Biodiversity and distribution of soil nematodes in Mount Ararat, Turkey

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Summary. The diversity and distribution of soil nematodes were studied in Mount Ararat from the altitude of 1523 to 5000 m a.s.l., in habitats with different ecological characteristics. A total of 2,561 individuals were identified belonging to 31 families, 62 genera and 70 species. The nematode diversity (species richness) and the nematode abundance display recognisable patterns of altitudinal distribution as the number of species reaches a maximum at intermediate elevations, whereas the nematode abundance was significantly higher at the elevated altitudes. The nematode community associated with the marshland habitat was significantly different from those associated to the other four types of habitat.

Key words: altitude, community analysis, distribution patterns, mountain ecology.

Nematodes (phylum Nematoda) are a diverse group of ecdysozoa, *i.e.* invertebrate animals characterised by a simple body plan, nearly ubiquitous distribution, wide variety of feeding habits and life strategies, and they play an important role in the food webs of the habitats in which they dwell. With nearly 25,000 nominal species (Zhang, 2011), some conservative estimates of their existing diversity reach up to 1,000.000 of living forms (Hugot *et al.*, 2001), certainly being the most diverse animal phylum after Arthropoda. Many species are free-living, inhabiting soils and both freshwater and marine sediments, and displaying a wide feeding spectrum, including predation, algivore, fungivore, omnivore, saprovore, *etc.* (Yeates *et al.*, 1993). Other species are parasites of plants and animals, including humans where they cause severe diseases (Jasmer *et al.*, 2003).

Spatial distribution of nematodes remains a poorly explored area of study. Soil nematodes are not an exception in this regard, even though they are important for fundamental and applied purposes, and there has been some recent progress in the research area (van den Hoogen *et al.*, 2019). Many important contributions, including Yeates (1979), Freckman & Caswell (1985), Procter (1990), Neher (2010) and Liu *et al.* (2019), compiled the most relevant advances in the knowledge of the general ecology of nematodes. However, less work was devoted to detect major distributional patterns, for instance, latitude (Procter, 1984), elevation, and soil and sediment depth gradients (Weischer & Almeida, 1995), and only a few papers tried to elucidate the causal agents (processes) of the observed distributional patterns of particular taxa as it occurred with the members of the family Longidoridae (Dalmasso, 1970; Topham & Alphey, 1985; Navas *et al.*, 1993). Several authors (Yeates, 2003; Hánėl, 2010; McSorley, 2011) showed that most ecological studies used genera and families as taxonomical units in their analyses and suggested species-level identification should be a requirement to reach more significant progress in the discipline.

Elevation gradients are regarded as interesting natural environments to conduct field observations and to test experimental ecological hypotheses as both abiotic and biotic variations may take place over short distances (Hodkinson & Jackson, 2005).

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Table 1. Altitudes, coordinates, eco-habitat, time, date and air temperature at 29 sampling sites in Mount Ararat, Turkey.

Sample no.	Altitude (m a.s.l.)	UtmX	UtmY	Sub-ranges (m a.s.l.)	Habitat
1	4957	39°42'5.34" N	44°17'31.68" E	–	Frozen igneous Soil
2	4752	39°41'52.74" N	44°17'21.48" E	–	Igneous Soil
3	4531	39°41'42.96" N	44°17'13.14" E	–	Igneous Soil
4	4372	39°41'34.62" N	44°17'9.36" E	–	Igneous Soil
5	4184	39°41'24.72" N	44°17'3.84" E	3500-4000	Wildflower meadow
6	3972	39°41'11.64" N	44°17'1.26" E	3500-4000	Mountain grassland
7	3972	39°41'11.09" N	44°17'2.00" E	3500-4000	Wildflower meadow
8	3757	39°41'3.91" N	44°16'49.80" E	3500-4000	Wildflower meadow
9	3754	39°41'2.22" N	44°16'46.98" E	3500-4000	Wildflower meadow
10	3562	39°41'2.51" N	44°16'54.26" E	3000-3500	Wildflower meadow
11	3563	39°40'50.40" N	44°16'38.74" E	3000-3500	Mountain grassland
12	3372	39°40'46.86" N	44°16'1.77" E	3000-3500	Mountain grassland
13	3372	39°40'46.37" N	44°16'1.43" E	3000-3500	Wildflower meadow
14	3144	39°40'33.30" N	44°15'41.46" E	2500-3000	Mountain grassland
15	3140	39°40'33.29" N	44°15'41.45" E	2500-3000	Mountain grassland
16	3053	39°40'21.48" N	44°15'24.12" E	2500-3000	Chalk grassland
17	2952	39°40'14.64" N	44°15'12.72" E	2500-3000	Riverbed
18	2756	39°39'51.66" N	44°15'0.06" E	2500-3000	Mountain grassland
19	2742	39°39'51.26" N	44°15'0.25" E	2500-3000	Mountain grassland
20	2554	39°39'39.59" N	44°14'36.53" E	2000-2500	Chalk grassland
21	2552	39°39'39.21" N	44°14'36.73" E	2000-2500	Mountain grassland
22	2488	39°39'35.12" N	44°14'27.68" E	2000-2500	Riverbed
23	2486	39°39'35.51" N	44°14'27.29" E	2000-2500	Riverbed
24	2337	39°39'16.46" N	44°13'54.55" E	2000-2500	Mountain grassland
25	2337	39°39'16.76" N	44°13'54.55" E	2000-2500	Mountain grassland
26	1900	39°38'28.47" N	44°12'7.30" E	1500-2000	Wildflower meadow
27	1900	39°38'28.47" N	44°12'7.50" E	1500-2000	Wildflower meadow
28	1524	39°36'19.66" N	44° 8'45.45" E	1500-2000	Marsh
29	1523	39°36'19.26" N	44°8'45.15" E	1500-2000	Marsh

However, there is only limited knowledge about the distribution of soil nematode communities over elevation gradients.

In Mount Ararat, which is the highest peak in Turkey (5,137 m a.s.l.), due to harsh and long winter periods, flora and fauna change drastically in different elevations. Depending on the geographical side of Mount Ararat, mainly flora are located between 2100-3800 m a.s.l., which is dominated by grasslands (Koyuncu, 2005). The general purpose of this contribution is to explore the altitudinal distribution of nematode fauna in Mount Ararat, using species as taxonomical units and covering a large elevation transect. More specifically, this work aims: *i*) to characterise the nematode fauna associated with such transect; *ii*) to know the distribution of every species; *iii*) to detect tentative patterns of nematode diversity, and *iv*) to study the distribution of nematodes.

Table 2. Species abundance and occurrence in Mount Ararat, Turkey.

Taxon name	Order	Total abundance	Relative abundance (%)	Occurrence (%)
Eucephalobus mucronatus	Rhabditida	305	12.2 a	88 A
Plectus spp.	Plectida	238	9.5 a	80 A
Aphelenchoides spp.	Rhabditida	204	8.1 a	72 B
Panagrolaimus rigidus	Rhabditida	202	8.0 a	68 B
Rotylenchus sp.	Rhabditida	162	6.4 a	28 C
Acrobeloides nanus	Rhabditida	133	5.3 a	68 B
Mesodorylaimus sp.	Dorylaimida	129	5.1 a	28 C
Aphelenchus spp.	Rhabditida	113	4.5 a	64 B
Seleborca complexa	Rhabditida	110	4.4 a	24 D
Acrobeles andalusicus	Rhabditida	98	3.9 b	48 C
Geocenamus koreanus	Rhabditida	79	3.1 b	56 B
Malenchus sp.	Rhabditida	59	2.3 b	68 B
Chiloplacus bisexualis	Rhabditida	57	2.2 b	40 B
Chronogaster sp.	Plectida	47	1.8 b	8 D
Paratylenchus sp.	Rhabditida	47	1.8 b	32 C
Heterodorus magnificus	Dorylaimida	41	1.6 b	28 C
Acrobeles ciliatus	Rhabditida	38	1.5 b	8 D
Aporcelaimellus spp.	Dorylaimida	36	1.4 b	36 C
Tylencholaimellus montanus	Dorylaimida	33	1.3 b	32 C
Tylenchus sp.	Rhabditida	30	1.2 b	44 C
Enchodelus lucinensis	Dorylaimida	28	1.1 b	36 C
Nagelus camelliae	Rhabditida	27	1.0 b	16 D
Monhystera sp.	Monhysterida	23	0.9 c	8 D
Tylocephalus auriculatus	Plectida	23	0.9 c	12 D
Ecumenicus monhystera	Dorylaimida	20	0.8 c	16 D
Geomonhystera sp.	Monhysterida	18	0.7 c	16 D
Aporcelaimellus obtusicaudatus	Dorylaimida	17	0.6 c	12 D
Eudorylaimus subdigitalis	Dorylaimida	17	0.6 c	8 D
Tylenchorhynchus mangiferae	Rhabditida	17	0.6 c	16 D
Eudorylaimus sabulophilus	Dorylaimida	16	0.6 c	40 C
Cervidellus vexilliger	Rhabditida	15	0.6 c	36 C
Chiloplacus trilineatus	Rhabditida	14	0.5 c	28 C
Tylencholaimus teres	Dorylaimida	14	0.5 c	32 C
Acrolobus longigubernaculum	Rhabditida	13	0.5 c	8 D
Coslenchus sp.	Rhabditida	12	0.4 d	28 C
Teratocephalus terrestris	Rhabditida	12	0.4 d	16 D

