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CHANGES OF PHOSPHORUS CONTENT IN MEADOW SOILS UNDER THEIR PROGRESSIVE ACIDIFICATION AS A RESULT OF MINERAL FERTILIZATION

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A b s t r a c t. The results of pot experiment conducted in 1987-1989 on Italian ryegrass on four mountain soils with much diversified properties have been presented in this paper. Mineral, mainly nitrogen fertilization, caused an increase in soil acidification, chiefly by launching of exchangeable aluminium in soil.

If no high acidification followed as a result of fertilization, the initial proportions of P fraction in soil used in our experiment did not much change afterwards. In acid soils, the highest increase was noticed in aluminium phosphates fractions and slightly lower in the fractions of iron phosphates. In much acidified soils, concentractions of phosphorus in soil solutions were much lower, with similar content of soluble phosphorus according to Egner-Riehm method.

K e y w o r d s: phosphorus, meadow soils, acidification, mineral fertilization, Italian ryegrass

INTRODUCTION

Apart from its effect on both quality and quantity of yields, mineral fertilization has also influenced the soil environment [3,4,9].

Changes in the content and forms of phosphorus compounds in soil depend on many factors [2,5,10] among which the soil reaction is a most important one [7,8].

The aim of the studies was to determine the influence of solely mineral fertilization on various phosphorus contents in soil in conditions of progressive acidification.

MATERIAL AND METHODS

Pot experiment was carried out 1987-1989 on four soils with extremely different physical and chemical properties (Table 1). The soil for the pot experiments was collected from A_1d horizons of mountain meadow soils localized in Jaworki (I,II), in Grodziec Śląski and in Czarny Potok. The scheme and doses of fertilizers were the same in all experiments:

1. 0 - no fertilization	5. N_3P_1
	6. N_3P_2
2. N_1	7. N_4P_2
3. N_1P_1	8. $N_3P_2K_2$
4. N_2P_1	9. $N_4P_2K_2$

Nitrogen - 0.25 g per pot filled with 5 kg of air dry soil was introduced in NH_4NO_3 two times: a dose of 0.15 g N per pot before the experiment outset and 0.10 g N per pot after the first cut. Phosphorus in the amount of 0.25 g per pot (P_1) in $Ca(H_2PO_4)_2$ was applied once, before the experiment outset. Potassium dose K_1-0.25 g K in KCl per pot was divided into two parts. One half was used before the experiment outset, the second after the first cut.

Italian ryegrass cv. Kroto was the test plant. Three cuts were harvested each year.

The following values were assayed in soil samples: mechanical composition with the use of areometric method, hydrolytic acidity with Kappen method, exchangeable aluminium content with Sokolov method and organic carbon content with Tiurin method. Total amount of nitrogen was determined with Kjeldahl method and total phosphorus by digesting of soil material with a mixture of concentrated HNO_3 and $HClO_4$ acids.

Chang and Jackson fractional analysis method [6] was used to determine various mineral phosphates. The content of available phosphorus was assayed with the use of Egner-Riehm method, whereas its active form was assayed in 0.01 mol $CaCl_2$ dm^{-3} extract.

RESULTS

Soils used in the experiments showed high differentiation in their reaction (pH KCl 4.1-6.6) (Table 1). After three years of fertilization, there occurred a decrease in pH value in all soils. The highest increase in acidity was noted in the objects with the highest level of nitrogen fertilization (Table 2). In the investigations where the experimental soils showed

Table 1. Some soil properties before the experiment outset

Investigated properties	Jaworki I	Jaworki II	Grodziec Śląski	Czarny Potok
% of fractions in mm:				
< 0.02	68	55	41	35
< 0.002	19	20	19	12
$pH_{(KCl)}$	4.38	6.32	6.55	4.12
Hydrolytic acidity cmol (+)/kg	4.80	0.90	0.50	3.74
Sorption capacity cmol (+)/kg	26.60	25.10	29.6	8.52
C org. %	2.92	2.44	2.45	1.92
N total %	0.34	0.276	0.265	0.164
P total mg/100 g	99.1	85.6	94.7	40.6
Available P mg P_2O_5/100 g	2.1	14.7	27.2	3.9

an acid reaction (Jaworki I, Czarny Potok), a further increase in exchangeable soil acidity was observed. Over threefold increase in exchangeable acidity in heavy soil from Jaworki I was caused mainly by further launching of exchangeable aluminium. Its share in the acidity rose from 30 % before the experiment to 70 % in the objects fertilized with nitrogen (Table 3). In the soil from Jaworki II with a slightly acid reaction, where initially no exchangeable acidity was noted, its systematic in-

Table 2. The influence of mineral fertilization on pH_{KCl} changes in soil

Fertilized object	Jaworki I	Jaworki II	Grodziec Śląski	Czarny Potok
0	3.85	5.79	6.60	3.62
N_1	3.76	5.68	6.52	3.62
N_1P_1	3.72	5.63	6.51	3.58
N_2P_1	3.65	5.48	6.28	3.54
N_3P_1	3.60	5.45	6.19	3.63
N_3P_2	3.61	5.43	6.20	3.75
N_4P_2	3.45	4.86	5.89	3.56
$N_3P_2K_1$	3.58	5.52	6.22	3.57
$N_4P_2K_2$	3.60	5.40	6.18	3.56

crease was noted as the nitrogen dose rose in the fertilizer dose. Only in the soil from Grodziec Śląski, with a neutral reaction (pH_{KCl} 6.6) mineral fertilization did not cause exchangeable acidity to appear in soil.

