ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 4 2011

Tomasz SOSULSKI[1] and Marian KORC[1]

EFFECTS OF DIFFERENT MINERAL AND ORGANIC FERTILIZATION ON THE CONTENT OF NITROGEN AND CARBON IN SOIL ORGANIC MATTER FRACTIONS

WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA MINERALNEGO I ORGANICZNEGO NA ZAWARTOŚĆ AZOTU I WĘGLA WE FRAKCJACH MATERII ORGANICZNEJ GLEBY

Abstract: Studies on carbon and nitrogen content in the selected fractions of the soil organic matter were carried out on the basis of a soil sample collected in 2005 at the experimental field of Department of Chemistry, Warsaw University of Life Sciences in Lyczyn near Warsaw. After 10 crop-rotations manure fertilization resulted in an increase in the content of organic carbon and total nitrogen in soil on all objects treated with this fertilizer. Exclusive mineral fertilization led to an increase in the content of both organic carbon and total nitrogen in soil on the majority of objects. This increase was lower than that caused by the manure fertilization. The manure treatment caused an increase in the content in soil of carbon of the studied organic matter fractions. The share of carbon of individual organic matter fractions remained similar on the objects treated and not treated with manure. Among the studied nutrients applied in the form of mineral fertilizers, only nitrogen increased the content of organic carbon, total nitrogen and its fractions in soil independent of other factors, as treatment with manure or liming. The effects of mineral fertilizers on the content of organic carbon and soil nitrogen and its fractions in soil were diverse. The humin-acids-carbon to fulvic-acids-carbon ratio indicated that the amount of fulvic acids generated in the soil had exceeded that of humic acids. In sandy-loam soils, which have not been treated with organic fertilization for years, there is a growing deficit of nitrogen used by crops to build the yield. This is confirmed by the very high C:N ratio found in the soil applied only mineral fertilizers, which amounted to 14:1, whereas the one observed in the manure fertilized soil equaled to 11.7:1. The vast majority of soil nitrogen is included in humin and fulvic acids, which are the most dynamic and susceptible to mineralization.

Keywords: long-term experiment, fertilization, soil organic matter, soil carbon, soil nitrogen

The effect of mineral and organic fertilization on organic carbon and total nitrogen in soil is well described in domestic and foreign literature [1–4]. Many authors indicate that the increase in content of organic matter and nitrogen in soil is possible by

[1] Department of Soil Environments Sciences, Warsaw University of Life Sciences, Nowoursynowska 159, 02–686 Warszawa, Poland, phone: +48 22 593 26 30, email: tomasz_sosulski@sggw.pl

multimanure fertilization [4, 5]. The impact of multimineral fertilization on organic carbon and total nitrogen in soil is highly variable. Depending on soil, climatic and agronomic conditions a slight increase or decrease in the content of organic carbon and total nitrogen in the soil was obtained [4, 6–8]. In contrast, omission of fertilization reduces the content of these elements in soil. In studies on diagenesis of the organic matter in different soil types the importance is given to both, the quantitative, and qualitative changes in the carbon and nitrogen soil content [9, 10]. Fertilization, which impacts not only the intensity of transformation of organic matter in soil, but also its chemical properties (eg pH, the contents of components) and physical ones (eg water capacity), may also affect the humus composition. The aim of this work was to determine the effect of mineral, mineral-organic and organic fertilization on the carbon and nitrogen content in selected soil organic matter fractions.

