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Department of Agricultural and Environmental Chemistry,
University of Life Sciences in Lublin
ul. Akademicka 15, 20-950 Lublin
e-mail: wiesław.bednarek@up.lublin.pl

WIESŁAW BEDNAREK, RENATA RESZKA

Influence of liming and mineral fertilization on the content of available forms of magnesium and potassium in soil

Wpływ wapnowania i nawożenia mineralnego na zawartość przyswajalnych form magnezu i potasu w glebie

Summary. The influence of liming and fertilization with various nitrogen forms on the content of available forms of magnesium and potassium was determined in a two-year pot experiment. The factors of the study were liming, fertilization with two nitrogen forms at two levels and fertilization with phosphorus at two doses. Spring barley was harvested at its full maturity. The content of available magnesium was significantly related to liming and fertilization with various nitrogen forms. The application of calcium carbonate and the nitrate form of nitrogen led to the decrease of available magnesium concentration in soil. Differentiated rates of phosphorus and nitrogen were not the significant factors modifying the available magnesium content in soil. Liming and the applied form of nitrogen had the greatest effect on the content of available potassium in soil. Calcium carbonate as well as calcium nitrate contributed to the significant decrease of analyzed element concentration. A similar effect was caused by the application of increased rates of phosphorus.

Key words: liming, mineral fertilization, magnesium, potassium, soil

INTRODUCTION

One of the main factors causing limitation of plant production in Poland is the low content of available magnesium and potassium forms in soils. As it is indicated by various studies, the participation of soils with very low and low abundance in available magnesium is 34% and in available potassium – 47%, of the farmland surface [Lipiński 2005 a, b]. Nutrient deficiency leads to a decrease of the amount and deterioration of yields quality. It is necessary to make them up by means of fertilization. Transformations of potassium and magnesium from mineral fertilizers depend on physico-chemical properties of soils, as well as on other components, applied coordinately, especially including nitrogen. In the case of applying nitrogen fertilizers not only the rate is significant but also the form of nitrogen used in the fertilizer. To a large extent, it determines the degree of soil environment acidification, and, consequently, the amount of nutrients in available form [Wiater 1994, Czekała *et al*. 2001, Łabętowicz and Rutkowska 2001a, b].

The adverse effects of acidification can be counteracted with the use of calcium fertilizers. Liming affects physical, physico-chemical and biochemical properties of the soil. It diminishes the content of toxic aluminum ions, decreases hydrolytic acidity and fundamentally affects the startup or retro-gradation of many soil components indispensable for the plants [Filipek 1989, Gładysiak *et al*. 1999, Kaniuczak 1999].

The purpose of our studies was to assess the influence of liming and fertilization with various nitrogen forms on the soil content of available magnesium and potassium forms.

MATERIAL AND METHODS

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 was characterized with very acid reaction (pH = 4.00), low abundance with available potassium (56 mg kg^{-1}) and a very low content of available magnesium (17 mg kg^{-1}). The experiment was conducted in pots containing 5 kg of 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 two forms of nitrogen: ammonium – F1 or nitrate – F2, two levels of fertilization with nitrogen: N1 – 0.1 g N kg^{-1}, N2 – 0.2 g N kg^{-1} and fertilization with phosphorus in two rates: P1 – 0.06 g P kg^{-1}, P2 – 0.12 g P kg^{-1}. The above-mentioned experimental factors were applied against the background of control object (K). In all combinations there was permanent application of potassium (0.1 g K kg^{-1}) and magnesium (0.025 g Mg kg^{-1}). $CaCO_3$ liming was applied once, before establishing the experiment, in the amount calculated according to 1 Hh. Fertilization with nitrogen, phosphorus, potassium and magnesium was applied in each year of the study before sowing the plants. Phosphorus was added in the form of triple, granulated superphosphate (20.1% P), nitrogen in the form of ammonium sulphate (20% N) or calcium nitrate (15.5% N), potassium in the form of high-percentage potash salt (49.8% K), and magnesium – as magnesium sulphate (9.6% Mg). During vegetation constant soil moisture was maintained on the level of 60% field water capacity. The test plant was spring barley which was harvested at its full maturity.

