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INFLUENCE OF LIMING AND MINERAL FERTILIZATION ON THE CONTENT OF MINERAL NITROGEN IN SOIL

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Abstract

Nitrogen is a key factor which shapes the fertility and fecundity of soils. Liming and mineral fertilization significantly modify transformations of nitrogen compounds in soil. The aim of our experiment was to evaluate the influence of liming and ammonium sulphate or calcium nitrate fertilization on the content of total nitrogen and its mineral forms in soil. The study was based on chemical analysis of the soil material obtained from a two-year pot experiment. The design of the experiment comprised 9 treatments in 4 replications on acidic soil and an analogous number of trials on limed soil. The experimental factors were: liming (acidic soil, limed soil), fertilization with ammonium or nitrate nitrogen at two levels (N_1, N_2) as well as fertilization with phosphorus at two levels (P_1, P_2). Liming was applied only once, before setting the experiment. The mineral fertilizers were applied every year before plant sowing in the form of fertilizers: ammonium sulphate, calcium nitrate and triple granulated superphosphate. The test plant was spring barley, which was harvested at its full ripeness. The results indicated that the biggest influence on the $N\text{-}NH_4$ content was produced by liming and fertilization with nitrogen. The application of calcium carbonate as well as calcium nitrate led to a decrease in the ammonium nitrogen content in soil. The content of nitrate nitrogen was higher in objects fertilized with calcium nitrate than in those fertilized with ammonium sulphate. Liming and nitrogen fertilization had the largest effect on the formation of mineral nitrogen content in soil. Liming contributed to decreased mineral nitrogen amounts in soil. A reverse situation was observed after increasing the rates of fertilization. The application of calcium carbonate and nitrate form of nitrogen contributed to a decrease in the total nitrogen content in soil. This fact can be explained by increased yield of spring barley in the objects limed and fertilized with calcium nitrate compared with the barley yield in the non-limed and ammonium sulphate fertilized trials.

Key words: nitrate nitrogen, ammonium nitrogen, liming, soil.

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WPŁYW WAPNOWANIA I NAWOŻENIA MINERALNEGO NA ZAWARTOŚĆ AZOTU MINERALNEGO W GLEBIE

Abstrakt

Azot ma decydujący wpływ na kształtowanie żyzności i urodzajności gleb. Istotnymi czynnikami modyfikującymi przemiany związków azotowych w glebie są wapnowanie i nawożenie mineralne. Celem badań było określenie wpływu wapnowania oraz nawożenia siarczanem amonu lub saletrą wapniową na ogólną zawartość azotu oraz jego mineralnych form w glebie. Badania oparto na analizie chemicznej materiału glebowego otrzymanego z dwuletniego doświadczenia wazonowego. Schemat doświadczenia obejmował 9 kombinacji w 4 powtórzeniach na glebie kwaśnej i wapnowanej. Czynnikami doświadczalnymi były: wapnowanie (gleba kwaśna, gleba wapnowana), nawożenie formą amonową lub azotanową azotu stosowane na dwóch poziomach (N_1, N_2) oraz nawożenie fosforem w dwóch dawkach (P_1, P_2). Wapnowanie zastosowano jednorazowo przed założeniem doświadczenia. Nawozy mineralne stosowano w każdym roku badań przed siewem roślin w postaci nawozów: siarczanu amonu, saletry wapniowej i superfosfatu potrójnego granulowanego. Rośliną testową był jęczmień jary, który zbierano w fazie pełnej dojrzałości. Wykazano, że największy wpływ na zawartość N-NH_4 miało wapnowanie oraz nawożenie azotem. Zastosowanie węglanu wapnia, a także saletry wapniowej prowadziło do zmniejszenia ilości azotu amonowego w glebie. Zawartość azotu azotanowego w obiektach nawożonych saletrą wapniową była większa niż w kombinacjach z siarczanem amonu. Wapnowanie oraz zastosowana dawka azotu miały największy wpływ na kształtowanie zawartości azotu mineralnego w glebie. Wapnowanie przyczyniło się do zmniejszenia ilości azotu mineralnego w glebie. Odmienną sytuację zaobserwowano po zwiększeniu dawek analizowanego składnika. Zastosowanie węglanu wapnia oraz azotanowej formy azotu prowadziło do zmniejszenia ogólnej zawartości azotu w glebie, co można wyjaśnić zwiększeniem plonu jęczmienia jarego w obiektach wapnowanych i nawożonych saletrą wapniową w porównaniu z plonem rośliny testowej w obiektach nie wapnowanych i nawożonych siarczanem amonu.