Material and methods

Studies on carbon and nitrogen content in selected fractions of the soil organic matter were carried out on the basis of a soil sample collected in 2005 at the experimental field of Department of Agricultural Chemistry, Warsaw University of Life Sciences in Lyczyn near Warszawa. A long-term experiment, on which the studies were carried out, was set up in 1960. The following fertilization objects (4 replications) were distributed randomly within two blocks, with and without manure: control, with individual components (N, P, K), with two constituents (NP, NK, PK), and with full dose NPK fertilizer; each object in two versions: with and without liming. Plants were grown in the following rotation pattern: potatoes, barley, oilseed rape, rye. On the manure--fertilized objects manure was applied at the dose of 37.5 $Mg \cdot ha^{-1}$ (25 $Mg \cdot ha^{-1}$ before the potatoes and 12.5 $Mg \cdot ha^{-1}$ before rape) in per a crop-rotation. Soil samples were collected after harvesting of rye, which completed the tenth crop-rotation. The Lyczyn soil with texture of a sandy loam belongs to the haplic luvisol type with the silt and clay content of 11 % and 22 % in the Ap and Bt soil layers, respectively. The following parameters were measured using the Tiurin method: the content of organic carbon in soil, the alkaline extract (0.1 M NaOH 0.1 M $Na_4P_2O_7 \cdot 10\ H_2O$) carbon soil content, and the humin acids carbon soil content, the latter following precipitation of humin acids with sulfuric acid. The fulvic acids carbon soil content was calculated as the difference between the alkaline extract carbon soil content and the humin acids carbon soil content. The content of the following parameters was measured using a modified Kiejdahl method: the total nitrogen soil content, the alkaline extract nitrogen soil content, and the humin acids nitrogen soil content. The fulvic acids nitrogen soil content was calculated as the difference between the alkaline extract nitrogen soil content and the humin acids nitrogen soil content. Additionally, carbon and nitrogen contained in the post-alkaline-extraction fraction were calculated respectively as the difference between the content of organic carbon in soil and the alkaline extract carbon soil content, and the difference between the total nitrogen soil content and the alkaline extract nitrogen soil content.

Results and discussion

The paper presents average values of the measured parameters, which characterize the main effects of the studied nutrients applied in the form of mineral fertilizers (nitrogen, phosphorus, potassium and liming) and manure. In order to characterize the main effects of the studied nutrients applied in the form of mineral fertilizers (nitrogen, phosphorus, potassium and liming) and manure, the studied parameters are depicted in this paper as values averaged of the results obtained on the objects fertilized with the nutrients in question.

Influence of fertilization on the content of organic carbon and its fractions in soil

The baseline content of organic carbon in soil, before the experiment set-up in 1960, was 5.8 g C $\cdot$ kg^{-1} [11]. After 10 crop-rotations manure fertilization resulted in an increase in the content of organic carbon in soil on all objects treated with this fertilizer. Exclusive mineral fertilization led to an increase in the content of organic carbon in soil on the majority of objects. This increase, however, was significantly lower than that caused by the manure fertilization. The content of organic carbon in soil was decreased versus the baseline only on the objects, which had not been treated with nitrogen and potassium (Table 1).

From among the studied factors, the manure fertilization was shown to have the biggest influence on the content of organic carbon in soil and the content in soil of carbon of individual organic matter fractions (Table 1).

Regardless of the fact that the manure treatment caused an increase in the content of carbon of the studied organic matter fractions in soil, the share of carbon of individual organic matter fractions remained similar on the objects treated and not treated with manure. It can be concluded that manure affects the nature and specific properties of the soil organic matter only to a limited extent, whereas it is essential to its quantitative development. The effects of mineral fertilizers on the content of organic carbon and its fractions in soil were diverse. As expected, the lowest content of organic carbon and its fractions in soil was found on the objects, which had not been treated with nitrogen fertilizers nor manure. Among the studied nutrients applied in the form of mineral fertilizers, only nitrogen increased the content of organic carbon and its fractions in soil independent of other factors, as treatment with manure or liming. The influence of other nutrients (phosphorus and potassium) and liming on organic carbon content and its fractions in soil was lower than the effect of nitrogen, and dependent on the manure fertilization. On the non-manure-treated objects the use of potassium led to a 15 % increase in the content of organic carbon in soil. However, application of potassium fertilization and liming to manure-fertilized objects did not result in major differences in the content of organic carbon in soil. Neither liming nor fertilization with phosphorus influenced the content of organic carbon in soil on the non-manure-treated objects. To note, the content of organic carbon in soil found on these objects was lower than on the objects treated with potassium. On the other hand, the application of phosphorus to the

Table 1

Soil pH and the content of organic carbon and its fraction in soil.

