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Lumbricidae FAMILY IN BROWN FOREST SOILS: ABUNDANCE, BIOMASS, PROFILE DISTRIBUTION

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Abstract

The Lumbricidae family of brown forest soils in natural and agricultural ecosystems located in the central zones of the Republic of Moldova has been investigated in May, 2021 and 2022. Earthworms sampling was carried out from test cuts by manual sampling of soil layers to the depth of soil fauna occurrence. The number and biomass of Lumbricidae family in natural brown soils are greater by 3.8-17.9 times and by 2.6-16.5 times compared to brown soils of agricultural ecosystems. The highest values of abundance and biomass of earthworms were registered in the typical brown forest soils under natural vegetation and the smallest values - in arable luvic brown forest soils. A characteristic feature of the natural brown soils is the high concentration of invertebrates and Lumbricidae family in the upper layers of soils. The species Lumbricus terrestris, Lumbricus rubellus, Aporrectodea caliginosa and Aporrectodea longa and other were identified in the faunal samples from the natural brown forest soils.

Key words*: Lumbricidae family, brown forest soil, natural and agricultural ecosystems.*

INTRODUCTION

Lumbricidae family belong to the phylum *Annelida*, class *Clitellata,* subclass *Oligochaeta*, order *Opisthopora,* superfamily *Lumbrcoidea*.

Charles Darwin was the first scientist to draw attention to the important role of earthworms in soil formation processes (Darwin, 1881). The structure-forming role of earthworms attracts attention of many scientists (Lee & Foster, 1991; Edwards & Bohlen, 1996; Jouquet et al., 2008; Lapied et al., 2009). The activity of earthworms produces a significant effect, not just on the structure, but also on the chemical composition of the soil, since a large part of the organic matter ingested by earthworms returns to the soil in the form easily used by plants. Earthworms contribute nutrients to the soil and improve porosity, tilth, and root development (Fragoso et al., 1997).

Earthworms are the dominant macrofauna and a functionally significant component of the soil. *Lumbricidae* family are recognized as a key factor to the functioning of many terrestrial ecosystems (Bartlett et al., 2010). Earthworms can serve as indicators of anthropogenic land use, soil quality and a factor for soil biological site classification (Martinez-Salgado et al., 2010; Römbke et al., 2005; State of Knowledge of Soil Biodiversity. Status, challenges and potentialities. Report 2020. Retrieved from Report Soil Biodiversity.pdf).

In the 1960s, nine species of earthworms were identified in the soils of Moldova (Perel, 1962; Prokhina, 1965; 1968; Striganova, 1968). The edaphic species of fauna, unique only to brown soils, especially from *Lumbricidae* family, have been discovered (Gilyarov, 1965).

Aporrectodea rosea predominated in most soils in the 1990s, *Aporrectodea caliginosa, Aporrectodea trapezoides, Octalazion transpadanum, Aporrectodea jassiensis* and *Allolobophora leoni* are much less common (Cherevatov, 1991).

In this context, the purpose of the research was to investigate the abundance, biodiversity and profile distribution of *Lumbricidae* family in brown soils of natural and agricultural ecosystems for the biodiversity conservation and development of the monitoring system for the status of useful edaphic fauna.

MATERIALS AND METHODS

Experimental sites are located in central zones of the Republic of Moldova. The content of *Lumbricidae* family in brown forest soils with

the normal profile in the condition of the long-term use in agricultural production were investigated in comparison with the undisturbed soils in natural ecosystems of forest. Two experimental sites have been tested.

Experimental sites with typical and luvic brown soil are located in the central zone of the Republic of Moldova, in the wooded steppe of the central - Moldovan forest province, in the district No. 8 of brown, gray forest soils and leached chernozems of the wooded steppe of hilly Kodru Forests.

The site with typical brown soil (profile 1 under forest; profile 2 under arable) is situated in the Tuzara village and Gorodische com., Kalarash region (Figure 1).

