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EFFECT OF LIMING AND FERTILIZATION WITH NITROGEN ON THE PHYSICOCHEMICAL PROPERTIES OF SOIL

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Abstract. The aim of the experiment was agrochemical evaluation of the influence of liming and fertilization with ammonium or nitrate nitrogen on changes of pH, acidity and saturation of sorption complex with exchangeable cations. The study was based on chemical analysis of soil materials obtained from a two-year pot experiment. The factors of the study were: liming, fertilization with ammonium sulphate or calcium nitrate at two levels and fertilization with phosphorus in two doses. The obtained results indicated that liming as well as nitrogen forms influenced significantly the indicators of soil acidification. The use of $CaCO_3$ and nitrate nitrogen caused an increase of pH and decrease of hydrolytic acidity, exchangeable acidity and mobile aluminium. The content of mobile aluminium also was significantly lower in treatments fertilized with superphosphate in higher level. The content of Mg^{2+}, Na^{+} and K^{+} was higher in treatments fertilized with ammonium sulphate than with calcium nitrate. A different situation was observed in the case of Ca^{2+}. The content of calcium ions was the highest in treatment limed and fertilized with calcium nitrate at higher dose. Granulated triple superphosphate fertilization did not essentially influence the sorption complex of soil.

Keywords: acidification, soil, nitrogen forms, liming

INTRODUCTION

In the group of factors influencing soil fertility a significant role is played by mineral fertilization. The direction of changes in the soil properties under the influence of fertilization depends, among other things, on the kind of applied fertilizers. Nitrogen fertilizers influence the physical and chemical properties of soil the most. Not only the dosage but also the form of nitrogen is significant in fertilizers, because it determines the pH of the soil (Barszczak and Gębski 1994, Filipek and Badora 1999). The reaction intensely affects the ionic equilibrium and the sorption properties of soil environment (Bednarek and Lipiński 1996, 1998, Chwil 2002, Czekała 2002). Excessive participation of acid cations in the sorption complex leads to intense elevation of basic cations into the soil profile, disorders in nutrient uptake by plants and, consequently, to yield quality deterioration. One of the ways of preventing chemical degradation of soil is liming (Bednarek and Lipiński 1996, Łabętowicz *et al*. 1998, Łabętowicz *et al*. 2004).

The aim of these studies was agrochemical evaluation of the influence of liming and fertilization with nitrogen in the form of ammonium or nitrate on changes in reaction and saturation of soil sorption complex with exchangeable cations.

MATERIAL AND METHOD

The basis of the presented paper was a two-year pot experiment. It was set up on soil material with the grain size composition of light loamy sand. The soil had very acid reaction (pH_{KCl} 4.00), low content of available phosphorus and potassium, as well as very low content of available magnesium. Sorption capacity of the soil was 42.35 mmol (+) kg^{-1}, and base saturation degree was 13.15%.

For our tests we used pots that held 5 kg of the soil material. The scheme of the experiment comprised 9 combinations in 4 replications on limed (G2) and non-limed soil (G1). The experimental factors were: liming, fertilization with ammonium (F1) or nitrate (F2) form of nitrogen applied at two levels (N1 – 0.1 g N kg^{-1}, N2 – 0.2 g N kg^{-1}), as well as fertilization with phosphorus, also in two doses (P1 – 0.06 g P kg^{-1}, P2 – 0.12 g P kg^{-1}). The above-mentioned experimental factors were applied on the background of permanent fertilization with potassium (0.1 g K kg^{-1}) and magnesium (0.025 g Mg kg^{-1}). Liming with $CaCO_3$ was applied once, before establishing the experiment, in the amount calculated according to 1 Hh. On the other hand, fertilization with nitrogen, phosphorus, potassium and magnesium was applied every year of the studies, before sowing the plants. Nitrogen was applied in the form of ammonium sulphate or calcium nitrate, phosphorus as granulated triple superphosphate, potassium was in the form of potassium chlorine, whereas magnesium was in the form of magnesium sulphate.

In the vegetation period permanent soil moisture was maintained on the level of 60% field water capacity by watering the plants up to constant weight with distilled water. The test plant was Bryl variety of spring barley. The plants were harvested in the phase of their full ripeness.

