Effect of K, Ca and Mg Treatments on the Nutrient Content of Spring Barley in an Acidic Soil

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Introduction

The nutrient content of plants is influenced by several factors: nutrient and water applications, nutrient pool of the soil, buffer capacity of the soil, etc. These factors cannot be examined satisfactorily all together (due to their large number), therefore it was necessary to select appropriate circumstances for the experiments so we could study the important factors jointly. The multifactorial pot experiments and the estimation methods used at the Department of Agricultural Chemistry of DATE are suitable for reaching these goals.

In the case of acidic soils, the most important factor is liming. However, liming has to be supplemented with magnesium fertilizers (BALOGH et al., 1983). Furthermore, when applying Ca and Mg it is recommended to use K fertilizers to avoid extreme ion ratio and ionantagonism (LOCH et al., 1986).

Objectives of the present study were:

1. to examine the effect of K, Ca and Mg treatments on the nutrient content of spring barley in a multifactorial pot experiment with an acidic sandy soil poorly supplied with Mg; and
2. to study the interaction between ion uptake and K, Ca and Mg treatments.

Materials and Methods

Soil characterization and analysis

Samples of the sandy soil originating from Kisvárda – taken from the 0-20 cm layer – were air-dried and passed through a 2 mm sieve.

Particle-size analysis was carried out by the pipette method (DAY, 1965). Organic matter was determined by the wet oxidation method (TYURIN & KONONOVA, 1934). The quantities of exchangeable cations and CEC were determined, using non-buffered $BaCl_2$ (HOUBA et al., 1989). Analysis of Ca and Mg was performed by atomic absorption spectrophotometry (Varian Spectra AA 10 Plus); K and Na were analyzed by flame emission spectrophotometry (Unicam SP 90B). The clay composition of soil was obtained from the „Map of Clay Mineral Associations of Soils in Hungary" (STEFANOVITS & DOMBÓVÁRI, 1989). The chemical and physical properties of the soil are shown in Table 1.

Table 1
Selected chemical and physical properties of the acidic sandy soil (Kisvárda)

Soil property	
pH (1:2.5 soil/H_2O)	4.38
pH (1:2.5 soil/KCl)	3,42
Sand, %	86.6
Silt, %	6.6
Clay, %	6.7
Organic matter, %	0.66
K_A*	31
V, %	71.5
CEC, cmol/kg	2.67
$Ca_{ex.}$, cmol/kg	0.9
Mg_{ex}, cmol/kg	0.09
$K_{ex.}$, cmol/kg	0.43
$Na_{ex.}$, cmol/kg	0.49
AL-P, mg/kg	179.4
AL-K, mg/kg	87.4
$CaCl_2$-Mg, mg/kg	31.4
y_1	12.6
Clay minerals	
Illite	Dominant
Smectite	Little
Vermiculite	Little
Chlorite	Little

* K_A = upper limit of plasticity according to Arany

Pot experiments

Nutrient uptake was studied in multifactorial pot experiments with an acidic sandy soil from Kisvárda, using spring barley (*Hordeum vulgare* L.) as indicator plant. Each pot contained 12 kg previously sieved (2 mm) soil.

K, Ca and Mg treatments were performed on an identical N, P basis. Quantities of N and P were 100 and 80 mg/kg soil, respectively (introduced as a mixture of $NH_4H_2PO_4$ and NH_4NO_3). K and Mg were added as KCl and $MgSO_4$ solutions, respectively. Ca was introduced as lime. Water content was set to

75% of the water capacity. The applied combination of treatments was designed according to the method of BOX & WILSON (1951). (While in traditional design schemes the number of treatments increases with a certain power of the number of factors, in the above-mentioned method the number of necessary treatments is reduced drastically, by changing the factors simultaneously and systematically.) The applied treatment combination is shown in Table 2.

At the end of the growing season plant samples were taken (grain and straw). The samples were digested with H_2SO_4/H_2O_2, before being analyzed for K, Ca, Mg, N, P, Mn and Zn.

