Žarko S. Kevrešan,¹ Novica M. Petrović²

¹ Faculty of Technology, University of Novi Sad, Bul. Cara Lazara 1, 21000 Novi Sad, Serbia and Montenegro
² Faculty of Agriculture and Institute of Field and Vegetable Crops, University of Novi Sad, Trg D. Obradovića 8, 21000 Novi Sad, Serbia and Montenegro

EFFECT OF Cd ON CONTENT AND DISTRIBUTION OF SOME MACRO- AND MICRONUTRIENTS IN PEA PLANTS DIFFERING IN AGE

ABSTRACT: Contents and distribution of N, K, Mg, Cu, Mn and Zn in pea plants treated with Cd at different age was investigated. Plants were treated with 10⁻⁷ or 10⁻⁵ M Cd for 48h 25th or 63rd days after seed germination. Results showed that more Cd was accumulated in plants treated with Cd at latter stages of growth and development. Treatments with both concentration of Cd caused accumulation of Cd in roots. Contents and distribution of the investigated macro- and micronutrients depended on Cd concentration and plant age.

KEY WORDS: pea, cadmium, plant age, macronutrients, micronutrients

INTRODUCTION

Heavy metals (HM) present in nutrient solution can inhibit or enhance the uptake of mineral nutrients by plants (Selà et al., 1988). The effect of HM is based on the antagonism or synergism of mineral elements (Morgen, 1993). During uptake, structure and function of root cell membranes may be affected by HM present in nutrient solution. It is shown that the selectivity of cell membranes was reduced a few minutes after the exposure of plants to HM (Pandolfini et al., 1992). Also, contact with HM causes depolarization of cell membranes (Costa and Morel, 1994) and selectivity reduction of ion translators (De Vos et al., 1991).

HM could affect the uptake, transport (Hart et al., 1998) and distribution (Hernández et al., 1996a) of mineral nutrients in plants. The effect of HM depends on the element (Petrović et al., 1996), plant species (Obata and Umebayashi, 1997) and the length of treatment (Hernández et al., 1996b).
Cadmium (Cd) toxicity is also associated with the uptake and translocation of mineral nutrients. For example, leaf chlorosis observed in Cd presence is related to the deficiency of Fe (Root et al., 1975; Foy et al., 1978) or Zn (Turner, 1973). Cd present in nutrient solution can affect the uptakes of Zn, Fe, Cu and Mn acting as an antagonist (Root et al., 1975, Keck, 1978, Wong et al., 1984, Bjerre and Schierup, 1985) and/or synergist (Turner, 1973, Khan and Khan, 1983, Wong et al., 1984, Vasquez et al., 1989). However, opposite results of Cd effect on uptake of mineral nutrients have also been reported. For example, according to Wallace et al. (1980) and Sela et al. (1988), Cd present in nutrient solution increased Fe content, while Khan and Khan (1983) and Bjerre and Schierup (1985) noted the decrease of Fe content in treated plants. Therefore, the aim of this study was to investigate whether the age of pea plants plays a role in the effect of Cd on the content and distribution of some macro- and micronutrients.

MATERIAL AND METHODS

The trials with the pea cultivar „Jezero” were conducted in a greenhouse under semi-controlled conditions. The seeds were germinated in vermiculite in a thermostat at 25°C. After germination, young plants were transferred to 2 l pots containing a nutrient solution of the following composition: (mM) 2.5 Ca(NO₃)₂; 2.5 KNO₃; 1.0 KH₂PO₄; 1.0 MgSO₄ x 7H₂O; and (mM) 23.1 B; 4.6 Mn; 0.38 Zn; 0.16 Cu; 0.052 Mo and 8.59 Fe as Fe-Na-EDTA.

Two different Cd concentrations, 10⁻⁷ and 10⁻⁵ M, and their effect on plants differing in age were investigated. The first group of plants was treated on the 25th day after germination and the second group was treated on the 63rd day with 10⁻⁷ or 10⁻⁵ M Cd for 48 hrs. Cd was applied as CdCl₂.

During the 48-hr treatment, the nutrient solution of the control plants was replaced with deionized water. After treatment, plants were harvested and separated into roots and aboveground parts.

Dry weight (DW) of individual organs was determined after drying at 60°C to a constant mass. Content of N in plants was determined according to Kjeldahl method, while the contents of K, Mg, Cu, Mn, Zn and Cd were measured after dry ashing at 450°C, by AAS using Varian Spect AA 10.