Słowa kluczowe: azot azotanowy, azot amonowy, wapnowanie, gleba.

INTRODUCTION

Nitrogen is a key factor which shapes the fertility and fecundity of soils. Total nitrogen content in mineral soils varies from 0.02 to 0.35%. Most of the nitrogen in soils is present as organic compounds. Only 1-5% of total nitrogen is in the mineral form, the fact that has principal meaning in plant nutrition. The average content of mineral nitrogen in the Polish soils ranges from 76-90 kg N ha^{-1} in spring and 89-97 kg N ha^{-1} in autumn (FOTYMA et al. 2004). Its content is controlled by a combination of physical, chemical and biological processes: oxidation-reduction and mineralization-immobilization. The direction and range of these transformations depends on the type of soil, moisture, temperature, reaction, content of clay minerals, the amount of organic substance, activity of microorganisms, etc. Another significant factor which modifies transformations of nitrogen compounds in soil is mineral fertilization (ŁOGINOW et al. 1987, DECHNIK, BEDNAREK 1989, MAZUR, CIEĆKO 1998, FOTYMA 2000, KOÓS, NEMETH 2006, SOSULSKI et al. 2006a).

In order to secure high effectiveness of mineral fertilization in the formation of ammonium and nitrate nitrogen in soil, soil reaction needs to be suitably regulated. Liming influences the activity of ammonifying and nitrifying microorganisms, and through that – the amount of available forms of nitrogen in soil (KOZANECKA 1995, SAPEK 1995, MALHI 2002, FOTYMA et al. 2004, SOSULSKI et al. 2006b).

The aim of our study has been to define the influence of liming and ammonium sulphate or calcium nitrate fertilization on the total content of nitrogen and the content of its mineral (ammonium and nitrate) forms in soil.

MATERIAL AND METHODS

A two-year pot experiment has been completed, set up on soil material of grain-size distribution typical of light loamy sand. The soil was characterized by very acidic reaction (pH_{KCl} 4.00), low abundance of available phosphorus and potassium and very low content of available magnesium. The total nitrogen content was 0.73 g kg^{-1}, with 15.02 mg kg^{-1} of mineral nitrogen, 11.82 mg kg^{-1} of $N\text{-}NH_4$, and 3.20 mg kg^{-1} of $N\text{-}NO_3$.

The trials were set in 5 kg pots. Against the background of permanent potassium and magnesium on acid and limed soil, differentiated fertilization with phosphorus and nitrogen was applied: 1) 0; 2) $P_1N_1\text{-}NH_4$; 3) $P_1N_1\text{-}NO_3$; 4) $P_1N_2\text{-}NH_4$; 5) $P_1N_2\text{-}NO_3$; 6) $P_2N_1\text{-}NH_4$; 7) $P_2N_1\text{-}NO_3$; 8) $P_2N_2\text{-}NH_4$; 9) $P_2N_2\text{-}NO_3$.

Liming with $CaCO_3$ in the amount calculated according to 1 Hh was applied once before the establishment of the experiment. Fertilization with nitrogen, potassium and magnesium was applied every year, before sowing plants. Phosphorus was applied in the form of granulated triple superphosphate (20.1% P) in two rates (P_1 – 0.06 g P kg^{-1}, P_2 – 0.12 g P kg^{-1} d.m. of soil); nitrogen was used as ammonium sulphate (20% N) or calcium nitrate (15.5% N) at two levels (N_1 – 0.1 g N kg^{-1}, N_2 – 0.2 g N kg^{-1} d.m. of soil); potassium (0.1 g K kg^{-1} d.m. of soil) was added as potassium high-percentage potash salt (49.8% K) and magnesium (0.025 g Mg kg^{-1} d.m. of soil) was introduced as magnesium sulphate (9.6% Mg). The experimental factors were tested versus the control object. During the vegetation season, constant soil moisture was maintained at 60% field water capacity. The test plant was cv. Bryl spring barley, harvested at full ripeness.

In each year of the studies, after harvest, soil material was collected for chemical analyses, in which total nitrogen content was determined by Kjeldahl method, the ammonium nitrogen content was tested by Nessler method and the content of nitrate nitrogen was determined by the salicylate method (LITYŃSKI et al. 1976). The determinations were performed with the use of a Cecil 2011 photocolorimeter.

