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Sustainable management and conservation of biota in agricultural soils of the Republic of Moldova

SUSTAINABLE MANAGEMENT AND CONSERVATION OF BIOTA IN AGRICULTURAL SOILS OF THE REPUBLIC OF MOLDOVA

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Abstract

In present research the ways and methods of the sustainable management and conservation of the soil biota in the modern agricultural ecosystems of the Republic of Moldova are considered. The database of invertebrates, microorganisms and enzymatic activities of different zonal soils in the long-term field experiments has been developed and constantly is updated with a view to the operative evaluation of the degradation processes and ecological effectiveness of the land management. The current status of the biota of arable soils of the Republic of Moldova is characterized by the significant reduction in the abundance, biomass, activity and diversity in comparison with soil's standards that are in conditions of natural ecosystems. The long use of soils in agricultural production led to the imbalance between the processes of decomposition and humus formation and promoted the decrease of soil biota stability and degradation. The values of most soil biological indices decrease in the following sequence: virgin and fallow land → arable land under organic system with farming manure and incorporation of crop residues → arable unfertilized land. A soil management with the involvement of areas with natural vegetation in a crop rotation system created conditions for the improvement of the biota's vital activity in the soil which degraded as a result of a long-term arable use. The recovery rate of the population of Lumbricidae family reaches of 3.0-5.6 worms m^{-2} per year. Annual increase in the content of microbial biomass in the typical chernozem can be up to 81.3 kg C ha^{-1} in the layer of the 0-50 cm. The organic farming system greatly improves the enzymatic and humus status of the old - arable soils, but does not restore the biodiversity of invertebrates.

Key-words: *soil biota, humus, conservation, organic fertilizer*

INTRODUCTION

The definition of sustainable management of agricultural soils is a spatial or temporal harmonization of all soil and land uses in a given area, avoiding or minimizing irreversible natural and anthropogenic impacts. The agricultural land use can only be sustainable when all other land uses are sustainable as well [10]. The sustainability is determined by technical, ecological, social as well as by economic and cultural factors. Ecological indicators (soil and water quality, biodiversity and human health) are the most important and sensitive to external impacts. In this context, soil biological indicators contain the information about the landscape stability and environmental benefits for the agricultural politics at the national level.

Soil biota should be considered as a component of the integrated management of natural resources. Soil biota plays an important role in the realization of soil ecosystem services and land productivity [2, 8]. Soil biota provides intermediate services in agriculture. It supplies nutrients to plant [4], maintains the soil structure, improves the water infiltration, and participates in the soil organic matter decomposition [2, 9]. Nevertheless the functions and services provided by the soil biota in the agricultural ecosystems are poorly recognized in the ecological management of soils of the Republic of Moldova. Managers should take into account the recommendations on the use and management of soil biota for the long-term conservation and sustainable productivity of terrestrial ecosystems.

The problem of the fertility restoration in soils of the Republic of Moldova depends largely on the ability of the soil biota to recover their functions and to stabilize the enzymatic potential at a high level. To stop the degradation process and to restore the biological soil functions, it is necessary to carry out a set of measures aimed at increasing the carbon sink in degraded soils. Crop residues and animal wastes are the most accessible and can be used as the source of the organic matter for the soil biota and the plant nutrition.

The purpose of the research was to compare the influence of different land management practices on the biological properties of zonal soils and to evaluate the application of organic

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fertilizers for the biota's restoration of soils, degraded as the result of the long-term agricultural utilization.

MATERIAL AND METHODS

Experimental sites and soils. Three experimental sites located in different zones of the Republic of Moldova have been tested. Various ways of treatment-utilization of the soil and land management practices in the condition of long-term field experiments have been analyzed.

The first site was in the north, on the long-term field experiments of the Research Institute of Field Crops "Selectia" (Beltsy). It had 3 plots: fallow land (60-year-old), fallow land (10-23-year-old) and the long-term arable land with crop rotation (management without fertilizers and with the farmyard manure application in the dose of 60 t ha^{-1}). The soil was the typical chernozem.

