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MODIFICATIONS OF SOIL PHYSICO-CHEMICAL PROPERTIES AS A RESULT OF LONG-LASTING MINERAL AND ORGANIC FERTILIZATION

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A b s t r a c t. The effects of farmyard manure, slurry and mineral fertilizers were compared. In two static field experiments the fertilizers were balanced every year according to amounts of nitrogen introduced to the soil. Soil samples, for basic chemical and physicochemical analyses, were taken from 0-25 cm top layer after crop harvesting.

It was found that in majority of treatments an increase of hydrolytic acidity was higher for mineral than organic fertilisers. The level of base saturation of the sorption complex was similar. Mineral and organo-mineral fertilization contributed to a reduction of hydrogen cations in the sorption complex. Farmyard manure was more favourable than slurry at both applied rates.

Among the studied treatments, the highest concentration of basic cations was found in the soils supplemented with farmyard manure. In the sorption complex of the studied soils, the predominant cation was Ca^{2+}, at the same time the lowest share of Na^{+} was found.

K e y w o r d s: physicochemical properties, soil, mineral and organic fertilisers, long-lasting fertilization.

INTRODUCTION

The main factors which determine soil fertility are mineral fertilization and application of organic amendments. Organic substances enrich the soil in organic matter. They are also the source of essential nutrients. Mineral fertilisers provide crops with nutrients and their chemical composition determines their effect on the soil properties. The impact on the soil is measured as a modification of physicochemical properties which play an important role in plant nutrition and in preservation of agrocenoses quality. The above was shown by the results of numerous studies carried out in Poland as well as abroad [1,3,4,6-8,17]. Similar studies have also been performed in the Department of Environmental Chemistry of the University of Warmia and Mazury in Olsztyn [9,11,12].

The aim of the present studies was to compare of long-lasting application of farmyard manure, slurry and mineral fertilisers on the modification of sorption complexes of the two contrasting soil types.

MATERIALS AND METHODS

Impact of farmyard manure, slurry and mineral fertilisers was compared in two static field experiments. Experiment 1 on the influence of cattle slurry and farmyard manure, was established in 1972 in the Bałcyny Experimental Station near Ostróda, on the Luvisol developed on medium clay underlain with the light sand. Experiment 2 on pig manure and slurry, was established in 1973 in the Experimental Station in Tomaszkowo near Olsztyn on the proper brown soil developed of loamy sand. A more detailed description of the experiments and amount of nutrients introduced to the soil each year was published earlier [10,11,13]. The compared mineral and organic fertilisers were balanced each year according to amounts of nitrogen introduced to the soil. The organic amendments were balanced also with regard to the amount of organic carbon. On the background of organic fertilization, mineral fertilization 0.5, as in the treatment with NPK, of the total PK rate was applied. The scheme of the experiments is included in Tables 1-5. Soil samples taken from the depth of 0-25 cm after crop harvesting were analysed. In these samples the following chemical analyses were made:

- hydrolytic acidity according to the Kappen's method (Hh),
- basic cations extracted with 1 M ammonium acetate of pH 7.0; Ca^{2+}, K^{+} and Na^{+} were determined by flame photometry, and Mg^{2+} by the Varian Techtrons AAS spectrometer.

Table 1. Physicochemical properties of the Luvisol fertilised with farmyard manure, cattle slurry, and NPK (experiment 1)

Treatment	Hh	S	T	V
	mmol(+) 100 g^{-1}			%
No fertilizer	2.40	4.85	7.25	66.9
Slurry first rate	3.00	6.21	9.21	67.4
Slurry first rate + PK	3.07	6.97	10.04	69.4
Slurry second rate	2.40	7.46	9.86	75.7
Slurry second rate + PK	2.40	7.87	10.27	76.6
Farmyard manure	2.25	8.41	10.66	78.9
Farmyard manure + PK	2.25	8.47	10.72	79.0
NPK	3.45	5.93	9.38	63.2

On the basis of above analyses the following parameters were computed: sum of basic cations (S); sorption capacity (T); soil base saturation (V); quantitative relations between cations in the sorption complex.

