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Effect of differentiated fertilization on the content of soil organic carbon in the conditions of long-term fertilization experiment

ABSTRACT. On the basis of two long-term fertilization experiments performed on the SGGW experimental field at Łyczyn, the effect of particular fertilizer components (N, P, K, Ca) and manure as well as the application of the increasing doses of mineral fertilizers (0, 2 NPK, 3 NPK, 4 NPK) on the accumulation of organic carbon in the soil was studied. Long-term differentiated fertilization significantly modified the content of organic carbon in the soil. In the light soil, which was the subject of the study, the accumulation of organic carbon depended mainly on the application of manure. The content of organic carbon in the soil on the object fertilized with manure was about 33% higher as compared to the object fertilized with mineral fertilizers exclusively. Out of the main fertilizer components (N, P, K), the positive effect on the organic matter content in the soil was observed in the case of nitrogen fertilization and liming. On the objects fertilized with mineral fertilizers and liming the content of organic carbon in the soil increased about 7% in relation to the initial organic C content in the soil prior to the experiment. On the other hand, no effect of phosphorus and potassium fertilization on the soil organic carbon content was observed. An advantageous effect of liming on the content of organic carbon in the soil was marked mainly on the treatments fertilized with mineral fertilizers together with manure. On the limed treatments the level of the organic carbon content in the soil was about 7% higher as compared with the non-limed, highly acidified objects. Independently of the NPK dose the exclusive mineral fertilization does not affect the content of organic carbon in the soil. The application of the growing doses of mineral fertilizers (NPK) together with manure resulted in a systematic increase of the organic carbon content in the soil.

KEY WORDS: organic matter, soil, mineral fertilization, organic fertilization

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The organic carbon content in the soil is one of the basic components determining its fertility [Bauer, Black 1994]. The soil content of organic matter depends on many factors, out of which the following can be distinguished: type of soil, climatic conditions, and the amount of plant residues passing into the soil and also mineral and organic fertilization [Lass et al. 1994; Chander et al. 1997; Salinas-Garcia et al. 1997]. The application of manure and other organic fertilizers helps the accumulation of organic carbon in the soil. Mineral fertilization, and particularly nitrogen fertilization, applied separately or together with organic fertilizers may affect the accumulation of organic matter in the soil or it can lead to the loss of organic carbon as a result of acceleration of the process of mineralization of the soil organic matter [Gregorich et al. 1996, Raun et al. 1998].

The work aimed at determining the effect of various mineral fertilization, the use of manure and liming on the content of organic carbon in the light soil under the conditions of a long-lasting fertilization experiment.

METHODS

The studies were carried out on the basis of a long term static field experiment started in 1965 on the light soil. The soil of those treatments belongs to the fading type. The upper layer is the light loamy sand on the light boulder clay. As a result of various fertilization treatments the content of nutrients differed significantly. The content of available phosphorus varied from 8.7 to 174.5 mg P kg^{-1} soil, the content of available potassium ranged to from 16.6 to 166.0 mg K kg^{-1} soil, while the content of available, magnesium from 3.0 to 34.0 mg Mg kg^{-1} soil. The soil pH on the non limed treatments amounted to 4.0-4.6 pH in 1 mol KCl dm^{-3} and on limed objects to 5.8-7.2 pH in 1 mol KCl dm^{-3}. The content of total organic carbon amounted to 5.9 g kg^{-1} and total nitrogen 0.68 g kg^{-1}. In both experiments mineral fertilization was applied in the form of ammonium nitrate, triple superphosphate and potassium chloride.

Experiment I. This experiment was carried out on sixteen fertilization treatments which were fertilized at random with main nutrients such as: nitrogen, potassium phosphorus and lime with or without manure. Together, the experiment includes 32 fertilization treatments in four repetitions. The experiment is performed in a four course crop rotation: potatoes, spring barley, rape, rye. Mineral fertilization was applied in various doses under cultivated plants which amounts to 334 kg NPK per 1 ha yearly in crop rotation. Liming was applied every four years in the rate of 0.96 t CaO per 1 ha. Manure dose were applied 30 t ha^{-1} and 20 t ha^{-1} under potatoes and rape, respectively.

Experiment II. This experiment included treatments without manure, treatments with manure and 5 increasing levels of mineral fertilization: 0, NPK, 2 NPK, 3 NPK, 4 NPK. Together, the experiment included ten fertilization treatments in four repetitions. The experiment was performed in a four course crop rotation: potatoes, spring barley, charlock, winter wheat. The levels of mineral fertilization varied depending on the plant in crop rotation which in recalculation per 1 ha in crop rotation amounted to the doses: 0, 72, 144, 216, 288 kg NPK. The dose of manure calculated per 1 ha a year application was 12.5 t. Liming was applied every four years according to 1.5 hydrolytic acidity.

