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FRACTIONS OF HUMUS COMPOUNDS IN SOIL FERTILISED WITH SEWAGE SLUDGE AND VERMICOMPOSTS

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Abstract

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Four-year investigations conducted as a field experiment aimed to determine the effect of organic fertilisation with farmyard manure, tannery sludge and vermicompost obtained from it on soil humus compounds composition. Equal to farmyard manure effect of vermicompost on organic carbon and total nitrogen was determined in the discussed experiment. Organic carbon content diminished as a result of mineral treatment and fertilisation with untreated sludge. The number of most mobile humus fractions decreased in result of applied fertilisation where as the share of humus compounds not undergoing hydrolysis increased.

soil, fractions of humus, fertilisation, sewage sludge, vermicompost

Organic matter belongs to the most important soil components. It considerably modifies physical, chemical and biological soil properties and plays an important role in heavy metal sorption. Humus, which forms in result of breakdown, transformation and synthesis of organic compounds under climatic and biotic conditions changing in time, constitutes an essential part of soil organic matter (BORATYŃSKI et al., 1988). Intensive tillage and increasing shares in the cropping systems of plants degrading organic matter make necessary seeking alternative solutions to alleviate the results of soil depletion of this valuable substance.

Sewage sludge supplied to the soil pose a hazard of soil environment pollution with toxic substances but also brings considerable amounts of organic matter, which may recompense these negative effects. Utilisation of various kinds of tannery sludge and their composts for treatment may positively influence quantitative and qualitative composition of soil humus compounds (FLIS-BUJAK et al., 1986, NIEMYSKA-ŁUKASZUK and FILIPEK-MAZUR, 1996).

The investigations were carried as a four-year field experiment to determine the effect of organic fertilisation with farmyard manure and tannery sludge and vermicomposts obtained from it on the composition of humus compounds in soil.

MATERIAL AND METHODS

The field experiment was conducted in 1996-1999 at Sędziszów Małopolski near Rzeszów. The experimental materials were unprocessed sewage sludge from mechanical-and-biological sewage treatment plant of Krakow Tannery and vermicomposts based on the sludge with 20% addition of wheat straw and fruit tree leaves in relation to the sludge dry matter. The composting time was 9 months and after this period vermicomposting by Eisenia fetida redworm started in the composted mass and lasted for 6 months. Beside tannery sludge from biological sewage treatment plant and its vermicomposts, also unprocessed sludge from chemical tannery sludge treatment plant "Mat" at Cerekiew near Radom was used for fertilisation. Farmyard manure and mineral fertilisation were used to compare the fertiliser effect of the organic materials of tannery origin.

The experiment was set up by randomised block method comprising 7 objects in four replications.

The experiment was conducted on proper brown soil, medium compact with 40% of floatable particles and pH in 1 mol · dm^{-3} KCl solution 5.29. Cation exchange capacity was 138.6 mmol(+) · kg^{-1} and hydrolytic acidity 22.9 mmol(+) · kg^{-1}. The soil contained 1.70 g · kg^{-1} of total nitrogen, 14.5 g · kg^{-1} of organic carbon, 95.9 mg P · kg^{-1} soil of available phosphorus and 109.6 mg K · kg^{-1} soil of available potassium.

Chemical composition of the experimental materials was given in tab. I. The studies had commenced before the Regulation of the Minister of Natural Environment on the requirements concerning sewage sludge application for soil treatment came into force. Thus, high chromium concentrations did not prevent tannery sludge application.

I: *Chemical composition of organic materials used in experiment*

Determination	FYM	Not converted deposit		Vermicompost*	
		Biological	Chemical	Straw	Leaf
Dry mass %	26.25	34.15	23.17	43.75	46.88
% in dry mass					
Organic - C	27.30	23.60	16.20	19.00	18.00
Total – N	1.79	3.95	4.72	1.79	2.43
C : N	15.20	6.00	3.40	10.60	7.40
P_2O_5	0.93	0.96	0.21	1.22	0.83
K_2O	1.37	0.13	0.01	0.45	0.38
Ca	0.93	9.87	4.19	9.38	7.66
Mg	0.39	0.27	0.06	0.35	0.26
Na	0.95	0.44	0.34	0.27	0.23
mg · kg^{-1} dry mass					
Cu	8.38	28.20	4.53	64.50	47.30
Cr	150.00	7121.00	400.00	9584.00	7084.00
Pb	9.24	25.40	18.50	28.80	24.40
Cd	0.55	0.64	0.07	0.78	0.54

