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EFFECT OF MOLYBDENUM TRATMENTS ON GROWTH AND MOLYBDENUM UPTAKE OF GREEN PEA

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Abstract. *The main aim of the present study was to examine whether increasing molybdenum (Mo) concentration affects on the growth and Mo uptake of green pea plants (Pisum sativum* L.*) in pot experiment. In addition it was determined how much percent of the soil's total Mo content can be utilized for plants (soluble element content). In this experiment three types of soil were applied (calcareous chernozem soil, carbonate humus sandy soil, humus sandy soil) and Mo was used in form od sodium molybdate dissolved in distilled water.*
In this study we have found that there is a close connection between the acidity of different types of soil and the Lakanen-Erviö's soluble Mo concentration. According to our results 30 mg kg^{-1} Mo treatment affected positively on growth of plants in case of calcareous chernozem and acidic humus sandy soil however, in the case of carbonate humus sandy soil this Mo-treatment caused significant reduction in plant growth. Furtheremore we observed, molybdenum concentration in green peas were significantly elevated with increasing the concentration of Mo treatment in comparison with control.

Keywords: molybdenum, green pea, soil, dry weight

1. Introduction

Molybdenum is one of the seven microelements which is essential for the plants. Its relevance of plant physiology primarily lies in the fact that it is a necessary metal component of enzymes participating in nitrogen-metabolism [1]. On the one hand, it has a decisive role in the nitrogen supply of Fabaceae as the co-factor of the nitrogenase enzyme, on the other hand, it has an essential role in the process of nitrate reduction, since the presence of molybdenum is essential in order that the nitrate reductase could function optimally [2-3].

Absorption of Mo by plants occurs in the form of molybdate ion. Whenever molybdate anion enters into the roots, it stays biologically inactive until it is joined by a pterin compound which is called molybdenum cofactor (Moco) [4-5].

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The availability of molybdenum for plant growth strongly depends on the soil pH. In acidic soils which has less that 5.5 pH, molybdenum availability goes down when anion adsorption to soil oxides goes up. On the other hand, in alkaline soils, molybdenum are more soluble and is accessible to plants especially when it is in its anion form as MoO_4^- [6-7].

The objective of our study was to examine whetever molybdenum treatments affects the dry mass and molybdenum concentration of green pea plants (Pisum sativum L.) in pot experiment. In addition it was determined how much percent of the soil's total molybdenum content can be utilized for plants (soluble molybdenum content).

2. Materials and methods

Pot experiment was carried out in the Greenhouse of Institute of Agricultural Chemistry and Soil Science in University of Debrecen, in the spring of 2015. In this experiment green pea (Pisum sativum L.) was chosen as test plant since its molybdenum need is significant and it is one of the vegetables grown in the largest area in Hungary.

Three types of soil were applied in this experiment:

1.) calcareous chernozem soil (pH=6.58) – Faculty of Agricultural and Food Sciences and Environmental Management at University of Debrecen, Látókép Experimental Station of Plant Production

2.) carbonate humus sandy soil (pH=7.14) – University of Debrecen, Pallag Experimental Station of Horticulture

3.) acidic humus sandy soil (pH=5.09) – College of Nyíregyháza, Ferenctanya Educational Farm

Molybdenum was added to the soil in the form sodium molybdate ($Na_2MoO_4.2H_2O$) dissolved in distilled water. In the case of calcareous chernozem soil (Látókép) we applied 0, 3, 30, 90 és 270 mg kg^{-1} molybdenum treatments, in the case of carbonate humus sandy soil (Pallag) and the acidic humus sandy soil (Nyíregyháza) the applied treatments included the following: 0, 30 and 270 mg kg^{-1}. We did not add molybdenum to the control soil.