The results were statistically processed by the analysis of variance. Differences between the treatments were calculated using Duncan’s multiple range test.

RESULTS AND DISCUSSION

Cadmium content

The increased Cd concentration caused greater Cd accumulation in roots and aboveground parts of pea plants. Regardless of its concentration in the so-
lution and plant age, Cd tended to accumulate in roots and this could be a pattern of protection of the aboveground parts. Cd treatment on the 63rd day caused an increased accumulation of Cd as compared with the treatment on the 25th day. Difference in Cd contents between the plants treated with Cd on the 25th and those treated on the 63rd day showed that the Cd content was age-dependent (Figure 1). These results are in accordance with the findings of Petrović et al. (1999), which showed an increase in Cd content in plants in response to the increases of Cd concentration in nutrient solutions and plant age.

![Figure 1. Cd content in roots and aboveground parts of pea plants differing in age after treatment with Cd. A — treatment on the 25th day after seed germination, B — treatment on the 63rd day after seed germination, † — Duncan's test 5%](image)

**Effect of Cd on distribution of N, K and Mg**

Increased Cd concentrations in nutrient solution decreased the contents of N, K and Mg in the aboveground parts regardless of the day of plant treatment (Figure 2). Decreased levels of K in consequence to Cd treatment have also been observed in wheat (Trivedi and Erdéi, 1992), cucumber (Burzynsky, 1998) and corn plants (Walker et al., 1977). K content decreased only in the aboveground parts. High levels of Cd in Cd-sensitive plants can damage root cell membranes causing decreases of water and K uptake or even a release of K from the root. Damage of cell membranes also means that proteins like H+-ATP-ase are losing their function (Obata et al., 1996). There is a possibility that, following the same pattern, K+ transport proteins also may lose their function.

The contents of the investigated macronutrients in roots depended on plant age. The treatment with Cd on the 25th day decreased K and Mg contents while the treatment on the 63rd day increased N, K and Mg contents in roots. As a consequence of Cd treatment, the content of all investigated macronutri-
Figure 2. Effect of Cd on the N, K and Mg contents in roots and aboveground parts of pea plants differing in age. A — treatment on the 25th day after seed germination, B — treatment on the 63rd day after seed germination, $\text{T}$ — Duncan’s test 5%
ents decreased in the above-round parts of plants, regardless of plant age. The treatment on the 25th day did not change the content of N neither in roots nor in the aboveground parts (Figure 2).

Treatment with Cd affected the distribution of macronutrients between the aboveground parts and roots. The most significant effect on N distribution was caused by the higher Cd concentration and its application on the 63rd day. With the increase of Cd concentration in the nutrient solution, K and Mg tended to accumulate in roots regardless of plant age (Table 1). Also, the treatment of young corn plants with Cd has increased the Mg concentration in tissues (Nascimento et al., 1998).

Table 1. Effect of Cd on the aboveground/root content of N, K and Mg in pea plants differing in age

<table>
<thead>
<tr>
<th>Cd (M)</th>
<th>N</th>
<th>K</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Treatment on the 25th day after seed germination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>4.44</td>
<td>3.03</td>
<td>4.30</td>
</tr>
<tr>
<td>10−7</td>
<td>4.66</td>
<td>2.86</td>
<td>3.86</td>
</tr>
<tr>
<td>10−5</td>
<td>4.30</td>
<td>2.57</td>
<td>3.04</td>
</tr>
<tr>
<td></td>
<td>Treatment on the 63rd day after seed germination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>10.37</td>
<td>15.96</td>
<td>17.21</td>
</tr>
<tr>
<td>10−7</td>
<td>9.00</td>
<td>9.71</td>
<td>13.49</td>
</tr>
<tr>
<td>10−5</td>
<td>6.62</td>
<td>10.63</td>
<td>12.61</td>
</tr>
</tbody>
</table>

Effect of Cd on distribution of Cu, Mn and Zn

Cd treatment on the 25th day after germination lowered the contents of all investigated micronutrients in the aboveground parts and the Mn content in roots of the tested pea plants. The same treatment did not significantly alter the contents of Cu and Zn in roots. Cd treatment on the 63rd day after germination lowered the Mn content in roots while its content in the aboveground parts was not changed significantly. The Zn content decreased in roots and aboveground parts in consequence to Cd treatment on the 63rd day. The treatment on the 63rd day with the lower Cd concentration increased, while the higher Cd concentration decreased, the content of Cu in the aboveground parts. As in the aboveground parts, a more significant increase of Cu content in roots was observed in plants treated on 63rd day with the lower Cd concentration (Figure 3).