* prepared from biological deposit

The doses of sewage sludge and vermicomposts used in the first year of the experiments were calculated according to their nitrogen concentrations. They were equal to the nitrogen amount in farmyard manure dose. The accepted dose was 100 kg N · ha^{-1}. Doses of phosphorus and potassium were supplemented with mineral fertilisers to the highest amount per organic fertiliser dose. After organic treatment the following crops were cultivated: fodder beets in the first year, potatoes in the second, maize in the third and winter wheat in the fourth. Equal mineral fertilisation was applied under all cultivated crops (from the second to the fourth year) on the level determined according to agrotechnical requirements for the cultivated plants.

Soil was sampled for analysis from the 0-20 cm arable layer and prepared as weighed means from four replications on each object. In the way any randomness, due to soil changeability, was eliminated. The samples were collected after the first, and fourth year of the experiment.

In the mean soil samples, soil reaction was assessed by potentiometer in 1 mol · dm^{-3} KCl solution, total nitrogen by Kjeldahl's method in automatic Kjeltec II Plus apparatus and organic carbon by Tiurin's method. Humus fractional composition was analysed by Kononowa-Bielczikowa's method. The fractions of humus compounds were extracted from soil using 0.05 mol · dm^{-3} H_2SO_4 solution and a mixture of 0.1 mol · dm^{-3} $Na_4P_2O_7$ + 0.01 mol · dm^{-3} NaOH. In the obtained concentrates total carbon was assayed by Tiurin's method and extract humic acid carbon after its precipitation from the extract following extricating with $Na_4P_2O_7Na_4P_2O_7$ + 0.01 mol · dm^{-3} NaOH, whereas fulvic acid carbon was computed from the difference between the total amount of organic carbon in the extract and its amount in humic acids.

RESULTS

Fertilisation with organic materials of tannery origin caused a raise in soil reaction measured in 1 mol · dm^{-3} KCl solution (tab. II). The changes were clear after the first year, however, after four years the de-acidifying activity of organic materials was marked only on straw vermicompost treatment.

Fertilisation applied in the experiment influenced a diversification of organic carbon contents (tab. II). The changes depended on the amount of organic substance supplied to the soil. A decrease in organic carbon contents in relation to the control object was noted in soil as the effect of mineral fertilisation after the first year of the experiment. It deeped after four years. Treatment with vermicomposts based on biological sludge acted similarly as FYM treatment. Fertilisation with unprocessed, particularly chemical sludge, had some less positive effect on organic carbon concentrations.

Soil total nitrogen concentration after the first year of the experiment increased in relation to the soil prior to the experiment outset in result of mineral treatment, NPK, FYM and vermicomposts, whereas fertilisation with unprocessed sludge (biological and chemical) caused a slight decrease in this content (tab. II). As a consecutive effect of applied fertilisers the level of total N in soil was little diversified after four years of investigations.

Small changes of carbon and nitrogen soil contents did not cause any visible changes in C:N ratio (tab. II). Only in the soil receiving mineral fertilisation after the first year a considerable decrease in this ratio to 7.26 level was observed, which was by over one narrowest C : N ratio was found, like after the first year, in the soil receiving mineral treatment – NPK (6.92) and in the soil fertilised with unprocessed biological (6.91) and chemical (7.07) sludge. The decrease resulted from diminishing amount of organic carbon and increasing content of total nitrogen due to mineralisation occurring in soil.

II: *The changes of reaction, contents of organic C and total N in soil*

Fertiliser treatments	pH_{KCl}		Organic - C		Total - N		Ratio C : N	
			g · kg^{-1}					
Soil before experiment	5.29		14.5		1.70		8.52	
Year	1996	1999	1996	1999	1996	1999	1996	1999
A. Control	5.20	5.05	14.6	14.5	1.53	1.63	9.54	8.90
B. Mineral fertilisation	5.09	5.00	12.7	11.7	1.75	1.69	7.26	6.92
C. FYM	5.29	5.23	14.9	14.5	1.77	1.72	8.42	8.43
D. Straw vermicompost*	5.89	5.52	15.5	14.3	1.76	1.67	8.81	8.56
E. Leaf vermicompost*	5.57	5.29	14.3	13.7	1.75	1.64	8.17	8.35
F. Biological sludge	5.48	5.39	13.6	13.2	1.66	1.91	8.19	6.91
G. Chemical deposit	5.41	5.27	13.9	11.8	1.64	1.67	8.48	7.07