Element analysis of plant samples was carried out with inductively coupled plasma optical emission spectrometry (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS) [8]. Wet digestion with nitric acid and hydrogen peroxide was applied during sample preparation of these plants [9]. The elemental analysis of soil samples can be divided to two main components which are the following: 1. The determination of the total element content of the samples with atmospheric wet digestion using concentrated nitric acid and hydrogen peroxide [10]. 2. The determination of the samples' soluble element content easily available for plants using the extraction tool by Lakanen-Erviö [11]. Afterwards, we measured the element content of the appropriately prepared samples using the abovementioned ICP-OES equipment.

For the statistical analysis One-Way analysis of variance (ANOVA) and Duncan's test were used. The significance was evaluated at the $P<0.05$ level. The statistical analyses were carried out using SPSS v.22.0 software.

3. Results

During our results of soil analysis it was established that due to the Mo-treatments with increasing concentration, the total molybdenum content of the soil and Lakanen-Erviö soluble molybdenum content that can be utilized by the plants showed a significant increase but difference was found in the soluble Mo concentration of different types of soils (Table 1). In the case of the soil of Nyíregyháza (sour humus sand) with the smallest pH value (pH=5.09) 26-29%, in the case of the soil of Látókép (calcareous chernozem) (pH=6.58) 44-56%, while in the case of the soil of Pallag (carbonate humus sand) with the largest pH value (pH=7.14) 62-67% of the total molybdenum was available to the plants.

Table 1) Total molybdenum and Lakanen-Erviö soluble molybdenum content (mg kg^{-1}) of soil of Látókép, Pallag and Nyíregyháza

Mo-treatment (mg kg^{-1})	**Total Mo (mg kg^{-1}) (A)**	**Lakanen-Erviö soluble Mo (mg kg^{-1}) (B)**	**B/A**
		Látókép (pH=6.58)	
0	<LOD	$0.069±0.010^{a}$	-
3	$2.96±0.05^{a}$	$1.67±0.06^{a}$	0.564
30	$27.3±4.2^{b}$	$12.1±0.2^{b}$	0.443
90	$87.2±2.2^{c}$	$43.2±1.0^{c}$	0.495
270	$265±5^{d}$	$141±12^{d}$	0.532
		Pallag (pH=7.14)	
0	<LOD	$0.080±0.022^{a}$	-
30	$27.4±2.5^{a}$	$18.4±0.4^{b}$	0.672
270	$272±2^{b}$	$169±9^{c}$	0.621
		Nyíregyháza (pH=5.09)	
0	<LOD	$0.036±0.006^{a}$	-
30	$30.2±1.0^{a}$	$8.74±0.20^{b}$	0.289
270	$281±4^{b}$	$74.3±2.0^{c}$	0.264

The values with different alphabetical index are significantly ($P<0.05$) different whithin the individual columns. Abbreviations: LOD=limit of detection. n=3±s.e.

The results of our research on dry weight of green pea plants are summarized in Tables 2-4. The results showed that the growth of the green peas treated with molybdenum is considerably determined by the type and acidity of the used soil. In case of Látókép and Nyíregyháza soil, the 30 mg kg^{-1} Mo-treatment increased significantly the dry matter product of the plant in most cases, but the 270 mg kg^{-1} Mo-treatment hindered the growth of peas. However, in the case of green peas cultivated in the soil of Pallag the Mo-treatment did not caused an increase in any dry mass product which as we see it is the consequence of the extra-high molybdenum accumulation arising from the soil's nearly neutral pH value. In addition, it was found that the application of the 270 mg kg^{-1} Mo-dose not only hindered the growth of peas but also led to the destruction of plants.

