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PARTICULATE ORGANIC MATTER AND MICROBIAL BIOMASS C CONTENTS IN SOILS WITH DIFFERENT MECHANICAL STRUCTURE

Zawartość drobnocząsteczkowej frakcji materii organicznej i biomasy mikroorganizmów w glebach o różnym składzie granulometrycznym

ABSTRACT: The studies were based on a long-term microplot experiment located at Pulawy Experimental Station of the Institute of Soil Science and Plant Cultivation – National Research Institute (IUNG-PIB). There were 18 of 1.5 m^2 experimental microplots (1.0 m × 1.5 m, and depth 1.5 m) filled at the bottom with silt loam as a bed rock, and at the top with: 1 – black earth, 2 – alluvial soil, 3 – loess, 4 – light loam, 5 – light loamy sand underlaid with clay loam, 6 – light loamy sand underlaid with slightly loamy sand. The aim was to compare the particulate organic matter (POM) quantities and microbial biomass C contents in soils with different mechanical structure. The obtained results showed a significant correlation coefficient (R = 0.883, α = 0.05) between soil organic matter (SOM) and particulate organic matter (POM) contents. However, in our studies this relationship seems not to be a clear-cut one. For example, the highest amount of POM (5.5 g per kg of soil) was detected in the alluvial soil, which contained significantly less SOM than the black earth. Also, the coarse-textured soils contained almost the same amount of POM (2 g per kg of soil) as the light loam substantially richer in SOM and the silt-clay fraction. Moreover, the POM fraction expressed as the percentage of SOM was lowest (16.3%) in the black earth (richest in SOM) and highest (26.0%) in the loess soil. More interestingly, the two coarse-textured soils (light loamy sands) with low contents of SOM had also almost as high percentages (24–25%) of the POM fraction in their SOM as the loess soil. Microbial biomass expressed as a percentage of biomass C in the total amount of soil organic C content was highest in the black earth and lowest in the light loamy sand and it comprised 2.4–3.2% of the total amount of organic C in all tested soil types.

key words: ***słowa kluczowe:***
particulate organic matter – *drobnocząsteczkowa frakcja materii organicznej*, microbial biomass C – *C w biomasie mikroorganizmów*, soil – *gleba*, mechanical structure – *skład mechaniczny*

INTRODUCTION

Soil organic matter (SOM) is often defined as a series of fractions that comprise a continuum based on decomposition or humification rate (6). Various methods and concepts are used to separate and characterize these fractions. For example, particulate organic matter (POM) fraction of SOM represents a pool of organic materials that is intermediate in the decay continuum between organic residues and well-decomposed humic substances (6, 26). According to Cambardella *et al.* (6) POM is a physically isolated, size-defined fraction (0.053–2.0 mm) that is retained on a sieve with 0.053 mm openings after dispersion of the soil. Numerous studies have shown that particulate organic matter is a dynamic soil property responding faster than SOM to changes in various agricultural practices, e.g. crop sequences or soil tillage systems (2, 3, 6, 11, 12, 15, 17, 18, 24).

Microbial biomass is one of the essential, living components of all terrestrial ecosystems. It regulates many critical ecosystem processes, including decomposition of organic materials, nutrient transformations and cycling, and biophysical integration of organic matter with soil solid, aqueous, and gaseous phases (4, 7, 9, 10). The wide spectrum of biochemical activity of soil microorganisms enhance their extremely important role in ecological stability and productivity of soil.

The main objective of presented research was to compare the POM quantities and microbial biomass C contents in soils with different mechanical structure.

