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MICROBIAL BIOMASS IN CHERNOZEMS OF NATURAL AND AGRICULTURAL ECOSYSTEMS

Irina SENICOVSCAIA, Andriana DANILOV, Andrei DANILOV

Institute of Pedology, Agrochemistry and Soil Protection"Nicolae Dimo", 100 Ialoveni Street, MD 2070, Chisinau, Republic of Moldova

Corresponding author email: irina_sen@mail.ru

Abstract

Microbial biomass in calcareous, leached and podzolic chernozems has been studied in connection with the evaluation of soil degradation processes as a result of a long-term arable use. Experimental sites located in the southern and northern zone of the Republic of Moldova have been tested in August and September 2021. Microbial biomass sampling was carried out in 6 profiles per soil horizons to a depth of 150-240 cm. The highest values of microorganisms' abundance were registered in the upper horizon in chernozems of the natural ecosystem. Microbial biomass content constituted 535.0-1168.6 µg C g^{-1} soil and was much more than in arable chernozems. Microbiological indices in soil profiles decreased with the depth. Microbial biomass reserves in chernozems in the 0-100 cm layer has been reducing from natural chernozems (4925.2-11816.4 kg ha^{-}) to old-arable chernozems (2547.3-6659.2 kg ha^{-}). The microbial biomass was connected with humus content. Correlation coefficients constitute 0.94. The binding effect between microbial biomass and humus content decreases from natural chernozems (R^2 = 0.94) to arable ones (R^2 = 0.64).

***Key words**: microbial biomass, chernozem, degradation, natural and agricultural ecosystem.*

INTRODUCTION

Microbial indicators are at present suggested for the estimation of soil quality (Kennedy & Papendick, 1995; Hargreaves et al., 2003; Maharjan et al., 2017). Soil microbial biomass indicator is often used, as it is more susceptible and can therefore clearly indicate changes in the environment more responsively than physicochemical attributes (Masto et al., 2009). Microbial biomass is determined by the quantity and quality of organic matter that, at the same time, depends on the soil management. Therefore, when microbial biomass is high, it indicates microbial diversity and an optimal environment. However, if they are at low levels, then this may be a sign of negative changes in land use (Maharja et al., 2017). Thus, the processes of destruction of natural ecosystems and intensification of the biological degradation of soils are interdependent. In this regard, studies of microbial biomass in degraded chernozems and soils of reference plots (which are in balance, retain all the main parameters and have not lost their ecological and genetic links with landscape components) are of particular importance.

The objective was to obtain an indication of the microbial biomass status of the chernozems and to assess the impact of the long-term use of soils on the microbial carbon in the connection of the soil carbon sequestration and the diagnostics of degradation processes.

MATERIALS AND METHODS

Experimental sites and soils. Our comparative study has been performed in the southern and northern zone of the Republic of Moldova. *The first site* was located in the southern zone, on the South Plains steppe area, in the district no. 13 of ordinary and calcareous chernozems of the South Bessarabian steppe plains (Figure 1). The plot with calcareous chernozem (profile 11 under fallow; profile 12 under arable) and the plot with ordinary chernozem (profile 13 under fallow; profile 14 under arable) were situated in the Ursoaia village of the Lebedenco district, Cahul region. *The second site* was located in the zone of the hilly wooded steppe of the Northern Plain (1), in the district of wooded steppe of the middle Prut (2) with gray forest soils, podzolic and leached chernozems (Figure 2). The plot with podzolic chernozem (profile 17 under fallow; profile 18 under arable) was

situated in the Shaptebani village, Ryshkani region.
The content, reserves and profile distributions of the microbial biomass of zonal undisturbed chernozems in natural ecosystems were investigated in comparison with the arable chernozems. Investigations were performed on the calcareous, ordinary and podzolic chernozems. Microbial biomass sampling was carried out in 6 profiles per soil horizons to a depth of 150-240 cm.