Table 2) Dry weight (g plant^{-1}) of individual plant's part of green pea plants grown in the calcareous chernozem soil of Látókép in case of different molybdenum treatments (0, 3, 30, 90, 270 mg kg^{-1})

Mo-treat.	**Dry weight (g plant^{-1}) of green pea plant grown in soil of Látókép**				
(mg kg^{-1})	**Leaf**	**Stem**	**Root**	**Pod**	**Seed**
0	0.4640±0.1238^{a}	0.3829±0.0759^{a}	0.0687±0.0023^{ab}	0.2326±0.0697^{a}	0.2092±0.0190^{a}
3	0.5022±0.0776^{a}	0.3948±0.0513^{a}	0.0806±0.0064^{bc}	0.2489±0.0306^{a}	0.2123±0.0505^{a}
30	0.7956±0.0993^{b}	0.7475±0.1335^{b}	0.0898±0.0108^{c}	0.3259 ±0.0373^{a}	0.2333±0.0557^{a}
90	0.5193±0.1411^{a}	0.5490±0.2454^{ab}	0.0519±0.0137^{a}	0.2501±0.0563^{a}	0.1895±0.0595^{a}
270	0.3787±0.0861^{a}	0.3118±0.1202^{a}	0.0537±0.0172^{a}	0.2370±0.0453^{a}	0.1737±0.0430^{a}

The values with different alphabetical index are significantly (P<0.05) different whithin the individual columns. n=3±s.e.

Table 3) Dry weight (g plant^{-1}) of individual plant's part of green pea plants grown in the carbonate humus sandy soil of Pallag in case of different molybdenum treatments (0, 30, 270 mg kg^{-1})

Mo-treat.	**Dry weight (g plant^{-1}) of green pea plant grown in soil of Pallag**				
(mg kg^{-1})	**Leaf**	**Stem**	**Root**	**Pod**	**Seed**
0	0.3290±0.6436^{a}	0.4526±0.1084^{a}	0.0613±0.0074^{a}	0.3077±0,0126^{a}	0.2263±0,0334^{a}
30	0.2121±0.7021^{b}	0.2373±0.0935^{b}	0.0396±0.0137^{b}	0.2363±0.0344^{b}	0.1487±0.0238^{b}
270	-	-	-	-	-

The values with different alphabetical index are significantly (P<0.05) different whithin the individual columns. n=3±s.e.

Table 4) Dry weight (g plant^{-1}) of individual plant's part of green pea plants grown in in acidic sandy soil soil of Pallag in case of different molybdenum treatments (0, 30, 270 mg kg^{-1})

Mo-treat.	**Dry weight (g plant^{-1}) of green pea plant grown in soil of Nyíregyháza**				
(mg kg^{-1})	**Leaf**	**Stem**	**Root**	**Pod**	**Seed**
0	0.1938±0.0030^{a}	0.2202±0.0543^{a}	0.0409±0.0096^{a}	0.1968±0.0038^{a}	0.2343±0.0769^{a}
30	0.2440±0.0185^{b}	0.3218±0.0421^{b}	0.0587±0.0042^{b}	0.2451±0.0128^{b}	0.2706±0.0285^{a}
270	0.1961±0.0289^{a}	0.2194±0.0261^{a}	0.0480±0.0113^{ab}	0.2067±0.0099^{ab}	0.2384±0.0500^{a}

The values with different alphabetical index are significantly (P<0.05) different whithin the individual columns. n=3±s.e.

In Tables 5-7. changes of Mo concentration in individual plant's part of green pea plants depending on Mo treatments that has been shown. This results showed that the Mo-treatments increased the Mo accumulation of peas and the effect of treatment was verifiable in all parts of the pea plants. We couldn't only observed a significant increase in the vegetative organs between the control and the 3 mg kg^{-1} treatments. In addition, the results of green peas cultivated in different types of soil affirm the fact that the capability to uptake Mo is primarily determined by the soil's acidity. Since the only utilizable Mo form for the plants is the molybdate anion (MoO_4^{2-}) which is available depending on pH and can be absorbed in a much larger quantity from alkaline soils. Accordingly, during this experiment we established that the treated plants accumulated the largest amount of molybdenum from the soil with the largest pH value (Pallag; pH=7.14), while the smallest amount from the Nyíregyháza soil with the smallest pH value (pH=5.09), the results show a close conjunction with the Lakanen-Erviö's soluble Mo contents.