MATERIALS AND METHODS

The studies, conducted during the years 1999–2000, were based on a long-term microplot experiment established in 1974 at Pulawy Experimental Station of the Institute of Soil Science and Plant Cultivation (IUNG) (21). There were 18 of 1.5 m^2 experimental microplots (1.0 m × 1.5 m, and depth 1.5 m) filled at the bottom with silt loam as a bed rock, and at the top with: 1 – black earth, 2 – alluvial soil, 3 – loess, 4 – light loam, 5 – light loamy sand underlaid with clay loam, 6 – light loamy sand underlaid with slightly loamy sand. Some characteristics of the investigated soils are presented in Table 1. In 1999 winter wheat cv. Roma and in 2000 barley cv. Rataj were grown on the experimental microplots. The crops were fertilized according to Polish crop management recommendations. Soil samples were taken randomly from each experimental field 6 times during each vegetation season from 0–20 cm profile depth. To determine soil water content samples were dried for 24 h at 105^{o}C. For POM analysis representatives air dried soil samples were dispersed with 100 ml of 5 g l^{-1} sodium hexametaphosphate and shook for 18 h on reciprocal shaker. After shaking soil was passed through a 500 μm sieve and then through a 53 μm sieve. Particulate organic matter (POM – 0.053 mm fraction) quantities in the soils were determined using Cambardella and Elliott (5) modified method in which POM was estimated by the Loss-On-Ignition procedure (LOI); (27). Microbial biomass C content was determined by the fumigation-incubation method as described by Jenkinson and Powlson (19, 20) with modifications given in Martyniuk *et al.* (25).

Once a year estimation of total N content (Dumas method – FP-528-LECO) and organic C content were performed in the certified Central Laboratory of IUNG at Pulawy.

Obtained results were statistically analyzed using ANOVA method.

Table 1

Some characteristics of the tested soils
Niektóre właściwości badanych gleb

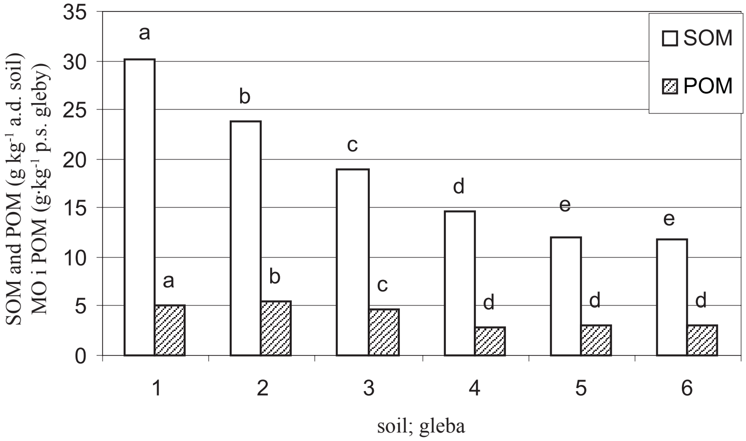
Number and soil type Numer i typ gleby	Soil texture (%) Skład mechaniczny (%)			Soil textural group Gatunek gleby	N total N og. (%)	Organic C C org. (%)	Ratio C:N	d.w. s.m. (%)
	sand piasek 1.0–0.1 mm	silt pył 0.1–0.02 mm	silt and clay cz. spław. <0.02 mm					
1 black earth czarna ziemia	43	18	39	medium-heavy loam underlaid with heavy loam gs.gc	0,17 a	1,75 a	10,3	86,2
2 alluvial soil mada	14	53	33	silt płz	0,12 b	1,38 b	11,5	87,0
3 brown soil gleba brunatna	14	54	32	loess ls	0,07 c	1,10 c	15,7	89,1
4 brown soil gleba brunatna	48	21	31	light loam underlaid with clay loam gl.gc	0,06 d	0,85 d	14,2	89,2
5 brown soil gleba brunatna	69	17	14	light loamy sand underlaid with clay loam pgl.gc	0,04 e	0,70 e	17,5	93,0
6 brown soil gleba brunatna	68	18	14	light loamy sand underlaid with slightly loamy sand pgl.ps	0,03 e	0,69 e	22,7	93,3