The second site was located in the center of the country, in the Ivancha village, Orhei region. The natural land under fallow (40-60-year-old), forests and the long-term arable land with crop rotation without fertilizers and organic manure with crop residues treatments were tested. Crop residues were plowed annually; farmyard manure was introduced in the dose of 60 t ha^{-1} in 1991, 1996 and 2005. Soils were presented by the leached chernozem and the gray forest soil.

The third site was located in the southern zone, in the Ursoaia village of the Lebedenco district and in the Tartaul de Salchie village, Cahul region. These were plots with the fallow (55-year-old) land and the long-term arable land management without organic fertilizers and with the sheep manure application in the dose of 50 t ha^{-1}. The soil was the ordinary chernozem.

Sampling was carried out from the 0-30 cm layer. Samples of the experimental plots without organic fertilizers and with the sheep manure application on the ordinary chernozem were collected from the 0-25 cm layer.

Status of invertebrates. The state of invertebrates was identified from test cuts by manually sampling the soil layers to the depth of soil fauna occurrence applying Gilyarov and Striganova's method [5]. The identification of invertebrate's diversity at the level of families and their classification according to nutrition was conducted by Gilyarov and Striganova's method [5].

Microbiological properties. The microbial biomass was measured by the rehydratation method based on the difference between C extracted with 0.5 M K_2SO_4 from dried soil at 65-70^{0}C within 24 h and fresh soil samples with K_c coefficient of 0.25 [3]. K_2SO_4 – extractable organic C concentrations in the dried and fresh soil samples were simultaneously measured by dichromate oxidation. The quantity of K_2SO_4 – extractable C was determined at 590 nm with "Specol-221" spectrophotometer (Germany).

Counts of microorganisms (heterotrophic bacteria, humus-mineralizing microorganisms, actinomycetes, fungi, bacteria from the *Azotobacter* genus) were obtained on agar plates [11].

Enzymatic activity. The (potential) urease activity was measured by estimating the ammonium released on incubation of soil with buffered urea solution by colorimetrical procedure [6]. The (potential) dehydrogenase activity was determined by the colorimetric technique on the basis of triphenylformazan (TPF) presence from TTC (2. 3. 5-triphenyltetrazolium chloride) added to air-dry basis of soil [6]. The (potential) polyphenoloxidase activity was determined by the colorimetric technique with the use of hydroquinone as a substrate [7].

Soil chemical properties. Organic C was analyzed by the dichromate oxidation method. The humus content was calculated using the coefficient of 1.724 [1].

The database of the soil biological indicators covers the period between 1989 and 2011. The biological indices were evaluated statistically using the variation analysis. Statistical parameters of the state of soil invertebrates were calculated taking into account the depth of soil fauna occurrence, microorganisms and enzymes – for the layer of 0-30 cm and 0-25 cm.

RESULTS AND DISCUSSIONS

The current status of the biota of agricultural soils in the all zones of the Republic of Moldova is characterized by the significant reduction in the abundance, biomass and activity in comparison with soil's standards that are in conditions of natural ecosystems (Table 1 and 2). The long use of soils in agricultural production led to the imbalance between the processes of decomposition and humus formation that promoted the decrease of soil biota's stability and its degradation. The decline of the natural resistance of soils is mainly determined by the reduction of their biochemical potential and the diminution of zones of homeostasis of invertebrates and microorganisms.

Biota of virgin and fallow soils exists in conditions of the high supply of the organic matter and the conservation of resources that have been formed within the limits of the ecosystem. Undisturbed virgin and fallow soils are medium for the reproduction of various species of invertebrates and microorganisms and have a high level of the biomass and enzyme activity.

The number of invertebrates in natural soils is reached to 195.8-448.0 ex m^{-2}, *Lumbricidae* family – to 83.0-340 ex m^{-2}, and its biomass – to 46.9-84.0 and 41.5-74.8 g m^{-2} accordingly (Table 1). The exception is the leached chernozem under fallow with the low faunal abundance. Perhaps this fact is connected with the low moisture content in the soil during the selection of faunal samples. The share of earthworms in the total abundance of invertebrates constitutes of 35.3-75.9 % and their biomass – 59.1-89.0 % in the soils of natural ecosystems. It should be noted the tendency towards increasing the share of *Lumbricidae* family in the total number of invertebrates in the direction from the north to the south. The weight of one exemplar of *Lumbricidae* family in chernozems constitutes 0.22-0.27 g, in the gray forest soil – 0.5 g. The largest share of invertebrates and *Lumbricidae* family is concentrated in the 0-10 cm layer of soil and in the debris layer. The soils of natural ecosystems are characterized by a high diversity of invertebrates. In addition to the *Lumbricidae* family species from the families of *Formicidae*, *Arthropoda, Carabidae, Aranei, Apidae, Forficulidae, Pieridae, Pentatomidae, Coccinelidae* and other have been found in soils of natural ecosystems. The soil under the natural vegetation contains 5-12 families of invertebrates.

