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THE INFLUENCE OF EXOGENIC ORGANIC MATTER ON SELECTED CHEMICAL AND PHYSICOCHEMICAL PROPERTIES OF SOIL

Abstract. Organic matter plays an important role in stability and fluxes of trace greenhouse gases between land surface and atmosphere. A steady decline of soil organic matter in Poland is observed, therefore the pending problem and new challenge is to increase its level, particularly in sandy soils. In the last decades a growing interest in various sources of organic matter, for example brown coal, its derivatives and composts – has been observed. Organic matter applied in the form of the brown coal (Rekulter preparation), brown coal, peat, and farmyard manure resulted in changes of selected chemical and physicochemical properties of the soil. One year after application of organic matter, the highest increase in soil reaction pH was found in the case of Rekulter, and the same behaviour was observed seven years after its application. Remarkable influence on sorption properties of soil was in the case of brown coal and brown coal preparation. Exogenic organic matter increased the TOC and the total N, occurring mainly in the case of the Rekulter. The highest value of the TOC to Nt ratio equalling 20 obtained for the soil sample with the Rekulter was due to the highest carbon content in this object. It was found that after introduction of this organic matter into the soil, the value of the C:N ratio increased as compared to control soil ones.

Agricultural and ecological function of humus is usually appreciated because its quantity and quality decides about soil fertility [9]. The addition of organic matter (OM) to soil has been shown to improve aggregation, water-holding capacity, hydraulic conductivity, bulk density, the degree of compaction, and resistance to water and wind erosion [2, 5, 7, 14, 21]. Soil chemical properties are improved by organic amendments through their contribution to soil cation

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exchange capacity, enhancing the ability of soils to buffer pH changes, and cation complexation [21].

Consequently, the significant problem is the maintenance of constant level of humus or even its increase. The basic sources of soil humus are plant residues, traditional organic fertilisers, and the substance obtained from various materials of organic origin. It is, however, widely accepted that not only the quantity but also the quality of the organic matter applied has a significant influence on properties of soil. However, there is little fundamental knowledge about the specific effects of various kinds, i.e. qualities of OM, on soil properties and functions. A growth of interest in the fertilisers obtained from brown coal has been noted in the last years [4, 12, 13, 16]. The advantageous influence of brown coal on the soil results from its properties, chemical composition, and its structure. The advantage of brown coal as a substratum and fertiliser is the big resistance to decomposition which causes that once the brown coal has been applied, the contents of organic matter in the soil are kept increasing even for a period of nine years. The research carried out by Maciejewska et al. [15] has proven that fertilisation soil with brown coal preparations causes both enriching the soil with humus and increasing sorption and water capacity of soil.

The purpose of the study has been to investigate the influence of exogenic organic matter from different sources introduced into Haplic Luvisols on selected chemical and physicochemical properties of soil as well as on contents of organic carbon and Nt in the soil.

MATERIAL AND METHODS

The research was carried out in ground pots called “stonepots” of 40cm in diameter and 120cm in height filled up with 56 kg of prepared soil’s material, situated in an open area. They are filled with lessive soil originated from light clay sand on light clay (7% clay, 6% silt, 87% sand). The Rekulter, brown coal, peat and farmyard manure were mixed and introduced 20 cm deep into the soil as one-off inserts. Brown coal preparation “Rekulter” contained 85% of brown coal, 10% of peat and 4% of brown coal ash. Chemical compositions of applied brown coal, Rekulter, peat and farmyard manure are outlined in the Table 1. In autumn 1999 the amendments mentioned above were accordingly applied in doses: 140, 180, 390 and 630g per a stonepot, respectively, which was 5 t C-org per ha converted to organic carbon. Soil samples were taken at the depth of 0-20cm, before the start of the experiment in 1999 and after the crop harvesting in 2006. The air-dried soil samples were gently shaken by hand over sieves of mesh sized 2 mm. The following parameters were determined: pH_{H20} and pH_{KCl} was measured potentiometrically in a 1:2.5 soil:extract, hydrolitic acidity (Hh) and total exchangeable bases (TEB) – by means of the Kappen’s method, the total organic carbon (TOC) – by means of the Tiurin’s method, and the total nitrogen (Nt) content – by means of the Kjeldahl's method. Additionally, cations exchange capacity (CEC) and base saturation (BS) were calculated. The influence of the addition of organic matter at selected chemical and physicochemical properties of soil was tested by means of the variance analysis, using Statgraphics 4.1 and significant differences between means (3 replications) were determined by means of the Tukey's test.

