Janina GOSPODAREK¹ and Aleksandra NAGÓRSKA-SOCHA²

CONSEQUENT EFFECT OF SOIL CONTAMINATION WITH HEAVY METALS ON HEAVY METAL CONCENTRATIONS IN BROAD BEAN (Vicia faba L., ssp. maior)

NASTĘPCZY Wpływ SKAŻENIA GLEBY METALAMI CIĘŻKIMI NA ZAWARTOŚĆ METALI CIĘŻKICH W ROŚLINACH BOBU (Vicia faba L., ssp. maior)

Summary: Broad bean (Vicia faba L. ssp. maior), White Windsor c.v. was cultivated in 4 series, differing with the date of soil contamination with heavy metals. The soil was contaminated in 2002 (III), 2003 (II), 2004 (I) and 2005 (0). In each series the plants were cultivated in the following objects: unpolluted soil - with natural concentrations of heavy metals (Control); unpolluted soil - with natural concentrations of heavy metals and receiving mineral fertilization (Control + NPK); soil polluted with 4 mg · kg⁻¹ d.m. of cadmium, soil contaminated with 530 mg · kg⁻¹ d.m. of lead, soil polluted with 85 mg · kg⁻¹ d.m. of copper, soil contaminated with 1000 mg · kg⁻¹ d.m. of zinc and soil polluted with 110 mg · kg⁻¹ d.m. of nickel. Samples for chemical analyses were collected at milk ripeness of seeds. Chemical analysis of the plant material comprised an assessment of heavy metal concentrations (cadmium, lead, zinc, copper and nickel). From among the analysed heavy metals, cadmium might have the longest toxic effect on broad bean plants. With the lapse of three years from the moment of the soil contamination with this element on III level of contamination in IUNG classification, its content in broad bean plants has not declined. With the lapse of time from the moment of the soil contamination with copper or lead, the content of these elements in broad bean aboveground parts may decline. However, for the root parts an apparent decline in the above mentioned metal concentrations occurs only in the 2nd and 3rd year from the moment of pollution. The content of zinc or nickel in broad bean plants may decrease only after 2 or 3 years from the moment of the soil contamination with these elements. The process is faster for nickel.

Keywords: heavy metals, accumulation, plants

The investigations were conducted to determine the impact of soil contamination with single heavy metals on III level of contamination according to the IUNG classification [1] on their concentrations in broad bean plants (Vicia faba L., ssp. maior) with the lapse of time from the moment of soil contamination.

Material and methods

The experiment was conducted in 2005 at Zagaje Stradowskie village in the Świętokrzyskie province, in the area with unpolluted air. The experimental soil was degraded chernozem developed from loess, revealing acid reaction (pH = 5.7 in 1 mol·dm⁻³ KCl solution and 6.5 in water), with organic carbon content = 1.13%. Broad bean (Vicia faba L., ssp. maior), White Windsor c.v. was cultivated in 4 series differing with the date of soil pollution with heavy metals. The soil was contaminated in 2002 (III), 2003 (II), 2004 (I) and 2005 (0). In each series the plants were grown in the following treatments: unpolluted soil - with natural concentrations of heavy metals (Control); soil unpolluted and with natural content of heavy metals receiving mineral fertilizers (Control +

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+ NPK); soil contaminated with 4 mg · kg⁻¹ d.m. of cadmium, soil polluted with a lead dose of 530 mg · kg⁻¹ d.m., soil contaminated with copper dosed 85 mg · kg⁻¹ d.m., soil contaminated with zinc dosed 1000 mg · kg⁻¹ d.m. and the soil polluted with nickel dosed 110 mg · kg⁻¹ d.m. The heavy metals were added to the soil as water solutions of the following salts: 3CdSO₄ · 8H₂O, NiSO₄ · 7H₂O, CuSO₄, ZnSO₄ · 7H₂O and Pb(NO₃)₂. Since in the case of Pb(NO₃)₂ a certain amount of nitrogen was supplied into the soil, its dose was diminished accordingly in the basic fertilization applied. The basic fertilization, equal on all treatments (except unfertilized control) and using the following fertilizer doses: 0.7g N (as NH₄NO₃); 0.8 g P₂O₅ (in KH₂PO₄) and 1.2 g K₂O (as KCl) per pot was applied simultaneously with heavy metal introduction to the soil in each year of the experiment. The pots in which the plants were cultivated contained 9.8 kg d.m. of soil.