Soil samples for the study were collected in both experiments in the autumn, after harvest, and the content of organic carbon was determined in them with the help of dry distillation using the C-MAT 5500 apparatus.

Results

Long term differentiated fertilization significantly modified the content of organic carbon in the soil (Tab. 1). Out of four analyzed systems of fertilization (exclusively mineral fertilization, mineral fertilization with liming, mineral fertilization with manure and mineral fertilization with manure and liming) the highest increase of the soil organic carbon content as compared to the initial organic carbon content was noted in the case of mineral fertilization applied together with manure and liming. It was an increase by 46% as compared to the organic carbon content in the soil prior to the experiment (Tab. 1).

Table 1. The influence of mineral fertilization, farmyard manure and liming on the soil organic carbon content

Fertilization	Fertilizing element								Mean
	0	N	P	K	NP	NK	PK	NPK	
	g kg^{-1} of soil								
Mineral	6.3	6.5	5.5	6.0	7.4	6.4	6.0	6.4	6.3
Mineral + CaO	6.8	6.5	5.7	6.2	6.6	6.5	6.3	6.1	6.3
Mineral + FYM	8.0	8.0	8.0	8.1	7.8	8.5	7.9	7.8	8.0
Mineral + FYM +CaO	8.6	8.7	8.2	8.2	8.4	8.8	9.0	8.8	8.6
Mean	7.4	7.4	6.9	7.1	7.6	7.6	7.3	7.3	

The content of organic carbon in the soil on the object fertilized with manure was about 33% higher as compared to the object fertilized with mineral fertilizers exclusively (Fig. 1). A beneficial effect of organic fertilization on the content of organic carbon in the soil was confirmed in the studies by many authors [Lass et al. 1994; Chander et al. 1997; Kanchikerimath, Singh 2001].

On the fertilized treatments with mineral fertilizers only (mineral and mineral + CaO) the content of organic carbon in the soil increased only by about 7% in relation to the initial org-C content in the soil prior to the experiment (Tab. 1). While studying the effect of particular fertilizer components on the soil content of organic carbon no changes in the org-C content were observed as an effect of potassium fertilization but a slight decrease of the content of organic carbon was noted in the case of phosphorus fertilization. The nitrogen fertilization and liming resulted in the increase of the content of organic carbon in the soil (Fig. 1). Mineral fertilization and in particular nitrogen fertilization may promote the accumulation of organic matter in the soil or may lead to the loss of org-C from the soil as a result of the increase of the rate of mineralization of the soil organic matter [Mercik et al. 1995].

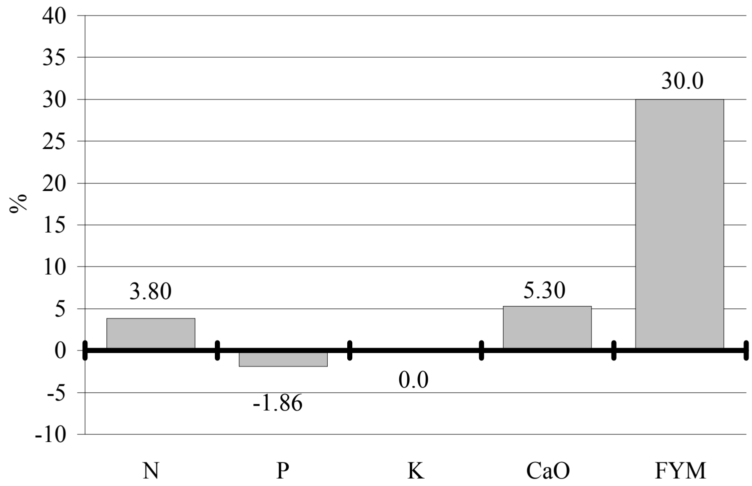

Figure 1. Effect of mineral fertilization, liming and the use of manure on the content of organic carbon in the soil (main effects presented in relative numbers)

On the basis of long term fertilization experiments in which high doses of nitrogen were applied, Havlin et al. [1990] observed the increase of the organic carbon content in the top layer of the soil within the range from 0 to 35%. Nitrogen fertilization is a factor affecting the accumulation of organic carbon in the soil, particularly under the condition of no manure fertilization (Fig. 2). High doses of nitrogen fertilizers help the accumulation of organic carbon in the soil because they are favorable for the production of large amounts of plant biomass thanks to which after harvest more organic residues are left in the soil which are the components of the soil organic matter [Gregorich et al. 1996; Raun et al. 1998].

An advantageous effect of liming on the content of org-C. in the soil was marked mainly on the fertilized treatments with mineral fertilizers together with manure (Fig. 2, Fig. 3).

