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CONTENT OF MICROBIAL BIOMASS NITROGEN IN DIFFERENTLY USED SOILS OF THE CARPATHIAN FOOTHILLS

ZAWARTOŚĆ AZOTU BIOMASY MIKROBIOLOGICZNEJ W RÓŻNIE UŻYTKOWANYCH GLEBACH POGÓRZA KARPACKIEGO

Abstract: The paper presents results of studies on microbial biomass nitrogen content in agriculturally managed soils of the Silesian and Ciezkowickie Foothills. We used soil material from 14 soil profiles located in pairs – on adjoining arable lands and grasslands. In soil material was assessed the basic properties and microbial biomass nitrogen by chloroform fumigation-extraction method. The analyzed soils were characterized by a high share of microorganism biomass nitrogen in its total content, which may evidence their high biological activity. The contents of microbial biomass nitrogen and its share in the total nitrogen content in grassland soils were significant higher than in arable soils. The content of microorganism biomass nitrogen in the studied soils was positively correlated with the contents of total nitrogen and organic carbon, cation exchange capacity and soil abundance in magnesium (available and exchangeable forms) and with exchangeable sodium.

Keywords: Silesian and Ciezkowickie Foothills, soil management method, total nitrogen, microbial biomass nitrogen

Microbial biomass constitutes a small quota of the soil organic matter, but due to its considerable biochemical activity plays a major role in energy and nutrient cycling in the ecosystems. The share of microbial biomass nitrogen in its total contents in arable soils may be a sensitive indicator of the ecological balance in soils. Its values generally fall within the 1–6 % range, and the higher the share, the “healthier” the soil [1]. It results from a faster cycle of microorganism biomass circulation than the other organic matter in soil [1, 2].

The content of microbial biomass nitrogen in soils depends on the physicochemical and chemical properties of soils [2–8] and is related to the way of their use – the highest in the forest soils, lower in grassland soils and the lowest in soils of arable lands [2, 9].

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In soils of arable land it is under the effect of the cultivation method [4, 7]. The impact of fertilization and cultivation systems on the change of the level of the microbial biomass nitrogen content is often analyzed basing on the results of field experiments [5, 7]. The content of carbon and microbial biomass nitrogen in the soils is also used for the complete characterization of the soil environment of the same areas [2, 4, 8, 10]. In the scientific literature there is a lack of such data for the agricultural soils of Carpathian Foothills.

The paper aimed to determine the content of microbial biomass nitrogen and its share in the total nitrogen content in the soils of the Silesian and Ciezkowickie Foothills and the impact of soil management methods and some chemical and physicochemical properties of investigated soils on changes of these parameters.

Material and methods

The paper used the soil material from 14 profiles of brown soils and soil lessives, formed from the rock waste of the Śląsk unit, of the Carpathian Flysch localized in 7 sites (Table 1), in pairs – on adjoining arable lands and grasslands, so that when comparing the analyzed soil properties it was possible to exclude the effect of soil forming factors, other than the management method.

Table 1

Localization of analyzed soils

No	Localization			Elevation [m a.s.l.]
	Locality	Latitude	Longitude	
Silesian Foothills				
1	Ustroń	49°43′18,7–19,5″N	018°49′14,3–15,7″E	379
2	Ustroń	49°43′25,5–25,6″N	018°49′48,8–49,3″E	437
3	Górki Wielkie	49°46′38,6–38,9″N	018°51′15,8–15,9″E	353
Ciezkowickie Foothills				
4	Swoszowa	49°50′27″N	021°11′47,3″E	402
5	Joniny	49°51′12,6–13,8″N	021°11′17,6–19,6″E	435
6	Czermna	49°49′10,1″N	021°19′17,1″E	361
7	Dobrocin	49°50′23,1″N	021°09′58,7″E	416