The influence of the experimental factors on the formation of N_{total}, Nmin., $N\text{-}NH_4$ and $N\text{-}NO_3$ in soil was determined by variance analysis including Tukey's confidence half-intervals. The results presented in the tables are mean values from a two-year experiment. Only significant LSD values were given.

RESULTS AND DISSCUSION

In the experiment the content of ammonium nitrogen was significantly greater in acidic than in limed soil (Table 1). The reason for that might have been the reduction of the nitrification process at low soil pH values. Another important fact was that the plants cultivated in acidic soil environment took up NO_3^- ions quicker than NH_4^+ ions. Besides, a decrease in the amount of ammonium nitrogen at increased pH may have resulted from losses caused by ammonia disappearing from soil. According to SAPEK (1995), soil acidification and lower pH enhance ammonification and accumulation of $N\text{-}NH_4$ in soil. Lower ammonium nitrogen content coinciding with increased soil pH was also observed by SOSULSKI et al. (2006a). Similarly, KOZANECKA (1995) as well as BEDNAREK and TKACZYK (2003) found that $N\text{-}NH_4$ content was lower in limed than non-limed soil. The application of ammonium sulphate caused a significant increase of the $N\text{-}NH_4$ content as compared to its content in soil fertilized with calcium nitrate. This effect was clearly caused by the application of the ammonium form of nitrogen in the fertilizer. The results are in accord with the observations reported by SOSULSKI et al. (2006a). In our experiment, increasing nitrogen rates were associ-

Table 1

Effect of experimental factors on the content of ammonium nitrogen and nitrate nitrogen in soil (mg N kg^{-1})

Object	Content	$N\text{-}NH_4$				$N\text{-}NO_3$			
	soil	acidic		limed		acidic		limed	
	N form	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
P_1N_1		41.54	12.19	17.89	8.04	9.64	22.11	11.09	28.78
P_1N_2		61.58	13.39	22.18	7.33	9.78	29.71	13.32	32.32
P_2N_1		37.75	11.41	17.59	7.99	9.43	26.85	13.75	28.64
P_2N_2		46.58	12.47	28.18	6.62	12.17	32.03	9.64	31.37
$\bar{x}$ soil		29.61		14.48		18.96		21.11	
$\bar{x}$ form				34.16	9.93			11.10	28.97
LSD (p=0.05)		soil, N dose, N form – 3.75 soil x N form, N dose x N form – 7.03				N form – 4.19			
Control		15.63		7.44		4.86		11.40	

ated with a significant increase in the amount of ammonium nitrogen in combinations with ammonium sulphate. Such a dependence was not observed in the objects fertilized with calcium nitrate. Increased ammonium nitrogen in soil after application of increased rates of nitrogen fertilizer has been reported by other authors (CHMIELEWSKA, DECHNIK 1987, KOZANECKA 1995, CZEKAŁA et al. 2002, BEDNAREK, TKACZYK 2002, 2003). In conrast, The differentiation of phosphorus rates did not significantly affect the content of $N\text{-}NH_4$ in soil, a finding which is confirmed by the results of studies performed by BEDNAREK and TKACZYK (2002).

Nitrate nitrogen is an unstable part of mineral nitrogen. The content of this nitrogen form can indicate a potential threat to groundwater (FOTYMA et al. 2004). In the present experiment, the content of $N\text{-}NO_3$ ranged from 4.86 to 32.32 mg kg^{-1} of soil (Table 1). Among the tested factors, statistically proven effect was produced only by this form of nitrogen. Both in very acidic and in limed soils increased amounts of nitrate nitrogen were observed under the influence of calcium nitrate. Significantly more nitrate form of nitrogen after an application of nitrate fertilizer was also found by SAPEK (1995) and SOSULSKI et al. (2006a). The mean values from the objects indicate that calcium carbonate raised the content of $N\text{-}NO_3$, which was most probably caused by favorable conditions for nitrification. The stimulating effect of this procedure on the content of $N\text{-}NO_3$ was also observed by KOZANECKA (1995), BEDNAREK and TKACZYK (2003) and SOSULSKI et al. (2006b). In the present experiment, the content of nitrate nitrogen was not significantly related to the rates of nitrogen and phosphorus. However, other authors reported positive influence of increased rates of nitrogen fertilizers on $N\text{-}NO_3$ in soil (CHMIELEWSKA, DECHNIK 1987, DECHNIK, BEDNAREK 1989, MALHI 2002, BEDNAREK, TKACZYK 2002, 2003, QIAN et al. 2004, KOÓS, NEMETH 2006).

