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# WAYS OF INCREASING THE MAGNESIUM CONTENT IN SWARD FROM A LONG-TERM FERTILIZER EXPERIMENT*

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**Abstract**

The paper discusses fluctuations, and their underlying causes, in the magnesium content of meadow sward from a fertilizer experiment set up on a mountain meadow in 1968. The fertilization experiment comprised 8 different treatments, with the following modifications: liming, magnesium and microelement fertilization and a change in the sward use made during the experiment so as to regenerate the sward and to improve the yielding potential. In the initial period, magnesium concentrations in the sward were assessed using the ASS technique after dry mineralization of samples and dissolution of the residue in diluted nitric acid. Later, the ICP technique was applied, including an internal reference sample for the methods. The cultivation measures caused variations in magnesium concentrations in the sward, depending on a number of factors, among which direct fertilization was not the most significant one. For example, the ambient temperature during the plant growing season strongly influenced the magnesium content, irrespectively of a cut. There was no effect of rainfall of the magnesium content, although atmospheric precipitation was able to raise considerably the charge of this element. In the second cut and under neutral soil pH, higher concentrations of magnesium were noted in the sward. This could have resulted from either the lower second swath yielding or the optimum conditions for the uptake of magnesium by the sward that occurred during its growth. The investigation results failed to provide an unambiguous answer to the question whether magnesium fertilization affected the concentrations of this element. Nonetheless, in order to maintain the production of valuable fodder it is essential to return systematically the elements taken up with plant yield to the soil. In intensively managed meadows, amounts of magnesium removed from the soil with the harvested biomass can be as high as several kilograms per hectare.

**Keywords**: magnesium, fertilization, NPK, liming, uptake, temperature, precipitation, pH.

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## INTRODUCTION

Magnesium is an important component of fodder, as it helps an animal to maintain the ionic balance in the organism. Proper magnesium management is particularly important in the context of potassium ions and the 'luxurious' uptake of elements from soil by plants that are supplied through excessive or unbalanced fertilization (Wiśniowska-Kielian, Stepień-Olkuśnik 2001, Edmeades 2004, Olszewska 2005, Hrevušovà et al. 2009). More intensive plant growth caused by high fertilization levels leads to a negative magnesium balance in soil (Kopeć 2002, Burzyńska 2009). It is therefore necessary to regain the proper balance and prevent depletion of manganese resources in soil for the sake of animal welfare and safety of produced foodstuffs. Skillful utilization of base cation resources, including magnesium, is an important element of agrotechnology (Kopeć 2002, Edmeades 2004, Kopeć, Szewczyk 2006, Vargovà et al. 2012, Zielińska et al. 2006).

Disturbances in magnesium uptake are particularly common in the spring, when temperatures reduce its absorption by plants and consequently its intake by animals. Currently, it is possible to alleviate the problem by nutrient supplementation of farm animals, but hay fed also outside the plant growing season should meet the criterion of containing well-balanced nutrients, as this favours their absorption and utilization.

Numerous investigations indicate the risk of depleting soil magnesium resources if this element is not returned to soil, especially when large doses of nitrogen or potassium diversify and stimulate plant communities, thus raising several-fold the uptake of magnesium with the plant yield (Wiśniowska-Kielian, Stępień-Olkuśnik 2001, Hejcman et al. 2006, Burzyńska 2009, Grzegorczyk et al. 2013, Kopeć and Gondek 2015).

The aim of this study was to trace changes in magnesium concentrations in grass sward grown in a permanent field experiment and subjected to different cultivation measures. The above objective was justified by the current depletion of magnesium resources and its diminishing content in the sward due to a negative balance of the element in soil.