Treatments		pH_{KCl}	$C_{org.}$	Alkaline extract. carbon		Humin acids carbon (C_H)		Fulvic acids carbon (C_F)		C_H/C_F	Extraction residue carbon	
			[g · kg^{-1}]	[% in $C_{org.}$]	[g · kg^{-1}]	[% in $C_{org.}$]	[g · kg^{-1}]	[% in $C_{org.}$]	[g · kg^{-1}]		[% in $C_{org.}$]	[g · kg^{-1}]
Without manure	without N	5.3	5.649	35.4	1.934	17.3	0.936	18.1	0.998	0.9:1	64.6	3.715
	with N	4.9	6.800	42.2	2.868	19.3	1.302	22.8	1.566	0.8:1	57.8	3.932
	without P	4.9	6.233	40.2	2.506	18.7	1.136	21.5	1.370	0.8:1	59.8	3.727
	with P	5.3	6.216	37.3	2.297	17.9	1.103	19.4	1.195	0.9:1	62.7	3.919
	without K	5.0	5.796	39.7	2.310	20.9	1.196	18.8	1.114	1.1:1	60.3	3.486
	with K	5.2	6.653	37.8	2.493	15.7	1.042	22.1	1.451	0.7:1	62.2	4.160
	without lime	4.7	6.209	35.4	2.219	15.2	0.930	20.2	1.289	0.7:1	64.6	3.990
	with lime	5.5	6.240	42.2	2.584	21.5	1.309	20.7	1.275	1.0:1	57.8	3.656
	mean	—	6.225	38.8	2.401	18.3	1.119	20.5	1.282	0.9:1	61.2	3.823
With manure	without N	5.4	8.638	36.5	3.132	17.9	1.542	18.6	1.590	1.0:1	63.6	5.506
	with N	5.3	9.892	40.5	3.978	16.3	1.604	24.2	2.373	0.7:1	59.6	5.914
	without P	5.4	9.742	38.6	3.764	16.9	1.642	21.7	2.122	0.8:1	61.4	5.978
	with P	5.3	8.788	38.3	3.346	17.3	1.504	21.1	1.842	0.8:1	61.7	5.442
	without K	5.3	9.388	39.0	3.640	18.5	1.707	20.5	1.933	0.9:1	61.0	5.748
	with K	5.3	9.142	37.9	3.469	15.7	1.438	22.2	2.030	0.7:1	62.1	5.673
	without lime	5.0	9.238	38.6	3.565	16.9	1.549	21.7	2.016	0.8:1	61.4	5.673
	with lime	5.6	9.292	38.3	3.544	17.3	1.597	21.1	1.947	0.8:1	61.7	5.748
	mean	—	9.265	38.5	3.555	17.1	1.573	21.4	1.982	0.8:1	61.1	5.710

manured objects led to a 10 % decrease in the content of organic carbon in soil. The lowest content of humin acid carbon in soil was found on the objects, which had not been treated with nitrogen fertilizers and in those, which had not been limed. The use of nitrogen fertilizers and liming resulted in a similar increase in the humin acids carbon content in soil. These relationships were independent of manure fertilization. The application of nitrogen fertilizers and liming to the non-manure-treated objects resulted in an increase in the share of humin acid carbon in the soil organic carbon. No such relationship was shown on the manured objects. The omission of phosphoric and potassium fertilization resulted in an increase in the soil humin acid carbon as compared with the objects, where these fertilizers had been applied. In most instances it caused an increase in the share of humin acid carbon in the soil organic carbon. The humin-acids-carbon to fulvic-acids-carbon ratio indicated that the amount of fulvic acids generated in the soil had exceeded that of humic acids. Similar quantities of humin and fulvic acids were generated solely on the manure-treated objects, which had been limed and those that had not been treated with potassium, and on non-manure-treated objects, which had not been treated with nitrogen. Opposite results were obtained by Kusinska on a sandy loam soil in the Skierniewice experiment [12]. Regardless of the use of manure, both nitrogen and potassium treatments increased the content of fulvic acid carbon in soil, whereas liming and phosphorus treatment decreased this parameter. In most instances, the application of nitrogen, phosphorus and potassium fertilizers to the non-manure-treated objects increased the soil alkaline extraction residue carbon. On the manured objects the use of nitrogen increased the soil alkaline extraction residue carbon, whereas application of phosphorus, potassium and lime had no influence on the soil alkaline extraction residue carbon.