Figure 1. Fragments of natural and agricultural landscapes located in the southern zone of the Republic of Moldova

Figure 2. Fragments of natural and agricultural landscapes located in the northern zone of the Republic of Moldova

The microbial biomass carbon (C) 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 for 24 h and fresh soil samples with K_c coefficient of 0.25 (Blagodatsky, Blagodatskaya et al., 1987). K_2SO_4 - extractable organic C concentrations in the dried and fresh soil samples were simultaneously measured by dichromate oxidation. The ratio between microbial and organic carbon was determined according to Kennedy & Papendick (1995). Reserves of microbial biomass have been calculated taking into account the carbon content of the microbial cell and the bulk density of soils (Senicovscaia et. al., 2012). Organic C was analysed by the dichromate oxidation method (Arinushkina, 1970). The microbial biomass index and humus content was evaluated statistically by the correlation analysis.

RESULTS AND DISCUSSIONS

The distribution of microorganisms on the genetic horizons in soils of natural and anthropogenic ecosystems is different. The highest level of the microbial biomass and organic carbon content have been determined in the A_1 horizon (layer 0-10 cm, 0-8 cm, 0-9 cm) of the calcareous, ordinary and podzolic chernozems which have been formed in natural ecosystems. The quantity of the microbial biomass reaches in the natural calcareous chernozem to 535.0 µg C g^{-1} soil, in the ordinary chernozem - to 819.4 µg C g^{-1} soil, in the podzolic chernozem - to 1168.6 µg C g^{-1} soil (Table 1). A similar trend has been noticed in the humus content, the value of which in these chernozems constitutes 2.65%, 3.63% and 4.99% respectively. Microorganisms in natural soils are concentrated in the A genetic horizon (70.3-77.3%), the biomass index decreases in the soil profile to a depth of 96-220 cm.
The long-term use of arable management leads to the decrease of the content and reserves of microbial biomass in arable chernozems as in the upper horizons, and as a whole in the soil profile. The concentration of microorganisms in horizon A in chernozems is much lower and amounts to 47.6-658%. Microbial biomass index gradually decreases in the soil profile to a depth of 72-151 cm.
The share of microbial carbon in the total carbon content of natural chernozems constitutes 2.02-2.34% in the A_1 genetic horizon, in arable chernozems - 0.98%, 1.11% and 1.15% in the soil layer 0-40 cm, 0-31 cm and 0-38 cm (Ap genetic horizon).
Thus, the share of microbial carbon in its total content in natural chernozems is higher than in arable ones.

Table 1. The content of microbial and carbon content in chernozems in conditions of natural and agricultural ecosystems

Genetic horizon	Depth, cm	Organic C (C_{org}), %	Microbial biomass (MB), μg C g^{-1} soil	C_{MB}/C_{org}, %	Reserves of MB, kg ha^{-1}
Natural calcareous chernozem (P11)					
A_1	0-10	2.65	535.0	2.02	1348.2
Ak	10-49	1.60	212.9	1.33	2192.0
B_1k	49-71	1.25	184.5	1.48	1104.1
B_2k	71-102	0.55	34.1	0.62	300.2
BCk	102-151	0.30	0	0	0
Ck	151-170	0.27	83.1	3.07	448.4
Arable calcareous chernozem (P12)					
Apcal	0-40	1.59	155.7	0.98	1756.3
B_1k	40-59	0.92	101.7	1.11	533.3
B_2k	59-72	0.49	69.8	1.42	257.7
BCk	72-114	0.30	0	0	0
Ck	114-150	0.18	0	0	0
Natural ordinary chernozem (P13)					
A_1	0-8	3.63	819.4	2.26	1455.3
A	8-47	1.89	208.4	1.10	2015.7
B_1k	47-64	1.43	228.8	1.60	1081.3
B_2k	64-96	0.78	40.5	0.52	344.7
BCk	96-160	0.51	0	0	0
Ck	160-175	0.21	32.2	1.53	132.3
Arable ordinary chernozem (P14)					
Ap	0-31	1.81	200.7	1.11	1418.6
A	31-48	1.67	157.0	0.94	693.9
B_1k	48-66	1.34	109.5	0.82	520.3
B_2k	66-93	0.77	61.0	0.79	457.9
BCk	93-151	0.38	15.2	0.40	250.4
Ck	151-170	0.33	0	0	0
Natural podzolic chernozem (P17)					
A_1	0-9	4.99	1168.6	2.34	1893.1
A	6-47	2.33	613.8	2.63	6341.8
B_1	47-65	0.80	404.4	5.01	1950.8
B_2	65-96	0.44	166.4	3.78	1454.7
BCk	96-170	0.27	144.7	5.36	3255.2
Ck	170-190	0.20	39.4	1.97	238.0
Arable podzolic chernozem (P18)					
Ap	0-38	1.95	224.4	1.15	2285.3
A	38-53	1.93	398.2	2.06	1732.7
B_1	53-82	0.79	281.1	3.56	2641.2
B_2	82-100	0.26	248.7	9.57	1468.3
BCk	100-220	0.20	134.8	6.74	not determined
Ck	220-240	0.15	0	0	0

