Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 2, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

ABUNDANCE AND BIODIVERSITY OF INVERTEBRATES IN BROWN SOILS OF NATURAL AND AGRICULTURAL ECOSYSTEMS

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Abstract

The invertebrates' abundance and biodiversity of virgin and arable brown soils in the central zone of the Republic of Moldova have been investigated. Invertebrates sampling was carried out from test cuts by manual sampling of soil layers to the depth of soil fauna occurrence. The virgin brown soil in the natural ecosystem is characterized by a high abundance, biomass and biodiversity of the edaphic fauna compared to the soil under long-term agricultural use. A characteristic feature of the natural brown soils is the high concentration of invertebrates and Lumbricidae family in the upper layers of soils. Indicators of the edaphic fauna in soil profiles decreased with the depth. The relations between trophic levels are stronger in brown soils under forest, and trophic pyramids are more stable in the typical brown soil than in the luvic brown soil. The number and biomass of invertebrates in arable brown soils are lower by 2.8-3.4 times and by 2.2-7.5 times compared to brown soils of natural ecosystems. The number of edaphic fauna families decreased from 10-11 to 4-7. The disruption of trophic connections between invertebrates has been observed.

Key words*: biodiversity, soil invertebrates, typical and luvic brown soil, natural and agricultural ecosystem.*

INTRODUCTION

The primordial importance of the biodiversity for the environment maintaining stability and the stable development of communities is reflected in the Convention on Biological Diversity which was adopted by the United Nations Conference on Environment and Development in Rio de Janeiro on July 3-14, 1992 (Retrieved from https://www.cbd.int/doc/legal/cbd-en.pdf).

The Status of the World's Soil Resources (FAO, 2015) concluded that the loss of soil biodiversity is considered to be the one of the main global threats to soils in many regions of the world (Retrieved from http://www.fao.org/documents/card/ru/c/c6814873-efc3-41db-b7d3-2081a10ede50/).

Report FAO 2020 defines "soil biodiversity as the variety of life belowground from genes and species to the communities they form, as well as the ecological complexes to which they contribute and to which they belong, from soil micro-habitats to landscapes" (*State of Knowledge of Soil Biodiversity. Status, challenges and potentialities. Report 2020.* Retrieved from Report Soil Biodiversity.pdf).

Soil invertebrates' biodiversity is one of the most important evaluation criteria of ecosystems (Lavelle et al., 2006; Naeem et al., 2002; Schwartz et al., 2000), resistance to different forms of degradation (Schaefer & Schauermann, 1990). In some ecosystems the local diversity of soil fauna may be more enormous, then the diversity of different groups of aboveground plants or animals (Schaefer & Schauermann, 1990). Excessive reduction of the soil biodiversity, especially the loss of keystone species and/or species with unique functions may have some cascading ecological effects, which lead to the long-term deterioration of soil fertility and loss of agricultural productive capacity (Barrios, 2007; Huhta, 2007). Indices of soil invertebrates are the global indicators of soil quality and sustainability of ecosystems. The preservation of soil ecosystem services largely depends upon the preservation of soil invertebrates. Soil biodiversity also can have indirect effects to soil whether it functions as a carbon sink or source.

Soil invertebrates present an important trophic level in the ecological chain nutrition of biocenosis. Invertebrates have a great importance for biological processes in soil,

increase the fertility and humus formation by mechanical decomposition of plant residues and formation of water-stable soil structure (Fragoso et al., 1997; Gilyarov & Striganova, 1987; Huhta, 2007; Jouquet et al., 2006).

In the Republic of Moldova the type of brown soils is formed under the European deciduous forests (beech, sessile oak, silver lime, hornbeam. Their formation is conditioned by the predominant altitudes (280-430 m), climatic conditions, age of geological deposits and they are spread on the highest hills of the Central Plateau of the Forests. These soils are considered as specific, because their surface does not exceed 20 thousand ha (Baltyanskiy, 1984). It was found that in the central forests, in the soil under deciduous forests (rock oak, beech), many species of invertebrates are widespread and typical burozems in the Carpathians and mountainous regions of Central and Southern Europe. The edaphic species of fauna, unique only to brown soils, especially from *Carabidae* and *Lumbricidae* fam. have been discovered (Gilyarov, 1965).

