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An effect of liming on magnesium content in meadow vegetation and leachate water

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Abstract

The aim of the study was to evaluate an effect of liming on chemical properties of the soil, magnesium content in the meadow vegetation and leachate water moving through the soil profile. The study was conducted in the growing seasons in the years 2012–2014. The study included three plots in two series: with lime and without lime.

The plant material was subjected to dry digestion and ash was dissolved in HNO_3 (1:3). The soil was mineralized in a muffle furnace and the ashes were dissolved in a mixture of HNO_3 and $HClO_4$ (3:1 v/v). In the obtained samples and in leaching water, estimated the content of phosphorus, potassium, magnesium and sodium by induction plasma emission spectrophotometer. In the soil content of assimilable phosphorus and potassium was determined by the Egner–Riehm method. The content of assimilable magnesium was determined by the Schachtschabel method and the pH of the soil by potentiometric method in water and in mol KC1·dm^{-3}.

Liming positively affected on soil pH and magnesium content in plants increasing its amount of about 15–21% of dry matter with respect to not limed plots. In turn, lime fertilization negatively affected the content of magnesium in leachate water and the load eluted per unit area. Magnesium content in leachate water and the amount of loads eluted from limed plots were lower on average by 16–23% with respect to not limed plots.

Key words: *leachate water, liming, magnesium, meadow vegetation*

INTRODUCTION

Magnesium is an essential component for the plant world. Its most important functions include participation in the construction of chlorophyll and participation in the transfer of phosphate groups or the creation of high energy compounds (ATP), which determine almost all vital functions of an organism [MAGUIRE, COWAN 2002]. For example ÇELIK *et al.* [2010], reported that the concentration of magnesium in the leaves is an indicator of the plant's view of potassium. According to many researchers GRZEBISZ *et al.* [2010], POTARZYCKI [2011], SZULC *et al.* [2011], SZCZEPANIAK *et al.* [2016] the content of magnesium in the leaves can be used as an indicator of plant growth conditions or stress. The availability of these components by the plants is essentially determined by chemical properties of the soil. Especially limiting factor of magnesium intake by plants is low soil pH [GRZEBISZ *et al.* 2005; IGRAS *et al.* 2010; REID, HORVATH 1980]. Low abundance of the plants in this component enhances its deficiency in consumers of these plants, since among the macroelements, magnesium is characterized by the lowest assimilation by the animal organism. According to MIKOŁAJCZAK and PREŚ [1983], this availability is 10–20% compared to other components which availability is 50–80%. In the opinion of KOPIŃSKI [2011], low soil pH is responsible in our country for the large consumption of fertilizer per unit of crop production. In turn, SMYK

[1994] reports that the decreased antibiotic potential is observed in acidic soils, which favors the growth of fungi and the formation of nitrosamines.

Having above in mind, the authors undertook the study concerning determination of liming effect on magnesium content in the meadow vegetation and water moving through the soil profile of a mountain meadow.

MATERIAL AND METHODS

The study was conducted in the growing seasons in the years 2012–2014 on the experimental plot located on a mountain meadow, the foothills of the Jaworzyna Krynicka, 610 m a.s.l., the slope was inclined to 4° towards to NE (20°55'32" E, 49°24'57" N). The soil with a granulometric composition of medium clay, which is classified according to WRB as Haplic Cambisol (Dystric) was observed on the field [PTG 2011]. At the beginning of the study the soil was acidic (pH_{KCl} – 4.3 mol dm^{-3}) and the following chemical composition: P = 9.8, K = 85, Mg = 80 mg·kg^{-1} DM. Plant community was dominated by red fescue (*Festuca rubra* L.) and common bent grass (*Agrostis capillaris* L.) The study included three plots in triplicates, and two series: with lime and without lime.

Non-limed series:
1. O – control object
2. Phosphate and potassium fertilizers ($P_{18}K_{50}$)
3. Phosphate, potassium and nitrogen fertilizers ($P_{18}K_{50}N_{120}$).

Limed series:
1. O – control object
2. Phosphate and potassium fertilizers ($P_{18}K_{50}$)
3. Phosphate, potassium and nitrogen fertilizers ($P_{18}K_{50}N_{120}$).