Table 2 (continued). Species abundance and occurrence in Mount Ararat, Turkey.

Taxon name	Order	Total abundance	Relative abundance (%)	Occurrence (%)
Dorylaimus lineatus	Dorylaimida	11	0.4 d	8 D
Pratylenchus neglectus	Rhabditida	10	0.4 d	12 D
Crassolabium cylindricum	Dorylaimida	6	0.2 d	8 D
Longidorella okhlaensis	Dorylaimida	6	0.2 d	8 D
Nagelus hexagrammus	Rhabditida	6	0.2 d	12 D
Pungentus sp.	Dorylaimida	6	0.2 d	24 D
Rhabdolaimus sp.	Plectida	6	0.2 d	12 D
Tylenchorhynchus maximus	Rhabditida	6	0.2 d	16 D
Discolaimium sp.	Dorylaimida	5	0.2 d	8 D
Heterodera trifolii	Rhabditida	5	0.2 d	4 D
Tylencholaimus proximus	Dorylaimida	5	0.2 d	4 D
Funaria cf. *obtusa*	Dorylaimida	4	0.1 d	4 D
Microdorylaimus sp.	Dorylaimida	4	0.1 d	12 D
Stegelletina spp.	Rhabditida	3	0.1 d	8 D
Tobrilus sp.	Triplonchida	3	0.1 d	8 D
Alaimus sp.	Enoplida	2	0.08 d	8 D
Ditylenchus sp.	Rhabditida	2	0.08 d	8 D
Dorylaimellus sp.	Dorylaimida	2	0.08 d	8 D
Helicotylenchus sp.	Rhabditida	2	0.08 d	8 D
Hoplolaimus sp.	Rhabditida	2	0.08 d	8 D
Nygolaimus sp.	Dorylaimida	2	0.08 d	4 D
Pratylenchus thornei	Rhabditida	2	0.08 d	8 D
Zeldia sp.	Rhabditida	2	0.08 d	8 D
Achromadora sp.	Chromadoridae	1	0.04 d	4 D
Anaplectus sp.	Plectida	1	0.04 d	4 D
Criconema sp.	Rhabditida	1	0.04 d	4 D
Kochinema sp.	Dorylaimida	1	0.04 d	4 D
Mesorhabditis sp.	Rhabditida	1	0.04 d	4 D
Nothacrobeles sp.	Rhabditida	1	0.04 d	4 D
Paracrobeles sp.	Rhabditida	1	0.04 d	4 D
Propanagrolaimus hydrophilus	Rhabditida	1	0.04 d	4 D
Scutellonema sp.	Rhabditida	1	0.04 d	4 D
Trichodorus sp.	Triplonchida	1	0.04 d	4 D
Xiphinema sp.	Dorylaimida	1	0.04 d	4 D
Total abundance	–	**2561**	–	–

*The total abundance number was a sum from 29 samples. Each soil sample was a volume of 200 cm^{-3}.

Fig. 1. Geographic location of Mount Ararat, Turkey.

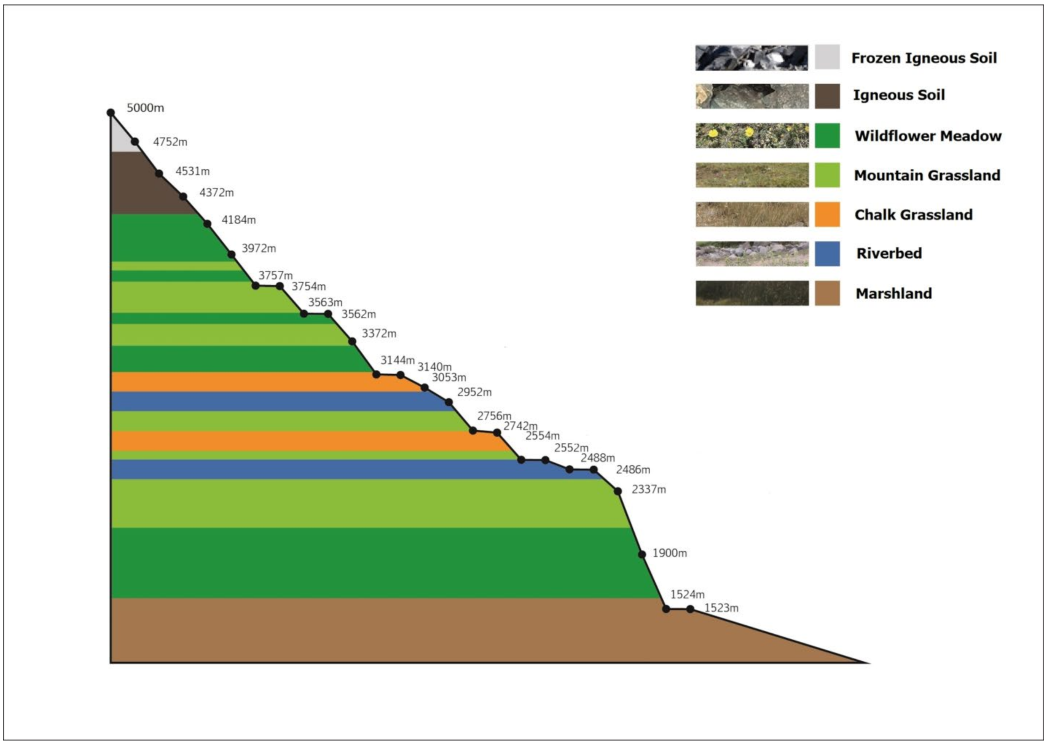

Fig. 2. Vertical distribution of sampling sites and corresponding ecological characteristics in Mount Ararat.

MATERIAL AND METHODS

Geographical area. Mount Ararat is a dormant volcanic cone, located in the Eastern Anatolia Region of Turkey, between Doğubayazıt and Iğdır, near the border with Iran, Armenia and Nahcivan (Fig. 1), in the most thinly populated region of the country. It last erupted in 1840 and has a permanent ice cap of 400 m diameter at the summit. The mountain is a stratovolcano (conical volcano), made of many layers (strata) of hardened lava, tephra, pumice and volcanic ash. Farming is difficult because of the long, severe winters, steep slopes and eroded soil. However, grain, chiefly summer wheat and barley, are grown at its foothills, and there are pastoral nomads who raise sheep and goats at its lower parts. Due to harsh and long winter periods, flora and fauna change drastically with elevation. The surface of the mountain is covered by many endemic plant species (Koyuncu, 2005).

Sampling. A total of 30 (29 soil and one ice) samples (Table 1) were collected following an elevational transect/gradient ranging from 1523 to 5000 m a.s.l., along five habitats with different ecological characteristics, namely wildflower meadow, mountain grassland, chalk grassland, riverbed and marshland (Fig. 2). The total elevation range (1523-5000 m a.s.l.) was divided into five (sub) ranges in order to study and to analyse the distribution of the nematode fauna. Each sample was taken from a 15 × 15 plot at 30 cm depth, put into zip lock sampling bags, stored in portable cooler during the transportation, and brought to nematology laboratory of Department of Plant Protection, Faculty of Agriculture, University of Çanakkale, Turkey. The survey was conducted on 20-26th July, 2013.