The information about the soil management methods were obtained from the farmers cultivating them. Crop rotation: potatoes, wheat, cereal mixture (wheat, barley and oat) was used on the arable lands, except for site 7 (potatoes, rye and oat). The soils were fertilized every 2–3 years with farmyard manure and with mineral fertilizers, but much lower doses of nitrogen fertilizers were applied on the Ciezkowickie Foothill (ca 10–30 kg $N \cdot ha^{-1}$) than on the Silesian Foothill (approximately 100–160 kg $N \cdot kg^{-1}$). Lower nitrogen fertilization was recompensed by higher farmyard manure doses and on the sites 4 and 5 additionally poultry manure was applied. On the grasslands mineral fertilizers were used only on the sites: 3 (ca 100 kg $N \cdot kg^{-1}$), 4 (14 kg $N \cdot kg^{-1}$) and 6

(23 kg N · kg^{-1}) and farmyard manure and (or) slurry on sites: 2 (the highest dose), 3 and 6. The grasslands on sites 1 and 7 were left unfertilized.

In the fine earth parts of the analyzed soils, texture was assessed using aerometric Casagrande method in Proszynski's modification [11], pH in H_2O using potentiometric method [12], the sum of exchangeable bases (BC) by means of determining individual cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) after their extraction with 1 mol · dm^{-3} CH_3COOHN_4, potential acidity (H^+) with Kappen method using 1 mol · dm^{-3} CH_3COONa for extraction and the contents of: available phosphorus and potassium using Egner-Riehm method, available magnesium with Schachtschabel method [13], *total organic carbon* (TOC) with Euro Thermoglas TOC-TN 1200 apparatus, *total nitrogen* (TN) with Kjedahl method by Kjeltec apparatus and microbial *biomass nitrogen* (BN) using chloroform fumigation-extraction method [14].

The significance of differences between arithmetic means of selected properties of corresponding arable soils and grasslands were assessed using Tukey test at significance level $p < 0.05$. The value of correlation coefficient was also computed according to Spearman's rank order. The calculations were made using the *STATISTICA* program.

Results and discussion

The analyzed soils were characterized by diversified texture, chemical and physico-chemical properties, however in the surface horizons of grassland soils mean contents of organic carbon, total nitrogen, microbial biomass nitrogen and available magnesium were apparently higher, whereas average concentrations of available phosphorus and potassium forms were lower than in the arable soils (Table 2, 3). Significant higher contents of TOC, TN and BN in the grassland soils than in arable soils was in the first place due to the fact that greater amount of organic biomass, processed by a greater number of microorganisms was supplied to them [2, 5, 15]. Lower contents of available P and K forms in the grassland soils can by connected with lower fertilization applied on these lands in comparison with the plough lands, or with a total lack of fertilization (Table 3). There are also higher average content of exchangeable base (except K^+), higher average potential acidity and average cation exchange capacity in the surface horizons of grassland soils (Table 4).

Soil profiles, compared in pairs, representing arable lands and grasslands situated close by, were approximate considering their morphology and some physicochemical and chemical properties, particularly in lower situated genetic horizons. In the surface horizons of these soils, some chemical properties became more or less diversified in result of various methods of soil management and accompanying fertilization. On all analyzed sites, the surface horizons of the grassland soils contained bigger amounts of organic carbon, total nitrogen and microorganism biomass nitrogen than the analogous soil horizons of the arable soils. These soils were also characterized by a higher share of microorganism biomass nitrogen in its total content (Table 2). The highest differences between the content of discussed components in arable soils and grassland soils were assessed in soils from Czermna and Dobrocin villages (sites 6 and 7). The grassland soils situated there contained almost 4 times more TOC, over twice more TN and

5 times more BN. These differences resulted from low contents of these components in the arable soils (Table 2).

Table 2

Contents of total organic carbon (TOC), total nitrogen (TN) and microorganism biomass nitrogen (BN) in surface horizons of analyzed arable soils and grasslands

