ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 16, No. 1–2 2009

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INFLUENCE OF SOIL CONTAMINATION WITH NICKEL AT VARIOUS ACIDITY ON A BASE OF CALCIUM AND MANGANESE CONTENTS IN BEANS

OCENA WPŁYWU ZANIECZYSZCZENIA GLEBY NIKLEM PRZY ZRÓŻNICOWANYM JEJ ODCZYNIE NA PODSTAWIE ZAWARTOŚCI WAPNIA I MANGANU W FASOLI

Abstract: The four-year pot experiment dealt with the influence of soil contamination with nickel (0, 50, 100, and 150 mg Ni · kg^{-1} soil) and liming (without or with liming according to 0.5, 1, and 1.5 Hh soil) on calcium and manganese contents in particular parts of Aura cv. bean plants (roots, stems, leaves, siliques, and seeds). Concentrations of Ca and Mn in plant material were determined by means of ICP-AES technique after previous combustion in muffle furnace at 450 ^{o}C and dissolving the ash in 10 % HCl. Numerical results were statistically processed applying variance analysis and using F-Fisher–Snedecor's test (F.R.Anal. ver. 4.1. software), while LSD values were calculated with a help of Tukey's test. Soil contamination with nickel and liming did not differentiate mean calcium and manganese levels over study years in analyzed bean parts, except from seeds, for which liming caused the decrease of manganese concentration.

Keywords: bean, soil contamination with nickel, liming, calcium, manganese

In general, the industrial pollution contribute to stronger degradation of agricultural production area leading, among others, to accumulation of heavy metals in the soil. Due to that, most of metals are involved into the trophic chain – soil → plants → animals → people with opportunity to accumulate in human's organisms. Nickel is a heavy metal that, in small amounts, is necessary to grow and development of living organisms, while at excess, it is toxic. Nickel concentration in the soil environment may greatly increase under influence of anthropogenic factors, which causes negative ecological effects. Nickel contamination of ecosystems is a threat mainly for plants that are first link of the nutrition chain [1]. Excessive nickel amounts at plants reduce their photosynthesis and transpiration. Nickel also disturbs the cation-anion balance within green parts of plants [2]. The Ni^{2+} toxicity is considerably affected by other metals [3]. Nickel takes part in

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antagonistic interactions with Ca, K, Mg and Mn, in possible antagonism with Co, whereas with Cu and Zn, nickel can be present both in antagonistic and synergistic systems [4].

The aim of present study was to evaluate the influence of soil contamination with nickel at various acidity on calcium and manganese contents in bean plants.

Material and methods

The four-year pot experiment was carried out in the greenhouse owned by University of Podlasie in Siedlce, in completely randomized pattern. Following factors were examined: I – soil contamination with nickel (0, 50, 100, 150 mg Ni · kg^{-1} soil – nickel in the form of $NiSO_4 \cdot 7H_2O$ solution applied at the beginning of June); II – liming (without or with liming according to 0.5, 1.0, and 1.5 Hh soil – in the form of $CaCO_3$ applied at the beginning of May).

Pots were not tilled for the first season, maintaining only the moisture content at the level of 60 % field water capacity, then dwarf bean (Aura cv.) was cultivated for four subsequent years. Once at each vegetation period, before sowing, following mineral fertilization was applied: N – 0.17 g · kg^{-1} soil in the form of NH_4NO_3 (34 % N); P – 0.053 g · kg^{-1} soil in the form of $Ca(H_2PO_4)_2$ (19 %); K – 0.17 g · kg^{-1} soil in the form of KCl (40 % K). The soil material used for the experiments was collected from the humus layer of typical podzolic soils that had following features: pH_{KCl} – 5.49; $C_{org.}$ – 6.5 g · kg^{-1} soil; $N_{tot.}$ – 0.61 g · kg^{-1} soil; P and available K (mg · kg^{-1} soil) – 71 and 110, respectively; total nickel content: 10.1 mg· kg^{-1}. Every year after harvest, samples were divided into particular plant fragments (roots, stems, leaves, siliques, seeds) and dried to estimate the dry matter content. Concentrations of Ca and Mn in plant material were determined by means of ICP-AES technique after combustion in muffle furnace at 450 ^{o}C and dissolving the ash in 10 % HCl [5]. Results were statistically processed by means of variance analysis applying F-Fisher–Snedecor's tests and using F.R. Anal. Ver. 4.1. software, while $LSD_{0.05}$ values were calculated according to Tukey's test. To find the interactions between studied traits, also linear correlation analysis was presented in the paper.