* prepared from biological deposit

The contents of low-molecular humus compounds extracted from soil with 0.05 mol · dm^{-3} H_2SO_4 solution immediately after fertilisation (the first year of the experiment) was small and ranged between 1.4 and 2.4% of carbon total (tab. III). An increase in this content was found after four years of the experiment. The soil concentrations of these compounds ranged between 2.1 and 4.0% C total. The highest increase (in relation to the amount found after the first year) occurred as a consecutive effect of organic tannery materials and ranged between 45 and 123%.

After the first year the biggest number of carbon fractions were extracted from soil by a mixture of 0.1 mol · dm^{-3} $Na_4P_2O_7$ + 0.01 mol · dm^{-3} NaOH solutions. The amounts ranged between 32 and 44% in relation to carbon total and diversification of the discussed humus compound fractions was mainly conditioned by the kind of treatment. Soil fertilised with organic materials (vermicomposts and unprocessed sludge) was poorer in this humus fraction as compared to the soil receiving mineral NPK and farmyard manure. After four years of the investigations the amount of the discussed fraction declined in soil of all treatments (tab. III). In relation to the soil sampled in the first year the greatest decline after four years occurred in soil fertilised with FYM and mineral NPK, on an average by over 37%, then on control soil by over 27%, whereas the lowest decrease

III: *The changes of fractional composition of organic matter*

Fertiliser treatments	C extracted				C Nonhydrolizing	
	0.05 mol · dm^{-3} H_2SO_4		0.1 mol · dm^{-3} $Na_4P_2O_7$ + 0.1 mol · dm^{-3} NaOH			
	% total C					
Soil before experiment	1.7		32.7		67.3	
Year	1996	1999	1996	1999	1996	1999
A. Control	1.8	2.1	37.9	27.4	62.1	72.6
B. Mineral fertilisation	2.4	4.0	44.0	32.2	56.0	67.8
C. FYM	2.0	2.4	41.4	21.0	58.6	79.0
D. Straw vermicompost*	1.4	2.9	31.6	22.5	68.4	77.5
E. Leaf vermicompost*	1.7	3.6	35.0	23.9	65.0	76.1
F. Biological deposit	1.7	3.8	36.8	24.4	63.2	75.6
G. Chemical deposit	2.2	3.2	36.0	33.6	64.0	66.4

* prepared from biological deposit

in comparison to the first year was noted on organic treatments (on an average by 25%).

Both in the soil analysed immediately after applied fertilisation and after four years, humic acid content was almost in each case lower than fulvic acid amount (tab. IV). The quantity of humic acid carbon (after the first year of the investigations) was the biggest in soil fertilised with farmyard manure (20.3% C total), whereas the smallest concentrations of humic acids in % of C total were found in the soil fertilised with unprocessed biological and chemical sludge, respectively 19.2% and 16.1% C total, and in the soil receiving vermicompost with added straw (12.2%). After four years the amount of humic acids lowered most in the soil fertilised with farmyard manure (by over 75%) and in soil receiving unprocessed biological sludge (by over 67%). In the soil fertilised with vermicomposts and unprocessed chemical sludge the average decrease reached 49%.

The quantity of fulvic acids was lower in the soil fertilised with organic materials (tab. IV). The most of fulvic acids were found in the control soil and on farmyard manure and mineral NPK treatment. After four years the amount of fulvic acids, like humic acids decreased in the untreated soil, in the soil receiving mineral treatment, treated with FYM and vermicomposts, but it increased in result of unprocessed sludge treatment.