## MATERIAL AND METHODS

The investigations were conducted on a long-term fertilizer experiment set up in Czarny Potok near Krynica. The meadow fertilizer experiment was started in 1968. The magnesium content was assessed in the meadow sward from the following treatments: without fertilization, with P, N or PK and PK fertilization with two doses of nitrogen (90 and 180 kg ha$^{-1}$). In 1994, magnesium phosphate was applied once, dosed 8 kg Mg ha$^{-1}$. Over the 47-year period, the experimental design was changed, e.g. by introducing a limed series or a microelement treatment. The long research period spanning the years 1968 and 2013 supported a thorough interpretation of the magnesium content in the sward under various cultivation systems. For example, fluctuations in the magnesium content were investigated in the context of breaks in fertilization or decreasing NPK doses (2011-2013), considering the amount of absorbed elements, which enabled achieving their good balance owing to the implemented fertilization system.

The paper contains a synthetic interpretation of the results, in which mean values for the following time periods were calculated: 1 – 1968-1974; 2 – 1975-1985; 3 – 1986-1994; 4 – 1995-2005; 5 – 2006-2010 and 6 – 2011-2013.

The first period represents the time of interference with mineral fertilizers incorporated into the turfed ploughland, which had most probably been fertilized only with natural fertilizers. The second and third are the periods during which the largest yields of swards were documented as well as their gradual decline, particularly in the treatment with 180 kg N+PK. The fourth period took place after a regenerative application of magnesium. Since the fifth period, the effect of microelements has been studied, whereas during the final period the NPK dose was lowered and a two-cut harvesting system was changed into a three-cut one.

Since the autumn 1985, two series: limed and unlimed one, were carried out, both with the same level of NPK. In 1995 and 2005, liming was repeated. The first and third liming were performed having calculated the dose of lime on the basis of 0.5 of Hh, but the second treatment included the results of the total soil hydrolytic acidity marked in the year before the limning treatment. Initially, liming was applied in the form of post-soda lime, and then as calcium carbonate.

The amounts of biomass gathered from each cut and replication were converted into Mg ha$^{-1}$ of dry mass per fertilizer treatment. The yield determinations led to the computation of the weighted average magnesium content.

In the initial period, magnesium concentrations in the sward were assessed using the ASS technique after dry mineralization of samples and dissolution of the residue in diluted nitric acid. Later, the ICP technique was used, including an internal reference sample for the methods.

In addition, the results of pH measured in the soil suspension and 1 mol dm$^{-3}$ KCl solution were considered. The soil material for the analyses was taken from the 0-10 cm layers. The soil samples were collected in autumn each year and presented as an average for each fertilizer treatment.

The paper used the data provided by the closest meteorological stations in order to present the dependencies of mean monthly temperature and monthly precipitation totals and the magnesium content.

# RESULTS AND DISCUSSION

Continuous removal of meadow sward yield without returning magnesium to soil has led to a decrease in its content in the sward, particularly during the intensive growth of the first cut. Magnesium fertilization was an efficient measure, elevating the sward concentrations of this element, which – over a long period of time – remained on a level that justified the classification of fodders as the ones with an adequate Mg content. The research confirmed that sward yields were more distinctly varied than the content of magnesium, which resulted from the botanical composition of the sward grown in the fertilizer treatments. The low magnesium content variability was masked by the properties of the species found in the treatments. This, for example, happened in the treatments intensively fertilized with nitrogen. *Holcusmolis* present on these objects absorbed much more of this element, which might have been also due to its displacement from the sorption complex and mobilization as a consequence of the acidification caused by the higher nitrogen fertilization level applied in this treatment. The effect of biodiversity on macroelement concentrations has also been implicated by WIŚNIOWSKA-KIELIAN and STĘPIEŃ-OLKUŚNIK (2001).