No.	Arable soils				Grasslands			
	TOC	TN	BN	BN/TN	TOC	TN	BN	BN/TN
	[g · kg^{-1} d.m.]		[μg · g^{-1} d.m.]	[%]	[g · kg^{-1} d.m.]		[μg · g^{-1} d.m.]	[%]
1	19.08	1.73	42.50	2.46	24.17	2.06	97.41	4.73
2	19.08	2.00	43.99	2.20	26.03	2.88	223.88	7.79
3	17.10	2.00	40.85	2.04	34.42	3.20	128.94	4.03
4	11.62	1.35	37.26	2.77	30.33	2.99	132.56	4.43
5	9.88	1.32	23.94	1.82	19.89	2.43	111.96	4.60
6	6.47	1.15	19.18	1.68	29.02	2.29	121.98	5.32
7	9.82	0.85	25.01	2.94	34.95	2.22	126.65	5.70
Mean*	13.29^{a}	1.49^{a}	33.25^{a}	2.27^{a}	28.40^{b}	2.58^{b}	134.77^{b}	5.23^{b}

* Means marked in column with the different letters are significant at $p < 0.05$ according to Tukey test.

The indicator characterizing the soil health state is the share of microbial biomass nitrogen in total nitrogen content [1, 15]. The values of this indicator (1.68–2.94 % for plough lands and 4.03–7.79 % for grasslands) allow to regard the studied soils as microbiologically active and in good health state. The highest value of the discussed indicator was noted on site 2 for grasslands (7.79 %). High biological activity of soil on this land might have been affected by annual farmyard manure application. The quota of microbial biomass nitrogen in its total content was also high in the meadow soil from Dobrocin (site 7), which was left unfertilized (Table 2). It confirms the reports of other authors, that farmyard manure fertilization and/or lack of mineral treatment stimulate soil biological activity [5].

The content of microorganism biomass nitrogen in the analyzed soils was positively correlated with total nitrogen and organic carbon concentrations, cation exchange capacity and soil abundance in magnesium (both available and exchangeable forms) and in exchangeable sodium and negatively with clay content (Table 5). The problem of dependence of microorganism biomass nitrogen content on organic carbon and total nitrogen contents are often brought up aspects of soil investigation [2, 3, 15]. Former investigations [2, 16] also pointed to the dependence of the discussed parameter on pH, which was not corroborated by the conducted research. It is most frequently assumed that pH assessed in H_2O, which is most advantageous for microorganism activity in soil is 6.5 [2, 16]. In the investigated soils pH ranged widely between 4.9 and 7.7 (Table 3), however its effect on microorganism biomass content was not registered. In the soils with pH values approximate to assessed in the analyzed soils Kara and Bolat [2] demonstrated its negative correlation with BN, significant at $p < 0.01$. The same authors

Table 3

Selected properties of surface horizons of analyzed soils

No.	Arable soils					Grasslands				
	pH in H_2O	< 0.002 mm [%]	Available components [$mg \cdot kg^{-1}$]			pH in H_2O	< 0.002 mm [%]	Available components [$mg \cdot kg^{-1}$]		
			P	K	Mg			P	K	Mg
1	5.6	11	91.8	496.9	154.4	5.5	9	1.1	74.6	109.8
2	5.6	15	109.9	482.3	191.7	5.6	11	35.8	671.6	260.0
3	5.9	18	364.6	313.4	96.3	5.3	9	48.3	138.6	118.9
4	5.5	24	11.5	113.7	98.8	5.5	14	16.7	188.6	180.4
5	5.3	10	61.2	269.7	54.9	6.6	5	16.7	51.3	114.6
6	7.7	15	52.8	226.0	70.8	6.4	4	25.5	176.1	72.1
7	5.1	7	158.6	101.2	39.6	4.9	5	36.7	169.8	318.3
Mean	5.8	14.3	121.5	286.2	100.9	5.7	8.1	25.8	210.1	167.7