RESULTS AND DISSCUSION

Application of slurry, manure and mineral fertilisers distinctly affected properties of the sorption complex in the studied soils. After 26 years of the experiment 1 (Table 1), hydrolytic acidity of arable horizons ranged from 2.25 to 3.45 mmol $H^{+}100\ g^{-1}$.

In the case of treatments with organic supplements of the balanced carbon the value of the hydrolytic acidity decreased (farmyard manure) or remained at the same level (slurry second rate) as in the control. In other treatments, an increase in the concentration of hydrogen cation was found. This increase ranged from 0.60 in the treatment with the first rate of slurry application to 1.05 mmol H^{+} 100 g^{-1} in the treatment with farmyard manure. In the case of treatments with mineral fertilisers, the amount of H^{+} was lower by 0.24 mmol $H^{+}/100\ g^{-1}$ when compared to the treatment with manure. Additional PK fertilisers application did not affect the amount of hydrogen ions, as compared to organic fertilization. Hydrogen amounted to 27.9% of the Luvisol sorption complex. When compared to unfertilised control treatments with organic or organic-mineral fertilization showed a decrease in hydrogen amount, whereas an increase in the case of treatment with mineral fertilization only were observed. This decrease was higher in the treatment with farmyard manure than with two slurry rates. Similar relations were reported by other authors [2,6,8]. In our studies, fertilisers used at all the studied rates contributed to the increase of the sum of base cations compared to the control. Base saturation ranged from 63.2% to 79.0% for mineral fertilisers and farmyard manure, respectively. For the treatment with NPK, base saturation was lower by 3.7% compared to the control. Among organic supplements, farmyard manure affected base saturation more favourably than slurry, especially at the first application rate.

In the second experiment (Table 2) with pig slurry, hydrolytic acidity ranged from 1.95 to 2.50 mmol H^{+} 100 g^{-1}.

In the majority of fertilization treatments, an increase in soil acidity compared to the control was observed. The highest increase of H^{+} was observed for mineral fertilization. In the case of farmyard manure, acidity was slightly lower than for the two slurry rates. Application of PK fertilizers with first slurry rate and manure showed a decreasing trend in the concentration of hydrogen cations. It was observed in the treatment with the second slurry rate. Base saturation of the brown soil sorption

Table 2. Physicochemical properties of brown soil fertilised with farmyard manure, pig slurry, and NPK (experiment 2)

Treatment	Hh	S	T	V
	mmol(+) 100 g^{-1}			%
No fertilizer	1.95	4.06	6.01	97.6
Slurry first rate	2.18	5.25	7.43	70.7
Slurry first rate + PK	1.95	5.41	7.36	73.5
Slurry second rate	2.25	6.37	8.62	73.9
Slurry second rate + PK	2.25	6.35	8.60	73.8
Farmyard manure	2.10	7.60	9.70	78.3
Farmyard manure + PK	1.95	7.42	9.37	79.2
NPK	2.50	5.00	7.50	66.7

complex was reduced in all the treatments except mineral fertilization where some enhancement was found. An average reduction of these cations amounted to 7.4%. It was higher for farmyard manure than for the two slurry rates.

For all the studied fertilization treatments, an increase of exchangeable cations in relation to the control was found. This increase was more distinct for organic supplements than NPK treatment. It seems that in the case of brown soil developed from loamy sand, it might be related not only to the uptake of nutrients by the crops but also to their leaching down the soil profile. Farmyard manure favourably enhanced the amount of exchangeable cations compared to both slurry rates. Base saturation ranged from 66.7% to 79.2% for mineral fertilization treatment and farmyard manure + PK, respectively. For all the fertilization treatments, an increase of base saturation was found compared to the control. The only exception was reduction by 0.8% in the treatment with mineral fertilization.