RESULTS AND DISSCUSSION

The soils examined in this study differed markedly, both with respect to their physical and chemical characteristics (Table 1). The content of silt and clay fraction ranged from 39% in the soil no. 1 (black earth) to 14% in the two brown sandy soils (no. 5 and 6). The soils no. 2 (alluvial soil) and 3 (loess) contained the highest percentages (53–54%) of silt fraction 0.1–0.02 mm. The studied soils differed also significantly (with the exception of the soils no. 5 and no. 6) with respect to the soil organic C content, which ranged from 1.75% in the black earth (soil no. 1) to 0.69% in the light loamy sand (no. 6); (Table 1). The black earth was also richest in total N (0.17%) while the two light sandy soils (no. 5 and 6) contained the lowest amounts of this compound (0.03–0.04%).

Soil organic matter content in the tested soils, calculated from the organic C content multiplied by the factor 1.724, was highest (over 30 g kg^{-1} soil air dry weight; a.d.w.) in the black earth. The alluvial soil contained almost 23 g of SOM and in the brown soils the content of SOM ranged from about 12 to 19 g kg^{-1} soil a.d.w. (Fig. 1).

Particulate organic matter (POM) and other size-defined fractions, as well as density-flotation fractions of soil organic matter (SOM), collectively known as light fractions of SOM, have been shown to be dynamic and more sensitive to change than total SOM (6, 13, 23). For these reasons POM has been intensively studied as an indicator of changes in soil quality in response to various soil management systems, particularly soil tillage intensity and crop rotations (2, 3, 13, 17, 22). Substantially less is known about POM as an intrinsic fraction of SOM in various soil types. Since



* description of soils is given in Table 1; opis gleb podano w tab. 1

Fig. 1. Content of SOM and POM in the studied soils
Zawartość MO i POM w badanych glebach

the soils we studied have been under the same management system (including the same crop sequence, mineral fertilization and crop protection measures) and climatic conditions for many years (1974–2000) it was interesting to compare contents of the POM fraction in these soils. Results presented in Figure 1 and a significant ($\alpha = 0.05$) correlation coefficient between SOM and POM contents in the tested soils (Fig. 2) would indicate that the level of the POM fraction in soils is related to their richness in total SOM. This relationship seems not to be a clear-cut one, however. For example, in this study the highest amount of POM (5.5 g per kg of soil) was detected in the alluvial soil, which contained significantly less SOM than the black earth (Fig. 1). Secondly, the coarse-textured soils no. 5 and 6 contained almost the same amount of POM (2 g per kg of soil) as the soil no. 4 substantially richer in SOM and the silt-clay fraction (Fig. 1).

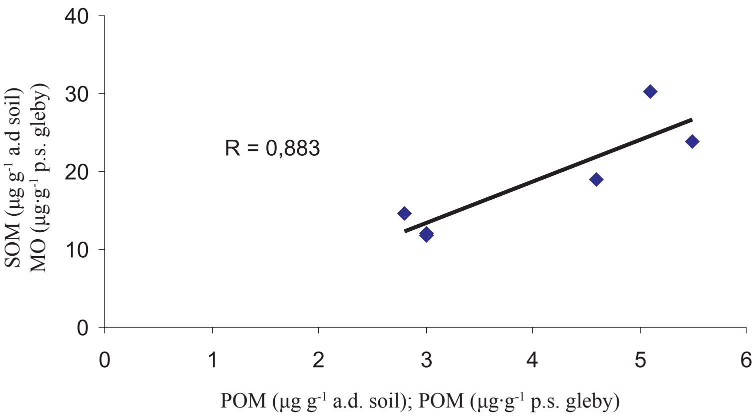
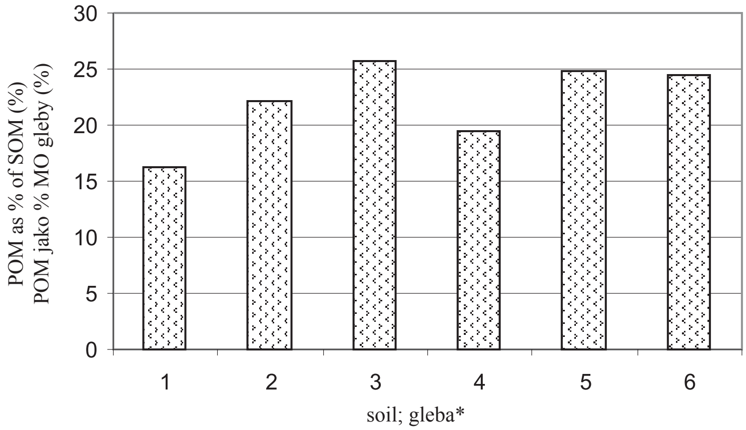