Table 2
Combinations of treatments used in the pot experiments

Treatment	K mg/kg	$CaCO_3$ mg/kg	Mg mg/kg
1	150	900	30
2	50	900	30
3	150	300	30
4	50	300	30
5	150	900	10
6	50	900	10
7	150	300	10
8	50	300	10
9	200	600	20
10	0	600	20
11	100	1200	20
12	100	0	20
13	100	600	40
14	100	600	0
15	100	600	20

Statistical procedure

The relationship between the measured quantities (yield, nutrient content) and experimental factors was described by a second order polynomial. The numerical evaluation was carried out according to KAFAROV (1976), using the software written by TOLNER & BICZÓK (LOCH et al., 1986, 1987a,b).

Data were evaluated by a non-linear, multivariable regression analysis. These calculations yielded the quadratic equation that describes the relationship between the measured quantities and the individual experimental variables and has the following general form:

$$y = b_0 + b_1K + b_2Ca + b_3Mg + b_{12}KCa + b_{13}KMg + b_{23}CaMg + b_{11}K^2 b_{22}Ca \;\; + b_{33}Mg^2$$

where: y = measured quantity;
K, Ca, Mg = nutrient doses;
b_1, b_2, b_3 = linear regression coefficients;
b_{12}, b_{13}, b_{23} = regression coefficients of interactions;
b_{11}, b_{22}, b_{33} = coefficients of quadratic effects.

To estimate the significance level of the factors the regression coefficients were evaluated by the Student t-test.

Results and Discussion

The effect of treatments on nutrient concentrations in spring barley grain is shown in Table 3. According to the data, K treatment decreased the Mg and P content of grain. The well-known phenomenon of K-Mg antagonism (MATULA, 1989; EVANYLO, 1990; etc.), also appears in our experiment.

The reason of the negative relation between K application and P concentration might be that the soil became more acidic due to K fertilization (FILEP, 1998), which results in higher solubility of aluminium and finally in the precipitation of Al-phosphates.

While calcium addition increased the Ca content of the grain. it caused a decrease in K, Mg, N, P, Zn and Mn concentrations. As the soil used in the experiment is acidic, liming increased the yield significantly, which ends in the

Table 3

Effect of treatments on nutrient concentration of spring barley grain in pot experiments

	K	Ca	Mg	N	P	Mn	Zn
K			* (-)		** (-)		
Ca	*** (-)	* (+)	*** (-)	*** (-)	** (-)	*** (-)	*** (-)
Mg		* (-)	* (+)				
KCa							
KMg	+ (-)				+ (-)		
CaMg	+ (-)						
K^2							
Ca^2			+ (+)				
Mg^2							
R^2	0.48	0.41	0.61	0.84	0.33	0.94	0.60
F value	68.5***	50.2***	117.2***	393.8***	36.3***	1301***	111.1***

*, **, *** significant at $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively.

so-called dilution effect. The dilution effect attributed to a faster rate of dry matter accumulation than of nutrient uptake (JARRELL & BEVERLY, 1981).

Magnesium treatment increased the Mg concentration and decreased the Ca concentration in grain.

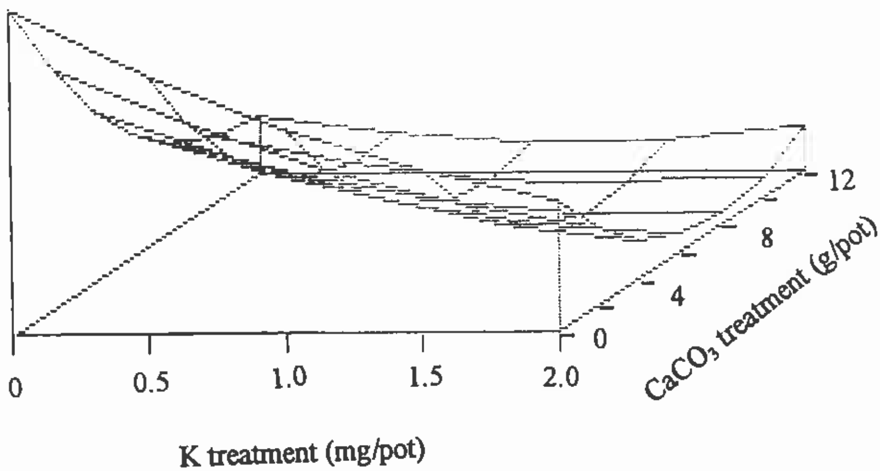

Figure 1
The effect of K and $CaCO_3$ treatment on Mg content of spring barley grain in acidic sandy soil at medium Mg application