Samples for chemical analysis were collected at full milk maturity of the seeds. Chemical analysis of the plant material comprised an assessment of heavy metal concentrations (cadmium, lead, zinc, copper and nickel). Plant material was washed in tap and in distilled water, dried in 105°C to a constant weight and ground to fine powder, then mineralized and dissolved in 10% HNO₃. After filtration: Zn, Pb, Ni, Cu and Cd content was measured using Flame Atomic Absorption Spectrometry (FAAS).

**Results and discussion**

With the lapse of time from the moment of the soil contamination with cadmium its concentrations in broad bean aboveground parts remained on a similar level or even increased slightly (Tab. 1). On the other hand in roots this element content reached the highest level in plants growing in the soil contaminated a year before the analysis was conducted. The lowest concentration (but still several times higher than in plants growing in soil with natural heavy metal concentrations) characterized plant roots growing in the soil contaminated two years previously. Cadmium concentrations in plant roots growing in the soil contaminated in the year when the analysis was conducted were similar to this metal content in plant roots growing in the soil contaminated 3 years before. Especially in acid soils (like the one used for the discussed experiment), cadmium reveals a considerable mobility and quickly enters the food chain. It has been reported that the content between 5 and 30 ppm in the aboveground parts may be cause the symptoms of toxicity. Cadmium content in the described experiment was on the level of about 2 ppm and did not lead to any toxicity symptoms in broad bean plants [2].

With the lapse of time from the moment of the soil contamination with copper a gradual and significant decrease in its content was observed in broad bean aboveground parts. Its content in the plants grown in the soil contaminated 3 years earlier was only about 1.5-times higher than in the control plants, whereas its concentration in the plants growing in soil contaminated in the year of the experiment was almost 4 times higher than in the plants cultivated in the unpolluted soil. Such dependence was not registered for broad bean roots. Roots of plants growing in the soil contaminated the year before contained significantly larger amounts of copper than plant roots growing in the soil polluted in the year of the experiment. The lowest copper concentrations (about thrice highest than the control) were assessed in plant roots growing in the soil contaminated two years before the analysis was conducted.
Consequent effect of soil contamination with heavy metals on heavy metal concentrations in broad bean …

A considerable decrease in nickel concentrations was observed in broad bean aboveground parts in the second and third year after the moment of the soil pollution. Over twice higher nickel concentrations were detected in plant roots growing in the soil contaminated a year prior to the analysis than in plants growing in the soil contaminated in the year when the analysis was conducted or 2 years before. However, this metal concentrations in roots and aboveground parts of plants contaminated 3 years earlier were again significantly higher than in plants growing in the soil contaminated 2 years prior to plant sampling for analysis. Nickel is easily absorbed by plants and easily transported to the aboveground parts. This metal toxicity is greatly dependant on the degree of plant sensitivity [3].

