Title
Cadmium in fresh matter of shoots in lettuce cultivars grown in Cd enriched soil

Permalink
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Publication Date
2009-04-28

Peer reviewed
1. Introduction

The intensity of plant metal build in crops in general depends on the part of the plant analyzed, the plant species, as well as on the cultivar studied. The care with the quality of the agricultural products in general, and the vegetables in particular, is an important issue concerning the presence of undesirable chemicals in the foods. Their presence in the edible parts of vegetables may constitute a potential way of transference of toxic elements from soil to food chain. The undesirable health effects from “excessive” intake of several toxicants, including toxic metals, are addressed by safety factors which describe the safe levels of metal intake by the human body (Silva et al., 2005). A possible danger to the food chain needs to be evaluated in terms of chemical elements availability to plants which is related to their solubility as well as to the element mobility in soils and their uptake by plants (Alleoni et al., 2005).

The heavy metal Cd occurs naturally in soils, has no essential function in plants and can be readily taken up and accumulated by plants (Green et al, 2003). In comparison to other groups of foods, the vegetables are responsible for 23.9 % of the daily intake of Cd, being second to cereals with 54.3 % (Chen and Gao, 1993). Cadmium is in the “contaminant” functional class and has a provisional tolerable weekly intake level (PTWI) of 0.007 mg/kg of body weight (bw) (WHO, 2006). According to the US Bureau of Foods, the mean daily intake of Cd is estimated to be 39 µg and the safe upper limits for Cd daily intake set by WHO/FAO is 57-71 µg Cd and by U.S. EPA is 71 µg Cd (Pais and Jones Jr., 2000). In Brazil, the food legislation allows a maximum of 1.0 mg kg$^{-1}$ Cd in the fresh matter (Mesquita Filho et al., 2001). Cadmium is the most mobile metal in plants, being more toxic than Pb and easily accumulated in the plant tissues (Wong et al., 1984). Plants tolerate 0.05 to 0.2 µg g$^{-1}$ Cd in the dry matter, with 5 to 30 µg g$^{-1}$ being considered a toxic range (Kabata-Pendias and Pendias, 1992).

The concentrations of Cd in dry and fresh matter of plant shoots from two cultivars of lettuce (*Lactuca sativa* L.) were compared to critical levels for toxicity. The accumulation and distribution of Cd in the shoots was also evaluated. The plants were grown in a loam Red-Yellow Latossol (Oxyssol) that received doses of Cd in greenhouse conditions.

2. Material and Methods

Plants were grown in a loam Red-Yellow Latossol (Oxyssol) from the city of João Pinheiro, Minas Gerais State, Brazil, in soil collected in the 0-20cm surface layer, air dried, and sieved (4 mm) for determination of soil physical and chemical characteristics (Table 1).

Table 1. Chemical and physical characteristics of the soil (Red-Yellow Latossol)

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH in water (1:2.5)</td>
<td>5.16</td>
</tr>
<tr>
<td>Organic carbon (dag kg$^{-1}$)</td>
<td>1.00</td>
</tr>
<tr>
<td>P (mg dm$^{-3}$)$^2$</td>
<td>0.93</td>
</tr>
<tr>
<td>K (mg dm$^{-3}$)$^2$</td>
<td>23.00</td>
</tr>
<tr>
<td>Al$^{3+}$ (cmol$_{c}$ dm$^{-3}$)$^3$</td>
<td>1.80</td>
</tr>
<tr>
<td>Ca$^{2+}$ (cmol$_{c}$ dm$^{-3}$)$^3$</td>
<td>0.02</td>
</tr>
<tr>
<td>Mg$^{2+}$ (cmol$_{c}$ dm$^{-3}$)$^3$</td>
<td>0.23</td>
</tr>
<tr>
<td>H + Al (cmol$_{c}$ dm$^{-3}$)$^4$</td>
<td>4.76</td>
</tr>
<tr>
<td>Sum of bases (cmol$_{c}$ dm$^{-3}$)$^5$</td>
<td>0.31</td>
</tr>
<tr>
<td>Effective CEC (cmol$_{c}$ dm$^{-3}$)$^6$</td>
<td>2.13</td>
</tr>
<tr>
<td>CEC at pH 7.0 (cmol$_{c}$ dm$^{-3}$)$^7$</td>
<td>5.07</td>
</tr>
</tbody>
</table>

$^a$ Walkley- Black Method (Gaudette et al., 1974); $^b$ Mehlich-1 extraction (Defelipo e Ribeiro, 1981);
$^c$ KCl 1 mol.L$^{-1}$ extraction (Defelipo e Ribeiro, 1981); $^d$ Ca(OAc)$_2$, 0.5 mol.L$^{-1}$, pH 7.0 extraction (Defelipo e Ribeiro, 1981)
$^e$ Pipet Method (EMBRAPA, 1997); $^f$ Richards Method (EMBRAPA,1997)
Volumes of 2.5 dm$^3$ of soil in plastic bags were limed with CaCO$_3$ and MgCO$_3$ (CFSEMG, 1999) based on previous incubation curves, to reach the soil pH 5.8, supply Ca and Mg for the plants, and precipitate the exchangeable Al in the soil solution. The soil plus liming agents were incubated by 25 days in 3 dm$^3$ polyethylene recipients, with moisture maintained at field capacity.