In each year of the studies the soil material was collected for analyses, and the following determinations were made:

- pH values in the solution of 1 mol KCl dm^{-3} by means of the potentiometric method, with soil-to-solution ratio of 1:2.5;
- hydrolytic acidity by titration method, after extraction with the solution of 1 mol CH_3COONa dm^{-3} (Kappen method);

- exchangeable acidity and contents of mobile aluminium by titration method, after extraction with the solution of 1 mol KCl dm^{-3} (Sokolov method);
- contents of exchangeable cations K^{+}, Na^{+}, Mg^{2+}, Ca^{2+} by means of AAS method, after extraction with 1 mol CH_3COONH_4 dm^{-3};
- sum of exchangeable bases (S), total sorption capacity (T) and degree of soil saturation with bases (V) were calculated.

The influence of experimental factors on the examined soil properties was determined by means of variance analysis with the application of Tukey confidence half-intervals ($p = 0.05$). The results presented in tables constitute mean values from the two-year experiment.

RESULTS AND DISSCUSION

Liming and the applied form of nitrogen had the strongest effect on the soil pH (Tab. 1). Using calcium carbonate contributed to changing the pH from very acid to slightly acid. Ammonium sulphate caused a decrease of pH, whereas calcium nitrate caused its increase. The effect of interaction between liming and form of the used nitrogen on the increase of pH was more distinct when we used calcium nitrate than when we applied ammonium sulphate. Increasing the doses of nitrogen in the form of ammonium led to a decrease of pH, regardless of using calcium carbonate. A different situation was observed in the case of nitrogen doses in the form of nitrate. Positive effect of higher doses of N-NO_3 was especially distinct in non-limed soil. Differentiated dosage of phosphorus did not cause any significant changes. A significant influence of liming on the increase of pH was also found by Bednarek and Tkaczyk (2002). However, in the experiment conducted by Łabętowicz *et al*. (2004) significant changes of reaction were observed only when the dosage of $CaCO_3$ calculated in accordance with 2 Hh was applied. Acidifying effect of ammonium sulphate results from the fact that it is a physiologically acid fertilizer and this compound undergoes nitrification in the soil. In the process of biological oxidation of ammonium nitrogen, 1 mol of NH_4^+ gives 2 mol of protons in the soil. However, calcium nitrate is a physiologically alkaline fertilizer. Significant effect of ammonium and nitrate forms of nitrogen on the soil pH was confirmed by many authors (Barszczak and Gębski 1994, Filipek and Badora 1999). Lack of significant influence of phosphorus doses on the discussed soil properties is also indicated by the results of Bednarek and Lipiński (1996) studies.

Liming contributed to the largest decrease of soil hydrolytic acidity values (Tab. 1). The form of used nitrogen also significantly affected the Hh formation, but its influence was smaller than that of liming. Ammonium sulphate caused a increase of hydrolytic acidity values. A different situation was observed after

Table 1. Influence of experimental factors on the indicators of acidification of soil

Object*	pH_{KCl}				Hydrolytic acidity (mmol (+) kg^{-1})				Exchangeable acidity (mmol (+) kg^{-1})				Mobile aluminium (mg Al^{3+} kg^{-1})			
	G1		G2		G1		G2		G1		G2		G1		G2	
	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
P1N1	3.88	4.37	5.73	6.76	41.25	27.50	13.88	6.38	17.51	4.51	1.40	0.44	123.90	33.87	7.09	2.66
P1N2	3.79	4.66	5.36	7.04	42.00	25.88	18.75	4.88	18.64	3.07	2.24	0.52	127.18	27.17	15.75	3.15
P2N1	3.91	4.41	5.78	6.75	39.38	27.38	13.88	6.25	14.53	4.23	1.18	0.37	91.59	31.90	7.88	2.76
P2N2	3.85	4.79	5.36	7.07	39.75	25.88	18.75	4.25	16.32	1.88	2.19	0.27	104.21	11.42	15.75	1.97
$\overline{x}$ G	–		–		33.63		10.88		10.08		1.07		68.90		7.13	
$\overline{x}$ F	–		–				28.45	16.05			9.25	1.91			61.67	14.36
LSD ($p = 0.05$)	–		–		G, F – 1.36 GF, NF – 2.55				G, P, F – 0.78 GF, NF – 1.47				G, P, F – 3.91 GP, GF, PF, NF – 7.32 GPF – 12.35			
Control	3.96		6.36		37.00		9.38		14.35		0.62		106.02		3.75	

* - explanations as in Methods.

using calcium nitrate. The ammonium form of nitrogen caused the change of Hh value in limed soil to a greater extent, whereas the effect of the nitrate form was greater in very acid soil. According to Łabętowicz *et al*. (1998), light soils have much greater buffer properties towards alkalisation than towards acidification. In the conditions where there has been no liming for many years, the proportion of buffer surface of soil undergoing acidification and the surface that is subject to alkalisation equals even 1:4. It gets narrowed under the influence of liming to 1:2. In the analysed experiment, what turned out to be significant was also the interaction between the dosage and form of nitrogen. Fertilization with phosphorus had no significant effect on soil hydrolytic acidity values. However, in the experiment performed by Bednarek (2002) as well as by Bednarek and Lipiński (1998) fertilization with phosphorus contributed to increase of soil hydrolytic acidity values.