Table 5) Mo concentration (mg kg^{-1}) of individual plant's part of green pea plants grown in the calcareous chernozem soil of Látókép in case of different molybdenum treatments (0, 3, 30, 90, 270 mg kg^{-1})

Mo-treat.	**Mo concentration (mg kg^{-1}) of green pea plant grown in soil of Látókép**				
(mg kg^{-1})	**Leaf**	**Stem**	**Root**	**Pod**	**Seed**
0	2.85 ± 0.10^a	4.01 ± 0.42^a	10.0 ± 0.9^a	2.61 ± 0.14^a	4.82 ± 0.52^a
3	7.21 ± 1.73^a	12.0 ± 0.1^a	11.0 ± 0.3^a	15.5 ± 4.0^b	5.62 ± 0.38^a
30	119 ± 3^b	187 ± 15^b	337 ± 40^b	48.3 ± 5.9^c	42.6 ± 1^b
90	483 ± 33^c	431 ± 17^c	964 ± 27^c	134 ± 7^d	131 ± 3^c
270	1050 ± 41^d	822 ± 2^d	1322 ± 132^d	165 ± 9^e	200 ± 6^d

The values with different alphabetical index are significantly (P<0.05) different whithin the individual columns. n=3±s.e.

Table 6) Mo concentration (mg kg^{-1}) of individual plant's part of green pea plants grown in the carbonate humus sandy soil of Pallag in case of different molybdenum treatments (0, 30, 270 mg kg^{-1})

Mo-treat.	**Mo concentration (mg kg^{-1}) of green pea plant grown in soil of Pallag**				
(mg kg^{-1})	**Leaf**	**Stem**	**Root**	**Pod**	**Seed**
0	2.39 ± 0.02^a	6.45 ± 0.21^a	34.5 ± 4.9^a	8.47 ± 2.45^a	5.19 ± 0.54^a
30	1886 ± 85^b	1183 ± 57^b	3473 ± 146^b	305 ± 5^b	253 ± 6^b
270	-	-	-	-	-

The values with different alphabetical index are significantly (P<0.05) different whithin the individual columns. n=3±s.e.

Table 7) Mo concentration (mg kg^{-1}) of individual plant's part of green pea plants grown in in acidic sandy soil soil of Nyíregyháza in case of different molybdenum treatments (0, 30, 270 mg kg^{-1})

Mo-treat.	**Mo concentration (mg kg^{-1}) of green pea plant grown in soil of Nyíregyháza**				
(mg kg^{-1})	**Leaf**	**Stem**	**Root**	**Pod**	**Seed**
0	1.79 ± 0.04^a	3.15 ± 0.38^a	5.61 ± 0.58^a	1.93 ± 0.19^a	6.25 ± 0.96^a
30	61.3 ± 1.2^b	74.8 ± 4.5^b	294 ± 2^b	26.1 ± 6.2^b	32.5 ± 0.1^b
270	711 ± 13^c	449 ± 20^c	2558 ± 23^c	140 ± 7^c	170 ± 5^c

The values with different alphabetical index are significantly (P<0.05) different whithin the individual columns. n=3±s.e.

Conclusion

In this study we have found that there is a close connection between the acidity of different types of soil and the Lakanen-Erviö's soluble molybdenum concentration.

According to our results 30 mg kg^{-1} Mo treatment affected positively on growth of plants in case of calcareous chernozem and acidic humus sandy soil however, higher content reduced the dry mass of green pea. In the case of carbonate humus sandy soil 30 mg kg^{-1} Mo treatment caused significant reduction in plant growth and application of the 270 mg kg^{-1} Mo led to the destruction of plants.

In addition, we observed that molybdenum concentration in green peas were significantly elevated with increasing the concentration of molybdenum treatment in comparison with control.

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