TABLE 1. CHEMICAL COMPOSITION OF ORGANIC AMENDMENTS (IN % D.M.)

Element	Brown coal	Rekulter	Peat	Farmyard manure
Organic carbon (C)	70.00	62.00	50.00	32.00
Calcium (Ca)	3.90	8.00	2.10	1.02
Nitrogen (N)	0.65	0.68	2.50	2.34
Phosphorus (P)	0.10	0.50	0.14	1.01
Potassium (K)	0.07	0.25	0.08	1.33
Magnesium (Mg)	0.90	0.50	0.25	0.19

RESULTS AND DISCUSSION

The application of organic matter in the form of the brown coal Rekulter preparation, brown coal, peat, and farmyard manure had a significant effect on the soil chemical and physicochemical properties. Basic properties of soil are given in the Table 2. On all of the organically amended plots, the values of basic properties of soil samples were greater than on the unfertilised once. The results of the analysis of changes in basic soil properties due to application of the Rekulter, brown coal, peat and farmyard manure were at the similar level in the first year (1999) after application of these amendments and in the consecutive experimental year (2006). There were even significant differences between the application of different exogenic organic matter, with the highest values of basic properties of soil on the Rekulter plots, followed by the brown coal, farmyard manure and peat. The soil reaction (pH_{KCl}) increased from 4.95 (control) up to 6.09 and 6.13 in 1999 year after introduction of organic matter from brown coal and the Rekulter, respectively. The smallest value of soil reaction (pH_{KCl}) as compared between exogenic organic matter, was for the peat plot. This was the effect of the role of organic matter in soil which has the ability to moderate major changes in the soil pH. Organic matter buffers the soil against major swings in pH by either taking up or releasing H^+ into the soil solution, making the concentration of soil solution H^+ more constant. The result of application of organic matter from brown coal was a stable pH close to neutral. There is the same one referred to in the literature about the effect of organic matter on soil reaction [18].

Exogenic organic matter increased the total organic carbon (TOC) and the total nitrogen (Nt), occurring mainly in the case of the Rekulter (Table 2). In the A horizon (0-20 cm) the content of total organic carbon (7.0 g kg^{-1}) in soil control material represents – in view of Barancikova [1] – the results of the middle degree of humus for Haplic Luvisols, which is characteristic for agriculture soils. In plots with the Rekulter, the TOC decreased from about 16.9 $g\,kg^{-1}$ after one year (1999) to 15.9 $g\,kg^{-1}$ after seven years (2006) of its application. This data may be an indication that, after 7 years ameliorated with brown coal and/or brown coal preparation sites, accumulated carbon in light mineral soil, they contain more carbon as compared to soil in natural conditions. However, a comparison of absolute amounts of the TOC accumulation in soil in warmer and drier climates is smaller than in soil in cooler and moister climates [7]. The farmyard manure plot had surprisingly low level of total organic carbon, almost similar to the organically unfertilised control plot. Generally, higher amounts of total organic carbon (from 7.8 to 16.9 $g\,kg^{-1}$) were found in soil with organic amendments. Normally, accumulation of soil organic carbon at the soil surface is a result of surface placement of crop residues and a lack of soil disturbance that has kept residues isolated from the rest of the soil profile [7]. A more rapid increase in carbon content has been suggested by Valera et al. [19] for a Spanish mine soil, with the carbon content of 30 $g\,kg^{-1}$ after only 5 years of revegetation. Rumpel et al. [17] has shown the same situation of the reclamation sites, too. In general, soil organic matter turnover rates are determined by the proportion of "old" (stable) and "younger" (less resistant) organic matter. Soils with a low organic matter content contain relatively high proportions of "young" soil organic matter, resulting in rapid initial organic matter decomposition.