Inorganic phosphates composition in the investigated soils was much differentiated (Table 4). In very acid soils, from Jaworki and Czarny Potok iron phosphates were dominant among soil phosphates and their share exceeded 50 %. In spite of the noticed differences in chemical properties of these soils, initial proportions of phosphorus fractions were similar. Characteristic of these soils was a low content of phosphorus loosely bound with the solid phase of soil which did not exceed 2 % of inorganic phosphates sum. The soils from Jaworki II and Grodziec Śląski with slightly acid to neutral reaction and much higher degree of base sorption complex saturation (Table 1) were characterized with a markedly bigger share in phosphorus fraction of calcium phosphates and loosely bound phosphorus (Table 4). Changes of various phosphorus fraction contents in soils of particular fertilized objects, presented in Table 4 show that fertilizing phosphorus introduced into the soil gathered as its different fractions, but mainly as aluminium phosphates.

While studying the transformations of phosphorus compounds in various soils Moskal [7] stated that the amount of this element found in different fractions only to some extent depended on the applied fertilizer, whilst initial proportions of P fractions in the soil

Table 3. Changes of exchangeable acidity (H_{ex}) and exchangeable aluminium (Al_{ex}) under the influence of fertilization

Fertilized objects	Jaworki I			Czarny Potok			Jaworki II
	H_{ex}	Al_{ex}	Al/H	H_{ex}	Al_{ex}	Al/H	H_{ex}
	cmol(+)/kg		%	cmol(+)/kg		%	cmol(+)/kg
Before experiment	0.98	0.29	30	2.09	1.78	85	0.00
0	1.64	0.94	57	2.75	2.50	91	0.16
N_1	2.05	1.30	63	2.85	2.50	87	0.20
N_1P_1	2.66	1.32	50	2.75	2.42	88	0.16
N_2P_1	2.34	1.63	70	3.36	2.95	88	0.20
N_3P_1	3.08	1.80	58	3.28	2.66	81	0.16
N_3P_2	3.03	1.51	50	2.99	2.42	81	0.41
N_4P_2	4.47	2.33	52	2.75	2.21	80	0.20
$N_3P_2K_1$	2.91	1.58	54	2.83	2.42	85	0.20
$N_4P_2K_2$	2.83	1.54	58	3.28	2.87	88	0.20

Table 4. The influence of fertilization on changes of various phosphorus fraction content in soil (mg P_2O_5/100 g)

Fertilized objects	P-loos. bound.	P-Al	P-Fe	P-Ca	P-loos. bound	P-Al	P-Fe	P-Ca
	Jaworki I				Jaworki II			
Before exp.	0.7	6.5	14.4	7.2	2.6	17.6	22.5	25.4
0	0.4	6.5	15.0	6.8	1.5	14.2	16.5	22.0
N_1	0.3	6.2	15.3	6.2	1.1	14.0	16.0	22.0
N_1P_1	1.1	13.5	16.8	6.0	2.9	16.0	20.5	22.5
N_2P_1	1.0	13.2	16.8	6.5	2.9	16.1	21.5	22.5
N_3P_1	0.7	12.5	16.8	7.2	2.7	17.5	23.9	20.1
N_3P_2	1.6	16.8	18.4	9.0	3.5	22.3	22.2	22.6
N_4P_2	1.4	22.8	26.8	8.6	4.5	23.2	24.2	23.4
$N_3P_2K_1$	0.7	15.4	21.0	8.6	4.1	23.8	23.8	21.4
N_4P_2K	0.5	18.6	24.9	9.6	3.3	21.7	20.0	20.4
	Grodziec Śląski				Czarny Potok			
Before exp.	3.4	31.6	40.5	55.0	0.5	10.0	13.6	2.4
0	1.7	23.7	31.0	55.5	0.5	8.2	13.6	2.0
N_1	1.2	21.6	31.5	55.0	0.6	8.0	13.6	2.1
N_1P_1	2.5	28.3	37.8	55.0	1.1	18.8	20.6	2.6
N_2P_1	2.3	28.6	38.1	56.0	1.2	18.6	20.1	2.6
N_3P_1	2.2	28.3	39.5	57.2	1.1	19.5	20.2	3.0
N_3P_2	3.7	31.6	41.0	56.1	1.8	25.4	23.2	2.9
N_4P_2	4.0	35.6	34.8	56.6	1.6	28.8	24.6	3.1
$N_3P_2K_1$	4.2	28.3	42.0	55.0	1.8	23.6	23.7	3.6
N_4P_2K	4.5	29.8	42.5	51.5	1.6	22.6	22.0	2.8

used for the experiments did not undergo any major changes afterwards.

