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CHANGES IN THE SOIL MAGNESIUM AND SULPHUR CONTENT AFTER KIESERITE APPLICATION INTO HAPLIC LUVISOL AND THE EFFECT ON YIELDS OF BARLEY BIOMASS

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Abstract

LOŠÁK TOMÁŠ, HLUŠEK JAROSLAV, LAMPARTOVÁ IVANA, MÜHLBACHOVÁ GABRIELA, ČERMÁK PAVEL. 2017. Changes in the Soil Magnesium and Sulphur Content after Kieserite Application into Haplic Luvisol and the Effect on Yields of Barley Biomass. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 65(4): 1225–1229.

In 2016 a pot experiment (5 kg of soil – Mitscherlich pots) with 4 treatments (incl. unfertilized control treatment) was established with spring barley, variety KWS Irina, in the outdoor vegetation hall. Haplic luvisol from Jaroměřice nad Rokytnou (with a good supply of magnesium and slightly acid soil reaction – 6.01) was used for this trial. The rates of magnesium (0.075–0.15–0.3 g Mg per pot) and sulphur (0.1–0.2–0.4 g S per pot) were increased by using the ESTA Kieserite fertiliser (25% MgO; 20% S), treatments 2–4. Nitrogen was applied in the form of CAN (27% N) at a rate of 1 g N per pot in all the treatments incl. the control. The content of post-harvest soil magnesium and sulphur increased significantly with the applied rate (196–227–261 mg Mg/kg and 40.1–76.8–208.6 mg S/kg, respectively). The soil reaction (pH) increased significantly in all the fertilised treatments (6.42–6.57–6.60) against the unfertilised control treatment (6.10). Dry matter yields of the aboveground biomass (41.75–42.25–44.75–44.25 g DM per pot) increased significantly only when the two highest rates of fertilisers were applied (44.75–44.25 g DM per pot) as against the other treatments.

Keywords: magnesium, sulphur, fertilisation, barley, soil, supply, aboveground biomass

INTRODUCTION

The importance of Mg in crop production was underestimated in the past decades. Indeed, compared to other nutrients, little attention was paid to this mineral nutrient by agronomists and scientists in the past decades. Therefore, the term ‘the forgotten element’ was introduced (Cakmak and Yazici, 2010). Balanced nutrition and fertilisation are essential components of the growing technology in barley in terms of achieving the required yields and quality. Optimal range of soil reaction (pH) for barley is 6–7 (Fecenko and Ložek, 2000). Magnesium is an important macronutrient with a number of physiological functions in the plant. The importance of magnesium in the plant is in many ways connected with photosynthesis. It is the central atom of chlorophyll and it activates enzymatic processes. Magnesium also favourably influences assimilation (Marschner, 2002; Mengel and Kirkby, 2001; Dorenstouter *et al.*, 1985). Magnesium is the basic nutrient supporting nitrogen uptake and simultaneously controlling processes responsible for photosynthesis and assimilate production and partitioning among plant parts (Cakmak and Kirkby 2008; Shaul 2002).

The acreage of arable soil (%) in the Czech Republic in terms of Mg-supply categories are as follows: low – 17.21%, satisfactory – 34.55%, good – 32.12%, high – 8.99%, very high – 7.13%. More than 4/5 of arable land in the Czech Republic (low category–satisfactory–good) therefore requires magnesium fertilisation. The situation is similar in orchards, vineyards and hop fields (Smatanová and Sušil, 2015). The uptake of magnesium (and sulphur) converted to 1 ton of cereal yield (grain plus straw) is 2.3 kg Mg and 3.5 kg S (Klír *et al.*, 2008).

Soil testing is a remarkable and unique activity that synthesises a large amount of research information and scientific knowledge for practical needs of the identification and prevention of the majority of disproportions in plant nutrition in the given fields. Soil testing provides farmers with the greatest amount of practically applicable information (Raij, 1994; 1998). Regardless of their present drawbacks chemical methods of agricultural soil testing are the most frequently used tools of diagnostics of the nutrient status of soil and the need for fertilisation derived from it. The main advantage of soil tests is the possible prevention of potential disorders in the nutrient status of the crop before its cultivation in a given field (Matula, 2009; Mercik *et al.*, 1983). To a certain degree the combination of soil and plant analysis and the use of calibration experiments on production sites admittedly allow the development of recommendations for Mg nutrition of crops (Gransee and Führs, 2013).

MATERIALS AND METHODS

The vegetation pot experiment was established on 30th March 2016 in the outdoor vegetation hall of the Botanical Garden and Arboretum of Mendel University in Brno, Czech Republic. Mitscherlich vegetation pots were filled with 5 kg of medium heavy soil characterised as haplic luvisol from Jaroměřice nad Rokytnou; Tab. I gives the agrochemical properties.