The amount of the Nt was also significantly affected by exogenic organic matter, and the increase in soil organic total nitrogen varied between treatments.

TABLE 2. BASIC PROPERTIES OF SOIL

Treatment	pH		TOC	N_t	$TOC:N_t$
	H_2O	KCl	($g\,kg^{-1}$)		
1999 year					
Control (soil)	5.20	4.95	7.0	0.51	13.6
Brown coal	6.32	6.09	15.4	0.80	19.3
Rekulter	6.36	6.13	16.9	0.83	20.4
Peat	5.24	4.98	9.1	0.60	15.2
Farmyard manure	5.26	5.06	7.8	0.55	14.2
LSD $\alpha = 0.05$	0.019	0.009	0.13	0.009	0.06
2006 year					
Control (soil)	5.15	4.85	7.1	0.54	13.1
Brown coal	6.19	6.04	14.9	0.78	19.1
Rekulter	6.25	6.05	15.9	0.80	19.9
Peat	5.09	4.91	9.0	0.64	14.0
Farmyard manure	5.20	4.96	6.2	0.54	11.5
LSD $\alpha = 0.05$	0.023	0.022	0.42	0.021	0.08

TOC – total organic carbon; N_t – total nitrogen.

This may have been a result of the specific properties and quality of the applied organic matter (e.g. humification coefficient). The Nt content ranged from 0.51 to 0.83 $g\,kg^{-1}$ in 1999 year (Table 2). As for the Nt, the highest values were found on the Rekulter plots and the lowest – on farmyard manure plots. The Rekulter application in soil caused almost 40 % increase in the Nt (1999) as compared to the control one and was found almost at the some level in 2006. In other experiments with the Rekulter and brown coal amendments, similar results were obtained [16].

The highest value of the TOC to Nt ratio equalling 20.4 obtained for the soil sample with the Rekulter was due to the highest carbon content in those plots (Table 2). It was found that after introduction of this organic matter into the soil, the value of the TOC:Nt ratio increased as compared to non-treatment ones. On the basis of the values of the TOC: N_t ratio, the content of nitrogen of soil material is at the medium level and characteristic for Haplic Luvisols. Those tendencies were also observed in 2006 year. It is common knowledge that aggregate stability is correlated with the soil organic carbon content [3, 6] and all studies referred to [2, 10, 11] reported a considerable increase in soil organic carbon content because of organic fertilisation. It was surprising that significant effects of organic fertilisers on the soil physicochemical properties occurred after shorter than 1 year of organic matter application.

Selected chemical and physicochemical properties of soil after application of different sources of organic matter are presented in the Table 3. The remarkable influence on sorption properties of soil was found in the case of brown coal and brown coal preparation. The decrease in hydrolytic acidity (Hh) was observed after

TABLE 3. PHYSICOCHEMICAL PROPERTIES OF SOIL

Treatment	Hh	TEB	CEC	BS
	(cmol(+)·kg^{-1})			%
1999 year				
Control (soil)	4.7	2.7	7.4	36.5
Brown coal	1.1	14.2	15.3	92.8
Rekulter	1.0	15.6	16.6	93.9
Peat	1.8	13.1	14.9	87.9
Farmyard manure	3.4	6.2	9.6	64.6
LSD $\alpha = 0.05$	0.36	0.42	0.62	0.31
2006 year				
Control (soil)	4.5	3.9	8.4	46.4
Brown coal	1.7	14.4	16.1	89.4
Rekulter	1.3	15.4	16.7	92.2
Peat	1.8	12.1	13.9	88.2
Farmyard manure	3.5	6.0	9.5	63.2
LSD $\alpha = 0.05$	0.35	0.38	0.42	0.21

Hh – hydrolytic acidity; TEB – total exchange basic cations; CEC – cation exchange capacity; BS – base saturation.

addition of organic amendments but the highest decrease was found in soil sample with Rekulter (1.0 cmol(+) kg^{-1}) one year after application and (1.3 cmol(+) kg^{-1}) seven years after its application.