Data presented in Tables 3 and 4 clearly indicate that Ca^{2+} was predominant in the sorption complex; Na^{+} had the lowest share.

Cation content as well as base saturation of the sorption complex was related to fertilization treatment and soil type. In the two experiments, the amount of Ca^{2+} and Mg^{2+} cations were similar and increased as a result of fertilization. Cation content was most variable under the influence of fertilization. The above relationships were related to the amount of hydrogen cations which may displace magnesium and calcium cations first. The lowest amount of the above cations were found in both soils after NPK treatment. Farmyard manure contributed to a higher increase of exchangeable magnesium and calcium cations than slurry, irrespective of the rate. Additional PK fertilizers applied with the background of organic supplements in Experiment 1 did not affect concentration of the studied cations, whereas in

Table 3. Content of exchangeable cations in the Luvisol and its base saturation (experiment 1)

Treatment	Exchangeable cations mmol(+) 100 g^{-1}				% of base cations in (S)			
	Ca^{2+}	Mg^{2+}	K^+	Na^+	Ca^{2+}	Mg^{2+}	K^+	Na^+
No fertilizer	4.01	0.49	0.29	0.06	82.7	10.1	6.0	1.2
Slurry first rate	4.54	0.84	0.71	0.12	73.1	13.5	11.4	1.9
Slurry first rate + PK	4.59	0.90	1.20	0.28	65.8	12.9	17.2	4.0
Slurry second rate	5.17	0.98	1.07	0.24	69.3	13.1	14.3	3.2
Slurry second rate + PK	5.45	0.98	1.22	0.22	69.2	12.4	15.5	2.8
Farmyard manure	5.89	1.22	1.10	0.20	70.0	14.5	13.1	2.4
Farmyard manure + PK	5.89	1.19	1.19	0.20	69.5	14.0	14.0	2.4
NPK	4.29	0.59	0.93	0.12	72.3	9.9	15.7	2.0

Table 4. Content of exchangeable cations and base saturation in brown soil (experiment 2)

Treatment	Exchangeable cations mmol(+) 100 g^{-1}				% of base cations in (S)			
	Ca^{2+}	Mg^{2+}	K^+	Na^+	Ca^{2+}	Mg^{2+}	K^+	Na^+
No fertilizer	3.31	0.37	0.24	0.14	81.5	9.1	5.9	3.4
Slurry first rate	4.10	0.67	0.34	0.14	78.1	12.8	6.5	2.7
Slurry first rate + PK	4.04	0.61	0.55	0.21	74.7	11.3	10.2	3.9
Slurry second rate	4.61	0.87	0.53	0.36	72.4	13.7	8.3	5.6
Slurry second rate + PK	4.50	0.71	0.80	0.34	70.9	11.2	12.6	5.3
Farmyard manure	5.41	1.19	0.72	0.28	71.2	15.6	9.5	3.7
Farmyard manure + PK	5.29	1.09	0.80	0.24	71.3	14.7	10.8	3.2
NPK	3.69	0.58	0.63	0.10	73.8	11.6	12.6	2.0

Experiment 2, some reduction of content was found in comparison to the treatment with organic substances only. In all the fertilization treatments, saturation with calcium was lower but with magnesium higher than in control treatment.

Higher content of exchangeable potassium was found in the Luvisol than in the brown soil. Fertilization contributed to the increase of potassium content. The average increase was higher in the Luvisol than in the brown soil. The highest content of exchangeable potassium was found in the soils fertilised with farmyard manure and the lowest in the soil treated with the first rate of slurry. K^+cations in the Luvisol ranged from 6.0% (control) to 17.2% (slurry first rate + PK) and in the brown soil from 5.9% (control) to 12.6% (mineral fertilizers) of sum of bases.

The content of sodium cations in the studied soils was relatively low and not variable. Saturation of the sorption complex with sodium was higher in the brown soil than in the Luvisol. The highest percentage of sodium in the sorption complex was found when the second slurry rate was applied in both soils.