Influence of fertilization on total soil nitrogen and its fractions in soil

In the 40-year experiment fertilization with manure increased the total nitrogen content in soil by 78 % as compared with the objects treated with mineral fertilizers only (Table 2). In most instances, the effects of fertilization with nitrogen, phosphorus, potassium and lime on the content of total nitrogen in soil were found similar to the corresponding fertilization effects on the organic carbon content in soil. The nitrogen treatment applied to the non-manure-treated objects caused an average 22 % increase in the total soil nitrogen, whereas the same treatment applied to the manured objects led to the average increase in that parameter that reached only 12 %. Phosphorus fertilization resulted in a decrease in total soil nitrogen by 9 % on the objects not treated with manure and 6 % on the manured ones. In contrast, the use of potassium fertilizers caused only minor rise in the total soil nitrogen. Liming caused a more important increase in the total soil nitrogen, which reached 7 % on the manure-treated objects and 14 % on the other ones. The effects of mineral fertilizers on the total soil nitrogen and its fractions in soil were varied. Similarly to the effects on carbon, the biggest impact on the accumulation of nitrogen in different fractions of soil organic matter had the manure fertilization. The content of nitrogen bounded in humin acids, fulvic acids and in the

Table 2

The content of total nitrogen and content organic matter fractions nitrogen in soil and C:N ratio in soil and in organic matter fractions

Treatments		$N_{tot.}$ [g · kg^{-1}]	C:N	Alkaline extract		Humin acids		Fulvic acids		Alkaline extraction residue	
				N [g · kg^{-1}]	C:N	N [g · kg^{-1}]	C:N	N [g · kg^{-1}]	C:N	N [g · kg^{-1}]	C:N
without manure	without N	0.404	14.2:1	0.229	8.5:1	0.073	13.0:1	0.157	6.5:1	0.175	22.8:1
	with N	0.494	13.9:1	0.303	9.6:1	0.113	12.2:1	0.190	8.2:1	0.191	22.1:1
	without P	0.468	13.3:1	0.282	8.9:1	0.109	10.9:1	0.173	7.8:1	0.186	20.5:1
	with P	0.430	14.8:1	0.250	9.2:1	0.077	14.4:1	0.173	7.0:1	0.181	24.4:1
	without K	0.438	13.4:1	0.257	9.0:1	0.088	14.2:1	0.169	6.5:1	0.180	21.0:1
	with K	0.460	14.6:1	0.274	9.1:1	0.097	11.1:1	0.177	8.2:1	0.186	23.9:1
	without lime	O.419	15.1:1	0.270	8.2:1	0.088	11.8:1	0.182	6.8:1	0.113	28.2:1
	with lime	0.790	13.0:1	0.262	9.9:1	0.097	13.5:1	0.164	7.9:1	0.181	16.8:1
	mean	0.449	14.0:1	0.266	9.1:1	0.093	12.6:1	0.173	7.4:1	0.183	22.5:1
With manure	without N	0.754	11.6:1	0.447	7.1:1	0.126	12.3:1	0.321	5.1:1	0.306	18.7:1
	with N	0.839	11.9:1	0.504	7.9:1	0.167	9.7:1	0.338	7.1:1	0.334	18.3:1
	without P	0.820	12.0:1	0.483	7.8:1	0.158	10.6:1	0.325	6.5:1	0.337	18.1:1
	with P	0.773	11.5:1	0.469	7.2:1	0.135	11.4:1	0.334	5.7:1	0.304	19.0:1
	without K	0.779	12.1:1	0.485	7.5:1	0.143	12.4:1	0.344	5.6:1	0.294	20.1:1
	with K	0.814	11.3:1	0.467	7.5:1	0.153	9.6:1	0.315	6.7:1	0.347	16.9:1
	without lime	0.768	12.1:1	0.468	7.5:1	0.151	10.5:1	0.317	6.3:1	0.299	19.8:1
	with lime	0.825	11.3:1	0.484	7.5:1	0.142	11.6:1	0.342	6.0:1	0.341	17.2:1
	mean	0.797	11.7:1	0.476	7.5:1	0.147	11.0:1	0.330	6.1:1	0.320	18.5:1