Extraction and mounting of nematodes. Nematodes were extracted by using the Baermann's (1917) funnel technique. After separating rocks and big organic particles, a volume of 200 cc soil was used for each sample site. Samples were placed on plastic trays lined with paper towels and incubated on the laboratory. Nematodes were collected after 48 h by pouring the extraction tray over a 500-mesh sieve (25 μm opening) and put into DESS solution according to Yoder *et al.* (2006). Each extract was then labelled with corresponding sample number and transported in plastic tubes to the University of Jaén, Spain where all the preserved nematodes were rinsed with purified water to remove the debris. The staining blocks for each sample containing 1.25 cm deep volume of 96% ethanol plus a few drops of glycerol-formalin (4%) (1:99) with extracted nematodes was then placed in an airtight jar and left overnight at room temperature. Next morning, the staining block was removed from the jar and a few drops of five parts glycerol and 95 parts 96% ethanol solution were added, two thirds of the staining block's cavity was covered with a glass square, and the block placed in an incubator at 40°C. For gradual transition of glycerin, a few drops of glycerol-ethanol (5:95) solution was added every 2 h. The day after, individual nematodes were permanently mounted on glass slides (Yoder *et al.*, 2006). A total of 2561 nematodes were examined.

Light microscopy. Mounted nematodes were studied and identified using an Olympus BHS microscope (Olympus Optical, Tokyo, Japan). Morphometrics, including Demanian ratios and other measurements, were taken by means of a drawing tube (*camera lucida*) attached to the microscope.

Data analyses. For comparative purposes, species were classified into four groups based on their abundance and occurrence. For abundance the classifications were very abundant (a) (more than 4.0% of the total community), abundant (b) (1.0-4.0%), rare (c) (0.5-1.0%) and very rare (d) (< 0.5%); for occurrence, the classifications were: very frequent (A) (occurrence ≥ 75%), frequent (B) (≥ 50%), infrequent (C) (≥ 25%), and scarce (D) (< 25%). The abundance set of classifications was designed based on the total number of nematodes in respect to total community. On the other hand, the occurrence set of classification was focused on their distribution along the mountain. The nematode community structure was analysed through correspondence analysis and non-metric Multi-Dimensional Scaling (MDS) applying the Euclidean and Chord similarity tests. One-way ANOVA and post-hoc Tukey tests were performed to assess the significant differences of species abundance and richness among different altitudinal ranges. MDS and correspondence analyses were performed with the PAST 2.17c software (Hammer *et al.*, 2001). STATISTICA 7 software was used for ANOVA and post-hoc Tukey tests.

RESULTS

GENERAL COMPOSITION OF NEMATODES OF MOUNT ARARAT

Table 2 provides the basic data of the nematode fauna found in this study, including species composition, absolute abundance (number of specimens of each species), relative abundance (percentage of the total), and occurrence or frequency (number of samples in which each species was collected, expressed as percentage of the total number of 29 soil samples). The lowest nematode distribution range was 1500-2000 m a.s.l., and the greatest range was 3500-4200 m a.s.l.; nematodes were not found in samples from above 4200 m a.s.l.

A total of 70 species, belonging to 62 genera, 31 families and 3 orders were identified. The nematode fauna was dominated by members of the order Rhabditida/Tylenchina (35 species and 31 genera), followed by those of the order Dorylaimida (22 species and 19 genera).

According to relative abundance, nine species were determined as very abundant, 13 species were abundant, 12 species belonged to rare taxa and 36 species were very rare. Among very abundant species were *Aphelenchus* spp., *Aphelenchoides* spp., *Plectus* spp., *Seleborca complexa*, *Acrobeloides nanus*, *Eucephalobus mucronatus*, *Mesodorylaimus* sp., *Panagrolaimus rigidus*, *Rotylenchus* sp. Considering their occurrence, two species, namely *Eucephalobus mucronatus* and *Plectus* spp., were very frequent, 7 species were determined as frequent, 14 species less frequent, and 47 species very less frequent.

ELEVATIONAL DISTRIBUTION OF NEMATODES

Altitudinal distribution of the nematode fauna. 1. Nematode abundance. Table 3 provides the nematode abundance in different altitudinal sub-ranges of Mount Ararat. The number of nematodes did not differ statistically at level 1500-3000 m a.s.l. and the greatest nematode abundance was found at the highest sub-range (3500-4000 m a.s.l.). An increase in the nematode population density was generally caused by the increase in the numbers of species determined as very abundant (Tables 2 & 4). Distribution data have been statistically tested resulting in the existence of significant differences in the number of nematodes detected with increasing altitude ($P = 0.003675$). Remarkably, the nematode density at the highest altitudinal range was significantly greater than that at other ranges (Table 3). No nematodes were found in samples from over 4200 m a.s.l.

2. Species occurrence. The species found are ordered alphabetically and the abundance is provided as the number of specimens per soil sample (Table 4). Taking into consideration the presence/absence data, nematode species may be classified according to three basic distributional patterns.

(i) Widely distributed forms. Those species that were present in at least four altitudinal ranges: *Acrobeloides nanus*, *Aphelenchoides* spp., *Aphelenchus* spp., *Aporcelaimellus* spp., *Cervidellus vexilliger*, *Eucephalobus mucronatus*, *Eudorylaimus sabulophilis*, *Geocenamus koreanus*, *Malenchus* sp., *Panagrolaimus rigidus*, *Paratylenchus* sp., *Plectus* spp., *Tylencholaimellus montanus* and *Tylenchus* sp.

(ii) Species showing a more restricted but recognisable pattern. Those forms occurred in two or three continuous ranges with a distinguishable tendency. In this case, it is possible to separate three (sub) patterns. Firstly, a group of species only dwelling in lower altitudes: *Seleborca complexa*, *Chiloplacus bisexualis*, *Chronogaster* sp, *Coslenchus* sp., *Eudorylaimus subdigitalis*, *Monhystera* sp., *Nagelus hexagrammus* and *Stegelletina* sp. Secondly, species restricted to median altitudes: *Dorylaimellus* sp., *Heterodorus magnificus*, *Pratylenchus thornei*, *Tylencholaimus teres*, *Tylenchorhynchus maximus* and *Tylenchorhynchus mangiferae*. Thirdly, species inhabiting the high altitudes: *Acrobeles andalusicus*, *Geomonhystera* sp., *Mesodorylaimus* sp., *Plectus* spp. and *Rhabdolaimus* sp.

Table 3. Altitudinal distribution of nematodes in Mount Ararat, Turkey.

Elevation (m a.s.l.)	n[1*]	Abundance[2]
1500-2000	4	75.75 ± 19.50 (a)
2000-2500	6	91.6 ± 19.65 (a)
2500-3000	6	74.1 ± 13.63 (a)
3000-3500	4	86.2 ± 9.10 (a)
3500-4000	5	192.8 ± 46.46 (b)
Total	**25**	

[1]Number of soil samples collected from each altitudinal range.

*Four samples at the altitudinal range 4372-4957 m a.s.l. had a mean of zero nematodes so they were not included in the analysis.

[2]Number (mean ± s.d.) of specimens (200 cm^{-3} soil). Different letters indicate significant differences between means ($P < 0.05$, one-way ANOVA following post-hoc Tukey test).

(iii) Species with no recognisable pattern. Some taxa do not show a distinguishable distribution pattern as they are either rare or very rare or are present in several discontinuous ranges without a marked tendency.