The results presented in Table 2 suggest that the content of mineral nitrogen was significantly formed under the influence of liming and the applied rate of nitrogen. Calcium carbonate caused a decrease in the mineral N content in comparison with the content observed in non-limed soil, which was nevertheless higher than in the soil before the experiment was established. The decrease of N_{min} content can be justified by a large, distinct, over two-fold, increase of the test plant yield under the influence of this procedure (BEDNAREK, RESZKA 2007), and, consequently, the increased uptake of nitrogen. The absorption of nitrogen by spring barley being the main cause of depressed mineral nitrogen in soil is also indicated by the results of a study conducted by BEDNAREK and TKACZYK (2003). An increased rate of nitrogen, both in the form of ammonium sulphate and calcium nitrate, leads to an increased content of mineral nitrogen. This increase was greater in treatments on non-limed than on limed soil. High rates of nitrogen fertilizers favour the narrowing of C : N ratio and consequently the surplus nitrogen from fertilizers is not used by multiplying microorganisms and the soil accumulates mineral forms of nitrogen. A positive effect of increased rates

Table 2

Effect of experimental factors on the content of mineral nitrogen (mg N kg^{-1}) and total nitrogen (g N kg^{-1}) in soil

Object	Content	N-NH_4 + N-NO_3				N total			
	soil	acidic		limed		acidic		limed	
	N form	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3
P_1N_1		51.18	34.30	28.98	36.81	0.84	0.77	0.73	0.73
P_1N_2		71.36	43.10	35.50	39.65	0.99	0.79	0.79	0.79
P_2N_1		47.17	38.26	31.34	36.64	0.84	0.77	0.74	0.76
P_2N_2		58.74	44.50	37.82	37.99	0.97	0.79	0.81	0.81
$\bar{x}$ soil		48.57		35.59		0.85		0.77	
$\bar{x}$ form				45.26	38.90			0.84	0.78
LSD (p=0.05)		soil, N dose – 7.23 soil x N form – 13.55				soil, N dose, N form – 0.04 soil x N form, N dose x N form – 0.07 soil x N dose x N form – 0.1			
Control		20.49		18.83		0.73		0.70	

of nitrogen on the content of mineral nitrogen in soil is also indicated by the results obtained by Czekała et al. (2002). Smaller amounts of N-NH_4 + N-NO_3 were observed in the soil fertilized by the nitrate form as compared to the objects treated with ammonium sulphate, although these differences were not statistically confirmed. This fact can be explained by the increase (69%) of spring barley yield in the objects fertilized with calcium nitrate compared with the yield from those fertilized with ammonium sulphate (Bednarek, Reszka 2007). What was significant, however, was the correlation between the soil series and the form of nitrogen used.

In our own study, liming contributed to a significant decrease of total nitrogen content (Table 2). Sosulski et al. (2006a) also observed a decreasing tendency in the total N content in soil as the soil pH increased. The use of calcium nitrate significantly depressed the total amount of nitrogen as compared to its amount in objects fertilized with ammonium sulphate, which was most probably caused by the difference in the amount of this nutrient taken up by plants. Formation of the total N content was also significantly affected by the rate of ammonium sulphate. A significant increase of total nitrogen in soil was observed at higher ammonium sulphate fertilization rates.

CONCLUSIONS

1. Liming and nitrogen fertilization significantly affected the $N\text{-}NH_4$ content in soil. The application of calcium carbonate, as well as calcium nitrate contributed to a significantly lower content of this N form in soil in comparison with ammonium sulphate fertilization.

2. The $N\text{-}NO_3$ content was significantly modified only by fertilization with differentiated forms of nitrogen. Calcium nitrate caused an increase in the nitrate nitrogen content, irrespective of the soil pH.

3. The biggest effect on the content of mineral nitrogen in soil was caused by liming and nitrogen rates. Lower content of N_{min} was found in soil from limed rather than non-limed combinations. Increased nitrogen rates enhanced a statistically proven increase of $N\text{-}NH_4 + N\text{-}NO_3$ content in soil.

4. The total content of nitrogen was significantly related to liming and nitrogen fertilization. The application of calcium carbonate and the nitrate form of nitrogen led to a decrease in the total nitrogen content in soil in comparison with acidic soil and ammonium sulphate fertilization.

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