Figure 1. Site with the typical brown forest soil in the Tuzara village and Gorodische com., Kalarash region

The site with luvic brown soil (profile 5 under forest; profile 6 under arable) is located in the Dolna com., Strasheni region (Figure 2).

Figure 2. Site with the luvic brown forest soil in the Dolna com., Strasheni region

Status of invertebrates and Lumbricidae family. Testing of semi-profiles in the amount of 3 units was carried out around the main test cut at a distance of 5-10 m. The state of invertebrates and *Lumbricidae* family was determined from test cuts by manual sampling of soil layers to the depth of soil fauna occurrence with application of Gilyarov and Striganova's method (1987). At the same time, earthworms were also selected from the litter layer and on the soil surface. Ethyl alcohol was used to immobilize (destroy) the earthworms. The taxonomic studies used during the identification were accomplished according to Vsevolodova-Perel T.S. (1997).

The studies were carried out in May of 2021 and 2022.

RESULTS AND DISCUSSIONS

The number and biomass of edaphic fauna including *Lumbricidae* family in brown forest soils of natural ecosystems are characterized by the higher values of these indicators in comparison with arable brown forest soils (Table 1). Number of invertebrates and *Lumbricidae* family in the typical brown forest soil decreases on average for 2 years (2021-2022) from 330.7 to 65.3 ex m^{-2} and from 152.0 to 61.4 ex m^{-2}, in the luvic brown forest soil - from 274.7 to 5.4 ex m^{-2} and from 140.0 to 4.0 ex m^{-2} accordingly. Similar changes were observed in the total biomass of the edaphic fauna and *Lumbricidae* family.

The share of earthworms in the total number of invertebrates in the typical brown forest soil of natural ecosystems constitutes of 51.8% in 2021 and 38.3% in 2022, in the luvic brown forest soil - 51.5% and 50.7% accordingly. Their contribution to the total biomass is 82.5% in 2021 and 51.0% in 2022 in the typical brown forest soil. The proportion of *Lumbricidae* family in the total biomass of the edaphic fauna is 89.3% and 81.6% in the the natural luvic brown forest soil in studied years.

The share of *Lumbricidae* family in the total abundance of invertebrates in arable forest soils constitutes 94.0% in the typical brown forest soil, and 74.1% in the luvic brown forest soil on average for 2 years of research. The contribution of earthworms to the total biomass is 99.1% and 92.1% accordingly.

Table 1. Number and biomass of invertebrates and *Lumbricidae* family in brown soils under forest and arable land (n = 3 for each profile)

Soil	Land use	Semi-profile	Number, ex m^{-2}		Biomass, g m^{-2}	
			total	*Lumbricidae* fam.	total	*Lumbricidae* fam.
2021						
Typical brown soil	forest	45	408.0	152.0	73.6	58.4
		46	352.0	144.0	60.0	38.4
		47	368.0	288.0	131.2	121.6
		mean values	376.0	194.7	88.3	72.8
	arable	48	144.0	144.0	68.0	68.0
		49	40.0	40.0	16.8	16.8
		50	96.0	80.0	29.0	28.4
		mean values	93.3	88.0	37.9	37.7
Luvic brown soil	forest	51	96.0	24.0	28.6	24.8
		52	240.0	152.0	100.8	96.0
		53	208.0	104.0	52.2	54.0
		mean values	181.3	93.3	60.5	54.0
	arable	54	8.0	0	1.6	0
		55	24.0	24.0	20.8	20.8
		56	0	0	0	0
		mean values	10.7	8.0	7.5	6.9
2022						
Typical brown soil	forest	99	416.0	152.0	117.0	47.2
		100	264.0	112.0	92.8	58.4
		101	176.0	64.0	41.4	22.4
		mean values	285.3	109.3	83.7	42.7
	arable	102	64.0	56.0	12.2	12.0
		103	40.0	40.0	9.6	9.6
		104	8.0	8.0	0.4	0.4
		mean values	37.3	34.7	7.4	7.3
Luvic brown soil	forest	93	208.0	72.0	34.0	25.4
		94	424.0	176.0	72.0	54.0
		95	472.0	312.0	120.8	105.8
		mean values	368.0	186.7	75.6	61.7
	arable	96	0	0	0	0
		97	0	0	0	0
		98	0	0	0	0
		mean values	0	0	0	0
Average value for 2021-2022						
Typical brown soil	forest	mean values	330.7	152.0	86.0	57.8
	arable		65.3	61.4	22.7	22.5
Luvic brown soil	forest		274.7	140.0	68.1	57.9
	arable		5.4	4.0	3.8	3.5