Indices of the number and biomass of invertebrates and earthworms decreased in arable soils by 1.9-7.4 and 3.7-10.3 times respectively in comparison with virgin and fallow soils. Agricultural soils contain only 2-5 families of invertebrates.

Table 1. Conservation of soil invertebrates in natural ecosystems in the Republic of Moldova (mean values, n = 3-32)

Index	North zone		Central zone				South zone	
	typical chernozem		leached chernozem		gray forest soil		ordinary chernozem	
	fallow land*	arable land	fallow land	arable land	virgin land	arable land	fallow land	arable land
Number of invertebrates, ex m^{-2}	339.6	141.4	81.6	84.9	195.8	63.8	448.0	76.4
Biomass of invertebrates, g m^{-2}	82.2	17.8	11.5	9.8	46.9	7.6	84.0	8.4
Number of *Lumbricidae* fam., ex m^{-2}	227.3	91.1	28.8	61.3	83.0	43.2	340.0	46.2
Biomass of *Lumbricidae* fam., g m^{-2}	61.2	16.5	6.8	9.7	41.5	6.8	74.8	7.3

* 60-year-old fallow land

The total biomass of microorganisms in natural soils constitutes in average 355.8-876.0 μ g C g^{-1} soil in the 0-30 cm layer. It is much greater than its abundance in arable soils (Table 2). A similar trend has been noticed in the number of the heterotrophic bacteria and fungi. But the number of the humus-destroying microorganisms and actinomycetes in most cases is much lower than in the soils of agricultural ecosystems. The greatest numbers of *Azotobacter* genus are in the typical and I the ordinary chernozem, in the gray forest soil these microorganisms are discovered only sometimes in conditions of the arable management.

Microorganisms in virgin and fallow soils are concentrated in the 0-60 cm layer (78-83 %), the biomass index decreases sharply in the soil profile to a depth of 30-50 cm. The highest levels of the microbial biomass, enzyme activities and organic carbon content have been determined in the A_1 horizons of soil profiles. Microorganisms in the virgin and fallow soils were found at the depth of 138 cm, and some species were encountered at the depth of 200 cm. The abundance of heterotrophic microorganisms in soils under the natural vegetation is provided by the high level of the organic matter content. The humus content (confidence intervals, $P \leq 0.05$) in virgin and fallow soils constitutes: 4.0-5.7 % in the gray forest soil, 3.8-4.0 % in the ordinary chernozem, 3.7-4.6 % in the leached chernozem and 4.9-5.1 % in the typical chernozem.

Table 2. Microorganisms, enzymes and humus content in soils of the Republic of Moldova under different land management (mean values, 0-30 cm layer)

Index	North zone		Central zone				South zone	
	typical chernozem		leached chernozem		gray forest soil		ordinary chernozem	
	fallow land*	arable land	fallow land	arable land	virgin land	arable land	fallow land	arable land
Microorganisms (n = 8-33)								
Microbial biomass, μ g C g^{-1} soil	355.8	318.4	492.5	314.7	876.0	244.3	415.6	288.3
Heterotrophic bacteria, CFU g^{-1}soil*10^6	6.3	5.2	5.4	4.3	5.9	3.3	4.7	4.5
Humus-mineralizing microorganisms, CFU g^{-1} soil*10^6	6.5	16.2	2.7	9.6	1.9	8.9	5.5	11.9
Actinomycetes, CFU g^{-1} soil*10^6	2.5	3.1	1.6	2.8	2.5	2.4	5.4	3.3
Fungi, CFUg^{-1} soil*10^3	64.6	37.4	60.0	30.2	110.0	40.5	53.6	35.0
Azotobacter gen., CFUg^{-1} soil	127.3	209.3	11.2	91.6	0	8.1	74.5	179.5
Enzyme activity (n = 3-30)								
Urease, mg NH_3 10 g $^{-1}$soil 24 h^{-1}	12.5	4.5	8.6	3.1	8.1	1.4	5.5	3.5
Dehydrogenase, mg TPF 10g^{-1} soil 24h^{-1}	2.92	1.94	2.31	1.47	2.40	0.74	2.79	1.78
Polyphenoloxidase, mg 1,4-p-benzoquinone 10 g^{-1} soil 30 min^{-1}	7.4	6.8	5.5	3.9	4.1	2.3	20,1	18.6
Humus content, %	4.9-5.1	4.4-4.7	3.7-4.6	3.2-3.8	4.0-5.7	2.1-2.4	3.8-4.0	2.9-3.2