3. Species richness. The distribution of nematode diversity, here focused on the number of species, is other interesting aspect of this study. Table 5 presents the results, which include the variation in the total number of species and the average of species per soil sample for each

Table 4. Altitudinal distribution (m a.s.l.) of species abundance (mean number of specimens per each soil sample).*

Taxon name	**1500-2000**	**2000-2500**	**2500-3000**	**3000-3500**	**3500-4000**
Achromadora sp.	0.0	0.0	0.0	0.0	0.2
Acrobeles andalusicus	0.0	0.0	7.0	12.3	1.4
Acrobeles ciliatus	0.0	7.6	0.0	0.0	0.0
Seleborca complexa	15.8	9.4	0.0	0.0	0.0
Acrobeloides nanus	0.0	0.4	2.2	4.5	20.0
Acrolobus longigubernaculum	0.0	0.0	0.0	0.0	2.6
Alaimus sp.	0.0	0.2	0.2	0.0	0.0
Anaplectus sp.	0.0	0.0	0.0	0.0	0.2
Aphelenchoides spp.	3.3	8.2	6.5	14.0	11.0
Aphelenchus spp.	4.3	5.8	9.0	2.8	0.4
Aporcelaimellus obtusicaudatus	0.0	3.2	0.0	0.3	0.0
Aporcelaimellus spp.	1.5	1.6	0.8	3.3	0.2
Cervidellus vexilliger	0.0	0.2	0.5	1.5	1.0
Chiloplacus trilineatus	0.0	0.0	1.3	0.5	0.8
Chiloplacus bisexualis	4.5	6.6	1.0	0.0	0.0
Chronogaster sp.	11.8	0.0	0.0	0.0	0.0
Coslenchus sp.	1.3	0.4	0.7	0.0	0.0
Crassolabium cylindricum	0.0	1.2	0.0	0.0	0.0
Criconema sp.	0.0	0.0	0.0	0.3	0.0
Discolaimium sp.	1.0	0.0	0.2	0.0	0.0
Ditylenchus sp.	0.0	0.2	0.0	0.3	0.0
Dorylaimellus sp.	0.0	0.0	0.2	0.3	0.0
Dorylaimus lineatus	0.0	0.0	0.0	0.0	2.2
Ecumenicus monohystera	0.0	0.4	0.0	4.3	0.0
Enchodelus lucinensis	0.0	2.4	0.0	3.0	0.8
Eucephalobus mucronatus	0.3	3.6	8.2	17.5	28.8
Eudorylaimus sabulophilis	0.0	0.6	0.7	0.5	1.4
Eudorylaimus subdigitalis	1.3	2.4	0.0	0.0	0.0
Funaria cf. *obtusa*	0.0	0.8	0.0	0.0	0.0
Geocenamus koreanus	0.5	5.0	2.5	3.3	4.8
Geomonhystera sp.	0.0	0.0	0.0	0.5	3.2
Helicotylenchus sp.	0.0	0.0	0.0	0.3	0.2
Heterodera trifolii	0.0	0.0	0.8	0.0	0.0
Heterodorus magnificus	0.0	4.0	3.0	0.8	0.0
Hoplolaimus sp.	0.3	0.0	0.2	0.0	0.0
Longidorella okhlaensis	0.0	1.2	0.0	0.0	0.0

Table 4 (continued). Altitudinal distribution (m a.s.l.) of species abundance (mean number of specimens per each soil sample).*

Taxon name	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000
Malenchus sp.	1.0	3.6	1.3	4.3	2.4
Mesodorylaimus sp.	0.0	0.0	0.2	0.5	25.2
Mesorhabditis sp.	0.0	0.0	0.2	0.0	0.0
Microdorylaimus sp.	0.0	0.6	0.0	0.3	0.0
Monhystera sp.	5.8	0.0	0.0	0.0	0.0
Nagelus camelliae	0.0	0.0	0.0	0.0	5.4
Nagelus hexagrammus	0.3	1.0	0.0	0.0	0.0
Nothacrobeles sp.	0.0	0.2	0.0	0.0	0.0
Nygolaimus sp.	0.0	0.4	0.0	0.0	0.0
Panagrolaimus rigidus	1.5	0.8	4.7	4.8	29.0
Paracrobeles sp.	0.0	0.2	0.0	0.0	0.0
Paratylenchus sp.	0.5	7.8	0.3	1.0	0.0
Plectus spp.	0.0	0.8	3.2	0.8	38.4
Pratylenchus thornei	0.0	0.0	0.2	0.3	0.0
Pratylenchus neglectus	0.0	2.0	0.0	0.0	0.0
Propanagrolaimus hydrophilus	0.3	0.0	0.0	0.0	0.0
Pungentus sp.	0.3	0.6	0.2	0.0	0.2
Rhabdolaimus sp.	0.0	0.0	0.0	0.5	0.8
Rotylenchus sp.	0.3	0.8	1.0	0.0	30.2
Scutellonema sp.	0.0	0.0	0.2	0.0	0.0
Stegelletina sp.	0.5	0.2	0.0	0.0	0.0
Teratocephalus terrestris	0.0	0.0	0.7	0.0	1.6
Tobrilus sp.	0.8	0.0	0.0	0.0	0.0
Trichodorus sp.	0.0	0.0	0.0	0.0	0.2
Tylencholaimellus montanus	0.3	0.4	1.7	3.5	1.2
Tylencholaimus teres	0.0	1.0	0.3	1.8	0.0
Tylencholaimus proximus	0.0	0.0	0.8	0.0	0.0
Tylenchorhynchus maximus	0.0	0.0	0.5	0.5	0.2
Tylenchorhynchus mangiferae	1.0	0.0	1.5	1.0	0.0
Tylenchus sp.	0.0	0.2	1.0	4.0	1.4
Tylocephalus auriculatus	0.0	0.0	0.0	0.0	4.6
Xiphinema sp.	0.0	0.2	0.0	0.0	0.0
Zeldia sp.	0.0	0.0	0.2	0.0	0.2

*Each altitude range was consisted of five sub samples. Each soil sample was a volume of 200 cm^{-3}.

Table 5. Distribution of nematode species richness at five altitudinal intervals in Mount Ararat, Turkey.

Interval (m a.s.l.)	n[1*]	S[2]	Ss[3]
1500-2000	4	25	9.8 ± 1.2 (a)
2000-2500	6	39	18.0 ± 2.1 (b)
2500-3000	6	36	16.3 ± 2.2 (b)
3000-3500	4	32	16.0 ± 1.3 (b)
3500-4000	5	32	14.0 ± 2.5 (b)
Total	**25**	**70**	

[1]Number of soil samples collected from each altitudinal range.

*Four samples at the altitudinal range 4372-4957 m a.s.l. had a mean of zero nematodes so they were not included in the analysis.

[2]Total number of species collected from each altitudinal range.

[3]Number (mean ± s.d.) of species (200 cm^{-3} soil). Different letters indicate significant differences between means ($P < 0.05$, one-way ANOVA following post-hoc Tukey test).

altitudinal range. In both cases, it is possible to note that there is a maximum species richness at medium altitudes and the number of species decreases at both the lowest and the highest altitudes.

4. MDS comparison of altitudinal ranges. A non-metric Multi-Dimensional Scaling (MDS) analysis was performed on the distribution of nematode genera into five altitudinal ranges (Fig. 3) relating to the presence of dissimilarities according to increasing altitude effects on the nematode composition. In relation to the similarity of nematode assemblages with altitudinal range, there were three main groups: *(i)* the lowest altitudinal range from 1500-2000 m a.s.l.; *(ii)* the mid-zone range from 2500-3500 m a.s.l.; and *(iii)* the highest altitudinal range between 3500-4000 m a.s.l.

Distribution of the nematode fauna according to habitat type. 1. Nematode abundance. The total number of collected nematodes in five habitats with different ecological characteristics showed high variability. The highest number of specimens per sample was found in the wildflower meadow habitat with 136.25 individuals. It was followed by mountain grassland (111.1 individuals per sample), chalk grassland (78 individuals per sample), riverbed (74 individuals per sample) and marshland (43 individuals per sample) (Table 6).

2. Species occurrence. Table 7 presents the distribution of species abundance at each habitat type with different ecological characteristics. The species are ordered alphabetically and the abundance is provided as the number of specimens per soil sample. Taking into consideration the presence/absence data, nematode species may be classified according to five basic distributional patterns for each ecological characteristic.

(i) Widely distributed forms. Those species that are present in all habitats. They are four in total: *Aphelenchus* spp., *Chiloplacus bisexualis*, *Eucephalobus mucronatus* and *Malenchus* sp.