Fig. 2. Relationship between total SOM and POM content in the studied soils
Zależność pomiędzy zawartością MO i POM w badanych glebach

Moreover, it is interesting to point out that the POM fraction expressed as the percentage of total SOM was lowest (16.3%) in the soil no. 1 (black earth) richest in SOM. The highest (almost 26%) percentage of POM was found in the soil no. 3 (loess). More interestingly, the two coarse-textured soils no. 5 and 6 (light loamy sands) with low contents of SOM had also almost as high percentages, 24.9% and 24.4%, respectively, of the POM fraction in their SOM as the soil no. 3 (Fig. 3). Cambardella *et al.* (6) reported even higher share of POM, reaching 45% of SOM, in a sandy soil (containing only 3% of the clay fraction) from the Great Plains (USA), while in heavier soils from this region POM amounted to 10–21% of SOM. As it was mentioned earlier the tested soils have been kept under the same agricultural and climatic conditions for over 26 years of the duration of the plot experiment (21). We did not measure amounts of crop residues, particularly those of roots, remaining in the



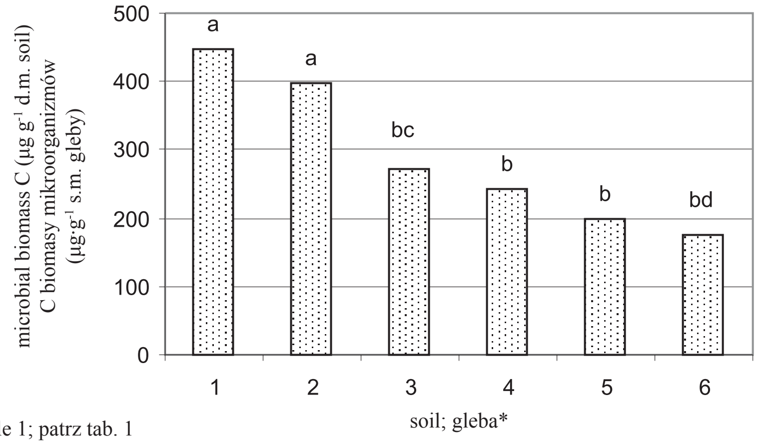
* see Table 1; patrz tab. 1

Fig. 3. The POM fraction as % of total SOM content in the studied soils
Udział % frakcji POM w całkowitej zawartości MO w badanych glebach

soils after the harvests. However, based on relatively similar crop yields harvested on these soils, e.g. 0.58–0.64 kg m^{-2} of winter wheat grain in 1999, it could be assumed that the soils received comparable amounts of organic residues each year. Therefore, higher accumulation of POM, as a proportion of SOM, in the coarse-textured soils could be related to a lower capacity of these soils to store water (Table 1), which resulted in a slower rate of POM decomposition in these soils, as compared to the fine-textured soils, e.g. the alluvial soil (no. 2). Janzen *et al*. (18) also reported that a soil from an arid region of Canada contained markedly higher proportion (17%) of the light fraction C in the total soil C than two soils (5 and 7% light fraction C) under humid conditions.