In the soil material we determined the content of available magnesium by means of AAS method after extraction with 0.0125 mol $CaCl_2$ dm^{-3} solution (the Schachtschabel method) and the available potassium by means of AAS method with the use of Hitachi Z-8200 apparatus with Zeeman polarization after extraction with lactate buffer (the Egner-Riehm method).

The influence of experimental factors upon the formation of the available magnesium and potassium content in soil was determined by means of variance analysis with the application of Turkey confidence half-intervals. The results presented in tables constitute mean values from the two-year experiment. Only the significant half-intervals values were given in the tables.

RESULTS AND DISCUSSION

The analysis of data contained in table 1 indicates that the significant effect upon the content of available magnesium was caused by liming and the form of nitrogen used. Under the influence of calcium carbonate, the amount of the component under discussion decreased. High content of available magnesium in non-limed soil was most probably related to high quantity of H^+ and Al^{3+} ions in these soil conditions. Besides, the increased acidity usually enhances the increase of magnesium carbonate and sulphate solubility. The decrease of available magnesium concentrations as an effect of liming was also observed by Filipek [1989]. However, Wiater [1994], Gładysiak *et al*. [1999] as well as Łabętowicz and Rutkowska [2001b] found that the content of the discussed form of nutrient increases with the increase of soil pH, whereas in the studies conducted by Kaniuczak *et al*. [1999], the content of available magnesium in Ap layer did not depend on liming, but this procedure affected the increase of the analyzed component's content in Bt layer.

Table1. Influence of experimental factors on the content of available forms of potassium and magnesium in soil ($mg \cdot kg^{-1}$)
Tabela 1. Wpływ czynników doświadczalnych na zawartość przyswajalnych form potasu i magnezu w glebie ($mg \cdot kg^{-1}$)

Object Obiekt	Available magnesium – Magnez przyswajalny				Available potassium – Potas przyswajalny			
	G1		G2		G1		G2	
	F1	F2	F1	F2	F1	F2	F1	F2
P1N1	51.73	30.05	27.40	23.90	140.94	87.44	81.88	71.50
P1N2	50.38	30.30	28.75	23.00	161.63	81.00	82.50	66.50
P2N1	47.50	27.35	25.50	27.40	136.00	76.25	80.13	72.75
P2N2	50.00	28.90	27.73	23.50	145.31	66.58	79.25	67.75
$\bar{x}$ G	39.53		25.90		111.89		75.28	
$\bar{x}$ F			38.62	26.80			113.45	73.72
LSD (p=0.05) NIR (p=0,05)	G, F – 5.15 GF – 9.65				G, P, F – 5.27 GP, GF, NF – 9.88			
K	43.25		25.63		138.56	70.25		

G1 – acid soil, gleba kwaśna; G2 – limed soil, gleba wapnowana; F1 – ammonium sulphate, siarczan amonu; F2 – calcium nitrate, saletra wapniowa; N1, N2 – nitrogen rates, dawki azotu; P1, P2 – phosphorus rates, dawki fosforu; K – control, kontrola

In this experiment, the application of ammonium sulphate stimulated the content of available magnesium more than the use of calcium nitrate. This fact can be explained by the antagonism between NH_4^+ and Mg^{2+} ions, as well as by a lower yield of the test plant in combinations fertilized with $(NH_4)_2SO_4$ [Bednarek and Reszka 2007] and, consequently, by a lower uptake of the analyzed nutrient. The absorption of magnesium by plants as a significant factor, affecting its content in soil, is also indicated by the results of Chwil [2000] as well as Łabętowicz and Rutkowska [2001b] studies.

The application of differentiated phosphorus and nitrogen rates had no statistically proven effect upon the content of available magnesium. However, the opinion about the decrease in the concentration of the discussed form of this nutrient with the increase of nitrogen rates prevails in literature [Bednarek 1994, Czekała *et al*. 2002].