Table 4
Effect of treatments on nutrient concentration of spring barley straw in a pot experiment

	K	Ca	Mg	N	P	Zn	Mn
K	*** (+)	* (-)	** (-)		** (-)		
Ca		*** (+)	** (-)	*** (-)	** (-)	*** (-)	*** (-)
Mg		+ (-)	*** (+)				
KCa							
KMg				+ (-)			
CaMg			*(-)				
K^2							
Ca^2							
Mg^2							
R^2	0.42	0.70	0.73	0.80	0.46	0.79	0.39
F value	53.9***	715.9***	201.5***	294.7***	61.3***	282.5***	47.8***

*, **, *** significant at $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively

Figure 1 shows that the Mg content of grain decreased with increasing K addition at the lowest $CaCO_3$ level. In case of the maximum lime dose the Mg concentration was not influenced by K treatment.

K treatment increased the potassium content of spring barley straw (Table 4). Ca. Mg and P concentrations decreased with increasing K doses. These results are similar to those given for spring barley grain.

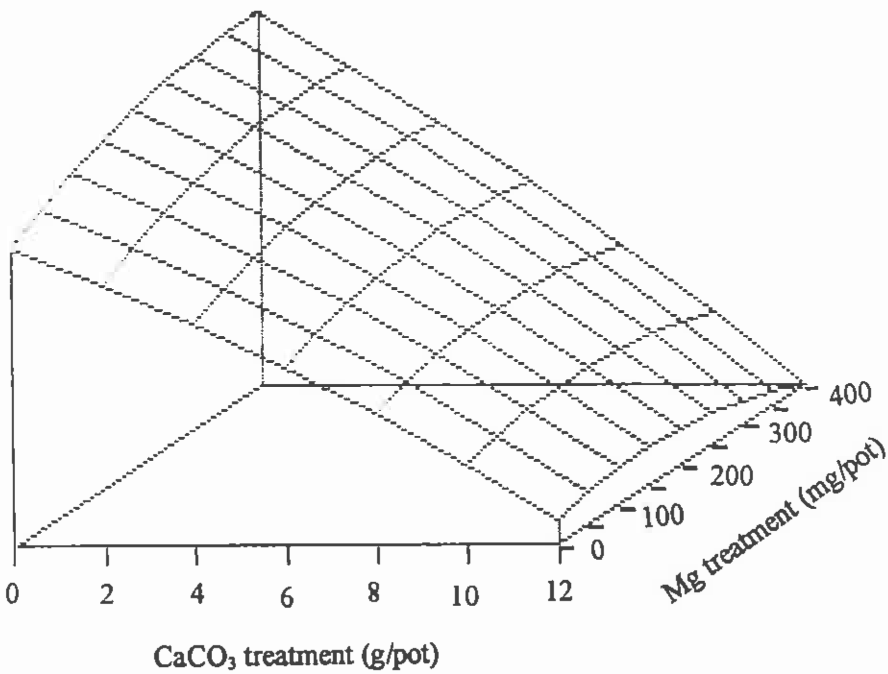

Figure 2
The effect of $CaCO_3$ and Mg treatment on Mn content of spring barley straw in acidic sandy soil at medium K dose

Due to $CaCO_3$ treatment the calcium content of straw increased, while Mg, N, P, Zn and Mn concentrations decreased.

As expected, liming reduced the Mn content in plants (Figure 2). At the lowest lime dose magnesium application increased the Mn concentration, which is in contradiction with findings of numerous papers about Mg-Mn antagonism (MENGEL, 1976; MATULA, 1992). Whereas at maximum level of $CaCO_3$ Mn concentration decreased with increasing Mg addition.

Summary

The effect of K, Ca and Mg treatments on the nutrient content of spring barley grown on an acidic sandy soil in a multifactorial pot experiment was studied.

The following observations were made:

K addition reduced Mg concentration in both grain and straw of spring barley. We not only found K-Mg antagonism, but K-P and Ca-Mg antagonism, too.

Nearly all element concentrations decreased due to liming, which stimulated the growth of plants, resulting in the so-called dilution effect.

There was a positive effect between Mg treatment and Mn concentration of barley grain at the minimum lime level in spite of the findings of numerous papers about Mg-Mn antagonism. It is true that this effect was not significant.

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