Microbial biomass reserves in natural chernozems in the 0-100 cm layer increase consecutively: natural calcareous chernozem (4925.2 kg ha^{-1}) → natural ordinary chernozem (5029.3 kg ha^{-1}) → natural podzolic chernozem (11816.4 kg ha^{-1}) (Figure 3).

The biomass reserves of microorganisms in arable chernozems are 1.6-1.9 times lower than in undisturbed chernozems. Microbial biomass reserves in arable chernozems in the 0-100 cm layer increase consecutively: arable calcareous chernozem (2547.3 kg ha^{-1}) → arable ordinary chernozem (3120.9 kg ha^{-1}) → arable podzolic chernozem (6659.2 kg ha^{-1}).

Because of the long-term use of arable land, homogenization of the arable layer and decrease in the reserves of microbial carbon and humus, the natural stability of chernozems reduces. The microbial biomass is connected with the humus content. The correlation coefficient (R^2) between the microbial biomass and humus content in the calcareous chernozem constitutes - $R^2 = 0.94$ ($n = 11$); in the ordinary chernozem - $R^2 = 0.94$ (n = 12), in the podzolic chernozem - $R^2 = 0.94$ (n = 12).

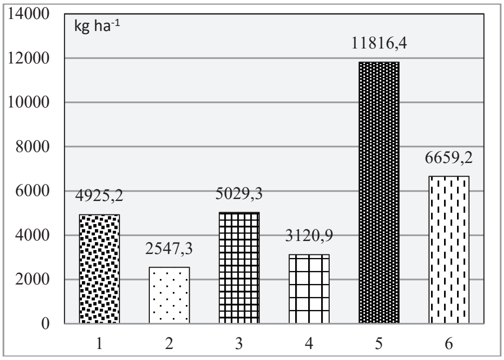

Figure 3. Reserves of microbial biomass in chernozems (0-100 cm)

The correlation coefficient between the microbial biomass and humus content in chernozems under natural vegetation is $R^2 = 0.94$ (n = 18); in arable chernozems - $R^2 = 0.64$ (n = 17).

CONCLUSIONS

Assessment of microbial biomass resources in chernozems in conditions of natural and agricultural ecosystems showed significant differences between these soils. Microorganisms of natural soils live in conditions of the high supply of the organic matter and its conservation within the limits of the ecosystem. As a consequence, undisturbed chernozems in conditions of the natural ecosystems are characterized by a higher biomass and reserves of soil microorganisms in comparison with arable soils.

The abundance and reserves of microorganisms and the humus content in soil profiles decreased with its depth. The microbial biomass, being a part of the labile organic matter, was connected with the soil organic carbon content. Prolonged use of chernozems in the agricultural production led to the reduction of humus content and contributed to the degradation and decrease of soil stability. Profiles of the arable chernozems are covered by the degradation process as a whole. The low content of microorganisms in the upper layers is characterized by arable chernozems. The biomass reserves of microorganisms in arable chernozems are 1.6-1.9 times smaller compared to undisturbed chernozems. The negative effects on soil microorganisms were observed as a result of mineralization processes and long-term land management practices without organic fertilizers. The results have proved that the interaction between microbial components and humus status is closer in soils of natural ecosystems. As a result, their resistance to natural and anthropogenic negative impacts is higher than that of the soils in agricultural ecosystems. The rupture and the attenuation of relations between the biotic and abiotic components of soils lead to the decrease in their natural stability and the development of degradation processes.

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