In this context, the ***purpose of the research*** was to investigate the abundance, biodiversity and ratio of trophic groups of invertebrates in brown soils of natural ecosystems and to determine the effect of the long-term agricultural land utilization of brown arable soils on the invertebrates' status for the biodiversity conservation and development of the national soil biota quality standards.

MATERIALS AND METHODS

Experimental sites 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 plot with typical brown soil (profile 1 under forest; profile 2 under arable) is situated in the Tuzara village and Gorodische com., Kalarash region. The plot with luvic brown soil (profile 5 under forest; profile 6 under arable) is located in the Dolna com., Strasheni region.

Invertebrate' state in the virgin brown soil in the old-growth (primary) forest in the condition of natural ecosystems has been investigated in comparison with the long-term arable brown soil in conditions of agricultural ecosystems.

Status of invertebrates. The state of invertebrates was identified 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). The identification of invertebrate's diversity at the family's level and their classification according to nutrition were carried out by Gilyarov and Striganova's method (1987).

RESULTS AND DISCUSSIONS

Brown soils are characterized by a low content of edaphic fauna (especially of the family of *Lumbricidae*) when conducting monitoring researches in 2020. There are many factors that have led to reduction in the number of invertebrates in the soil in this period. The main reasons are prolonged drought, low humidity and strong compaction of soil horizons, due to which the invertebrates have been migrated deeply or died. Meanwhile, significant differences were established between the abundance of biota in brown soils under forest and arable soils.

The number and biomass of the edaphic fauna in the typical brown soil under a forest are in 1.6 and 1.9 times higher than in the luvic brown soil under a forest (Table 1). However, the abundance of representatives of *Lumbricidae* family was higher in the luvic brown soil. It should be noted that moisture in the luvic brown soil was higher than in the typical brown soil in this period.

The biota status of brown arable soils is characterized by the significant reduction in the abundance and biomass of edaphic fauna in comparison with brown soils that was in conditions of natural ecosystems. Number of invertebrates and *Lumbricidae* fam. in the typical brown soil decreases on average from 72.0 to 21.3 ex m^{-2} and from 2.7 to 0 ex m^{-2}, biomass - from 12.0 to 1.6 g m^{-2} and from 0.5 to 0 g m^{-2}. Similar changes were observed in the luvic brown soil, where the number of invertebrates and *Lumbricidae* fam. decreases on average from 45.3 to 16.0 ex m^{-2} and from 10.7 to 8.0 ex m^{-2}, biomass - from 6.4 to 2.9 g m^{-2} and from 4.3 to 2.1 g m^{-2}.

The share of earthworms in the total abundance of invertebrates in the typical brown soil of natural ecosystems constitutes of 3.8% and their biomass - 4.2%. The average weight of one exemplar of *Lumbricidae* fam. in the virgin typical brown forest soil constitutes 0.19 g. The arable typical brown soil is characterized by a total lack of earthworms at the time of fauna sampling.

The share of *Lumbricidae* fam. in the total abundance of invertebrates in the luvic brown soil under the forest constitutes 23.6%, and the biomass - 67.2%. The average weight of a specimen of the *Lumbricidae* family in the luvic brown soil in conditions of natural ecosystems constitutes 0.40 g, and in conditions of agricultural ecosystems - 0.26 g. Thus, the weight of the earthworm in the arable soil has been significantly reduced.

Table 1. Number and biomass of invertebrates in typical brown soil under forest and arable land (n = 3 for each profile)

Soil	Land use	Profile	Number, ex m^{-2}		Biomass, g m^{-2}	
			total	*Lumbricidae* fam.	total	*Lumbricidae* fam.
Typical brown soil	forest	P1	72.0	2.7	12.0	0.5
	arable	P2	21.3	0	1.6	0
Luvic brown soil	forest	P5	45.3	10.7	6.4	4.3
	arable	P6	16.0	8.0	2.9	2.1

The base mass of fauna in brown soils under the forest is located in the 0-20 cm layer: in typical brown soil - 92.6%, in luvic brown soil - 76.6%. The number of invertebrates index decreases in the soil profile to a depth of 40 cm (Figures 1, 2).