The experiment involved 4 treatments given in Tab. II. Every treatment included 4 repeats.

Magnesium and sulphur were applied in the form of ESTA Kieserite (25% MgO; 20% S) and nitrogen in the form of CAN (27% N) at a rate of 1 g N per pot in all the treatments incl. the control. The pots were watered with de-mineralized water to a level of 60% of the maximal capillary capacity and were kept free of weeds. The aboveground biomass of spring barley (variety KWS Irina) was harvested at the stage of milk-wax maturity (10 plants/pot) on 22nd June 2016. Soil analyses were carried out before the experiment and after harvest using the Mehlich 3 method (0.015 M NH_4F + 0.2 M CH_3COOH + 0.25 M NH_4NO_3 + 0.013 M HNO_3) (Mehlich, 1984). The concentration of Mg and S in soil extracts was determined using ICP-OES, SPECTRO (Kleve, Germany).

The results were processed statistically using one-way ANOVA followed by testing according to Scheffe (P = 95%).

RESULTS AND DISCUSSION

The post-harvest soil reaction (pH) and level of soil magnesium and sulphur

The magnesium and sulphur content in soil and soil reaction (pH) after harvest are shown in Tab. III. The exchangeable soil reaction (pH/$CaCl_2$) remained unchanged only in the unfertilised control treatment (6.01 before sowing and 6.10 post-harvest). Post-harvest pH values increased significantly in all the fertilised treatments (2–4) as against the unfertilised treatment (1). The soil reaction increased (6.42–6.57–6.60) with the rate of applied fertiliser, or with the rate of Mg and S, although mutual differences were statistically insignificant.

Depending on the selective ion uptake by plants we divided the mineral fertilisers into physiologically acid (cation intake prevails), alkali (anion intake prevails) and neutral (Fecenko and Ložek, 2000). Based on our results it is clear that after the application of ESTA Kieserite the soil did not acidify but quite the contrary. The category of slightly acid soil (pH 5.6–6.5) of treatments 3–4 shifted into the category of neutral soil. It is assumed that plants take in both nutrients from the soil-magnesium and sulphur. Klír *et al.* (2008) went as far as to say that the uptake of sulphur by cereals was higher (3.5 kg S/1 t grain + straw) than the uptake of magnesium (2.3 kg Mg/1 t grain + straw). It is also commonly known that the uptake of Mg is strongly influenced

I: *Agrochemical characteristics of the soil prior to trial establishment (Mehlich III) – Regulation of Czech Republic No. 275/1998*

pH/$CaCl_2$	mg/kg			
	P	K	Mg	Ca
6.01	149	331	173	1,994
slightly acid	high	high	good	satisfactory

II: *Treatments of the experiment*

Treatment No.	Description	Rate of Mg (g/pot)	Rate of S (g/pot)	Rate of N (g/pot)
1	Mg_0S_0	0	0	1
2	Mg_1S_1	0.075	0.1	1
3	Mg_2S_2	0.15	0.2	1
4	Mg_3S_3	0.30	0.4	1

III: *The content of post-harvest soil reaction (pH)and soil magnesium and sulphur*

Treat. No.	Description	Soil pH	Mg content	S content
			mg/kg	
1	Mg_0S_0	6.10 a	168 a	14.4 a
2	Mg_1S_1	6.42 b	196 b	40.1 b
3	Mg_2S_2	6.57 b	227 c	76.8 c
4	Mg_3S_3	6.60 b	261 d	208.6 d

Mean values of post-harvest soil pH and soil magnesium and sulphur content ($n = 4$). Different small letters (a, b) indicate significant differences at the level of $\alpha = 0.05$ among individual treatments

by the availability of other cations like NH_4, Ca and K (Fageria, 2001). Reverse is hence the action of Mg-Ca antagonism as the higher level of soil Mg obstructs Ca uptake by the plant and which then remains in the soil in higher amounts. In chemical terms magnesium and calcium both rank among alkali earth metals with alkalifying effects on the environment. The ESTA Kieserite fertiliser increased the level of soil Mg and at the same time increased the soil reaction (6.42–6.57–6.60) against the unfertilised control treatment (6.10), Tab. III. By contrast Ponette *et al.* (1993) reported that on acid soils kieserite induced very few changes in soil pH, but dolomite increased soil pH. Mengel and Kirkby (2001) noted that the application of dolomitic limestone is particularly useful on acid soils which need regular liming. Decomposition of the dolomite is also assisted by low soil pH. On more neutral soils $MgSO_4$, e.g. kieserite, is more appropriate particularly on arable land where rapid application of high levels of Mg is required.