The average weight of one exemplar of earthworms in the natural typical brown forest soil constitutes 0.38 g, in the natural luvic brown forest soil - 0.41 g. The average weight of a specimen of the *Lumbricidae* family constitutes 0.37 g in the typical brown soil in conditions of agricultural ecosystems, and 0.88 g - in the arable luvic brown forest soil.

The base mass of fauna in the brown soils under the forest is located in the litter layer and 0-10 cm layer: in the typical brown soil - 90.8% and 95.3%, in luvic brown soil - 91.2% and 90.6% in the first and second years of research (Figure 3). The accumulation of edaphic fauna in the arable typical brown soil was registered in the 0-30 cm layer, in the arable luvic brown soil - in the 0-10 cm layer in 2021. The number of invertebrates index decreases in natural soil profiles to a depth of 40 cm, in arable soils - to a depth of 20-30 cm.

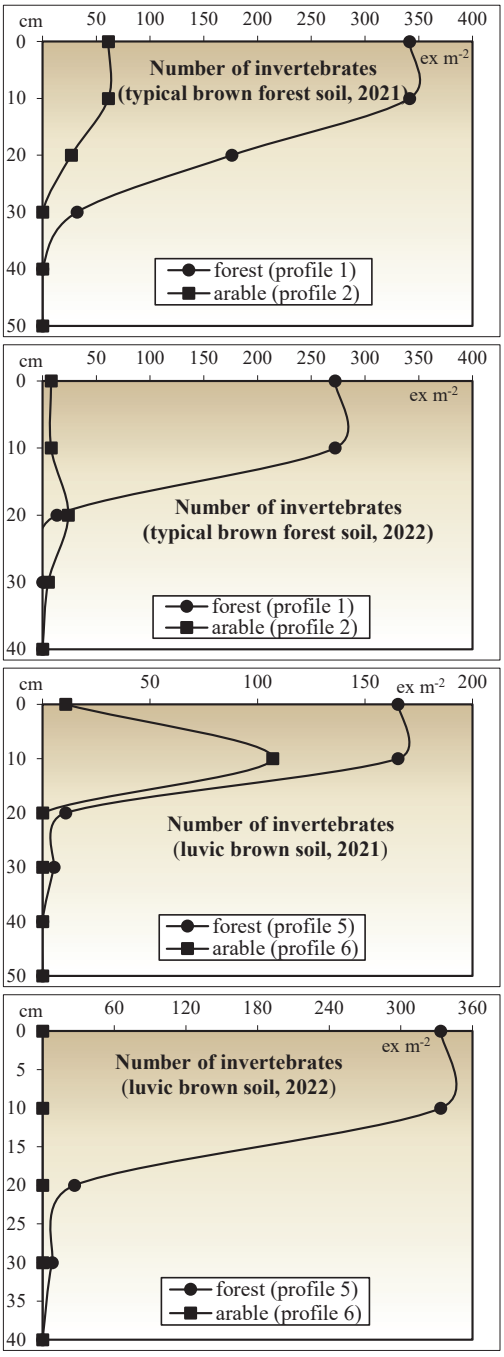

Figure 3. The profile distribution of invertebrates in brown forest soils of natural and agricultural ecosystems