Table 4

Sorption properties of surface horizons of analyzed soils

No	Arable soils								Grasslands							
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	BC[a]	H^{+}	CEC[b]	BS[c]	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	BC[a]	H^{+}	CEC[b]	BS[c]
	[mmol(+) · kg^{-1}]							[%]	[mmol(+) · kg^{-1}]							[%]
1	62.7	7.0	1.2	7.7	78.6	56.7	135.3	58.1	35.7	5.1	0.6	2.0	43.4	88.1	131.4	33.0
2	69.9	10.0	1.4	7.8	89.0	58.2	147.2	60.5	73.5	13.1	2.0	10.1	98.6	65.7	164.3	60.0
3	76.8	6.6	1.0	5.5	90.0	44.3	134.3	67.0	84.6	8.8	1.7	2.5	97.6	69.0	166.7	58.6
4	81.0	6.9	0.5	1.9	90.3	56.1	146.4	61.7	92.6	12.4	0.9	3.4	109.4	61.9	171.2	63.9
5	17.3	2.7	0.7	3.5	24.1	58.0	82.1	29.4	77.5	7.5	0.7	0.9	86.6	30.0	116.6	74.3
6	105.7	5.6	0.7	3.9	115.8	11.4	127.2	91.1	112.3	4.6	0.9	3.1	120.8	21.8	142.6	84.7
7	11.3	2.0	0.6	1.7	15.6	60.6	76.3	20.5	38.8	14.5	1.6	3.3	58.2	66.3	124.5	46.8
Mean	60.7	5.8	0.9	4.6	71.9	49.3	121.2	55.5	73.6	9.4	1.2	3.6	87.8	57.5	145.3	60.2

[a] BC – *exchangeable bases*; [b] CEC – *cation exchange capacity*; [c] BS – *base saturation ratio.*

obtained, similar as in presented results, a negative relationship between BN and clay content.

In the analyzed soils the share of microorganism biomass nitrogen in total nitrogen content depended on its soil concentrations. It was also positively correlated with magnesium content (Table 5).

Table 5

Values of Spearman rank correlation coefficients

Soil proper-ties	TN	BN/TN	TOC	pH in H_2O	< 0.002 mm	P	Mg	Mg^{2+}	Na^+	CEC
						available		exchangeable		
BN	0.914[b]	0.879[b]	0.903[b]	0.047	–0.681[a]	–0.281	0.665[a]	0.608[a]	0.558[a]	0.588[a]
BN/TN	0.681[b]	—	0.725[b]	–0.022	–0.532[a]	–0.437	0.454	0.345	0.273	0.368

[a] $p \le 0.01$, [b] $p \le 0.001$.

Conclusions

1. Arable soils of the Silesian and Ciezkowickie Foothills were characterized by a high share of microorganism biomass nitrogen in its total content, which allows them to include to soils with a high biological activity and in a good health state.
2. It was ascertained that, the soil management method was a significant factor affecting the microbial biomass nitrogen content. The contents of microorganism biomass nitrogen and its share in total nitrogen content in grassland soils were much higher than in arable soils.
3. The content of microorganism biomass nitrogen in the studied soils was positively correlated with the contents of total nitrogen and organic carbon, cation exchange capacity and soil abundance in magnesium (both available and exchangeable forms) and in exchangeable sodium.
4. The nitrogen content in soils was the factor determining the share of microbial biomass nitrogen in its total content.

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Abstrakt: W pracy przedstawiono wyniki badań nad zawartością azotu biomasy mikrobiologicznej w użytkowanych rolniczo glebach Pogórza Śląskiego i Ciężkowickiego. Wykorzystano materiał glebowy z 14 profili gleb zlokalizowanych parami – na gruntach ornych i użytkach zielonych sąsiadujących ze sobą. Oznaczono podstawowe właściwości gleb oraz zawartość azotu biomasy mikrobiologicznej metodą chloroformowej fumigacji-ekstrakcji. Badane gleby charakteryzowały się dużym udziałem azotu biomasy mikroorganizmów w jego ogólnej zawartości, co świadczy o ich wysokiej aktywności biologicznej. W glebach użytków zielonych zawartość azotu biomasy mikrobiologicznej i jego udział w całkowitej zawartości azotu były istotnie większe niż w glebach gruntów ornych. Zawartość azotu biomasy mikroorganizmów była dodatnio skorelowana z zawartością azotu ogółem i węgla organicznego, pojemnością wymienną kationową i zasobnością gleb w magnez (przyswajalny i wymienny) oraz sód wymienny.

Słowa kluczowe: Pogórze Śląskie i Ciężkowickie, sposób użytkowania gleb, azot ogółem, azot biomasy mikrobiologicznej