compounds remaining after alkaline extraction was higher by 58 to 91 % on the objects fertilized with manure that on the non-manure-treated ones. Both shares in the total soil nitrogen: the humin acid nitrogen share and that of nitrogen contained in the post-alkaline-extraction fraction were slightly lower on the objects fertilized with manure than on those, which had not been treated with this fertilizer, whereas the fulvic acids nitrogen share in the total soil nitrogen was slightly higher on the manured objects. Nitrogen fertilization increased the humin acid nitrogen content in soil by 55 % on the non-manure-treated objects and by 33 % on the manured ones. It had a smaller impact on the fulvic acids nitrogen content in soil (21 % and 5 % respectively). Application of nitrogen to both manured and non-manure-treated objects led to a similar increase in the content in soil of the nitrogen contained in the post-alkaline-extraction fraction, which amounted to 9 %. Phosphorus fertilization resulted in an increase in the humin acid nitrogen content in soil regardless of the use of manure fertilization. However, it did not affect the fulvic acids nitrogen content in soil, neither on the objects treated with manure nor on the other ones. Potassium fertilization caused an increase in the humin acid nitrogen content in soil both on the objects treated with manure and those, which had not been treated with this fertilizer. It led to an increase in the fulvic acid nitrogen content in soil on the non-manure-treated objects, whereas it decreased the fulvic acid nitrogen content in soil on the manured ones. Liming resulted in an increase in the humin acid nitrogen content in soil and decreased the fulvic acids nitrogen content in soil on the objects, which had not been treated with manure. Its influence on the manure-treated objects was opposite. Excepting nitrogen treatment applied in the form of mineral fertilization, no conclusive results were obtained regarding the effects of individual nutrients on the nitrogen contained in the post-alkaline-extraction fraction.

Influence of fertilization on C:N ratio in soil and soil organic matter fractions

Changes in the content of carbon and nitrogen in different soil organic matter fractions influenced the C:N ratio in soil and in the tested fractions (Table 2). The disparity in the accumulation of organic carbon and total nitrogen in soil between the objects fertilized with manure and those not treated with this fertilizer is particularly interesting. This shows that in sandy-loam soils, which have not been treated with organic fertilization for years, there is a growing deficit of nitrogen used by crops to build the yield. This is confirmed by the very high C:N ratio found in the soil applied only mineral fertilizers, which amounted to 14:1, whereas the one observed in the manure fertilized soil equaled to 11.7:1. High or low values of the ratio of organic carbon to total nitrogen in soil went along with similar C:N relations in all studied soil organic matter fractions. The highest C:N ratio was found in the post-alkaline extraction fraction, and the lowest one in the fulvic acids. The values of nitrogen content and C:N ratio in humin and fulvic acids indicate that the vast majority of soil nitrogen is included in the soil organic matter fractions, which are the most dynamic and susceptible to mineralization. The much higher C:N ratio in the post-alkaline-extraction fraction, ranging from 18.5:1 to 22.5:1, suggests that compounds contained in this fraction are less susceptible to microbial decomposition.

Approximately 40 % of total soil nitrogen is deposited in this fraction.

Conclusions

1. Manure fertilization results in an increase in the content of organic carbon and total nitrogen in soil. Exclusive mineral fertilization with nitrogen, phosphorus and potassium leads to an increase in the content of both parameters. This increase is lower than that caused by the manure fertilization.

2. In sandy-loam soil the amount of fulvic acids exceeds the amount of humic acids, as indicated by the humin-acids-carbon to fulvic-acids-carbon ratio.

3. The manure treatment increases the content of carbon of the following fractions in soil: the humin acids carbon, the fulvic acids carbon and the soil alkaline extraction residue carbon. The share of carbon of individual organic matter fractions remains similar in the soil treated with manure and in that not treated with this fertilizer. It can be concluded that manure influences the nature and specific properties of the soil organic matter only to a limited extent, whereas it is essential to its quantitative development.

4. From among the studied nutrients applied in the form of mineral nutrients and liming, only nitrogen increases the content of organic carbon and total nitrogen and its fractions in soil regardless of manure fertilization. The effects of mineral fertilizers on the content of organic carbon and soil nitrogen and its fractions in soil depend on the manure fertilization.

5. In sandy-loam soil, which have not been treated with organic fertilization for years, there exists a growing deficit of nitrogen used by crops to build the yield. This is confirmed by the very high C:N ratio found in the soil treated only with mineral fertilizers.

6. About 60 % of total soil nitrogen is included in humin and fulvic acids fractions, which are the most dynamic and susceptible to mineralization.