Table 1

<table>
<thead>
<tr>
<th>Objects</th>
<th>C (Control)</th>
<th>C II</th>
<th>C I</th>
<th>C 0</th>
<th>C+ NPK III</th>
<th>C+ NPK II</th>
<th>C+ NPK I</th>
<th>C+ NPK 0</th>
<th>M III</th>
<th>M II</th>
<th>M I</th>
<th>M 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu (A)</td>
<td>2.80 b*</td>
<td>2.87 b</td>
<td>2.72 b</td>
<td>2.85 b</td>
<td>2.81 b</td>
<td>2.16 a</td>
<td>3.00 b</td>
<td>2.83 b</td>
<td>4.65 c</td>
<td>5.50 d</td>
<td>6.77 e</td>
<td>8.76 f</td>
</tr>
<tr>
<td>Cu (B)</td>
<td>1.03 a</td>
<td>1.43 a</td>
<td>1.97 a</td>
<td>2.13 a</td>
<td>1.10 a</td>
<td>1.32 a</td>
<td>1.30 a</td>
<td>1.75 a</td>
<td>13.61 c</td>
<td>6.50 b</td>
<td>24.57 e</td>
<td>21.13 d</td>
</tr>
<tr>
<td>Cd (A)</td>
<td>0.63 b</td>
<td>0.26 a</td>
<td>0.70 b</td>
<td>0.62 b</td>
<td>0.51 b</td>
<td>0.42 b</td>
<td>0.47 b</td>
<td>0.17 a</td>
<td>1.90 d</td>
<td>1.98 d</td>
<td>2.07 d</td>
<td>1.69 c</td>
</tr>
<tr>
<td>Cd (B)</td>
<td>0.16 a</td>
<td>0.24 a</td>
<td>0.15 a</td>
<td>0.22 a</td>
<td>0.26 a</td>
<td>0.32 a</td>
<td>0.34 c</td>
<td>0.29 a</td>
<td>3.06 b</td>
<td>0.26 a</td>
<td>3.36 b</td>
<td>3.77 c</td>
</tr>
<tr>
<td>Pb (A)</td>
<td>0.15 a</td>
<td>0.50 b</td>
<td>1.02 b</td>
<td>0.09 a</td>
<td>1.05 b</td>
<td>0.56 a</td>
<td>0.87 b</td>
<td>0.68 b</td>
<td>7.08 c</td>
<td>7.53 c</td>
<td>11.4 d</td>
<td>27.96 e</td>
</tr>
<tr>
<td>Pb (B)</td>
<td>1.33 a</td>
<td>1.40 a</td>
<td>1.90 a</td>
<td>1.43 a</td>
<td>2.40 a</td>
<td>2.27 a</td>
<td>2.37 a</td>
<td>2.20 a</td>
<td>35.17 b</td>
<td>36.67 b</td>
<td>80.17 c</td>
<td>81.33 c</td>
</tr>
<tr>
<td>Ni (A)</td>
<td>0.94 a</td>
<td>1.46 a</td>
<td>1.75 a</td>
<td>1.32 a</td>
<td>2.00 a</td>
<td>1.33 a</td>
<td>1.36 a</td>
<td>1.40 a</td>
<td>67.72 c</td>
<td>56.36 b</td>
<td>160.45 d</td>
<td>165.38 d</td>
</tr>
<tr>
<td>Ni (B)</td>
<td>1.89 a</td>
<td>1.90 a</td>
<td>1.90 a</td>
<td>2.50 a</td>
<td>2.40 a</td>
<td>1.63 a</td>
<td>1.16 a</td>
<td>1.81 a</td>
<td>110.73 c</td>
<td>63.33 c</td>
<td>195.00 e</td>
<td>76.67 c</td>
</tr>
<tr>
<td>Zn (A)</td>
<td>20.4 a</td>
<td>22.1 a</td>
<td>19.9 a</td>
<td>24.1 a</td>
<td>19.2 a</td>
<td>20.6 a</td>
<td>21.0 a</td>
<td>4258.0 b</td>
<td>4282.3 c</td>
<td>5010.3 d</td>
<td>5094.3 e</td>
<td></td>
</tr>
<tr>
<td>Zn (B)</td>
<td>6.7 a</td>
<td>7.2 a</td>
<td>8.0 a</td>
<td>8.4 a</td>
<td>6.2 a</td>
<td>7.2 a</td>
<td>6.0 a</td>
<td>7.5 a</td>
<td>1379.3 b</td>
<td>1906.0 c</td>
<td>2820.0 e</td>
<td>2280.0 d</td>
</tr>
</tbody>
</table>

* Values in lines marked with different letters are statistically different at p = 0.05

The most apparent decline in metal content in broad bean aboveground parts occurring with lapse of time was observed for lead. Already a year after the soil contamination this metal content was over twice lower than in plants growing in the soil contaminated in the year of the analysis. Pb content in the plants from the soil contaminated even earlier was also lower, respectively. On the other hand a significant (twofold) decline in lead content was registered for plants growing in the soil contaminated 2 and 3 years earlier.