The liming applied 1.5 t·ha^{-1} of oxide and magnesium calcium (40% CaO, 20% MgO). Phosphorus and potassium were used in the fertilization once in the spring, and nitrogen in two parts: 60% of the dose for the first and 40% for the second offset. The first offset was collected at the beginning of flowering of red fescue – the third decade of June, the second in the first decade of September. Each plot of 12 m^2 was equipped with a lysimeter with a diameter of 50 cm installed in the soil at a depth of 40 cm due to the thickness. The amount of water moving through the soil profile was measured each time it was observed in the receiving tanks. The samples of a size of 10% were collected for chemical analysis. These samples were pooled by replicates creating the bulk sample for the period of vegetation. These samples were stored in a refrigerator. The plant material was subjected to dry digestion and ash was dissolved in HNO_3 (1:3). The soil was mineralized in a muffle furnace and the ashes were dissolved in a mixture of HNO_3 i $HClO_4$ (3:1 v/v). In the obtained samples and in leaching water, estimated the content of phosphorus, potassium, magnesium and sodium by induction plasma emission spectrophotometer (ICP-OES) on the Perkin-Elmer model Optima 7300 DV [JONES, CASE 1990]. In the soil content of assimilable phosphorus and potassium was determined by the Egner–Riehm method. The content of assimilable magnesium was determined by the Schachtschabel method and the pH of the soil by potentiometric method in water and in mol KC1·dm^{-3} [KARCZEWSKA, KABAŁA 2008].

The results were analysed statistically, taking into account one-factor analysis of variance and *LSD* test at a significance level of $\alpha < 0.05$; using Statistica 7 program.

RESULTS AND DISCUSSION

The results of soil analysis made after 3 years indicate about clear improvement of some soil quality indicators after liming (Tab. 1). The soil pH increased according to the beginning on average of 0.3 units in H_2O and 0.5 KCl. The content of assimilable forms of phosphorus slightly increased, but content of magnesium increased significantly by 15–22.2 mg Mg·kg^{-1} of soil. In turn, content of potassium reduced on average of 10 mg K·kg^{-1} of soil. On the other hand, after 3 years in plots without liming the soil pH and content of phosphorus were generally close to baseline. Potassium and magnesium content decreased by 6–8 mg and 2–5 mg·kg^{-1} of soil respectively. The changes in chemical properties of soil as a result of liming generally confirm the prevailing opinion. The exception in this respect was potassium, the reduction of the content in the soil demonstrates to low dose of fertilizer.

Table 1. Chemical properties of soil at the beginning of the study and after 3 years

Plots	pH		Assimilable mg·kg^{-1} DM of soil		
	H_2O	KCl	P	K	Mg
Beginning of the study	5.30	4.35	9.80	85.0	80.0
Non-limed					
0	5.30	4.40	9.68	79.0	78.0
$P_{18}K_{50}$	5.35	4.30	9.40	78.1	75.2
$P_{18}K_{50}N_{120}$	5.35	4.30	9.60	75.0	75.0
Limed					
0	5.60	4.95	10.90	78.2	102.2
$P_{18}K_{50}$	5.60	4.85	10.80	75.0	96.8
$P_{18}K_{50}N_{120}$	5.50	4.80	9.90	73.5	95.0

Source: own study.

Liming profitably affected the productivity of meadow vegetation expressed in the yield of dry matter only on the plot fertilized together with phosphorus and potassium (Tab. 2). This fertilization caused that dry matter yield increased on average by 20% per year. This was due to an increase in the share of white clover in this meadow, which contributed to the improvement of soil fertility in nitrogen. On the other hand, the lack of positive influence of liming on the yielding of sward on control plots and plots fertilized with PKN has to be explained by the high tolerance of

Table 2. The mean meadow vegetation dry matter yield, its magnesium (Mg) content and uptake with yield during the study period