References

[1] Jenkinson D. S., Bandbury N. J. and Koleman K.: [In:] Long-term Experiments in Agricultural and Ecological Sciencies, Leigh R. A. and Johnston A. E. (Eds), Wallingford, Oxfordshire 1994, 117–138.
[2] Körshens M. and Pfefferkom A.: Der Statische Düngungsversuch und andre Feldversuche UFZ-Umwelt-forsungszentrum Leipzig-Halle GmbH. 1998, 1–56.
[3] Leithold G.: Proc. of the Int. Symp. Long-term Sratic Fert. Exp. 1993, 77–85.
[4] Mercik S. and Stępień W.: Fragm. Agronom. 2005, **22**, 189–201.
[5] Maciak Cz. and Żebrowski J.: Zesz. Probl. Post. Nauk Roln. 1999, **465**, 341–351.
[6] Murawska B. and Spychaj-Fabisiak E.: Folia Univ. Agric. Stetin. 2002, **11**, Agricultura, 329–334.
[7] Rabikowska B.: Nawozy i Nawożenie 2002, **10**(1), 188–197.
[8] Szulc W., Łabętowicz J. and Kuszelewski L.: Zesz Probl. Post. Nauk Roln. 1999, **465**, 303–309.
[9] Kalembasa D. and Becher M.: Roczn. Glebozn. 2006, 57, 3/4, 44–54.
[10] Kalembasa D. and Becher M.: Roczn. Glebozn. 2008, **59**(2), 98–103.
[11] Kuszelewski L. and Żurawska A.: Zesz. Naukowe SGGW, Rolnictwo 1967, **9**, 53–81.
[12] Kusińska A.: Roczn. Glebozn. 1996, **47** (Suppl.), 85–96.

WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA MINERALNEGO I ORGANICZNEGO NA ZAWARTOŚĆ AZOTU I WĘGLA WE FRAKCJACH MATERII ORGANICZNEJ GLEBY

Katedra Nauk o Środowisku Glebowym
Szkoła Główna Gospodarstwa Wiejskiego w Warszawie

Abstrakt: Badania nad zawartością węgla i azotu w wybranych frakcjach substancji organicznej gleby przeprowadzono korzystając z próbek gleby zebrane w 2005 r. na polu doświadczalnym Zakładu Chemii Rolniczej SGGW w Łyczynie koło Warszawy. Po 10 rotacjach zmianowania nawożenie obornikiem zwiększyło zawartość węgla organicznego i azotu ogólnego w glebie na wszystkich badanych obiektach doświadczenia. Wyłączne nawożenie mineralne zwiększyło zawartość węgla organicznego i azotu ogólnego w glebie na większości obiektów. Jednak przyrost ten był mniejszy niż na obiektach nawożonych obornikiem. Nawożenie obornikiem zwiększyło zawartość węgla azotu frakcji materii organicznej w glebie. Udział węgla poszczególnych frakcji materii organicznej w węglu organicznym gleby na obiektach nawożonych i nienawożonych obornikiem był podobny. Wśród składników stosowanych w postaci nawozów mineralnych tylko azot zwiększał zawartość węgla organicznego, azotu ogólnego i ich frakcji w glebie niezależnie od nawożenia obornikiem. Wpływ pozostałych składników na zawartość węgla organicznego, azotu ogólnego i ich frakcji w glebie był zróżnicowany. Stosunek węgla kwasów huminowych do węgla kwasów fulwowych wskazywał, że w glebie powstawało więcej kwasów fulwowych niż huminowych. W nienawożonej przez wiele lat obornikiem glebie o składzie mechanicznym piasku gliniastego narastał deficyt azotu wykorzystywanego przez rośliny do budowy plonu. Świadczył o tym szeroki stosunek C:N wynoszący w glebach nawożonych wyłącznie nawozami mineralnymi 14:1. Wartość tego stosunku w glebach nawożonych obornikiem wynosiła przeciętnie 11,7:1.

Większość azotu w glebie była związana z kwasami huminowymi i fulwowymi – najbardziej dynamiczną i podatną na mineralizację frakcją glebowej materii organicznej.

Słowa kluczowe: doświadczenia wieloletnie, nawożenie, materia organiczna gleby, węgiel i azot w glebie