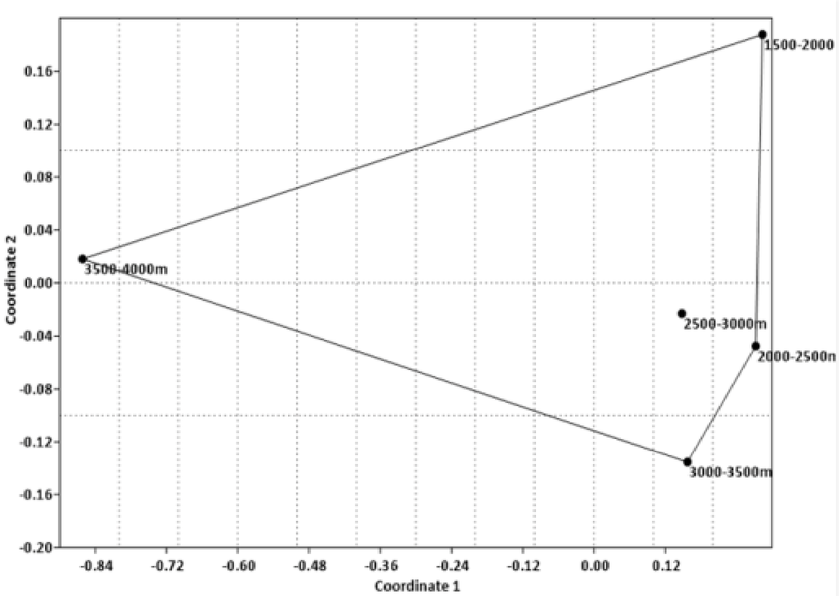

Fig. 3. Distance between five different altitudinal ranges. Species distribution was analysed by MDS (nonmetric Multi-Dimensional Scaling).

Table 7. Species distribution in habitats with different ecological characteristics with corresponding abundance (mean number).*

Taxon name	Wildflower meadow	Mountain grassland	Chalk grassland	Riverbed	Marshland
Achromadora sp.	0.0	0.1	0.0	0.0	0.0
Acrobeles andalusicus	1.4	10.3	1.0	0.0	0.0
Acrobeles ciliates	0.0	0.0	2.6	2.1	0.0
Seleborca complexa	7.6	5.9	0.0	0.0	0.3
Acrobeloides nanus	12.8	2.6	1.0	0.3	0.0
Acrolobus longigubernaculum	0.5	1.1	0.0	0.0	0.0
Alaimus sp.	0.0	0.3	0.0	0.0	0.0
Anaplectus sp.	0.1	0.0	0.0	0.0	0.0
Aphelenchoides spp.	13.9	9.5	1.1	1.0	0.0
Aphelenchus spp.	3.4	5.0	2.6	3.0	0.1
Aporcelaimellus obtusicaudatus	0.1	1.9	0.5	0.0	0.0
Aporcelaimellus spp.	1.9	1.9	0.5	0.4	0.0
Cervidellus vexilliger	0.9	1.0	0.0	0.0	0.0
Chiloplacus trilineatus	0.4	0.3	0.1	0.8	0.0
Chiloplacus bisexualis	2.1	3.3	1.1	0.5	0.1
Chronogaster sp.	0.0	0.0	0.0	0.0	5.9
Coslenchus sp.	0.1	0.6	0.0	0.1	0.5
Crassolabium cylindricum	0.0	0.5	0.0	0.3	0.0
Criconema sp.	0.0	0.1	0.0	0.0	0.0
Discolaimium sp.	0.5	0.0	0.1	0.0	0.0
Ditylenchus sp.	0.0	0.3	0.0	0.0	0.0
Dorylaimellus sp.	0.0	0.3	0.0	0.0	0.0
Dorylaimus lineatus	0.3	1.1	0.0	0.0	0.0
Ecumenicus monohystera	0.0	2.4	0.0	0.0	0.0
Enchodelus lucinensis	1.4	1.0	0.0	1.1	0.0
Eucephalobus mucronatus	13.5	19.1	3.6	1.9	0.1
Eudorylaimus sabulophilis	0.9	1.0	0.3	0.0	0.0
Eudorylaimus subdigitalis	0.1	1.5	0.0	0.0	0.0
Funaria cf. *obtusa*	0.5	0.0	0.0	0.0	0.0
Geocenamus koreanus	3.9	3.6	1.5	0.9	0.0
Geomonhystera sp.	0.6	1.6	0.0	0.0	0.0
Helicotylenchus sp.	0.0	0.3	0.0	0.0	0.0
Heterodera trifolii	0.0	0.0	0.0	0.6	0.0
Heterodorus magnificus	0.0	2.3	0.4	2.5	0.0
Hoplolaimus sp.	0.0	0.1	0.0	0.0	0.1
Kochinema sp.	0.1	0.0	0.0	0.0	0.0

Table 7 (continued). Species distribution in habitats with different ecological characteristics with corresponding abundance (mean number).*

Taxon name	Wildflower meadow	Mountain grassland	Chalk grassland	Riverbed	Marshland
Longidorella okhlaensis	0.0	0.8	0.0	0.0	0.0
Malenchus sp.	2.8	3.9	0.1	0.5	0.1
Mesodorylaimus sp.	12.6	3.5	0.0	0.0	0.0
Mesorhabditis sp.	0.0	0.0	0.0	0.1	0.0
Microdorylaimus sp.	0.1	0.4	0.0	0.0	0.0
Monhystera sp.	0.0	0.0	0.0	0.0	2.9
Nagelus camelliae	3.3	0.1	0.0	0.0	0.0
Nagelus hexagrammus	0.1	0.6	0.0	0.0	0.0
Nothacrobeles sp.	0.0	0.0	0.0	0.1	0.0
Nygolaimus sp.	0.0	0.3	0.0	0.0	0.0
Panagrolaimus rigidus	12.3	10.9	0.6	1.5	0.0
Paracrobeles sp.	0.1	0.0	0.0	0.0	0.0
Paratylenchus sp.	0.5	5.3	0.0	0.1	0.0
Plectus spp.	9.5	20.0	0.0	0.3	0.0
Pratylenchus thornei	0.0	1.0	0.1	0.1	0.0
Pratylenchus neglectus	0.1	0.0	0.1	0.1	0.0
Propanagrolaimus hydrophilus	0.0	0.0	0.0	0.0	0.1
Pungentus sp.	0.3	0.4	0.0	0.1	0.0
Rhabdolaimus sp.	0.8	0.0	0.0	0.0	0.0
Rotylenchus sp.	17.8	1.8	0.6	0.0	0.1
Scutellonema sp.	2.8	0.1	0.0	0.0	0.0
Stegelletina sp.	0.3	0.1	0.0	0.0	0.0
Teratocephalus terrestris	1.0	0.4	0.1	0.0	0.0
Tobrilus sp.	0.0	0.0	0.0	0.0	0.4
Trichodorus sp.	0.0	0.1	0.0	0.0	0.0
Tylencholaimellus montanus	0.5	3.4	0.3	0.0	0.0
Tylencholaimus teres	0.5	1.3	0.0	0.0	0.0
Tylencholaimus proximus	0.0	0.6	0.0	0.0	0.0
Tylenchorhynchus maximus	0.1	1.3	0.3	0.0	0.0
Tylenchorhynchus mangiferae	0.5	1.8	0.0	0.0	0.0
Tylenchus sp.	0.9	2.0	0.6	0.1	0.0
Tylocephalus auriculatus	2.8	0.1	0.0	0.0	0.0
Xiphinema sp.	0.0	0.1	0.0	0.0	0.0
Zeldia sp.	0.0	0.1	0.1	0.0	0.0

*A total number of 29 samples were analysed. Each soil sample was a volume of 200 cm^{-3}. The number of samples varied between 2-10 samples per habitat.