Liming based on fertilizers without magnesium did not diversify significantly the magnesium content in meadow sward (Figure 1), although the

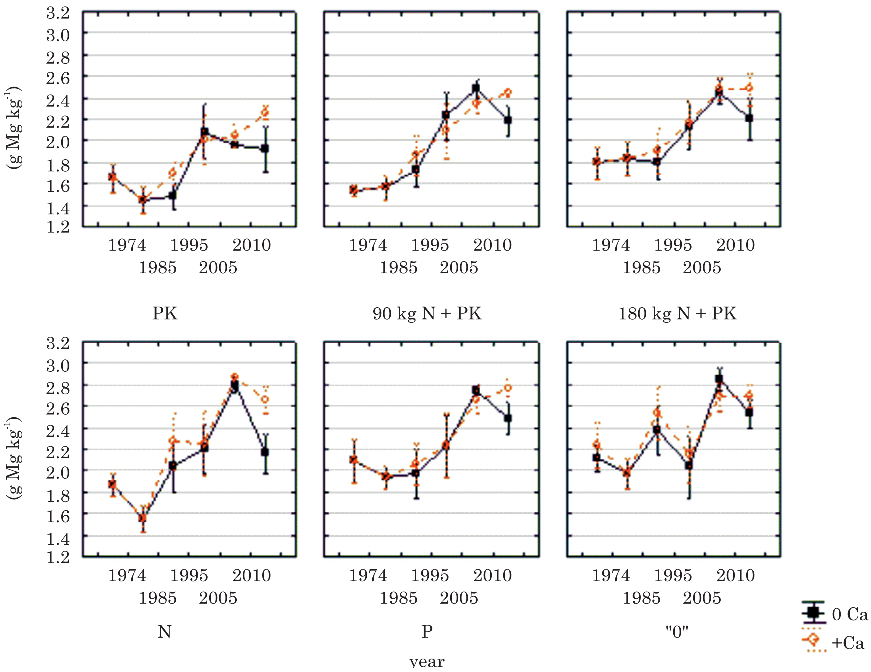


Fig. 1. Mean weighted average magnesium content per cuts in meadow sward – series 0 Ca and +Ca for the experiment periods discussed in Methods

content of this element in all the treatments in the limed series during the final period of the investigations was higher. The application of microelements or the change from a two-cut to a three-cut system slightly increased the magnesium content in the sward from most of the treatments, but the effect might have been masked by lower yields, as indirectly evidenced by the amounts of absorbed magnesium (Figure 2). Among the examined factors

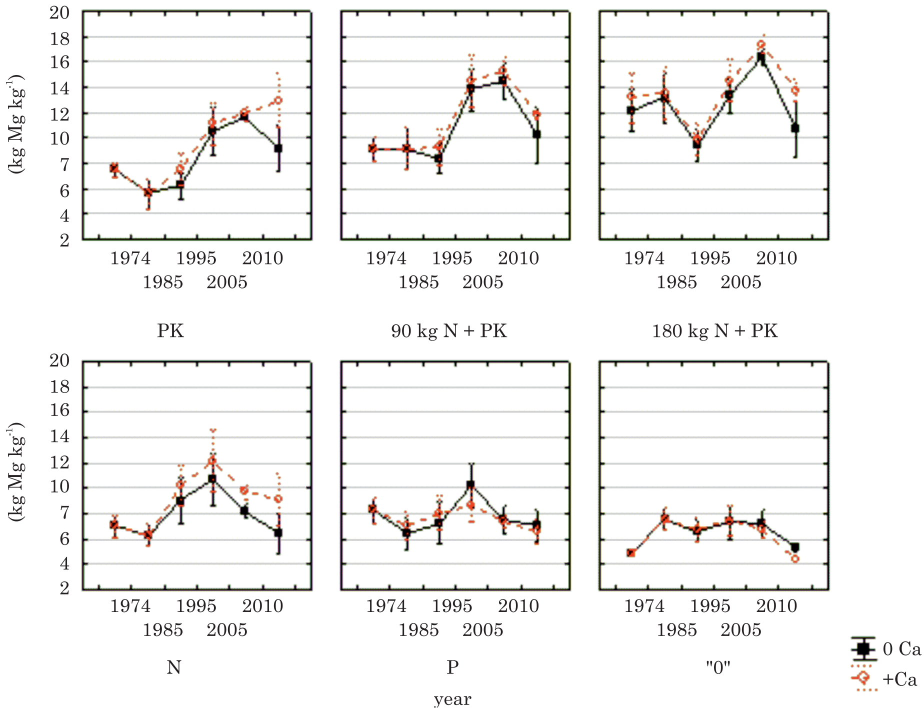


Fig. 2. Mean yearly amount of magnesium taken up by meadow sward – series 0 Ca and +Ca for the experiment periods discussed in Methods

that may have affected the amount of absorbed magnesium, the highest diversification was observed between the cuts (Figure 3), which was confirmed, for example, by VARGOVÀ et al. (2012).