The regularity mentioned above has been observed in the discussed experiments only in soils with initially slightly acid and neutral reaction, where no significant acidification occurred as a result of fertilization. In the soils from Jaworki I and Czarny Potok an increase in the contents of aluminium phosphates fraction was to a lesser degree accompanied by a raise in iron phosphates than a decrease in quantitative occurrence of calcium phosphates.

The soils used in the pot experiments represented high differentiation in phosphorus soluble with the use of Egner-Riehm method (2.1-27.2 mg P_20_5/100 g of soil). A relative share of its soluble forms in total phosphorus constituted from 0.9 % in very acid soil from Jaworki to 12.6 % in soil with neutral reaction from Grodziec Śląski (Table 5). An increase in

Table 5. Changes in the content of available phosphorus ($P_{avail.}$ in mg P_2O_5/100 g of soil) and active phosphorus (P_{act} in mg P_2O_5/dm^3) influenced by mineral fertilization

Fertilized object	Jaworki I	Jaworki II		Grodziec Śląski		Czarny Potok
	P-avail.	P-avail.	P-act.	P-avail.	P-act.	P-avail.
Before exp.	2.1	14.7	0.20	27.2	0.56	2.9
0	0.7	11.3	0.16	23.2	0.10	2.2
N_1	0.9	10.2	0.16	20.9	0.16	2.1
N_1P_1	2.7	16.2	0.54	33.8	0.40	7.3
N_2P_1	3.2	16.2	0.62	30.5	0.48	8.8
N_3P_1	3.2	16.8	0.76	27.5	0.32	9.7
N_3P_2	12.8	21.6	1.00	30.3	0.32	14.9
N_4P_2	11.8	22.1	1.94	31.5	0.32	15.4
$N_3P_2K_1$	7.3	21.6	1.20	34.5	0.38	14.5
$N_4P_2K_2$	7.5	19.3	0.90	34.0	0.32	14.1

the share of phosphorus soluble in Egner-Riehm extract in total P observed as a result of P-fertilization, did not reach the values mentioned in literature [1,8], particularly in acid soils.

In order to estimate phosphorus availability to plants active phosphorus was assayed in 0.01 mol $CaCl_2$ dm^{-3} extract. In case of very acid soils (Jaworki I and Czarny Potok), there were some methodical difficulties with measuring very small amounts of phosphorus in 0.01 mol $CaCl_2$ dm^{-3} extracts, even in the objects fertilized with phosphorus, where P content in Egner-Riehm extract was similar to other soils. In the soil from Jaworki II, in spite of a lower initial amount of available phosphorus than in the soil from Grodziec Śląski, the concentration of active phosphorus was decidedly higher in the objects fertilized with this element. Phosphorus buffer abilities in these soils influenced a better availability of P to plants in the soil from Jaworki, although the content of phosphorus determined with Egner-Riehm method has been lower.

CONCLUSIONS

1. Mineral, mainly nitrogen fertilization, led to a progressive acidification of mineral soils.

2. In the experiments conducted on acid soils mineral fertilization intensified the launching of exchangeable aluminium.

3. Phosphorus from fertilizers, not assimilated by plants, gathered in soil mainly as aluminium phosphates, and in very acid soils as iron phosphates.

4. In very acid soils phosphorus concentration in soil solution was much lower with the contents of phosphorus soluble according to Egner-Riehm method similar to other soils.

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ZMIANY ZAWARTOŚCI FOSFORU W GLEBACH ŁĄKOWYCH W WARUNKACH POSTĘPUJĄCEGO ICH ZAKWASZENIA POD WPŁYWEM NAWOŻENIA MINERALNEGO

W pracy przedstawiono wyniki doświadczenia wazonowego przeprowadzonego w latach 1987-1989 z życicą wielokwiatową na czterech górskich glebach łąkowych o bardzo zróżnicowanych właściwościach chemicznych. Nawożenie mineralne, głównie azotowe, spowodowało wzrost zakwaszenia gleby, głównie poprzez uruchomienie w glebie glinu wymiennego.

Jeżeli w wyniku nawożenia nie nastąpiło silne zakwaszenie gleb, to wyjściowe proporcje frakcji P w glebie użytej do doświadczeń, nie ulegały większym zmianom po zakończeniu doświadczeń. W glebach kwaśnych najwyższy przyrost obserwowany był we frakcjach fosforanów glinu i nieco mniejszy fosforanów żelaza. W glebach silnie zakwaszonych znacznie niższe były koncentracje fosforu znajdującego się w roztworze glebowym, przy podobnych zawartościach fosforu rozpuszczalnego według metody Egnera-Riehma.

S ł o w a k l u c z o w e: fosfor, gleby łąkowe, zakwaszenie, nawożenie mineralne, życica wielokwiatowa.