IV: *The content of humic acids in the fraction extracted by $Na_4P_2O_7$ 0.1 mol · dm^{-3} + NaOH 0.1 mol · dm^{-3}*

Fertiliser treatments	Humic acids					
	C-HA		C-FA		C-HA : C-FA	
	% total C					
Soil before experiment	17.4		15.3		1.14	
Year	1996	1999	1996	1999	1996	1999
A. Control	15.7	5.3	22.2	22.1	0.71	0.24
B. Mineral fertilisation	19.3	9.8	24.1	22.4	0.80	0.44
C. FYM	20.3	4.9	21.1	16.1	0.96	0.30
D. Straw vermicompost*	12.2	6.7	19.4	15.8	0.63	0.42
E. Leaf vermicompost*	17.3	7.5	17.7	16.4	0.98	0.46
F. Biological deposit	19.2	6.3	17.6	18.1	1.09	0.35
G. Chemical deposit	16.1	8.7	19.9	24.9	0.81	0.35

* prepared from biological deposit

The interdependence between humic and fulvic acids has been visible as the value of C_{Ha}: C_{Fa} ratio (tab. IV). The ratio decreased definitely (on average by 55%) after four years of the fertilisation application.

Humus compounds insoluble in the applied solutions so called non-hydrolysing carbon (tab. III) were the dominant fractions in the soil of all treatments. The insoluble fraction constituted up to 60% in the soil fertilised with mineral NPK and farmyard manure, whereas in the untreated soil and fertilised with organic tannery materials it exceeded 60%. The amounts increased after the fourth year of the studies and actually assumed the value over 70%, except the soil treated with mineral NPK and unprocessed chemical sludge.

DISCUSSION

The effect of fertilisation with organic materials on organic carbon and total nitrogen contents found in the discussed experiment is comparable with farmyard manure effect. On the other hand MAZUR and KOC (1976) reported a more beneficial effect of tannery sludge than farmyard manure on soil carbon contents total. The quoted authors ascribe this positive activity to a rate of decomposition in soil because due to organic mass character they decompose more slowly than farmyard manure. They also emphasise considerable changes in C:N ratio value under the influence of sludge treatment, which has not been found in the presented studies. In their investigations on fractional composition of humus in soil fertilised with farmyard manure, unprocessed and composted sludge FILIPEK-MAZUR et al. (1999) did not find any greater changes in organic carbon or total nitrogen content. However, they revealed decreased share of low-polymerised fractions in humus compounds and an increase in the share of humus substances which do not undergo hydrolysis by the applied extractants and no directed influence of the applied fertilisation on C_{Ha}: C_{Fa} ratio. In some earlier studies on fractional composition of humus compounds in composts and vermicomposts based on sewage sludge, FILIPEK-MAZUR and GONDEK (2000) found a slight share of humic and fulvic acids in the tested composts and vermicomposts, but a great share of humus compounds which do not undergo hydrolysis. The studies might partly explain no major influence of the organic materials used for the experiment on humic acid contents in the fertilised soil. Also NIEMYSKA-ŁUKASZUK and FILIPEK-MAZUR (1996) formulated similar conclusions while investigating the effect of fertilisation with farmyard manure, unprocessed biological sludge and composted sludge on fractional composition of soil humus.

CONCLUSIONS

1. The effect of applied treatment with tannery sludge composed by Eisenia fetida on organic carbon and total nitrogen contents approximated farmyard manure effect.
2. Fertilisation with organic materials and mineral treatment influenced increased amounts of humus compounds extracted by 0.05 mol · dm^{-3} H_2SO_4 solution.
3. Both fertilisation with farmyard manure and organic materials lowered the contents of low molecular humus compounds extracted from soil by 0.1 mol · dm^{-3} $Na_4P_2O_7$ + 0.01 mol · dm^{-3} NaOH solutions, but increased the share of humus compounds which do not undergo hydrolysis with the applied chemicals.

SOUHRN

Frakce humusových látek v půdě hnojené čistírenskými kaly a vermikomposty

Cílem čtyřletého sledování bylo posouzení vlivu hnojení chlévským hnojem, koželužskými kaly a vermikompostem vyrobeným z těchto kalů na složení humusových látek v půdě. Hnojení vermikompostem a hnojení chlévským hnojem mělo na obsah organického uhlíku a celkového dusíku v půdě stejný vliv. Při aplikaci minerálních hnojiv a při hnojení neupravovanými kaly se obsah organického uhlíku v půdě snížil. Obsah pohyblivých humusových látek se vlivem hnojení snižoval, zatímco podíl nehydrolyzovatelných humusových látek narůstal.

půda, humusové frakce, hnojení, čistírenské kaly, vermikompost

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