The application of calcium carbonate caused the decrease of exchangeable soil acidity values from 14.35 to 0.62 mmol (+) kg^{-1} (Tab. 1). Fertilizing with calcium nitrate also resulted in a decrease of exchangeable soil acidity, whereas ammonium sulphate contributed to its significant increase. The dosage of phosphorus was also quite important, although in this case the observed changes were not as great.

The content of mobile aluminium was determined to the greatest extent by liming (Tab. 1). The application of $CaCO_3$ caused a significant decrease of the contents of that component in the soil. Similar relationships were found by other authors (Bednarek and Lipiński 1996, Bednarek and Tkaczyk 2002, Brzeziński 2002, Łabętowicz *et al*. 2004). The kind of nitrogen fertilizer also had a significant effect. Using ammonium sulphate enhanced the increase of mobile aluminium content, whereas using calcium nitrate enhanced its decrease, which undoubtedly was related to the effect of these fertilizers on the pH of soil solution. The dosage of superphosphate also affected the decrease of concentration of the analysed component, which suggests the formation of sparingly soluble aluminium phosphates in the presence of a large quantity of phosphorus (Filipek and Badora 1999). Similarly, Brzeziński (2002), comparing the contents of aluminium in NPK and KN objects, found a distinct decrease of aluminium contents under the influence of applying phosphorus fertilization. However, Bednarek (2002) observed a significant increase of mobile aluminium contents as a result of increasing the dose of triple superphosphate.

Maintaining the appropriate number of exchangeable cations in the soil has a significant importance in plant nutrition. Analysis of the data contained in Tables 2 and 3 indicates that the number of alkaline cations depended on liming and the applied form of nitrogen. Calcium carbonate and calcium nitrate contributed to the decrease of basic cation contents, excluding calcium. Most probably, the reason for this was the significant increase of plant yields under the influence of $CaCO_3$ and $Ca(NO_3)_2$ (Bednarek and Reszka 2007) and, consequently, increase in alkaline cations uptake.

Table 2. Influence of experimental factors on the saturation of sorption complex with basic exchangeable cations

Object*	Ca^{2+} (mmol (+) kg^{-1})				Mg^{2+} (mmol (+) kg^{-1})				K^{+} (mmol (+) kg^{-1})				Na^{+} (mmol (+) kg^{-1})			
	G1		G2		G1		G2		G1		G1		G1		G2	
	F1	F2	F1	F2	F1	F1	F1	F2	F1	F2	F2	F1	F2	F2	F1	F2
P1N1	6.00	12.3	30.7	39.0	4.61	1.80	1.69	1.18	3.87	0.72	0.81	0.70	0.88	0.63	0.74	0.61
P1N2	7.77	17.7	31.3	43.2	4.63	1.77	1.69	1.44	4.10	1.09	0.65	0.61	0.81	0.65	0.70	0.57
P2N1	7.94	14.8	33.9	40.0	3.34	1.62	1.58	1.49	3.38	1.12	0.59	0.61	0.86	0.64	0.72	0.66
P2N2	8.05	18.7	32.2	44.4	4.34	1.66	1.48	1.28	3.83	0.78	0.61	0.52	0.76	0.56	0.71	0.61
$\overline{x}$ G	11.7		36.8		2.97		1.48		2.36		0.64		0.72		0.66	
$\overline{x}$ F			19.7	28.8			2.92	1.53			2.23	0.77			0.77	0.61
LSD ($p = 0.05$)	G, N, F – 1.6 NF – 3.0				G, F – 0.31 GF – 0.58				G, F – 0.20 GF – 0.38				G, N, F – 0.04 GF – 0.07			
Control	4.82		32.9		3.37		1.92		3.82		1.13		0.62		0.63	

* – explanations as in Methods.