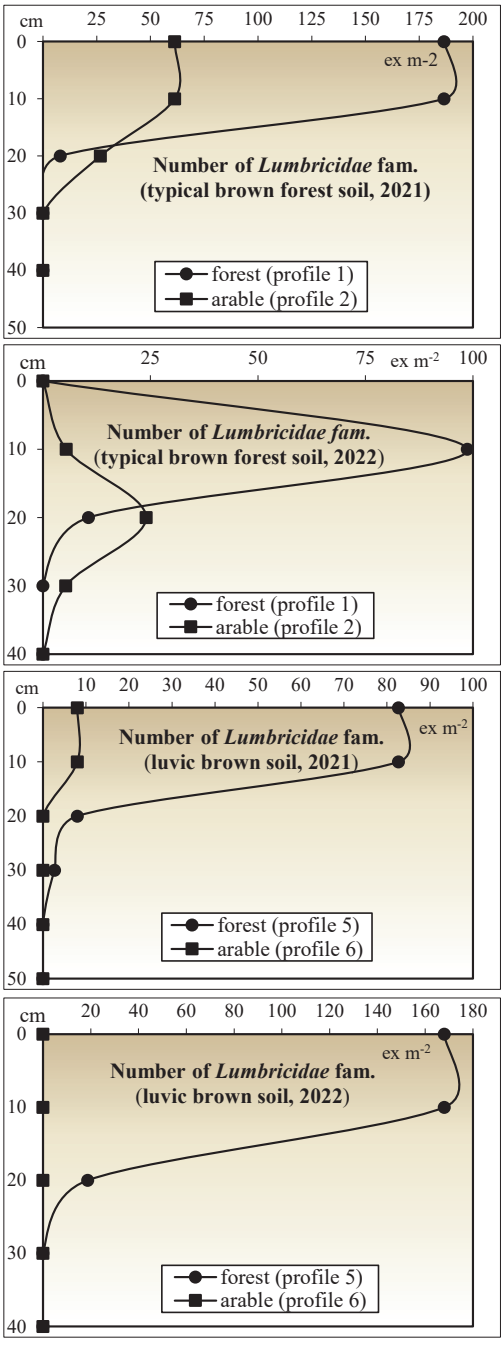

Figure 4. The profile distribution of *Lumbricidae* family in brown forest soils of natural and agricultural ecosystems

Lumbricidae family in the natural brown soils is located in the litter layer and 0-10 cm layer, amounting to 95.2% typical soil and 89.3% luvic soil in the total number (Figure 4).

The largest number of earthworms in the arable typical brown soil was found in the 0-30 cm layer, in the arable luvic brown soil - in the 0-10 cm. In the second year of research,

earthworms were absent in faunal semi-profiles.

Natural brown forest soils are characterized by a high diversity of invertebrates and *Lumbricidae* family compared to arable brown forest soils. There are 16 families of invertebrates in the natural typical brown soil and 15 families of edaphic fauna - in the natural luvic brown soil.

The long-term use of plowing leads to the considerable decrease of the invertebrates' biodiversity. Arable brown forest soils contain only 2 families of invertebrates in this period of fauna selection.

The species *Lumbricus terrestris, Lumbricus rubellus, Aporrectodea caliginosa* and *Aporrectodea longa* and other were identified in the faunal samples from the natural brown forest soils (Table 2). The greatest species biodiversity of *Lumbricidae* was in the forest ecosystems, which is inhabited by representatives of 4-5 species. The lowest species richness of earthworms was observed in the arable soils of agricultural ecosystems, where 1-3 species are widespread.

The epi-endogeic group in the natural typical forest soil is represented primarily by *Lumbricus rubellus*, the number of which in 2021 was especially high (41.1% of the total number). The saturation of the species composition of worms with anecic species *Aporrectodea longa* and *Lumbricus terrestris,* and also endogeic specie *Aporrectodea caliginosa* was also at a rather high level. *Aporrectodea caliginosa* has been also dominated in the *Lumbricidae* species composition in 2022 (70.8% of the total number). On average, over 2 years of research, 46.8% of earthworms in the natural typical forest soil belong to endogeic species, 24.3% - to anecic species and 20.5% - to epi-endogeic species.