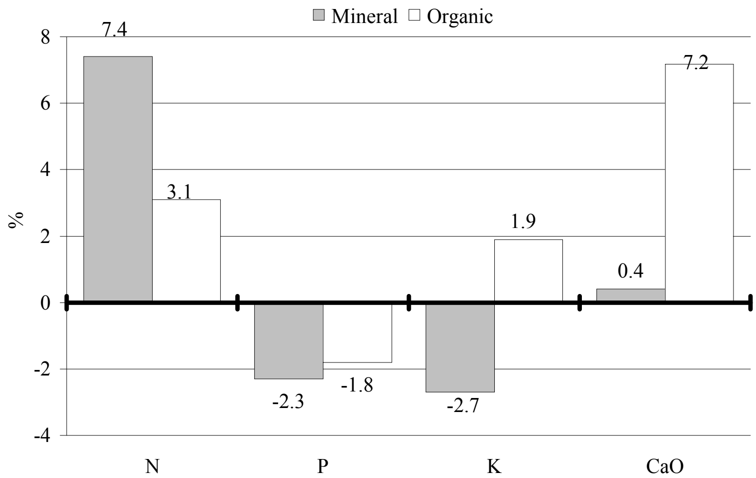

Figure 2. Changes of organic C content in the soil as a result of NPK fertilization and liming depending on the application of manure (main effects in relative numbers)

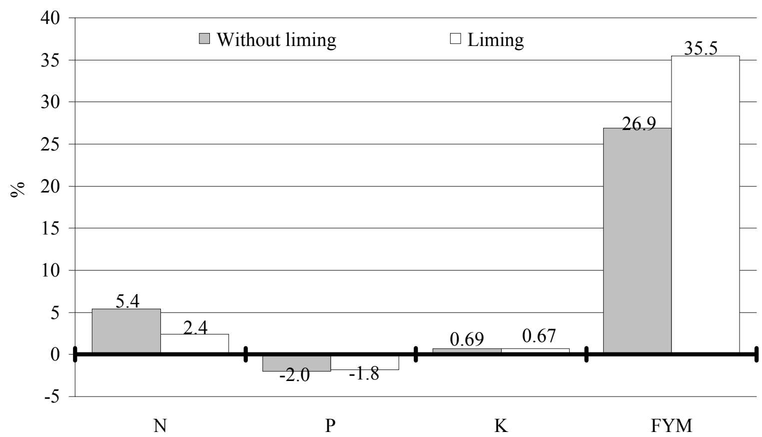

Figure 3. Changes of organic C content in the soil as a result of NPK fertilization and manure depending on the application of liming (main effects in relative numbers)

On the limed treatments the level of the organic carbon content in the soil was by about 7% higher as compared with the non-limed, highly acidified objects with pH 4 (Fig. 1). In the case of acid soils the loss of org-C. from the soil is usually observed as compared to the non-limed soils probably as a result of worsening the quality of humus compounds. There is a degradation of humus bonds, with a simultaneous increase of low molecular compounds, loosely tied with the mineral part of the soil and thus susceptible to washing out [Stevenson 1982; Jakubus et al. 1999].

Similarly as in the case of experiment I the lack of fertilization resulted in the decrease of the org-C content in the soil, and the application of manure caused the increase of the content of organic carbon in the soil. The exclusively mineral fertilization kept the content of organic carbon in the soil on the level similar to the initial one (Tab. 2). With the increase of the doses of mineral fertilizers against the manure a systematic increase of the organic carbon content in the soil was observed (Tab. 2).

Table 2. The effect of the use of increasing doses of mineral fertilizers (NPK) and manure on the content of organic carbon in the soil in g kg^{-1}

Fertilization	Doses of NPK					Mean
	0	NPK	2 NPK	3 NPK	4 NPK	
	Organic C g kg^{-1}					
Mineral	3.5	5.2	5.6	5.8	5.8	5.2
Mineral + FYM	7.1	8.2	8.4	8.5	8.8	8.2
Mean	5.3	6.7	7.0	7.2	7.3	

An increase of the org-C content in the soil resulting from the applied optimum, from the point of view of the plant nutritional requirements, doses of mineral fertilizers together with manure was observed in the studies by Jenkinson [1991] and Kanchikerimath, Singh [2001].

CONCLUSIONS

1. Accumulation of organic matter in the light soils mainly results from the application of manure. Also, fertilization with nitrogen and liming helps the increase of the content of organic carbon in the soil.

2. Systematic long term use of manure together with mineral fertilizers results in the increase of the content of organic carbon in the soil.

3. With the lack of fertilization the decrease of the content of organic matter in the soil is observed and the exclusively mineral fertilization keeps the organic carbon content in the soil on a relatively stable level.

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