Profile distribution of *Lumbricidae* fam. in the soils of natural ecosystems is uneven. The accumulation of *Lumbricidae* fam. in the typical brown soil was registered in the 10-20 cm layer (2.7 ex m^{-2}). The largest number of earthworms in the luvic brown soil was found in the 20-40 cm layer.

The typical brown soil under arable does not contain earthworms. In the luvic brown soil in conditions of agricultural ecosystem fam. *Lumbricidae* (100%) is located in layers of 0-10 cm and 20-30 cm. Moreover, the luvic brown soil under the forest is characterized by the migration of *Lumbricidae* family into the underlying layers to a depth of 120-130 cm.

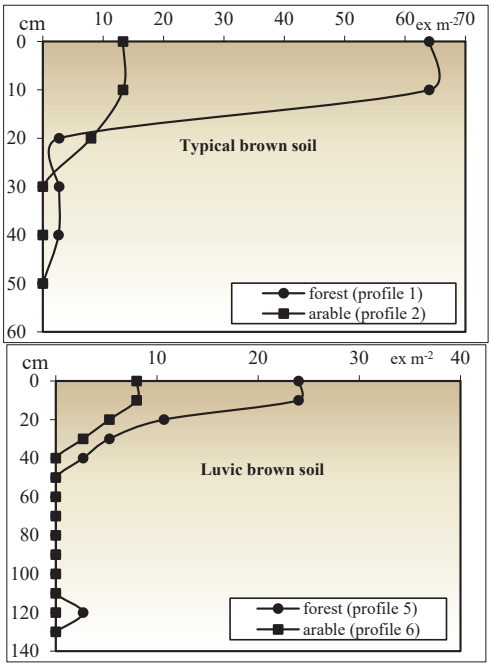

Figure 1. The profile distribution of invertebrates in the brown forest soils in natural and agricultural ecosystems (mean values, n = 3 for each soil layer)

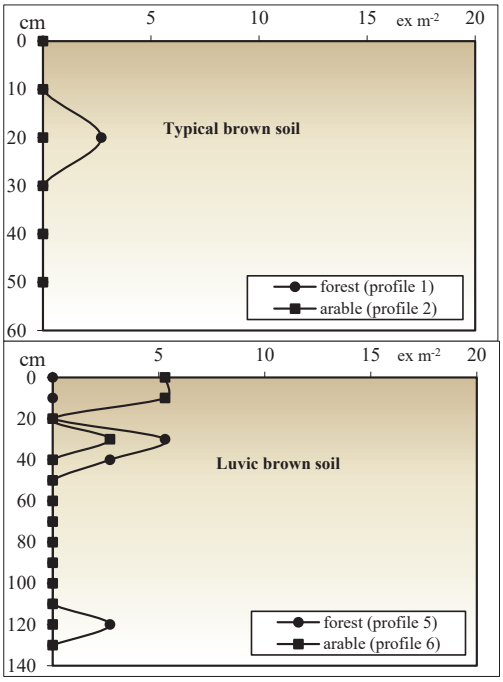

Figure 2. The profile distribution of invertebrates in the brown forest soils in natural and agricultural ecosystems (mean values, n = 3 for each soil layer)

Brown virgin soils are characterized by a high diversity of invertebrates compared to brown arable soils (Table 2). There are 10 families of invertebrates in the virgin typical brown soil. In addition to the *Lumbricidae* family the species from the families of *Clubionidae, Julidae, Hydromiidae, Carabidae, Coccinellidae, Scarabaeidae, Oniscidae, Geophilidae* and other have been found in the virgin typical brown soil. The abundant presence of the *Formicidae* family representatives is observed in virgin brown soils. *Formica rufa* is the typical representative of the *Formicidae* family. The number of anthills in the typical brown soil areals reaches about 200 units per hectare.

Edaphic fauna in the amount of 11 families has been identified in the luvic brown soil under forest. The species from the families of *Lumbricidae, Elateridae, Clubionidae, Julidae, Carabidae, Coccinellidae, Scarabaeidae, Oniscidae, Geophilidae, Chrysomilidae and Formicidae* have been found in the virgin luvic brown soil.