A high sorption capacity of organics, especially of brown coal, significantly influenced sorption properties of soil treated with them (Table 3). The high sorption capacity of the Rekulter significantly influenced the total exchangeable basic (TEB), cations exchange capacity (CEC), and base saturation (BS) of amended soil. A significant increase in soil sorption capacity as well as the degree of the saturation of sorption complex with alkali of the soil under consideration was found. The TEB of soil with the Rekulter in 1999 and 2006 ranged between 15.6 cmol(+) kg^{-1} and 15.4 cmol(+) kg^{-1}. Sorption capacity of soil amended with the Rekulter increased above twice (from 7.4 to 16.6 cmol(+)· kg^{-1}) in 1999, while the degree of saturation with alkali was near 94% (increased from 36.5 to 93.9%). Similar trends were also observed seven years after the Rekulter application in 2006.Typical values for the CEC of soils dominated by kaolinite and amorphous oxides ranged from 2 to 6 cmol kg^{-1} [8]. Besides, the TOC content of soil did not explain an additional significant part of the CEC. This has proven our assumption that differences in the CEC in this soil were due to differences in soil organic matter content. Thanks to its sorption abilities, organic matter contained in the Rekulter also increased buffering properties of soil. It is very important that improvement of soil sorption properties was at the same level seven years after the Rekulter application. A relatively constant concentration of organic carbon for about seven years of experiment has suggested that mineralization process of organic matter introduced with brown coal, the Rekulter and peat is rather slow. It is of great importance in the case of sandy and degraded soils, in which organic matter contents is usually low. As it results from this study, exogenic organic matter used just once significantly improved soil selected chemical and physicochemical properties. The activity of it was both direct and indirect. The first one resulted from its chemical composition, i.e. the content of macro- and micro-elements, while the second one was caused by its structure, especially by the well-developed porous system [12].

CONCLUSIONS

1. The treatment with brown coal, brown coal preparation – Rekulter, farmyard manure and peat improves selected chemical and physicochemical properties of soil, especially the increase in cations exchange capacity and base saturation.

2. As the result of organic matter application, the content of the TOC and Nt increased, besides their slight drop observed with time (seven years), they were kept at a high and advantageous level, not commonly found in very light soils. There also occurred a significant increase in the TOC: Nt ratio.

3. Exogenic organic matter from the different sources studied decreases soil acidity, soil reaction and hydrolytic acidity, both in a direct and sequential

way. The highest decrease in Hh was observed one year and seven years after its application.

4. The Rekulter had a beneficial impact on soil sorption properties increasing the total exchangeable bases (TEB), cations exchange capacity (CEC), and base saturation (BS) of soil. Sorption capacity of soil amended with it increased twice in 1999, while the degree of saturation with alkali was near 94%.

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WPŁYW EGZOGENNEJ MATERII ORGANICZNEJ NA WŁAŚCIWOŚCI FIZYKO-CHEMICZNE GLEB

Substancja organiczna zastosowana w postaci preparatu z węgla brunatnego Rekultera, węgla brunatnego, torfu i obornika poprawiała właściwości fizykochemiczne gleby. Rok po wprowadzeniu materii organicznej oraz siedem lat, najbardziej korzystnie na poprawę odczynu gleby i właściwości sorpcyjne jak również istotny wzrost zawartości węgla organicznego i azotu ogól-

nego wpłynął węgiel brunatny i Rekulter. Otrzymane wyniki potwierdzają rezultaty badań przeprowadzonych przez autora wcześniej, dotyczących właściwości sorpcyjnych węgla brunatnego oraz zawartości zasadowych kationów wymiennych.