Plots	Crop $t \cdot ha^{-1}$	Content, $g \cdot kg^{-1}$				Uptake, $kg \cdot ha^{-1}$			
		2012	2013	2014	mean	2012	2013	2014	mean
Non-limed									
0	3.50	1.8	1.6	1.8	1.7	6.90	5.41	6.00	6.10
$P_{18}K_{50}$	4.34	1.7	1.7	1.6	1.7	6.80	7.40	7.40	7.20
$P_{18}K_{50}N_{120}$	6.66	1.6	1.3	1.6	1.5	10.20	9.20	10.40	9.93
Limed									
0	3.56	2.2	1.9	1.9	2.0	8.00	6.61	6.50	7.04
$P_{18}K_{50}$	5.22	2.1	1.9	2.0	2.0	8.90	10.80	10.80	10.20
$P_{18}K_{50}N_{120}$	6.51	1.8	2.0	1.9	1.9	11.20	13.60	13.10	12.60
LSD ($p = 0.05$)	0.78	–	–	–	–	–	–	–	–

Source: own study.

Table 3. The amount of precipitation and leachate water from the soil profile during the growing season

Years	Participation water mm	Leachate water, mm						*LSD* (p=0.05)
		non-limed plots			limed plots			
		0	$P_{18}K_{50}$	$P_{18}K_{50}N_{120}$	0	$P_{18}K_{50}$	$P_{18}K_{50}N_{120}$	
2012	523	162	160	201	131	133	192	20.3
2013	412	185	188	212	169	168	186	21.0
2014	674	197	187	222	194	181	209	19.4
Mean	536	181	178	212	165	161	196	20.2

Source: own study.

Table 4. The content of magnesium (Mg) in leachate water from the profile and size of the load carried with it during the growing period

Plots	Content, $mg \cdot dm^{-3}$				Load, kg ha^{-1}			
	2012	2013	2014	mean	2012	2013	2014	mean
Non-limed								
0	1.05	0.78	1.08	0.97	1.70	1.44	2.13	1.72
$P_{18}K_{50}$	1.00	0.69	1.06	0.92	1.60	1.30	1.98	1.63
$P_{18}K_{50}N_{120}$	1.39	0.98	1.18	1.18	2.80	2.08	2.62	2.50
Limed								
0	0.96	0.70	0.91	0.86	1.26	1.18	1.76	1.40
$P_{18}K_{50}$	0.90	0.66	0.96	0.84	1.20	1.11	1.80	1.37
$P_{18}K_{50}N_{120}$	1.06	0.85	1.02	0.98	2.04	1.58	2.13	1.92
LSD ($p = 0.05$)	–	–	–	–	0.12	0.09	0.17	0.13

Source: own study.

grass vegetation on soil pH [GORLACH 1993; GRZEBISZ *et al*. 2005; KASPERCZYK, SZEWCZYK 2006]. According to their research, after providing grassy vegetation, the main components of nitrogen, phosphorus and potassium are capable of delivering large yields even on very acidic soils. Meadow vegetation in all limed plots was clearly more abundant in magnesium compared to not limed plots (Tab. 2). The difference in this component content between limed and non-limed vegetation was 0.03 to 0.04 $g \cdot kg^{-1}$ dry weight, which in relative figures gave a value of 15–21%. Among the analysed plots, the vegetation receiving full fertilization NPK was the poorest in this compound. On average for the three years, it contained 0.2 g less magnesium in non-limed plots, and 0.1 $g \cdot kg^{-1}$ DM in limed ones compared to other plots. Expressing these differences in percentages was 12% and 5%, respectively. Higher abundance of magnesium component in the vegetation from the plots without nitrogen fertilized should be related to higher share of dicotyledonous plants in the sward, which are usually richer in this component compared to grasses. There was no significant difference between the years in plant abundance in this component. The higher magnesium content in plants was reflected in plants yield (Tab. 2). Average annual collection of this component was higher by 13–30% compared to non-limed plots. The lowest difference was noted between the control plots and average 1 kg of $Mg \cdot ha^{-1}$, and the highest between the plots fertilized with phosphorus and potassium 2.7 kg $Mg \cdot ha^{-1}$. The positive influence of liming on the magnesium content and its uptake with plant yields is explained by two facts: the supply of this component to the soil in the amount of about 90 kg $Mg \cdot ha^{-1}$ with lime and improvement of soil pH. As the pH of the soil increases, some magnesium is released from the sorption complex into the soil solution and becoming available to plants. This thesis reflected in the study of GRZEBISZ *et al.* [2005] who reported difficult uptake of elements by plants in soils under conditions of low pH soil, with their concurrent increased leaching from soil.