Cation ratio is very important for the estimation of soil fertility. In our studies on the effects of the applied fertilisers on the cation content of the sorption complex, high variability was especially visible for the $Mg^{2+}$and K^{+} ratios (Table 5). In the fertilised Luvisol, the values of Mg^{2+} and K^{+} ratio were lower, whereas in brown they were higher in all the studied soils except the soils treated with mineral fertiliser, where it was twice lower. In the two experiments, the established ratios (Ca+Mg):K and Ca:K were lower than the Ca:Mg ratio. The lowest value of (Ca+Mg):K and Ca:K ratios were found in the treatment with NPK application and the highest at the first rate of slurry application. The value of Ca:Mg was the lowest for the treatment with farmyard manure. The ratio of basic cations (S) to hydrogen (H) is also an interesting parameter. After 26 years of the experiment, the highest values of the above mentioned ratio was found for the treatment with farmyard manure. The lowest number of basic cations per one hydrogen ion was in the case of treatments with mineral fertilization.

Taking into account the effects of slurry on the physico-chemical properties of the studied soils, it might be stated that its first rate of application as balanced to

Table 5. Ratios between the cations content in the sorption complex

Treatment	Mg:K	(Ca+Mg):K	Ca:K	Ca:Mg	S:M
	Experiment 1 with cattle slurry - Luvisols				
No fertilizer	1.7	15.5	13.8	8.2	2.0
Slurry first rate	1.2	7.6	6.4	5.4	2.1
Slurry first rate + PK	0.8	4.6	3.8	5.1	2.3
Slurry second rate	0.9	5.7	4.8	5.3	3.1
Slurry second rate + PK	0.8	5.3	4.5	5.6	3.3
Farmyard manure	1.1	6.5	5.3	4.8	3.7
Farmyard manure + PK	1.0	5.9	4.9	4.9	3.8
NPK	0.6	5.2	4.6	7.3	1.7
	Experiment 2 with pig slurry - brown soil				
No fertilizer	1.5	15.3	13.8	8.9	2.1
Slurry first rate	2.0	14.0	12.1	6.1	2.4
Slurry first rate + PK	1.1	8.4	7.3	6.6	2.8
Slurry second rate	1.6	10.3	8.7	5.3	2.8
Slurry second rate + PK	0.9	6.5	5.6	6.3	2.8
Farmyard manure	1.6	9.2	7.5	4.5	3.6
Farmyard manure + PK	1.4	8.0	6.6	4.8	3.8
NPK	0.9	6.8	5.9	6.4	2.0

farmyard manure with regard to nitrogen as well as the second rate balanced with the organic carbon content, were less favourable than farmyard manure. This could be related to the slurry chemical composition. Slurry affected soil more favourably compared to the effects of mineral fertilisers. Similar results were report by other authors [1,4,5,15,17].

CONCLUSIONS

In the light of the obtained results, the following conclusions can be drawn:

1. In two experiments on the effects of long-lasting fertilization, in the majority of treatments, an increase of hydrolytic acidity was higher for mineral than organic fertilisers. More hydrogen cations were found in the Luvisol than in the brown soil. Whereas the level of base saturation of the sorption complex was similar. Mineral and organo-mineral fertilization contributed to a reduction of hydrogen cations in the sorption complex. Farmyard manure was more favourable than slurry at both applied rates.

2. Among the studied treatments, the highest concentration of basic cations was found in the soils supplemented with farmyard manure. In the sorption complex of the studied soils, the predominant cation was Ca^{2+}, at the same time the lowest share of Na^{+} was found.

3. In two experiments application of farmyard manure contributed to the highest increase of exchangeable calcium and magnesium. In the case of exchangeable potassium in the Luvisol soil, the highest increase of content was found in the case of treatment with second slurry rate, and in the brown soil under mineral fertilization. The highest quantity of sodium was found in Experiment 1 for the treatment with farmyard manure and in Experiment 2 in treatment with the second slurry rate.

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