Magnesium and sulphur levels were found to differ significantly among the treatments, Tab. III. The content of post-harvest soil magnesium and sulphur increased significantly with the applied rate (196–227–261 mg Mg/kg and 40.1–76.8–208.6 mg S/kg, respectively). The postharvest Mg and S levels were the lowest in the unfertilised control what is logical; at the same time in this treatment (treatment 1) the postharvest magnesium content (168 mg/kg) was lower than at the beginning of the experiment (173 mg/kg). It is because magnesium uptake by barley plants in this unfertilised control treatment (treatment 1) was not compensated with an application of magnesium fertiliser and was not rendered sufficient from mineralization of organic matter in the pot. Grzebisz (2013) described that the degree of the yield increase depended on the stage of plant development and the amount of applied magnesium. Cereals cultivated on soils ranging from low to medium levels of soil available magnesium responded significantly to magnesium applied at the rate of 5 kg/ha.

Dry matter yields of the aboveground biomass

Magnesium application to cereals resulted in a higher number of ears and/or thousand grain weight (TGW), dressing the magnesium-sensitive stages of yield formation. The main conclusion gleaned from the review underlines the positive effect of magnesium on nitrogen uptake efficiency. The optimal yield-forming effect of the magnesium fertiliser can generally occur under conditions of a relatively low nitrogen supply (soil + nitrogen fertiliser), but high supply of magnesium. This phenomenon can best be described as "magnesium-induced nitrogen uptake" (Grzebisz, 2013). Most of the literary references mention the effect of Mg application on yields and quality of barley grain in the stage of full maturity (Fecenko and Benko, 1971). However, plants in our experiment were harvested at the stage of milk-wax maturity.

The yields of aboveground biomass (g DM/pot) are shown in Tab. IV. Dry matter yields of the aboveground biomass were the lowest in the control treatment not fertilised with Mg (41.75 g per pot) and increased significantly only with higher (treatment 3) and the highest (treatment 4) Mg rate applied (44.75–44.25 g per pot), although no significant differences were detected between these treatments (3–4).

Based on the physiological functions of magnesium it should be assumed that the shortage of magnesium can result in lowering the rate of dry matter (Shaul, 2002). There is some evidence that

IV: *Dry matter yields of the aboveground biomass (g DM/pot)*

Treatment No.	Description	Yields g DM/pot	%
1	Mg_0S_0	41.75 a	100.0
2	Mg_1S_1	42.25 a	101.2
3	Mg_2S_2	44.75 b	107.2
4	Mg_3S_3	44.25 b	105.9

Mean values of dry matter yields of the aboveground biomass ($n = 4$). Different small letters (a, b) indicate significant differences at the level of $\alpha = 0.05$ among individual treatments

Mg plays specific roles in dry matter formation and carbon partitioning to sink organs, as under Mg deficiency carbohydrates accumulate in source leaves (Cakmak *et al.*, 1994; Ding *et al.*, 2006). Therefore, an earlier response of plants to Mg deficiency is carbohydrate accumulation in source leaves and reduced root growth due to restricted supply of the roots with carbohydrates (Cakmak *et al.*, 1994a). Apart from magnesium the fertiliser ESTA Kieserite contains sulphur which also has a positive effect on yields. Several researchers (Zhao *et al.*, 2006; Järvan *et al.*, 2008) indicate a positive effect of sulphur fertilisation on cereal crop production; the positive response of cereal crops to sulphur fertilisation was caused by the fact that the initial levels of plant-available sulphur in soil were low (Olfs *et al.*, 2012). Many European countries are facing the problem of low plant-available sulphur levels in soil due to the decreasing use of fertilisers (Messick *et al.*, 2005; Shnug and Haneklaus, 2005). Insufficient levels of plant-available sulphur in soil block the positive effect of nitrogen fertilisation – yield is not increasing, and the excessive amount of nitrogen which was not consumed by plants becomes an environmental pollutant (Jamal *et al.*, 2010).

CONCLUSION

The contents of soil nutrients and the yield levels are primarily dependent on the concrete soil type and the soil properties. The results showed that soil applications of water-soluble magnesium and sulphur can significantly increase the Mg and S content in soils i.e. about tens of milligrams per kilogram of soil. The soil reaction increased significantly in all the fertilised treatments as against the unfertilised treatment. An adequate amount of available magnesium and sulphur in soils (in accordance with the soil test) increases the nutrient utilization efficiency which is reflected in higher biomass yields.

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