Liming also reduced water outflow from the soil profile (although the differences were within the error) (Tab. 3) and the magnesium content in it (Tab. 4). The content of this component in water moving through the soil profile in the limed plots was lower by 0.08–0.2 mg dm^{-3} compared to plots without liming. The lowest difference was found in control plot and the one fertilized with phosphorus and potassium, and the highest in the plots additionally fertilized with nitrogen. The lowest concentrations of magnesium in leachate water were found in 2013 where its highest outflow was noted. Magnesium load carried with leachate water in the limed plots was lower by 0.27–0.58 kg·ha^{-1} with respect to not limed ones, which gave the difference of 16–23%. Taking into account magnesium collection with plant yield and its load eluted with leachate water, an average annual loss of these components from the soil for the growing period ranged from 7.82 to 12.43 kg·ha^{-1} in non-limed plots, and from 8.44 to 14.52 kg·ha^{-1} in the limed plots. However, in the former plots, the loss due to leaching was 20%, and the latter it was 13%. Smaller magnesium load eluted with leachate water, also the lower outflow in liming plots, despite the higher content of magnesium in the soil, in relation to plots without liming deserves to attention as well. This phenomenon should be combined with improvement of soil pH. Under such conditions, certain amounts of magnesium are precipitated in the form of different salts: carbonates, phosphates which are not soluble in water and are available to the plants [GORLACH 1993; GRZEBISZ *et al*. 2005]. In addition, greater magnesium retention in soil and water in non-limed plots could have resulted from bigger root mass of plants [GERENDÁS, FÜHRS 2013; VERBRUGGEN, HERMANS 2013]. According to these researchers, there is a positive relationship between the supply of plants in magnesium and the amount of root mass.

CONCLUSIONS

Liming with simultaneously provided some magnesium, significantly increased content of magnesium in the meadow vegetation and its collection with dry matter yield. However, this treatment did not have a clear impact on the yielding of meadow vegetation. The positive reaction of vegetation fertilized with phosphorus and potassium for liming was the result of an indirect influence on changes in the floristic composition of this meadow.

Liming has a beneficial effect on the soil chemical properties. It has increased the pH of the soil and its retention with respect to water and magnesium.

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Wpływ wapnowania na zawartość magnezu w roślinności łąkowej i w wodzie przesiąkowej

STRESZCZENIE

Celem badań była ocena wpływu wapnowania na kształtowanie się właściwości chemicznych gleby, zawartość magnezu w roślinności łąkowej i wodzie przesiąkowej przemieszczającej się przez profil glebowy. Badania przeprowadzono w okresach wegetacji w latach 2012–2014. W badaniach uwzględniono trzy obiekty w dwóch seriach – z wapnem i bez wapna.

Materiał roślinny poddano suchej mineralizacji i roztworzono popiół w HNO_3 (1:3). Glebę mineralizowano w piecu muflowym i roztworzono popiół w mieszaninie HNO_3 i $HClO_4$ (3:1 v/v). W otrzymanych roztworach oraz w wodzie przesiąkowej oznaczono zawartość fosforu, potasu, magnezu i sodu na spektrofotometrze emisji atomowej z plazmą wzbudzoną indukcyjnie. Zawartość w glebie przyswajalnego fosforu i potasu oznaczono metodą Egnera–Riehma. Zawartość przyswajalnego magnezu oznaczono metodą Schachtschabla, a pH gleby metodą potencjometryczną w wodzie i w 1 mol $KC1 \cdot dm^{-3}$.

Wapnowanie dodatnio wpłynęło na pH gleby i zawartość magnezu w roślinach zwiększając jego ilość o 15–21% w suchej masie w odniesieniu do obiektów niewapnowanych. Nawożenie wapnem ujemnie natomiast wpłynęło na zawartość magnezu w wodzie przesiąkowej i ładunek wynoszony z jednostki powierzchni. Zawartości magnezu w wodzie przesiąkowej i ładunek wynoszony z obiektów wapnowanych były średnio mniejsze o 16–23% w odniesieniu do obiektów niewapnowanych.

Słowa kluczowe: *magnez, roślinność łąkowa, wapnowanie, woda odciekowa*