*10-23-year-old fallow land

The characteristic feature of microbial communities of agricultural soils is the high content of the humus-mineralizing microorganisms and actinomycetes and the low enzyme activity. More intensive land-use involving soil tillage stimulates the microbial decomposition of organic matter and tends to result in a decrease in the microbial carbon pool and ultimately in a decrease in the humus content. The humus content (confidence intervals, $P \leq 0.05$) in arable soils constitutes: 2.1-2.4 % in the gray forest soil, 2.9-3.2 % in the ordinary chernozem, 3.2-3.8 % in the leached chernozem and 4.4-4.7 % in the typical chernozem.

The process of natural recovery of the soil biota composition and activity in agricultural lands has been slow. The recovery rate of the population of *Lumbricidae* family reaches of 3.0-5.6

worms m^{-2} per year by the use of soils under recreation. Annual increase in the content of microbial biomass in the typical chernozem can be up to 81.3 kg C ha^{-1} in the layer of the 0-50 cm.

The manure application separately and with plant residues additives restores the biota of old arable soils. Biological parameters (by some indicators) are at the level of soils under natural vegetation (Table 3). The number of invertebrates increased by 1.2-1.7 times, the biomass of *Lumbricidae* family – 1.7-2.3 times respectively. The biomass of worms remained practically unchanged only in the ordinary chernozem. The share of saprophagous in the total population of soil invertebrates increased from 69.7-77.8 % to 72.0-85.9 %.

The recovery of components of soil invertebrates in conditions of the manure application was mainly due to the *Lumbricidae* and *Enchytraeidae* families. The diversity of the soil fauna was not significantly improved.

Table 3. Recovery of the biota of long-term arable soils in conditions of the land management with farmyard manure and plants residues (mean values, 0-30 cm layer)

Variant	Number of invertebrates, ex m^{-2}	Biomass of *Lumbricidae* fam., g m^{-2}	Saprophagous, ex m^{-2}	Microbial biomass, μ g C g^{-1} soil	Dehydrogenase, mg TPF 10 g^{-1} soil $24h^{-1}$	Polyphenoloxidase, mg 1,4-p-benzoquinone 10 g^{-1} soil 30 min^{-1}
North zone, typical chernozem (n = 6-8)						
Martor	175.6	14.7	122.3	298.4	2.32	9.2
Manure 60 t ha^{-1}	214.7	33.7	157.3	324.3	2.69	15.5
Central zone, leached chernozem (n = 8-34)						
Martor	76.0	7.0	56.0	314.7	1.47	3.9
Fond*	85.0	12.0	73.0	362.0	1.99	5.9
Central zone, gray forest soil (n = 6-33)						
Martor	96.0	7.6	74.7	244.3	0.74	2.3
Fond*	133.3	15.1	96.0	302.4	1.40	5.0
South zone, ordinary chernozem ** (n = 9)						
Martor	54.8	7.8	42.2	212.6	1.34	7.8
Manure 50 t ha^{-1}	94.1	7.0	72.3	300.9	1.28	8.6

* Fond: plant residues + farmyard manure 60 t ha^{-1}

** 0-25 cm layer

According to average values, the microbial biomass content increased from 212.6-314.7 μg C g^{-1} soil to 300.9-362.0 μ g C g^{-1} soil. A similar trend was evident in dehydrogenase and polyphenoloxidase activities. The effect of organic fertilizers on the soil biota of the central and northern zones of the country was more significant than in the soil of the southern zone.