In his previous investigations conducted on the same meadow, KOPEĆ (2000) stated that Mg leaching beyond the root zone was increasing with the growing fertilization intensity, whereas particularly high losses of this element were caused by the dose of 180 kg N+PK. After 30 years of fertilization, the estimated losses due to leaching were between 3 and 12 kg Mg ha$^{-1}$. These values were closely dependent on the available cation content. In their three-year investigations under similar agrotechnical conditions, KACORZYK and SZEWCZYK (2010) demonstrated a considerably lower decrease, corresponding to 2 kg Mg ha$^{-1}$ in response to fertilization equal 100 kg N ha$^{-1}$. It seems that the degree of leaching is largely affected by the botanical compo-

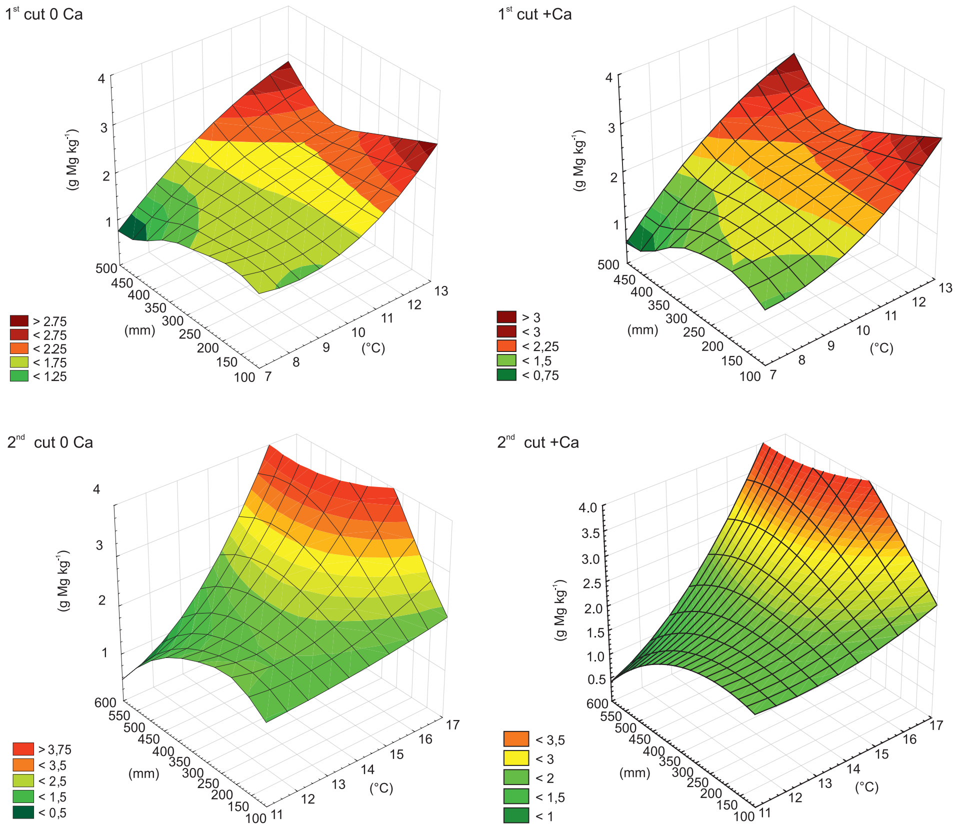


Fig. 3. Magnesium content (g $kg^{-1}$ DM) in the sward of the 1st and 2nd cuts depending on precipitations and temperature

sition of sward, which is shaped and diversified by long-lasting fertilization measures.