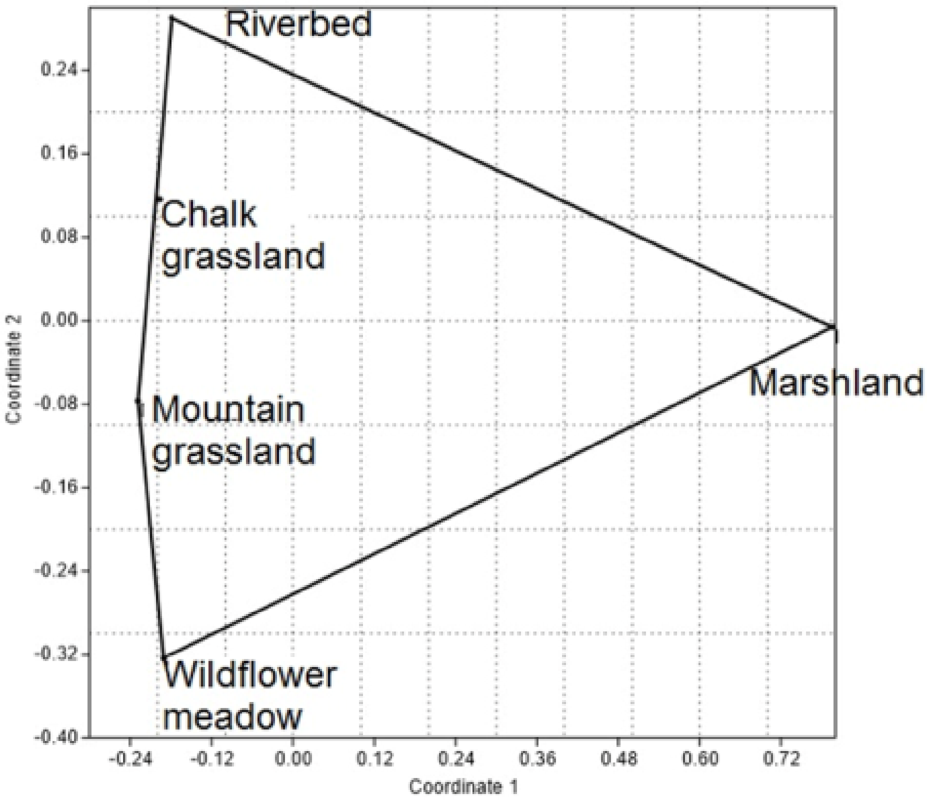

Fig. 4. Distance between nematode communities from different habitats. Distribution of nematode genera was analysed by MDS (nonmetric Multi-Dimensional Scaling).

(ii) Species that were only collected from the wildflower meadow: *Anaplectus* sp., *Funaria* cf. *obtusa*, *Kochinema* sp., *Paracrobeles* sp., *Rhabdolaimus* sp.

(iii) Species that were only collected from mountain grassland: *Achromadora* sp., *Alaimus* sp., *Criconema* sp., *Ditylenchus* sp., *Dorylaimellus* sp., *Ecumenicus monohystera*, *Helicotylenchus* sp., *Heterodera trifolii*, *Longidorella okhlaensis*, *Nygolaimus* sp.

(iv) Species that were only collected from the riverbed: *Mesorhabditis* sp., *Nothacrobeles* sp.

(v) Species that were only collected from marshland: *Chronogaster* sp., *Monhystera* sp., *Propanagrolaimus hydrophilus* and *Tobrilus* sp.

3. MDS comparison of ecological characteristic types. A non-metric Multi-Dimensional Scaling (MDS) analysis was performed on the distribution of nematode genera resulting in five ecological characteristic types (Fig. 4). MDS ordination analysis showed that the nematode communities were grouped into two main groups according to their ecological characteristics. Remarkably, the nematode community from marshland was almost entirely different from communities in mountain grassland, wildflower meadow, chalk grassland and riverbed.

Table 6. Nematode abundance in five ecological characteristics of Mount Ararat, Turkey.

Ecological characteristic	n[1*]	Abundance[2]
Wildflower meadow	9	136.2 ± 16.1 (a)
Mountain grassland	10	111.1 ± 15.3 (a)
Chalk grassland	2	78 ± 2.6 (ab)
Riverbed	2	74 ± 2.4 (ab)
Marshland	2	43 ± 3.1 (b)
Total	**25**	

[1]Number of soil samples collected in each altitudinal range.
*Four samples at the altitudinal range 4372-4957 m a.s.l. had a mean of zero nematodes so they were not included in the analysis.
[2]Number (mean ± s.d.) of specimens (200 cm^{-3} soil). Different letters in the column indicate significant differences between means (P < 0.05, one-way ANOVA following post-hoc Tukey test).

DISCUSSION

Species distribution. To understand the complete distributional patterns of nematode communities at Mount Ararat, we will discuss the matter of species distribution using three different approaches.

Firstly, species were examined according to their relative abundance and occurrence with an integrative and comparative approach. The results fit a very general pattern, as a few species (*Eucephalobus mucronatus* and *Plectus* spp. among others) are simultaneously very abundant or abundant and very frequent or frequent, whereas most species are rare or very rare and less frequent or very less frequent. For instance, *Rotylenchus* sp. is a very abundant but less frequent species since this taxon occurs in a few soil samples, but always with high density of specimens. This may be explained by the limitations of host plant availability for plant-parasitic nematodes.

Regarding the altitudinal distribution of nematode species, several patterns were distinguished, which should be tested and confirmed with further studies as there are no comparable studies in the specialised literature. Remarkably, several species were distributed only in the highest altitudes of habitable zone (3500-4000 m a.s.l.): *Acrobeles andalusicus*, *Geomonhystera* sp., *Mesodorylaimus* sp. and *Rhabdolaimus* sp. The presence of these nematodes in higher altitudes might be related to their general cold tolerance capabilities. Of special interest is the distribution of two cephalobid genera, which are represented by two or more species with a markedly different altitudinal distribution. Thus, together with two representatives of the genus *Acrobeles* and the only representative of the genus *Seleborca*, these can be spatially (altitudinally) ordered as *Seleborca complexa*, found only in the lowest range (1500-2000 m a.s.l.), *A. ciliatus* in the medium range (2000-2500 m a.s.l.) and *A. andalusicus* at higher altitudes (2500-4000 m a.s.l.) of the mountain. A similar distribution was observed in the two species belonging to the genus *Chiloplacus*, with *C. bisexualis* only occurring in the 1500-3000 m a.s.l. range, whereas *C. trilineatus* was found in the 2500-4000 m a.s.l. range. *Acrobeles* and *Chiloplacus* species are distributed world-wide. *Acrobeles ciliatus* and *A. compexus* have been reported from many different localities (*e.g.*, Vinciguerra, 1972; Andrássy, 1953, 1958, 1962, 1978, 2002, 2009; Boström, 1992; Abolafia & Peña-Santiago, 2004). However, *A. andalusicus* was frequently found at high altitudes in the Iberian Peninsula (Abolafia & Peña-Santiago, 2005).

Species distribution was analysed on the basis of five different ecological characteristics, resulting in a marked difference between the community associated with marshland habitat and the remaining ones. Several species were found to be restricted to only one ecological characteristic, in particular a few rare species collected from wildflower meadow, for instance *Anaplectus* sp., *Funaria* cf. *obtusa* and *Kochinema* sp. Generic composition of the nematofauna on meadow habitat is known to be the most stable community (Hánėl, 1995). This can explain the tendency and presence of the rare taxa in wildflower meadow habitats of Mount Ararat. Moreover, species, which occurred only in marshland (*Chronogaster* sp., *Monhystera* sp. and *Tobrilus* sp.), were also those found to be tolerant of fluctuating oxygen conditions (Abebe *et al.*, 2006). Since the marshland was in a wetland area, it may be expected to have fluctuations in oxygen level. Also, it has been mentioned by several authors that *Chronogaster* species have great abilities for physiological change (Heyns & Coomans, 1980; Poinar & Sarbu, 1994), whilst *Tobrilus* species are more known to have morphological plasticity in freshwater environments (Tsalolikhin, 2001).

Other interesting feature of the nematode community inhabiting Mount Ararat's soils is the presence of several genera that are considered to be commonly found in various extreme conditions (Abebe *et al.*, 2006), namely *Monhystera*, *Geomonhystera*, *Plectus*, *Mesodorylaimus* and *Eudorylaimus*. All of them are ecologically generalists and, additionally, *Monhystera* and *Plectus* are bacteriovorous forms without specialised stoma structures. They are considered to have high plasticity to physiological changes. Also, the dorylaims are known to be highly omnivorous and very abundant in terrestrial habitats (Yeates *et al.*, 1993). Some plant-parasitic nematodes are also well known and studied for their extreme survival strategies (Perry, 1999, 2002; Perry & Gaur, 1996), *e.g.*, cyst nematodes exhibit diapause, a physiological state where hatching does not occur until specific requirements have been satisfied. The survival strategies of cyst nematodes, which enables *Heterodera trifolii* to overcome harsh winters, is a nice example of their ability to adapt extreme conditions at Mount Ararat.