In the conducted experiment, the greatest and most significant influence on the content of available potassium was that of liming and the form of applied nitrogen (tab. 1). The use of calcium carbonate contributed to the decrease in the concentration of the discussed component, as compared to its content in non-limed soil. Most probably, a high content of available potassium in acid soil was caused by the increase in the number of H^+ ions in the conditions of low soil pH. The H^+ protons enhance passing of potassium cations absorber on the surface of soil colloids, as well as of those bound in inter-packet spaces of clay minerals, into their active forms. Besides, H^+ ions increase the intensity of hydrolysis process and positively influence the release of K^+ cations from primary alumino-sillicate minerals. Undoubtedly, in acid soils, potassium sorption is also limited by high content of Al^{3+}ions, which have high energy of entry into sorption complex and they easily displace K^+ ions into the soil solution. Decrease of available potassium concentration as an effect of liming was also observed by Filipek [1989]. However, in the studies conducted by Gładysiak *et al*. [1999], the increase of soil pH value contributed to the increased amount of the component under discussion. Similarly, Łabętowicz and Rutkowska [2001a], analyzing the concentration of potassium in the soil solution, found that it significantly increases in limed objects, as compared to non-limed combinations, whereas Wiater [1994] did not observe any effect of soil reaction upon the content of available potassium in it.

The application of ammonium sulphate both on acid and limed soil contributed to statistically proven increase of available potassium, compared to its concentrations in combinations fertilized with calcium nitrate. This fact can be justified by competition between K^+ and NH_4^+ ions for sorption places in inter-packet spaces of clay minerals. The diameter of an ammonium ion is very close to the diameter of a potassium ion and therefore an NH_4^+ ion can be immobilized just like a K^+ ion in clay minerals with 2:1 structures. It causes that retro-gradation of potassium in soils fertilized with the ammonium form of nitrogen is slower than in soils fertilized with the nitrate form of nitrogen. Łabętowicz and Rutkowska [2001a] also observed a significant increase of potassium concentration in soil solution as a result of displacing K^+ ions from the sorption complex by NH_4^+ cations. In this experiment, what contributed to the increase of available potassium content in combinations fertilized with $(NH_4)_2SO_4$ was also a significant difference in the test plant yield [Bednarek and Reszka 2007] and, consequently, in the amount of the nutrient taken up.

In the analyzed experiment, the increase of phosphorus rates lead to a significant decrease of the available potassium content in the soil, while the differentiation of nitrogen rates had no statistically proven effect. In the experiment carried out by Bednarek [1996], the increase of phosphorus rates enhanced the increase of available potassium content in the soil. However, the author found that the concentration of the analyzed component decreased with the increase of nitrogen rates. Similarly, Czekała *et al*. [2001] observed a significant decrease of available potassium content in the soil fertilized with increased rates of nitrogen.

Generally, it can be stated that fertilization with potassium and magnesium only, as well as the applied experimental factors, contributed to the increase of available magnesium and potassium content, as compared to their concentration in the soil before the experiment was set up.

CONCLUSIONS

1. The content of available magnesium significantly depended upon liming and fertilization with various forms of nitrogen. The application of $CaCO_3$ and the nitrate form of nitrogen led to a decrease of available nitrogen concentration.

2. Differentiated rates of nitrogen and phosphorus were not significant factors modifying the soil content of available magnesium.

3. Liming and the applied form of nitrogen had the greatest and significant effect upon the content of available potassium in soil. Calcium carbonate and calcium nitrate contributed to a significant decrease of the soil concentration of the nutrient under discussion. The application of increased phosphorus rate had a similar effect.

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Streszczenie. W dwuletnim doświadczeniu wazonowym oceniano wpływ wapnowania oraz nawożenia różnymi formami azotu na zawartość przyswajalnych form magnezu i potasu w glebie. Czynnikami doświadczalnymi było wapnowanie, nawożenie dwiema formami azotu stosowane w dwóch dawkach oraz nawożenie fosforem na dwóch poziomach. Jęczmień jary zbierano w fazie dojrzałości pełnej. Zawartość magnezu przyswajalnego była istotnie uzależniona od wapnowania i nawożenia zróżnicowanymi formami azotu. Zastosowanie $CaCO_3$ oraz azotanowej formy azotu prowadziło do zmniejszenia koncentracji magnezu przyswajalnego. Zróżnicowane dawki azotu i fosforu nie były istotnym czynnikiem modyfikującym zawartość magnezu przyswajalnego w glebie. Wapnowanie oraz zastosowana forma azotu miały największy wpływ na zawartość potasu przyswajalnego w glebie. Węglan wapnia oraz saletra wapniowa przyczyniły się do istotnego zmniejszenia koncentracji analizowanego składnika. Podobnie oddziaływało zastosowanie zwiększonej dawki fosforu.

Słowa kluczowe: wapnowanie, nawożenie mineralne, magnez, potas, gleba