The amount of magnesium absorbed by the sward in the experiment (Figure 2) increased markedly after the regenerative magnesium treatment in 1994, but is some cases it exceeded the applied dose. Liming, except for the phosphorus and non-fertilized treatments, also increased the quantity of magnesium taken up with the yield. The difference grew larger particularly during the final period of the research, when the cutting system was changed. This shows that under favourable conditions a younger sward takes up larger amounts of magnesium.

In their 16-year research, HERVUŠOVÀ et al. (2009) confirmed magnesium depletion at high doses of nitrogen fertilizer resulting from a larger previous uptake of this element. KACORZYK and SZEWCZYK (2010) found that mineral fertilization caused the uptake of 19 kg Mg $ha^{-1}$ with yield, but natural fertilizer application reduced this amount by almost a quarter. On the other hand, SOWIŃSKI and SZYDEŁKO (2012) confirmed the effect of the soil abundance (agronomic category) and use (cutting frequency) on the amount of magnesium taken up by sorghum mixture with sudan grass. A significant effect was also observed to be produced by differences in the date of sowing and in subsequent years of meadow management.

Figure 3 shows the dependence of magnesium concentrations in the sward of all treatments on the monthly sum of precipitation and average monthly temperature during the plant growing period of the first or second cut for both series (46 years · 8 objects = 368 cases for each cut and +Ca or 0 Ca series). The 3D model reveals that precipitations did not have any influence on the magnesium content in the sward, contrary to the temperature. The compiled data indicate that the higher the temperature, the greater the magnesium content in the sward. The same dependence was observed for both series. A larger content of magnesium was also determined in the second than in the first cut, which might have resulted from the higher mean temperature in that period. On the other hand, Kacorzyk et al. (2012) demonstrated that under conditions approximately the same as in the discussed experiment the magnesium load deposited with atmospheric precipitation during the growing season was larger than in the winter period. Undoubtedly, the precipitation load of 5.45 kg Mg $ha^{-1}$ $year^{-1}$ (in 2006-2008) had a major effect on the amount of magnesium taken up by the sward (Figure 2), but the temperature was the dominating factor. During the plant growing period, the magnesium load was 63% (Kacorzyk et al. 2012) of the annual load and might have caused an increase in this element's content in the sward of the $2^{nd}$ cut.

The problem of magnesium deficiency in the spring is usually more severe on cereal fields. Baran et al. (2011) confirmed differences in the magnesium content in various plant growing periods. On cool days, the symptoms of chlorosis appeared due to the inhibition of photosynthesis. Such extreme findings as noted in cereal monocultures are not demonstrated on meadow swards, although the dependence mentioned above is of pragmatic significance and allows for an earlier response such as magnesium fertilization of pastures on which farm animals will graze. Bednarek et al. (2009) found no dependencies of the magnesium content in orchard grass aerial parts on the meteorological conditions, but the effect of air temperature and insolation on this element's content in roots of the same grass species was verified. However, the same authors reported the influence of air humidity, soil moisture and soil temperature on the amount of absorbed magnesium.

Figure 4 illustrates the relationship of magnesium concentrations in the sward of all treatments depending on the soil pH and the period of the experiment (46 years · 8 objects = 368 cases for each cut and +Ca or 0 Ca series). Very acid soil reaction caused by intensive nitrogen fertilization was characterized by a lower magnesium content in sward. The diagram depicts the impact of a single magnesium fertilization in 1994, and the effect of an elevated Mg content persisted over a longer period. This fact should be explained by the lower yields, as mentioned before. Also, the microelement