Part of the earthworm's species in the natural luvic brown soil, living in the litter and in the upper soil layer, are surface-dwelling or litter-dwelling species (epi-endogeic earthworms). For example, the specific contribution of *Lumbricus rubellus* to the total number of *Lumbricidae* is 25.7% in 2021 and 27.2% in 2022.

A significant percentage of anecic species, such as *Lumbricus terrestris*, which were found in 2021 (34.3%), and endogeic species - *Aporrectodea caliginosa*, which were recorded in 2022 (48.6%), have been identified in the luvic brown forest soil of the natural ecosystem.

The number of *Aporrectodea longa* amounted to 14.3-15.7% in this soil. The epi-endogeic species *Aporrectodea trapezoides* was found in single specimens.

Endogeic species account for 32.9%, epi-endogeic species - 30.8% and anecic species - 20.7% of the total abundance of earthworms on average over 2 years of research.

Aporrectodea rosea (endogeic species) dominated in the arable typical brown forest soils in 2021, accounting for 63.6% of the total number of earthworms. Among the *Lumbricidae* family, the endogeic species *Aporrectodea caliginosa* prevailed (77.0%) in this soil in 2022.

Aporrectodea rosea has been found in the arable luvic brown forest soil in small quantities.

Table 2. Biodiversity of the *Lumbricidae* family (ex m^{-2}) at the species level in brown soils of natural and agricultural ecosystems

Lumbricidae family species	Typical brown soil, forest (P1)		Typical brown soil, arable (P2)		Luvic brown soil, forest (P5)		Luvic brown soil, arable (P6)	
	2021	2022	2021	2022	2021	2022	2021	2022
Lumbricus terrestris	21.3	5.3	0	0	32.0	13.3	0	0
Lumbricus rubellus	80.0	0	0	0	24.0	50.7	0	0
Aporrectodea caliginosa	29.3	77.4	21.3	26.7	5.3	90.7	0	0
Aporrectodea longa	58.7	21.3	0	0	13.3	29.3	0	0
Aporrectodea rosea	0	0	56.0	8.0	10.7	0	8.0	0
Octolasion lacteum	5.4	5.3	10.7	0	0	0	0	0
Aporrectodea trapezoides	0	0	0	0	8.0	0	0	0
Species unidentified	0	0	0	0	0	2.7	0	0
In total	194.7	109.3	88.0	34.7	93.3	186.7	8.0	0

The earthworms complex accounts 65.8-73.2% in the natural typical brown forest soil and 50.7-81.3% in the natural luvic brown forest soil from the total number of saprophagous. In arable soils their share is 97.0% and 100.0%.

CONCLUSIONS

Lumbricidae family is an important trophic level in the ecological chain nutrition of the ecosystem. Earthworms has a great importance for biological processes in soil, increase the fertility and humus formation by mechanical decomposition of plant residues and the formation of water-stable soil structure. Earthworms are indicators of soil quality, anthropogenic land use and a factor for soil biological classification. The highest values of abundance and biomass of earthworms were registered in the natural typical brown forest soils and the smallest values - in arable luvic brown forest soils. The number and biomass of *Lumbricidae* family in natural brown soils are greater by 3.8-17.9 times and by 2.6-16.5 times compared to brown soils of agricultural ecosystems. A characteristic feature of the natural brown soils is the high concentration of invertebrates and earthworms in the upper layers of soils. The species *Lumbricus terrestris, Lumbricus rubellus, Aporrectodea caliginosa, Aporrectodea longa* and other were identified in the faunal samples from the natural brown forest soils. *Aporrectodea rosea* and *Aporrectodea caliginosa* species is the most typical representative of the *Lumbricidae* in the arable brown forest soils.

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