Distribution of the investigated micronutrients depended on Cd concentration and plant age. The treatment on the 25th day decreased the Cu transport and increased the Mn transport in the aboveground parts. The treatment on the 25th day with the lower Cd concentration increased the Zn transport while the higher Cd concentration did not affect Zn transport in the aboveground parts. The treatment on the 63rd day increased the Mn transport in the aboveground parts. Conversely, the Cu transport in the aboveground parts decreased with Cd treatment on the 63rd day, especially when the lower concentration was applied. The treatment on the 63rd day with the lower Cd concentration increased the Zn transport in the aboveground parts while the higher concentration stimulated the accumulation of Zn in roots (Table 2).
Figure 3. Effect of Cd on the Cu, Mn and Zn contents in roots and aboveground parts of pea plants differing in age. A — treatment on the 25th day after seed germination, B — treatment on the 63rd day after seed germination, T — Duncan's test 5%
Table 2. Effect of Cd on the aboveground/root content of Cu, Mn and Zn in pea plants differing in age

<table>
<thead>
<tr>
<th>Cd (M)</th>
<th>Cu</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28.7</td>
<td>0.96</td>
<td>2.75</td>
</tr>
<tr>
<td>10−7</td>
<td>2.41</td>
<td>1.14</td>
<td>2.25</td>
</tr>
<tr>
<td>10−5</td>
<td>2.17</td>
<td>1.95</td>
<td>2.66</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment on the 63rd day after seed germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>10−7</td>
</tr>
<tr>
<td>10−5</td>
</tr>
</tbody>
</table>

A decrease of Mn content in pea plants 48h after Cd treatment (Figure 2) was also reported in a study by Hernández et al. (1996a). They noted a decrease in Mn content with an increase of Cd concentration in nutrient solution in another pea genotype. Increase of Mn transport to the aboveground parts was also observed by Hernández et al. (1996b). The authors considered the increase in Mn transport after Cd treatment to be a defense mechanism that prevents Cd accumulation in the photosynthetically active parts of plant. The lower Mn accumulation in plants and its increased transport to the aboveground parts after a short exposure to Cd was also observed by other authors (Obata and Umebayashi, 1997).

CONCLUSION

The results obtained in our study showed that the uptake of Cd depended on its concentration in the nutrient solution and on plant age. The accumulated Cd was mainly retained in roots. Our results pointed to the dependence of the contents and distribution of the investigated macro- and micronutrients on the Cd concentration applied and on plant age. The effect of Cd on the distribution of nutrients in relation to plant age varied for all nutrients except Zn.

REFERENCES


Petrović, N., Kastori, R., Arsenijević-Maksimović, I. (1996): Effect of cadmium and lead on the concentration of macro- and micronutrients in sugar beet plants. IXth international colloquium for the optimization of plant nutrition. 8th—15th September, Prague, Czech Republic.


Trivedi, S., Erdei, L. (1992): Effects of cadmium and lead on the accumulation of Ca i K, and on the influx and translocation of K in wheat of low and high K status. Physiol. Plant. 84: 94—100.


УТИЦАЈ Cd НА САДРЖАЈ И ДИСТРИБУЦИЈУ МАКРО И МИКРОЕЛЕМЕНATA КОД ГРАШКА РАЗЛИЧИТЕ СТАРОСТИ

Жарко С. Кеврешан,1 Новица М. Петровић2
1 Технолошки факултет, Универзитет у Новом Саду, Булевар Цара Лазара 1, 21000 Нови Сад, Србија и Црна Гора
2 Пољопривредни факултет и Научни институт за ратарство и повратарство, Универзитет у Новом Саду, Трг Д. Обрадовића 8, 21000 Нови Сад, Србија и Црна Гора

Резиме

У полуконтролисаним условима у стаклари, методом водених култура испитиван је третман Cd на масу суве материје и садржај Cd, N, K, Mg, Cu, Mn и Zn и њихова дистрибуција на грашку различитих старости. Биљке су третирани Cd-ом у трајању од 48 сати у концентрацији од 10−7M или 10−5M 25. или 63. дана након климања семена. Веће накупљање Cd уочено је у корену, третманом вишем испитаном концентрацијом и третманом у каснијим фазама. Садржај и дистрибуција испитиваних елемената зависила је од концентрације Cd као и од старости биљке у време третмана. Сем Zn, сви испитивани елементи су показали специфичну реакцију на присуство Cd у зависности времена његове примене.