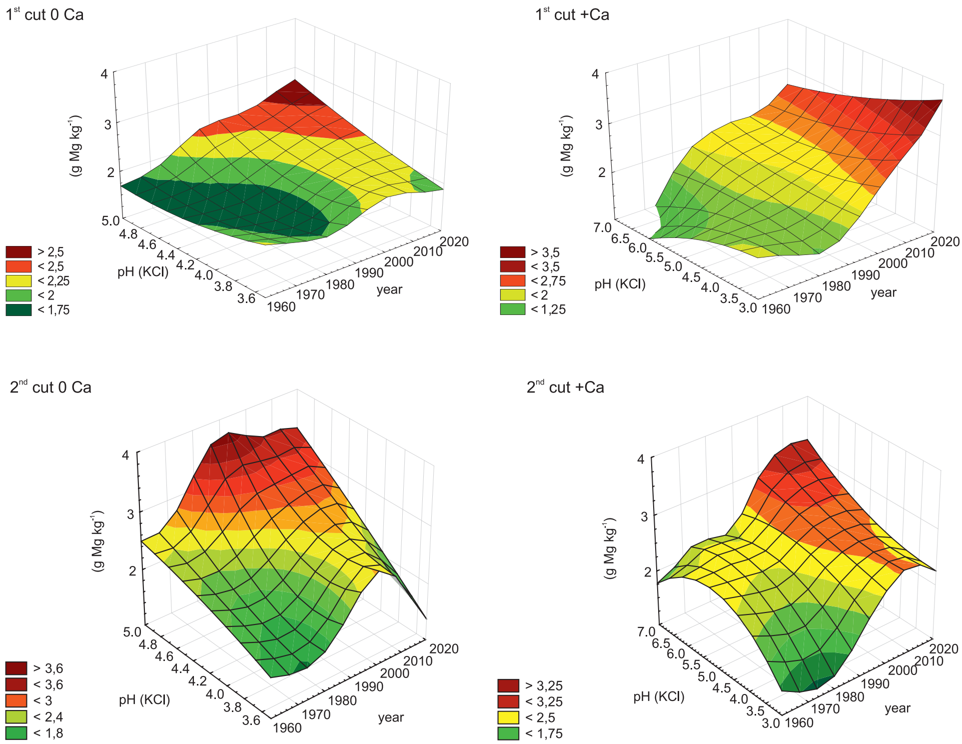


Fig. 4. Magnesium content (g $kg^{-1}$ DM) in the sward of the 1st and 2nd cuts depending on pH during the period of the experiment

treatment might have caused an increasing magnesium content. Magnesium fertilization acts longer when the soil pH is higher.

Changes in the magnesium content induced by cultivation measures are rather complex (Edmeades 2004, Hejcman et al. 2010). For example, relationships between magnesium and other elements, including phosphorus and calcium, should be borne in mind. Cultivation measures are often implemented to achieve a radical change in the level of some element, whereas for the sake of mainatining the balance of elements, agrotechnical practice must not lead to excessive levels of any element, as this disturbs the environmental homeostasis. Meadow plant assemblages are flexible. With various pressures exerted on a plant community, the species which are more adjustable will respond to changes more rapidly and thrive better. It is safe to say that dolomite lime containing carbonate magnesium systematically released into the environment is the best form of magnesium fertilization. When a quick response to magnesium deficiency is needed, an application of magnesium sulphate is a good solution. A dose of this element should not be much higher than the annual uptake by plants. A 3% solution of magnesium sulphate monohydrate is recommended at the time of fertilizing with urea solution.

# CONCLUSIONS

1. Any change in the magnesium content in sward is affected by several of factors, one of which, but not necessarily the most important one, is direct fertilization.

2. The temperature during the plant growing season has a strong influence on magnesium concentrations in the sward, irrespectively of a cut.

3. The highest magnesium content in the sward appeared in the second cut and under the neutral soil pH conditions.

4. The investigations did not provide a definite answer to the question whether micronutrient fertilization affects the magnesium content in the sward. Nonetheless, in order to maintain the production of valuable fodder it is essential to return systematically the elements taken up with plant yield, including magnesium, back to the soil.

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