Nematode abundance. The total nematode abundance was correlated with increasing altitude and it was significantly higher in the highest altitudinal range. Unfortunately, a very limited number of studies (Sohlenius & Boström, 1984; Popovici, 1984; Freckman *et al.*, 1987; Hoschitz & Kaufmann, 2004) have been conducted to assess the altitudinal gradient effects on nematode abundance. The results of these studies did not show any consistent pattern or correlation between abundance and altitude. In this context, our results, showing the highest abundance at the highest elevational range, should be regarded as a plausible hypothesis to test in the future. Actually, our survey was conducted during the summer season, a time in which environmental variables are optimal in high altitudes (Yeates & Bird, 1994; Stamou *et al.*, 2005).

Species richness. General knowledge about species richness and diversity of organisms presumes that biodiversity has a decreasing trend with increasing latitude and altitude due to increasingly severe climatic conditions (Procter, 1984; Meyer & Thaler, 1995; Heal *et al.*, 1998). Nevertheless, other patterns are known to occur (Rahbek, 1995) and several studies on nematode communities showed differing results (Boag & Yeates, 1998; Porazinska *et al.*, 2012). Our data follow a common general pattern in which the highest value of species richness is found at intermediate altitudes (*cf.* Rahbek, *op. cit.*), with a total of 39 species (55% of the total) inhabiting the 2000-2500 m a.s.l. range in association with chalk grassland and riverbed habitats. Previous studies from high alpine areas (Hánėl, 1998; Popovici & Ciobanu, 2000) also reported high species richness in more or less comparable habitats. Nevertheless, available literature does not provide totally comparable results.

The survey conducted on soils from Mount Ararat has revealed patterns of altitudinal distribution of nematode diversity (species richness) and nematode abundance. The number of species reaches a maximum at intermediate elevations, whereas the nematode abundance is significantly higher at the highest altitudes. Moreover, the nematode community associated with the marshland habitat becomes significantly different from those associated with the other four habitat types. These geographical and ecological trends, however, should be confirmed by future studies.

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REFERENCES

ABEBE, E., ANDRÁSSY, I. & TRAUNSPURGER, W. 2006. *Freshwater Nematodes: Ecology and Taxonomy*. UK, CAB International. 752 pp. DOI: 10.1079/9780851990095.0000

ABOLAFIA, J. & PEÑA-SANTIAGO, R. 2004. Nematodes of the order Rhabditida from Andalucía Oriental, Spain. The genus *Acrobeles* von Linstow, 1877 with description of *A. andalusicus* sp. n. and a key to species. *Journal of Nematode Morphology and Systematics* 6: 103-128. DOI: 10.1163/156854103767139743

ABOLAFIA, J. & PEÑA-SANTIAGO, R. 2005. Nematodes of the order Rhabditida from Andalucía Oriental: *Pseudacrobeles elongatus* (de Man, 1880) comb. n. *Nematology* 7: 917-926 DOI: 10.1163/156854105776186415

ANDRÁSSY, I. 1953. Freilebende Nematoden aus einer Torf-Probe. Nematologische Notizen, 1. *Zoologischer Anzeiger* 150: 30-35.

ANDRÁSSY, I. 1958. *Hoplolaimus tylenchiformis* Daday, 1905 (Syn. *H. coronatus* Cobb, 1923) and the genera of the subfamily Hoplolaiminae Filipjev, 1936. *Nematologica* 3: 44-56.

ANDRÁSSY, I. 1962. Nematoden aus dem Psammon des Adige-Flusses, II. *Memorie del Museo Civico di Storia Naturale di Verona* 10: 1-35.

ANDRASSY, I. 1978. Fresh-water nematodes from the Himalayas (Nepal). *Opuscula Zoologica Budapest* 15: 3-21.

ANDRÁSSY, I. 2002. Free-living nematodes from the Fertő-Hanság National Park, Hungary. In: *The Fauna of the Fertő-Hanság National Park, Hungary* (S. Mahunka Ed.). pp. 21-97. Budapest, Hungary, Hungarian National History Museum.

ANDRÁSSY, I. 2009. *Free-living nematodes of Hungary (Nematoda errantia), III. Pedozoologica Hungarica, no. 5* (C.S. Csuzdi & S. Mahunka Eds). Hungary, Hungarian Natural History Museum. 608 pp.

BAERMANN, G. 1917. Eine einfache Methode Zur Auffindung von Ankylostomum (Nematoden) Larven in Erdproben. *Mededeel mit H. Geneesk Laboratories Weltevreden, Feestbundel, Batavia*: 41-47.

BOAG, B. & YEATES, G.W. 1998. Soil nematode biodiversity in terrestrial ecosystems. *Biodiversity Conservation* 7: 617-630.

BOSTRÖM, S. 1992. Some Cephalobidae (Nematoda: Rhabditida) from Crete, Greece. *Fundamental and Applied Nematology* 15: 289-295.

DALMASSO, A. 1970. Influence directe de quelques facteurs écologiques sur l'activité biologique et la distribution des espéces françaises de la famille des Longidoridae (Nematoda-Dorylaimida). *Annales de Zoologie et Ecologie Animale* 2: 163-200.

FRECKMAN, D.W. & CASWELL, E.P. 1985. The ecology of nematodes in agroecosystems. *Annual Review of Phytopathology* 23: 275-296. DOI: 10.1146/annurev.py.23.090185.001423

FRECKMAN, D.W., WHITFORD, W.G. & STEINBERGER, Y. 1987. Effects of irrigation on nematode population dynamics and activity in desert soils. *Soil Biology and Fertility of Soils* 3: 3-10. DOI: 10.1007/BF00260571

HAMMER, Ø, HARPER, D.A.T. & RYAN, P.D. 2001. *PAST-PAlaeontological STatistics*. 31 pp. URL: https://www.uv.es/pardomv/pe/2001_1/past/pastprog/past.pdf (accessed: November 25, 2020).

HÁNĖL, L. 1995. Secondary successional stages of soil nematodes in cambisols of South Bohemia. *Nematologica* 41: 197-218. DOI: 10.1163/003925995X00170

HÁNĖL, L. 1998. Soil nematodes of grassland-meadow ecosystems in the Czech Republic, Central Europe. In: *Nematode Communities of Northern Temperate Grassland Ecosystems* (R.G.M. de Goede & T. Bongers Eds). pp. 95-122. Giessen, Germany, Focus Verlag.

HÁNĖL, L. 2010. An outline of soil nematode succession on abandoned fields in South Bohemia. *Applied Soil Ecology* 46: 355-371. DOI: 10.1016/j.apsoil.2010.10.005

HEAL, O.W., BROLL, G., HOOPER, D.U., MCCONNELL, J., WEBB, N.R. & WOOKEY, P.A. 1998. Impacts of global change on tundra soil biology. In: *Global Change in Europe's Cold Regions. European Commission Ecosystem Research Report 27* (O.W. Heal, T.V. Callaghan, J.H.C. Cornelissen, C. Körner & S.E. Lee Eds). pp. 65-134. Luxembourg City, Luxembourg, Office for Official Publications of the European Communities.

HEYNS, J. & COOMANS, A. 1980. Freshwater nematodes from South Africa. 5. *Chronogaster* Cobb, 1913. *Nematologica* 26: 187-208. DOI: 10.1163/187529280X00080

HODKINSON, I.D. & JACKSON, J.K. 2005. Terrestrial and aquatic invertebrates as bioindicators for environmental monitoring, with particular reference to mountain ecosystems. *Environmental Management* 35: 649-666. DOI: 10.1007/s00267-004-0211-x

HOSCHITZ, M. & KAUFMANN, R. 2004. Soil nematode communities of Alpine summits – site differentiation and microclimatic influences. *Pedobiologia* 48: 313-320 DOI: 10.1016/j.pedobi.2004.03.004

HUGOT, J.P., BAUJARD, P. & MORAND, S. 2001. Biodiversity in helminths and nematodes as a field of study: an overview. *Nematology* 3: 199-208. DOI: 10.1163/156854101750413270

KOYUNCU, M. 2005. Agri Dağı. In: *Türkiye'nin 122 Önemli Bitki Alani* (N. Özhatay, A. Byfield ve S. Atay Eds.). pp. 335-337. İstanbul, Türkiye, Doğal Hayatı Koruma Vakfı.