It should be noted that the biodiversity of edaphic fauna in both brown forest soils was similar.

The long-term use of plowing leads to the considerable decrease of the invertebrates' biodiversity. The typical brown soil in conditions of agricultural ecosystems contains 7 families of invertebrates, while the luvic brown soil - only 4 families of edaphic fauna. The species from the families of *Elateridae, Julidae, Scarabaeidae, Carabidae, Lasiocampidae, Reduviidae and Formicidae* were identified in the faunal samples from the arable typical brown soils. The arable luvic brown soil contains species of *Lumbricidae, Scarabaeidae, Carabidae* and *Formicidae* families.

Saprophagous predominate in the composition of the edaphic fauna in virgin brown forest soils. Their contribution to the total number of invertebrates is quite significant (Figure 3).

The share of saprophagous in the soil faunal complex in conditions of natural ecosystems constitutes 27.0% in the typical brown soil and 43.8% in the luvic brown soil respectively. The share of saprophagous in the total number of invertebrates in agroecosystems is 12.7% in the typical brown soil and 60.2% in the luvic brown soil.

The contribution of phytophagous in the total number of invertebrates is significantly lower and constitutes 23.0% in the typical brown soil and 25.1% in the luvic brown soil in natural ecosystems.

Table 2. Biodiversity of invertebrates (ex m^{-2}) at the family's level in brown forest soils (mean values)

Invertebrates' families	Typical brown soil under forest (P1)	Typical brown soil under arable (P2)	Luvic brown soil under forest (P5)	Luvic brown soil under arable (P6)
Lumbricidae	2.7	0	10.7	8.0
Elateridae (larvae)	0	2.7	2.7	0
Julidae	10.7	2.7	2.6	0
Scarabaeidae (larvae)	5.3	5.3	2.7	2.7
Carabidae (imago+larvae)	10.7	5.3	2.6	2.6
Coccinellidae	8.0	0	2.7	0
Geophilidae	2.7	0	8.0	0
Clubionidae	13.2	0	2.6	0
Hydromiidae	10.7	0	0	0
Oniscidae	5.3	0	5.3	0
Chrysomilidae	0	0	2.7	0
Lasiocampidae (larvae)	0	2.7	0	0
Reduviidae	0	2.6	0	0
Formicidae	+++++	++	+	+
Unidentified species	2.7	0	2.7	2.7
Total	**72.0**	**21.3**	**45.3**	**16.0**

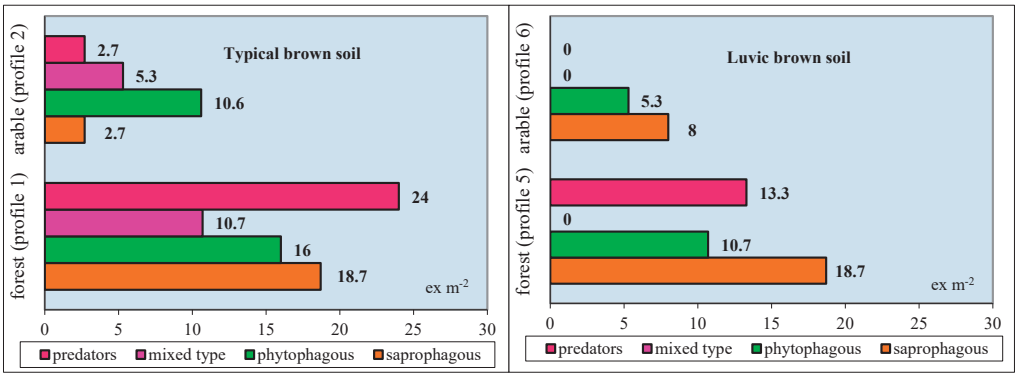

Figure 3. Composition of invertebrates according to the mode of nutrition in brown soils in natural and agricultural ecosystems (mean values, without *Formicidae* fam. and unidentified species)

The maximum number of phytophagous in percentage expression, registered in arable brown soils was the following: 49.8% in the typical brown soil and 39.8% in the luvic brown soil.