Table 3. Influence of experimental factors on the sum of exchangeable basic cations, total sorption capacity and base saturation degree of soil

Object*	S (mmol (+) kg^{-1})				T (mmol (+) kg^{-1})				V (%)			
	G1		G2		G1		G2		G1		G2	
	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
P1N1	15.4	15.5	33.9	41.5	56.6	43.0	47.8	47.8	27.1	36.0	71.1	86.5
P1N2	17.3	21.2	34.3	45.8	59.3	47.1	53.1	50.7	29.1	44.9	64.9	91.4
P2N1	15.5	18.1	36.8	42.8	54.9	45.5	50.7	49.0	28.1	39.7	72.6	87.2
P2N2	17.0	21.8	34.9	46.8	56.7	47.6	53.7	51.0	29.8	45.6	65.3	91.5
$\bar{X}$ G	17.72		39.59		51.3		50.5		35.0		78.8	
$\bar{X}$ F			25.64	31.67			54.1	47.7			48.5	65.3
LSD (p=0.05)	G, N, F – 1.9 GF, NF – 3.5				N, F – 1.7 GF – 3.2				G, F – 2.9 GF, NF – 5.4			
Control	12.63		36.57		49.6		45.9		25.3		79.5	

* - explanations as in Methods.

Nutrient uptake also had a decisive effect on quantitative changes of exchangeable cations in the experiment conducted by Czekała (2002).

In that experiment, the effect of calcium carbonate on the increase of the degree soil saturation with bases was distinctly greater than that of the nitrate form of nitrogen. Similarly, in the studies conducted by Chwil (2002), liming of very acid soil modified to the greatest extent the saturation of sorption complex with exchangeable cations and especially significantly affected the increase of the exchangeable calcium amount. In the analysed experiment the content of alkaline cations was not significantly conditioned on the dosage of triple superphosphate. However, in the studies conducted by Bednarek and Lipiński (1998), as a result of applying high doses of triple superphosphate there occurred a significant decrease of saturation of the sorption complex with calcium and sodium ions.

Generally, it can be stated that the application of liming together with mineral fertilization contributed to the improvement of physical and chemical properties of very acid soil through the increase of pH values, increase of the degree of saturation with alkaline cations, as well as decrease of mobile aluminium quantity.

CONCLUSIONS

1. Liming and the applied form of nitrogen had the greatest effect on the formation of soil acidification indicators. Calcium carbonate as well as calcium nitrate contributed to the significant decrease of hydrogen ions concentration, as well as the values of hydrolytic and exchangeable acidity of the soil.
2. Liming of very acid soil, as well as using the nitrate form of nitrogen, led to statistically proven decrease of mobile aluminium quantity. A similar effect was caused by the application of increased dosage of triple superphosphate, although in this case the observed changes were not as great.
3. The application of liming, as well as the use of calcium nitrate, contributed to the decrease of saturation of the sorption complex with Mg^{2+}, K^{+} and Na^{+} ions. A different situation was observed in the case of Ca^{2+} ions.

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Streszczenie. Celem badań była agrochemiczna ocena wpływu wapnowania i nawożenia formą amonową lub azotanową azotu na zmiany pH, kwasowość oraz wysycenie kompleksu sorpcyjnego gleby kationami wymiennymi. Badania oparto na analizie chemicznej materiału glebowego uzyskanego z dwuletniego doświadczenia wazonowego. Czynnikami doświadczalnymi były wapnowanie, nawożenie siarczanem amonu lub saletrą wapniową na dwóch poziomach oraz nawożenie fosforem w dwóch dawkach. Otrzymane wyniki badań wskazały, że zarówno wapnowanie jak również forma azotu miały istotny wpływ na wskaźniki zakwaszenia gleby. Zastosowanie $CaCO_3$, a także azotu azotanowego spowodowało wzrost pH oraz zmniejszenie wartości kwasowości hydrolitycznej i wymiennej gleby oraz ilości glinu ruchomego. Zawartość glinu ruchomego była także istotnie niższa w kombinacjach nawożonych zwiększoną dawką fosforu. Zawartość Mg^{2+}, Na^+ i K^+ była wyższa w obiektach nawożonych siarczanem amonu niż saletrą wapniową. Odmienną sytuację zaobserwowano w przypadku jonów Ca^{2+}. Zawartość jonów wapnia była największa w kombinacji wapnowanej i nawożonej saletrą wapniową w zwiększonej dawce. Nawożenie superfosfatem potrójnym granulowanym nie wpływało wyraźnie na wysycenie kompleksu sorpcyjnego gleby.

Słowa kluczowe: zakwaszenie, gleba, formy azotu, wapnowanie