Zinc concentrations in broad bean aboveground parts declined slightly when the plants were cultivated in the second and third year from the moment of the soil contamination with this element. An apparently higher zinc content was detected in the roots of plants growing in the soil contaminated a year before the analysis than in plants growing in the soil contaminated in the year of the experiment. The decrease in this metal root concentrations was detected, similarly as in the aboveground parts, in plants growing in the soil contaminated 2 and 3 years earlier.
Conclusions

1. From among the analysed heavy metals, cadmium might have the longest toxic effect on broad bean plants. With the lapse of three years from the moment of the soil contamination with this element on III level of contamination in IUNG classification, its content in broad bean plants has not declined.

2. With the lapse of time from the moment of the soil contamination with copper or lead, the content of these elements in broad bean aboveground parts may decline. However, for the root parts an apparent decline in the above mentioned metal concentrations occurs only in the 2nd and 3rd year from the moment of pollution.

3. The content of zinc or nickel in broad bean plants may decrease only after 2 or 3 years from the moment of the soil contamination with these elements. The process is faster for nickel.

References


NASTĘPCZY WPŁYW SKAŻENIA GLEBY METALAMI CIĘŻKIMI NA ZAWARTOŚĆ METALI CIĘŻKICH W ROŚLINACH BOBU (Vicia faba L., ssp. maior)

Streszczenie: Bób (Vicia faba L., ssp. maior) odm. Windsor Biały uprawiany był w 4 seriach, różniących się datą skażenia gleby metalami ciężkimi. Glebę skażano w latach: 2002 (III), 2003 (II), 2004 (I) i 2005 (0). W każdej serii rośliny uprawiano w następujących obiektach: gleba niezanieczyszczona - o naturalnej zawartości metali ciężkich (Kontrola); gleba niezanieczyszczona - o naturalnej zawartości metali ciężkich nawożona mineralnie (Kontrola + NPK); gleba zanieczyszczona kadmem w dawce: 4 mg · kg⁻¹ s.m., gleba zanieczyszczona ołowiem w dawce: 530 mg · kg⁻¹ s.m., gleba zanieczyszczona miedzią w dawce: 85 mg · kg⁻¹ s.m., gleba zanieczyszczona cynkiem w dawce: 1000 mg · kg⁻¹ s.m., gleba zanieczyszczona nikłem w dawce: 110 mg · kg⁻¹ s.m. Próby do analizy chemicznej zebrano w fazie dojrzałości nasion. Analiza obejmowała oznaczenie zawartości środowiska gleby metalami ciężkimi, z toksycznym działaniem na rośliny bobu, najołowej możemy mieć do czynienia w przypadku kadmum. W miarę upływu 3 lat od momentu zanieczyszczenia gleby tym pierwiastkiem na poziomie III stopnia zanieczyszczenia wg klasyfikacji IUNG jego zawartość w roślinach bobu nie maleje. W miarę upływu czasu od momentu skażenia gleby miedzią lub ołowiem zawartość tych pierwiastków w częściach nadziemnych bobu może spadać. Natomiast w przypadku części podziemnych wyraźne obniżenie koncentracji ww. metali następuje dopiero w 2 i 3 roku od momentu skażenia. Zawartość cynku lub niklu w roślinach bobu może spadać dopiero po upływie 2, 3 lat od momentu skażenia gleby tymi pierwiastkami. Proces ten przebiega szybciej w przypadku niklu.

Słowa kluczowe: metale ciężkie, akumulacja, rośliny