The content of invertebrates with the type of mixed nutrition in the typical brown soil under the forest was 15.4% and in conditions of arable - 24.9%. Invertebrates with mixed type of nutrition were not detected in the luvic brown soil.

The maximum number of predators in the amount of 31.1-34.6% was recorded in the brown soils under natural vegetation due to the high abundance of spiders. The contribution of predators in the total number of invertebrates in the typical arable brown soil was insignificant, the share constituted 12.6%. Predators in the arable luvic brown soil were absent.

Trophic pyramids in brown soils of natural ecosystems are characterized by a higher stability in comparison with arable brown forest soils. The quantitative relations between trophic levels of edaphic fauna of the typical brown soil are stronger in comparison to the luvic brown soil.

The long-term use of brown soils in agriculture leads to a decrease in the contribution of saprophagous and to a share growth of phytophagous in the total number of invertebrates (Table 3). The ratio between saprophagous and phytophagous decreased on the average by 4.5 times in the typical brown soil and by 15.9% in the luvic brown soil. These data indicate the dominance of phytophagous pests in the faunal complex of arable soils. Research results show that the balance between invertebrate populations is disturbed, which over time leads to a decrease in the quality and fertility of arable soils.

Table 3. The ratio of trophic groups of invertebrates in brown soils

Profile	Soil, land use	Saprophagous/ Total	Saprophagous/ Phytophagous	Phytophagous/ Total
P1	Typical brown soil under forest	0.26	1.17	0.22
P2	Typical brown soil under arable	0.13	0.26	0.50
P5	Luvic brown soil under forest	0.41	1.75	0.24
P6	Luvic brown soil under arable	0.50	1.51	0.33

CONCLUSIONS

The complex of invertebrates in brown soils of natural ecosystems is formed under the conditions of the share being he increased level of input and content of organic matter in the soil. 10-11 families of invertebrates were found in virgin brown soils. The edaphic fauna composition in natural ecosystems is complex and diverse. Saprophagous prevail in the composition of the edaphic fauna in the virgin brown soil under forest, accounting for 27.0% of the total abundance in the typical brown soil and 43.8% in the luvic brown soil, respectively. The relations between trophic levels are stronger in brown soils under forest, and trophic pyramids are more stable in the typical brown soil than in the luvic brown soil. A characteristic feature of the natural brown soils is the high concentration of invertebrates and

Lumbricidae family in the upper layers of soils. The base mass of fauna in the typical brown soil and in the luvic brown soil under the forest is located in the 0-20 cm layer - 92.6% and 76.6%, respectively. Indicators of the edaphic fauna in soil profiles have been decreased with the depth. During the drought *Lumbricidae* fam. migrates to the underlying layers at depths >120 cm. Forests are habitat and natural medium for the conservation and restoration of the diversity and abundance of invertebrates in brown soils. The conservation of soil virgin - standards in protected zones is important not only in terms of environmental protection, butalso for significant scientific information.

The current state of the edaphic fauna in arable brown soils is characterized by a considerable decrease in the abundance, biomass and biodiversity compared to those of virgin brown soils in natural ecosystems. Dehumification processes, compaction and destruction of the soil structure as a result of the long-term agricultural use have worsened the habitat of the soil invertebrates. Furthermore, the soil doesn't obtain the plant residues sufficiently for the supply of edaphic fauna. The number and biomass of invertebrates in arable brown soils are lower by 2.8-3.4 times and by 2.2-7.5 times compared to brown soils of natural ecosystems. In arable soils only species from 4-7 families of edaphic fauna have been identified. There is a decrease in the number of saprophagous, especially in the *Lumbricidae* family, the destruction of levels and trophic links between invertebrates. The negative effects on the edaphic fauna were observed as a result of mineralization processes and long-term land management practices without organic fertilizers.

A land management with the fallow areas is recommended for the regeneration of soil invertebrates and the natural restoration of the quality of brown soils.

ACKNOWLEDGEMENTS

This research work was carried out in the framework of the institutional project "Evaluation of the soil state of the Republic of Moldova in the agrocenosis conditions, improvement of the classifier and the soil rating system, elaboration of the methodological-informational framework for monitoring and enlarged fertility reproduction" (project code 20.80009.7007.17) in 2020.

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