The highest contents of C in microbial biomass, the living component of SOM, were found in the soil no. 1 (black earth) and soil no. 2 (alluvial soil), with 447.8 and 398.1 µg CO_2-C g^{-1} d.w. soil, respectively. Two coarse-textured sandy soils (no. 5 and 6) contained the lowest amounts of microbial biomass C, which averaged 199.0 and 174.2 µg C-CO_2 g^{-1} d.m. soil, respectively (Fig. 4). A high correlation coefficient between soil organic C and microbial biomass C contents in the tested soils (Fig. 5) confirm earlier findings (1, 8, 14, 16) that the development of soil microorganisms is strongly dependent on the content of SOM, which serves mainly as a source of nutrients and energy for soil microorganisms.

In our studies microbial biomass expressed as a percentage of biomass C in the total amount of soil organic C was the highest in the soil no. 2 (alluvial soil) and no. 1 (black earth), 3.2 and 2.8%, respectively (Fig. 6). Generally, the percentage of microbial biomass C in the total amount of organic C in all tested soils ranged from 2.4 to 3.2%, similarly to the results published by Anderson and Domsch (1) and Sparling (28), who reported that soil microbial biomass C comprises from 1 to 4% of the total organic C content in soils.



* see Table 1; patrz tab. 1

Fig. 4. Content of microbial biomass C in the studied soils
Zawartość C w biomasie mikroorganizmów w badanych glebach

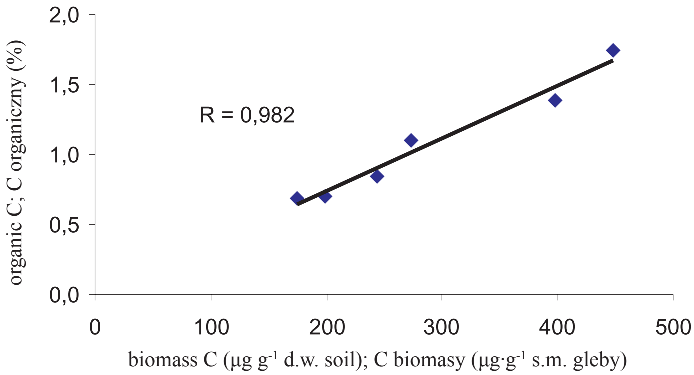
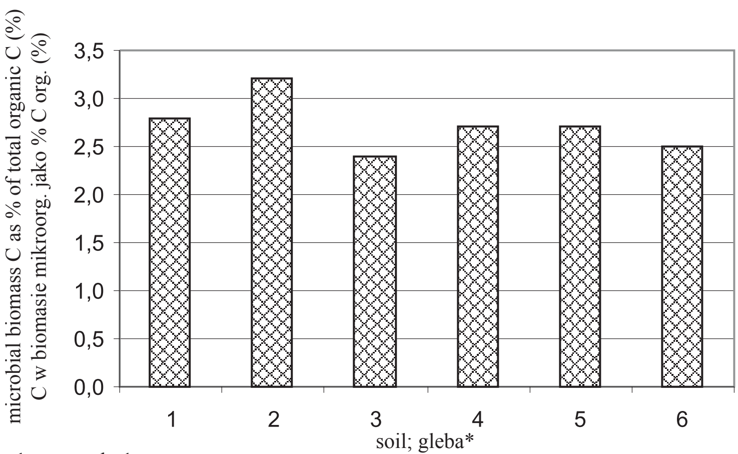


Fig. 5. Relationship between total organic C and microbial biomass C content in the studied soils
Zależność między zawartością C organicznego i C w biomasie mikroorganizmów w badanych glebach



* see Table 1; patrz tab. 1

Fig. 6. The microbial biomass C content as % of organic C in the studied soils
Procentowy udział C w biomasie mikroorganizmów w całkowitej zawartości C org. w badanych glebach

CONCLUSIONS

1. The content of the POM fraction ranged from about 3 g kg^{-1} in loamy sands to 5.6 g kg^{-1} in an alluvial soil. A significant correlation coefficient ($R = 0.883$, $\alpha = 0.05$) found between SOM and POM contents indicates that the level of the POM fraction in the tested soils was related to their richness in the total SOM.