The humus content level was higher under application of organic fertilizers by 0.2-0.3 %. Thus, the organic farming system greatly improves the biological properties and fertility of arable soils.

CONCLUSIONS

Landscapes with the natural vegetation play a particular role in the preservation, maintenance and restoration of the soil biota's vital activity. The wide spectrum of families and species of invertebrates and microorganisms, the high level of the microbial biomass and the soil enzymatic activity are inherent to soils of natural ecosystems. These features enhance their stability to various natural and anthropogenic impacts. The database of the biota's state of virgin and fallow soils has a practical importance as the natural standard for the operative evaluation of degradation processes and ecological effectiveness of the land management.

Multiannual fallow soils under natural vegetation are a source of the conservation and reproduction of different species of invertebrates and microorganisms; they have a high level of biomass and enzyme activity. A stable state of the biota is provided by the humus content in the level of 4.0-6.0 % in the 0-30 cm layer. A soil management with the involvement of areas with natural vegetation in a crop rotation system created conditions for the improvement of the biota's vital activity in the soil which degraded as a result of a long-term arable use.

The agricultural management without application of organic fertilizers leads to the degradation of soils. This is reflected in the deterioration of soil biological properties and in the reduction of humus content in the soil. In the arable soil humus-destroying microorganisms dominate. The values of most soil biological indices decrease in the following sequence: virgin and fallow land → arable land under organic system with farming manure and incorporation of crop residues → arable unfertilized land.

Application of organic fertilizers in the form of farmyard manure and the annual addition into degraded soils of crop residues helps to prevent ecological violations in the state of soil biota, to restore individual species and populations of invertebrates and microorganisms, stabilize and improve the enzymatic activity. Measures aimed to the enrichment of soils with organic matter and to reduce of the anthropogenic impact on natural conservation areas, the creation and preservation of the natural habitat of the soil biota will help to restore its functional activity and diversity.

BIBLIOGRAPHY

[1] Arinushkina, E.V. (1970). Guide for chemical analysis of soils. Moscow, Russia, MSU, 487 pp.

[2] Barrios, E. (2007). Soil biota, ecosystem services and land productivity. Ecological Economics, 64 (2), 269-285.

[3] Blagodatsky, S.A., Blagodatskaya, E.V., Gorbenko, A. J., Panikov, N. S. (1987). Rehydration method for the determining of the microbial biomass in the soil, Soil Science, Moscow, Russia, 4, 64–71.

[4] Fragoso, C., Brown, G., Patron, J., Blanchart, E., Lavelle, P., Pashanasi, B., Senapati, B., Kumar, T. (1997). Agricultural intensification, soil biodiversity and agroecosystem function in the tropics: the role of earthworms. Applied Soil Ecology, 6 (1), 17-35.

[5] Gilyarov, M.S., Striganova, B.R. (Ed.). (1987). Quantitative Methods in Soil Zoology. Moscow, Russia, Nauka, 228 pp.

[6] Haziev, F.H. (2005). Methods of soil enzymology. Ufa, Russia, In. Biol. Ur. Sci. Cen. Ac. Sci., 254 pp.

[7] Karyagina, L.A., Mikhailovskaya, N.A. (1986). Determination of polyphenoloxidase and peroxidase activities in the soil, Journal of the Academy of Sciences of BSSR, Minsk, Byelorussia, 2, 40- 41.

[8] Lavelle, P., Decaëns, T., Aubert, M., Barot, S., Blouin, M., Bureau, F., Margerie, P., Mora, P., Rossi, J.-P. (2006). Soil invertebrates and ecosystem services. European Journal of Soil Biology, 42, 3-15.

[9] Swift, M., Izac, A.-M., van Noordwijk, M. (2004). Biodiversity and ecosystem services in agricultural landscapes- are we asking the right questions? Agriculture, ecosystems and environment, 104 (1), 113-134.

[10] Winfried, E. H. Blum. (2006). New research concepts for the sustainable management of agricultural soils. Soil science and agrochemistry, 2 (37), 22-31.

[11] Zvyagintsev, D.G. (Ed.). (1991). Methods of soil microbiology and biochemistry. Moscow, Russia, MSU, 304 pp.