JASMER, D.P., GOVERSE, A. & SMANT, G. 2003. Parasitic nematode interactions with mammals and plants. *Annual Review of Phytopathology* 41: 245-270. DOI: 10.1146/annurev.phyto.41.052102.104023

LIU, T., HU, F. & LI, H. 2019. Spatial ecology of soil nematodes: perspectives from global to micro scales. *Soil Biology and Biochemistry* 137: 107565 DOI: 10.1016/j.soilbio.2019.107565

MCSORLEY, R. 2011. Overview of organic amendments for management of plant-parasitic nematodes, with case studies from Florida. *Journal of Nematology* 43: 69-81.

MEYER, E. & THALER, K. 1995. Animal diversity at high altitudes in the Austrian Central Alps. In: *Arctic and Alpine Biodiversity: Patterns, Causes and Ecosystem Consequences. Ecological Studies, Volume 113* (F.S. Chapin & C. Körner Eds). pp. 97-110. Heidelberg, Germany, Springer Verlag GmbH.

NAVAS, A., BALDWIN, J.G. & LAMBERTI, F. 1993. Contributions to the taxonomy status of *Longidorus latocephalus* Lamberti, Choleva & Agostinelli, 1983 and *L. pisi* Edward, Misra & Singh, 1964 (Nematoda: Longidoridae). *Nematologia Mediterranea* 21: 117-122.

NEHER, D.A. 2010. Ecology of plant and free-living nematodes in natural and agricultural soil. *Annual Review of Phytopathology* 48: 371-394. DOI: 10.1146/annurev-phyto-073009-114439

PERRY, R.N. 1999. Desiccation survival of parasitic nematodes. *Parasitology* 119 (Supplementary 1): 19-30. DOI: 10.1017/S0031182000084626

PERRY, R.N. 2002. Hatching. In: *The Biology of Nematodes* (D.L. Lee Ed.). pp. 147-169. London, UK, Taylor & Francis Group.

PERRY, R.N. & GAUR, H.S. 1996. Host plant influences on the hatching of cyst nematodes. *Fundamental and Applied Nematology* 19: 505-510.

POINAR, G.O. JR & SARBU, S.M. 1994. *Chronogaster troglodytes* sp. n. (Nemata: Chronogasteridae) from Movile Cave, with a review of cavernicolous nematodes. *Fundamental and Applied Nematology* 17: 231-237.

POPOVICI, I. 1984. Nematode abundance, biomass and production in a beech forest ecosystem. *Pedobiologia* 26: 205-219.

POPOVICI, I. & CIOBANU, M. 2000. Diversity and distribution of nematode communities in grasslands from Romania in relation to vegetation and soil characteristics. *Applied Soil Ecology* 14: 27-36. DOI: 10.1016/S0929-1393(99)00048-7

PORAZINSKA, D.L., GIBLIN-DAVIS, R.M., POWERS, T.O. & THOMAS, W.K. 2012. Nematode spatial and ecological patterns from tropical and temperate rainforests. *PloS ONE* 7: e44641. DOI: 10.1371/journal.pone.0044641

PROCTER, D.L.C. 1984. Towards a biogeography of free-living soil nematodes. I. Changing species richness, diversity and densities with changing latitude. *Journal of Biogeography* 11: 103-117.

PROCTER, D.L.C. 1990. Global overview of the functional roles of soil-living nematodes in terrestrial communities and ecosystems. *Journal of Nematology* 22: 1-7.

RAHBEK, C. 1995. The elevational gradient of species richness: a uniform pattern? *Ecography* 18: 200-205.

SOHLENIUS, B. & BOSTRÖM, S. 1984. Colonization, population development and metabolic activity of nematodes in buried barley straw. *Pedobiologia* 27: 67-78.

STAMOU, G.P., PAPATHEODOROU, E.M., HOVARDAS, A. & ARGYROPOULOU, M.D. 2005. Some structural and functional characteristics of a soil nematode community from a Mediterranean grassland. *Belgian Journal of Zoology* 135: 253-259.

TOPHAM, P.B. & ALPHEY, T.J.W. 1985. Faunistic analysis of Longidorid nematodes in Europe. *Journal of Biogeography* 12: 165-174.

TSALOLIKHIN, S.YA. 2001. Synopsis of the system of the family Tobrilidae (Nematoda: Enoplida). *Russian Journal of Nematology* 9: 19-24.

VAN DEN HOOGEN, J., GEISEN, S., ROUTH, D., FERRIS, H., TRAUNSPURGER, W., WARDLE, D.A., DE GOEDE, R.G.M., ADAMS, B.J., AHMAD, W., ANDRIUZZI, W.S., CREAMER, R., KORTHALS, G., QUIST, C.W., VAN DER PUTTEN, W. *ET AL.* 2019. Soil nematode abundance and functional group composition at a global scale. *Nature* 572: 194-198. DOI: 10.1038/s41586-019-1418-6

VINCIGUERRA, M.T. 1972. Descrizione dei maschi, finora ignoti, die due specie di Nematodi. *Bullettino delle Sedute della Accademia Gioenia di Scienze Naturali in Catania* 11: 3-7.

WEISCHER, B. & ALMEIDA, M.T.M. 1995. Ecology of longidorid nematodes. *Russian Journal of Nematology* 3: 9-21.

YEATES, G.W. 1979. Soil nematodes in terrestrial ecosystems. *Journal of Nematology* 11: 213.

YEATES, G.W. 2003. Nematodes as soil indicators: functional and biodiversity aspects. *Biology and Fertility of Soils* 37: 199-210. DOI: 10.1007/s00374-003-0586-5

YEATES, G.W. & BIRD, A.F. 1994. Some observations on the influence of agricultural practices on the nematode faunae of some South Australian soils. *Fundamental and Applied Nematology* 17: 133-145.

YEATES, G.W., BONGERS, T., DE GOEDE, R.G.M., FRECKMAN, D.W. & GEORGIEVA, S.S. 1993. Feeding habits in soil nematode families and genera – an outline for soil ecologists. *Journal of Nematology* 25: 315-331.

YODER, M., DE LEY, I.T., WM KING, I., MUNDO-OCAMPO, M., MANN, J., BLAXTER, M., POIRAS, L. & DE LEY, P. 2006. DESS: a versatile solution for preserving morphology and extractable DNA of nematodes. *Nematology* 8: 367-376. DOI: 10.1163/156854106778-493448

ZHANG, Z.Q., FAN, Q.H., PESIC, V., SMIT, H., BOCHKOV, A.V., KHAUSTOV, A.A., BAKER, A., WOHLTMANN, A., WEN, T., AMRINE, J.W., BERON, P., LIN, J., GABRYS, G. & HUSBAND, R. 2011. Order Trombidiformes Reuter, 1909. In: Zhang, Z.-Q. (Ed.) Animal biodiversity: an outline of higher-level classification and survey of taxonomic richness. *Zootaxa* 3148: 129-138. DOI: 10.11646/zootaxa.3148.1.24

T. Çakmak, Ç. Gözel, U. Gözel, D.T. Achiri and M.B. Kaydan. Биологическое разнообразие и распределение почвенных нематод горы Арарат, Турция.

Резюме. Исследованы биологическое разнообразие и распределение в местообитаниях с различными экологическими характеристками почвенных нематод на горе Арарат на высотах от 1523 до 5000 м над уровнем моря. Всего было определено 2561 экземпляров нематод, относящихся к 31 семейству, 62 родам и 70 видам. Разнообразие нематод (богатство видового состава) и численное обилие нематод показывают четкую приуроченность к высотам над уровнем моря. Было показано, что число видов достигает максимума на средних высотах, тогда как численное обилие нематод заметно увеличивалось с высотой. Сообщества нематод болотистых участков существенно отличались от сообществ нематод в других местообитаниях.