2. The POM fraction expressed as the percentage of SOM was lowest (16.3%) in the black earth soil (richest in SOM) and highest (26%) in the loess soil. The two sandy soils tested (light loamy sands) contained also high percentages (24–25%) of the POM fraction in their SOM.

3. Microbial biomass C was the highest in the black earth (about 450 μg g^{-1}) and lowest in the light loamy sand (174 μg g^{-1}) and it comprised 2.4–3.2% of the total amount of organic C in all tested soils.

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ZAWARTOŚĆ DROBNOCZĄSTECZKOWEJ FRAKCJI MATERII ORGANICZNEJ I C W BIOMASIE MIKROORGANIZMÓW W GLEBACH O RÓŻNYM SKŁADZIE GRANULOMETRYCZNYM

Streszczenie

Badania przeprowadzono w oparciu o wieloletnie doświadczenie mikropoletkowe (1,0 m × 1,5 m × 1,5 m) w Stacji Doświadczalnej IUNG w Puławach. Wybrany do badań materiał glebowy charakteryzował się różnym składem granulometrycznym: czarna ziemia – gs.gc, mada brunatna – płz, less – ls, glina lekka – gl.gc, piasek gliniasty na glinie – pgl.gc i piasek gliniasty na piasku – pgl.ps. Celem badań było porównanie zawartości drobnocząsteczkowej frakcji materii organicznej (POM) i C w biomasie mikroorganizmów w wymienionych glebach. Wykazano istotną korelację ($\alpha = 0,05$) drobnocząsteczkowej

frakcji materii organicznej (POM) z całkowitą zawartością materii organicznej (MO) w badanych glebach. Stwierdzono jednak, że zależność ta nie do końca potwierdziła się w przypadku naszych gleb, ponieważ najwyższą zawartością POM charakteryzowała się gleba nr 2 (mada) o istotnie niższej zawartości MO w porównaniu do gleby nr 1 (czarnej ziemi) o najwyższej zawartości MO. Ponadto, gleby piaszczyste (nr 5 i 6) o niskiej zawartości MO zawierały prawie taką samą ilość POM co gleba nr 4 (glina lekka), charakteryzująca się wyższą zawartością MO i wyższym udziałem części spławialnych. Należy zaznaczyć, że interesująco przedstawiała się także zawartość frakcji POM wyrażona jako % całkowitej zawartości MO w badanych glebach. Otóż, najniższy % POM w MO (16,3%) zawierała czarna ziemia (nr 1) o najwyższej zawartości MO, natomiast gleba lessowa (nr 3) oraz dwie gleby piaszczyste (nr 5 i 6) charakteryzowały się najwyższym procentowym udziałem frakcji POM w MO (około 25,0%). Wyższy udział POM w MO w glebach piaszczystych należy najprawdopodobniej tłumaczyć mniejszą zdolnością tych gleb do zatrzymywania wody, co powodowało wolniejsze tempo mineralizacji frakcji POM, w porównaniu z glebami o cięższej strukturze, np. z glebą nr 2. Również zawartość C w biomasie mikroorganizmów była dodatnio skorelowana z zawartością C organicznego w badanych glebach. Potwierdza to wyniki wcześniejszych badań, które wykazały, że rozwój mikroorganizmów glebowych jest ściśle związany z zawartością MO w glebie, która stanowi główne źródło energii i składników pokarmowych dla drobnoustrojów. Zawartość C w biomasie mikroorganizmów wyrażona jako % całkowitej zawartości C org. w badanych glebach wynosiła od 2,4 do 3,2%, co jest zgodne z wcześniejszym stwierdzeniem, że C zawarty w biomasie mikroorganizmów stanowi od 1 do 4% całkowitej zawartości C org. w glebie.

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