Results and discussion

Under the experimental conditions, average calcium content in particular bean parts calculated on a base of four-year results (Table 1) did not significantly change due to soil contamination with nickel and liming.

However, these results are not consistent with earlier achieved ones [6], that revealed that usually more calcium can be found in plants grown on limed as compared with not limed soils. Such discrepancy may be associated with the fact that liming was made five years before, hence its effects became negligible.

Mean calcium content for the whole bean plant (Table 1) was within the range between 17.8 and 20.8 g Ca · kg^{-1} d.m., which was the highest value in the case of plants grown on soils contaminated with nickel to the highest extent and limed with the calcium fertilizer according to 1.5 Hh soil. Content of calcium in particular bean plant fragments can be lined up in the following sequence: leaves > stems > roots > siliques > seeds.

Table 1

Mn content in bean [mg · kg^{-1} d.m.] (mean for four years of experiment)

Objects		Parts of plant					
Doses of nickel [mg · kg^{-1} soil]	Liming according to Hh	Roots	Bean stalks	Leaves	Stripped pods	Seed	Mean for plant
0	0	26.2	14.1	84.3	19.1	12.8	31.3
	0.5	31.5	13.3	81.0	18.1	10.6	30.9
	1.0	32.3	15.1	91.2	20.0	11.7	34.1
	1.5	31.1	15.0	75.3	16.8	12.2	30.1
50	0	27.1	16.3	112.0	20.3	12.9	37.7
	0.5	32.8	16.9	95.9	19.1	11.1	35.2
	1.0	23.7	14.9	92.8	16.0	10.5	31.6
	1.5	29.2	14.6	75.0	15.8	10.7	29.1
100	0	26.9	17.2	98.6	18.4	13.6	34.9
	0.5	31.8	17.0	85.0	17.8	10.7	32.5
	1.0	30.0	14.6	72.5	16.4	10.3	28.8
	1.5	25.7	14.0	87.4	20.0	11.0	31.6
150	0	30.2	12.2	82.7	20.7	10.5	31.3
	0.5	25.0	16.7	75.8	17.4	10.5	29.1
	1.0	30.8	13.6	90.4	18.2	11.2	32.8
	1.5	28.7	12.6	67.7	18.1	10.9	27.6
Mean for doses of nickel	0	30.3	14.4	83.0	18.5	11.8	31.6
	50	28.2	15.7	93.9	17.8	11.3	33.4
	100	28.6	15.7	85.9	18.2	11.4	32.0
	150	28.7	13.8	79.2	18.6	10.8	30.2
Mean for liming	0	27.6	15.0	94.4	19.6	12.5	33.8
	0.5	30.3	16.0	84.4	18.1	10.7	31.9
	1.0	29.2	14.6	86.7	17.7	10.9	31.8
	1.5	28.7	14.0	76.4	17.7	11.2	29.6
Mean in experiment		29.0	14.9	85.5	18.3	11.3	31.8

	Roots	Bean stalks	Leaves	Stripped pods	Seed
$LSD_{0.05}$ for:					
doses of nickel	n.i.	n.i.	n.i.	n.i.	0.623
liming	n.i.	n.i.	n.i.	n.i.	0.623
interaction: doses of nickel x liming	n.i.	n.i.	n.i.	n.i.	1.246

Mean manganese concentration in analyzed parts of the bean plants calculated on a base of four-year results (Table 2) did not considerably vary due to soil contamination with nickel and liming, except from seeds, for which following dependence was recorded: fragments from plants grown on nickel-polluted and not-limed soils were characterized by the highest manganese contents.

Table 2

Ca content in bean [g · kg^{-1} d.m.] (mean for four years of experiment)

