which is one of the most important abiotic factors for soil mites (Jones & Arp, 2017). Urban green areas were characterised by an impervious surface, with differing radiative, thermal, aerodynamic and moisture properties, resulting in elevated air temperatures compared to the adjacent ecosystems (Edmondson et al., 2016). Although Morii Lake is a wetland, frequent higher temperatures during summer and autumn cause high evapotranspiration and water depletion at depth in the soil (Zaharia & Găitănaru, 2018; Manu et al., 2021). Transect T2 on a peninsula had a microclimate that did not offer suitable environmental conditions for mite fauna (i.e. lowest average values of soil and air moisture content and the highest average value of air temperature). Despite T3 being grazed grassland, a more humid soil could be a favourable factor for the 7 species of mites, with 18 individuals. All transects were characterised by accidental and accessory species, demonstrating that these invertebrates are opportunistic and mobile, permanently searching for food, mainly as predators (Walter & Proctor, 2013; Klarner et al., 2013).

The most abundant species in the Morii Lake urban area were *Hypoaspis aculeifer* and *Rhodacarellus silesiacus*. In acarological studies, *Hypoaspis aculeifer* has been identified in various types of habitat from sand dunes to forest ecosystems. *Rhodacarellus silesiacus* has been found mainly in anthropogenic ecosystems, being used as a good indicator for the type of habitats, as well as for the ecological processes (as ecological succession) (Kaczmarek et al., 2012; Manu et al., 2013, 2015; Santarufo et al., 2015). Considering their preferences for urban habitats, both species were identified in managed and unmanaged green areas, as well as forests and meadows from suburban ecosystems (Manu et al., 2015, 2018, 2021; Niedbała et al., 1982, 1990). Based on the presence-absence of species (Jaccard index of similarity), we observed that there was a high similarity between the mite communities from the two habitats, island-T2 and grassland-T3 and dissimilarity between invertebrates from urban area-T1 and island T2. These differences appeared due to the difference of climatic conditions (Table 1). Comparing the abundance of mite communities in transects, through Bray-Curtis index of similarity, we observed a high similarity between the invertebrates in T1 and T2 and dissimilarity between T1 and T3. A significant factor influencing the abundance of mite communities was the soil resistance at penetration which was lowest in T1, possibly correlated with higher soil porosity and a higher quantity of organic matter (Jones & Arp, 2017).

Canonical correspondence analysis demonstrated that three environmental parameters influenced the distribution of three species: *Pergamasus laetus* (soil temperature), *Parasitus beta* (soil moisture content) and *Alliphis halleri* (air humidity). *Parasitus beta* is a predator species, widespread in soil, especially in grasslands, and found in managed and unmanaged urban areas (Manu et al., 2021). *Pergamasus laetus* is not so common in urban ecosystems, but is often recorded in forests, in habitats rich in organic matter (Manu et al., 2013, 2015, 2021). In Bucharest, species *Alliphis halleri* was found in three managed urban areas (Manu et al., 2021). In general, this species occurs in soil, leaf litter, dung and compost, where it appears to prey on nematodes (Halliday, 2019).

A more comprehensive study made in 2017, in eleven urban habitats from Bucharest, which investigated the relation between the type of management, environmental variables and structure of the soil mite communities, revealed that in unmanaged green areas the values of the community parameters (Shannon diversity, dominance and equitability) and the soil maturity index, were higher than those from managed green areas (Manu et al., 2021). If we make a comparison at the small scale, the present study, concerning the soil mite communities from the largest urban area from Bucharest, demonstrated that due to the higher anthropic impact from T3 (overgrazed grassland), due to the isolation of the transect T2 (natural area-island) and due to the better environmental conditions from T1 (park), where the area was irrigated, the results were reversed. On the other hand, acarological study from three types of managed green areas revealed that the species communities from metropolitan parks were richer than those from district parks. The study showed different values in relation to environmental factors, demonstrating important connections between mites and urban ecosystems, which are under anthropogenic pressure (Manu et al., 2021).

All this analysis constitutes a valuable argument in favour of the ecological study of the mite communities on a small scale.

CONCLUSIONS

In order to assess and compare mite communities from the Morii Lake urban area, three transects where established, investigating the taxonomic and compositional response of mites to the type of urban habitat (park area, natural area-island and grassland) and to selected environmental variables i.e. soil and air temperature; soil pH; soil and air moisture content; soil penetration resistance. Each transect was characterised by specific environmental conditions, which varied significantly between them. In total 17 mite species were identified, with 55 individuals and no immature stages. From the acarological point of view, transect T1 offered the most suitable conditions for development of mites, the least suitable being T2. Two species were identified as most abundant: *Hypoaspis aculeifer* and *Rhodacarellus silesiacus*. Ecological characterisation of an urban green area in Bucharest, Romania, revealed that, even at the local scale, the type of habitat and particular environmental variables (i.e. soil temperature, soil moisture content, air humidity) influenced the taxonomic and structural composition of the mite populations significantly.

The urban acarological investigations, either on small scale, either at regional large scale, are very important, demonstrating the role of the soil mite communities as bioindicators.

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