Objects		Parts of plant					
Doses of nickel [mg · kg^{-1} soil]	Liming according to Hh	Roots	Bean stalks	Leaves	Stripped pods	Seed	Mean for plant
0	0	9.33	17.6	660.5	7.66	1.61	19.3
	0.5	8.04	16.7	54.9	8.74	1.42	18.0
	1.0	9.13	19.7	57.8	9.03	1.40	19.4
	1.5	9.30	20.9	56.7	7.39	1.44	18.9
50	0	9.39	18.3	54.0	8.53	1.54	18.4
	0.5	9.48	19.7	49.5	8.88	1.49	17.8
	1.0	8.84	20.0	49.8	8.83	1.54	17.8
	1.5	10.2	19.3	56.0	7.68	1.38	18.9
100	0	7.27	18.9	57.9	9.13	1.55	19.0
	0.5	10.1	20.7	59.5	9.26	1.39	20.2
	1.0	8.92	20.2	52.6	8.72	1.42	18.4
	1.5	10.9	19.1	56.4	8.44	1.33	19.2
150	0	9.41	17.8	61.9	9.35	1.48	20.0
	0.5	10.1	19.7	53.6	8.54	1.37	18.7
	1.0	9.41	20.5	56.3	8.74	1.50	19.3
	1.5	9.17	18.6	60.9	8.75	1.32	19.7
Mean for doses of nickel	0	8.95	18.7	57.5	8.20	1.47	18.9
	50	9.48	19.3	52.3	8.48	1.49	18.2
	100	9.30	19.7	56.6	8.89	1.42	19.2
	150	9.52	19.1	57.5	8.84	1.41	19.3
Mean for liming	0	8.85	18.1	58.6	8.67	1.55	19.2
	0.5	9.43	19.2	54.4	8.85	1.42	18.7
	1.0	9.08	20.1	54.1	8.83	1.46	18.7
	1.5	9.89	19.5	57.5	8.06	1.37	19.3
Mean in experiment		9.31	19.2	56.1	8.60	1.45	18.9

	Roots	Bean stalks	Leaves	Stripped pods	Seed
$LSD_{0.05}$ for:					
doses of nickel	n.i.	n.i.	n.i.	n.i.	n.i.
liming	n.i.	n.i.	n.i.	n.i.	n.i.
interaction: doses of nickel x liming	n.i.	n.i.	n.i.	n.i.	n.i.

Other authors reported [7–11] that solubility, therefore availability of most of metals, including manganese, decreased along with the pH increase. Here achieved results for bean seeds completely confirmed that observation.

Mean manganese content for the whole bean plant ranged within 27.6 to 37.7 mg Mn · kg^{-1} d.m., which was the highest at plants cultivated of soils contaminated with nickel to the lowest extent (50 mg Ni · kg^{-1} soil) and not limed. Concentration of manganese in particular fragments of tested plant can be lined up in the following sequence: leaves > roots > siliques > stems > seeds.

Statistical analysis revealed significant correlations between average value for experimental years vs. calcium and manganese contents in bean seeds (r = 0.59*).

Both soil contamination with nickel and liming did not cause significant changes in calcium and manganese concentrations in analyzed bean plant fragments (except from seeds), which can be attributed to excessively long time from the agents introducing into the soil and their action disappearance. Here performed experiment did not confirm the antagonistic dependencies between nickel vs liming and manganese content, which was described in the literature [4].

Conclusions

1. Soil contamination with nickel did not significantly differentiate the mean value of calcium and manganese contents in analyzed parts of bean plants.
2. Applied liming did not differentiate the mean calcium concentration in analyzed parts of bean plants and it caused the decrease of mean manganese content in bean seeds with no differentiation of its level in other bean plant fragments.
3. Experiments did not confirm the antagonistic dependencies between nickel vs. calcium and manganese.

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OCENA WPŁYWU ZANIECZYSZCZENIA GLEBY NIKLEM PRZY ZRÓŻNICOWANYM JEJ ODCZYNIE NA PODSTAWIE ZAWARTOŚCI WAPNIA I MANGANU W FASOLI

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Abstrakt: W czteroletnim doświadczeniu wazonowym badano wpływ zanieczyszczenia gleby niklem (0, 50, 100 i 150 mg Ni · kg^{-1} gleby) i wapnowania (bez wapnowania i wapnowanie wg 0,5; 1 i 1,5 Hh gleby) na zawartość wapnia i manganu w poszczególnych częściach fasoli (korzenie, łodygi, liście, łuszczyny i nasiona) odmiany Aura. Zawartość Ca i Mn w materiale roślinnym oznaczono metodą ICP-AES po wcześniejszej mineralizacji „na sucho" w piecu muflowym w temperaturze 450 °C i rozpuszczeniu popiołu w 10 % roztworze HCl. Wyniki badań opracowano statystycznie analizą wariancji z wykorzystaniem rozkładu F-Fishera–Snedecora wg programu F.R.Anal.var 4.1., a wartość NIR obliczono wg testu Tukey'a. Zanieczyszczenie gleby niklem i wapnowanie nie różnicowały średniej z lat badań zawartości wapnia i manganu w analizowanych częściach fasoli z wyjątkiem nasion, w przypadku których wapnowanie spowodowało zmniejszenie zawartości manganu.

Słowa kluczowe: fasola, zanieczyszczenie gleby niklem, wapnowanie, wapń, mangan