In the day before the seedling transplanting, the soil received the Cd treatments (0.0; 0.4; 1.6; 3.2 and 9.6 mg dm$^{-3}$) plus 60 mg dm$^{-3}$ N, 88 mg dm$^{-3}$ P, 50 mg dm$^{-3}$ K and micronutrients, as recommended for lettuce (CFSEMG, 1999). The elements were applied in solution by using the sources CdCl$_2$.H$_2$O, NH$_4$NO$_3$, NH$_4$H$_2$PO$_4$ and K$_2$SO$_4$.

The lettuce seedlings were prepared in plastic trays, watered with distilled water and transplanted into the recipients with soil plus fertilizers plus the Cd treatments. Twenty one days after sowing, three lettuce seedlings were transplanted to each recipient and ten days after the transplanting two seedlings were removed. The soil moisture in the recipients was kept at field capacity by using deionized water. Forty four days after transplanting, the plants were harvested by cutting them near the soil surface. The eight leaves located at the lower positions in the base of the plants (lower leaves) were separated from the remaining leaves (upper leaves). Shoots and roots fresh weight was recorded and the vegetal material was dried at the 70 °C temperature to constant weight. The plant dry weight was recorded, the samples grounded in a Willey mill, sieved through a 16 mesh sieve, and analyzed for the determination of Cd in the vegetal tissues. A portion of 0.5 g of each plant sample was digested by using a nitric-perchloric solution (Zazoski and Burau, 1977) and the extracts analyzed for determination of Cd by atomic absorption spectrophotometry (Jordão et al, 2006). The metal concentrations in the fresh matter were calculated by the plant fresh matter and the metal concentrations in the dry matter.

The experiment was carried out with two lettuce cultivars (Mimosa and Regina Verao) and five Cd treatments (0; 0.4; 1.6; 3.2 and 9.6 mg dm$^{-3}$) arranged in a randomized block design with 4 replications. The experimental unit was a 2.5 dm$^3$ polyethylene recipient with one lettuce plant per recipient. The concentrations of Cd in the fresh matter were compared to threshold limits in foods.

3. Results and Discussion

There was an increasing transference of Cd from the soil to the shoots of the lettuce plants, in both cultivars, in all treatments (Table 2). The Brazilian legislation for foods reports the maximum Cd concentration allowed in food fresh matter as 1.0 mg kg$^{-1}$ (ABIA, 1991; Mesquita Filho et al, 2001). Based on that, only the plants grown in soil that received 0.0 and 0.4 mg dm$^{-3}$ Cd presented safe concentrations, in both cultivars (Table 2). The higher Cd concentrations in RV shoot fresh matter, combined with the higher fresh matter production, suggests that this cultivar has a greater potential to deal with high Cd in the soil.

These results alert for the need of monitoring the quality of fertilizers and agricultural inputs as related to the presence of Cd in their constituents to prevent its transference to plant shoots of vegetable crops.

4. Conclusions

There is a differential response between the Mimosa and Regina Verao lettuce cultivars in Latossols (Oxysols) enriched with Cd. The Regina Verao deals better with high Cd concentrations than Mimosa. Cadmium concentrations in the fresh matter of lettuce leaves may be used for monitoring the transference of Cd from soil amendments to lettuce plants.
Table 2. Fresh matter weight of shoots (FMWS) and Cd concentrations in the fresh matter of shoots (CdFMS) of two lettuce cultivars (Mimosa and Regina de Verao) after 44 days growth in a Red-Yellow Latossol enriched with increasing Cd doses, and the Cd distribution in the upper (UL) and lower (LL) leaves of the two cultivars.

<table>
<thead>
<tr>
<th>Cd dose (mg dm(^{-3}))</th>
<th>Fresh matter of shoots and Cd in the fresh matter of shoots</th>
<th></th>
<th>Mimosa</th>
<th></th>
<th>Regina Verao</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh matter weight of shoots (g)</td>
<td>Cd concentrations (mg kg(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FMWS</td>
<td>CdFMS</td>
<td>FMWS</td>
<td>CdFMS</td>
<td>FMWS</td>
<td>CdFMS</td>
</tr>
<tr>
<td>0.0</td>
<td>75.08</td>
<td>0.03</td>
<td>86.70</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>59.19</td>
<td>0.80</td>
<td>75.36</td>
<td>1.94</td>
<td></td>
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</tr>
<tr>
<td>1.6</td>
<td>55.26</td>
<td>1.99</td>
<td>80.90</td>
<td>3.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>54.23</td>
<td>3.56</td>
<td>64.22</td>
<td>10.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.6</td>
<td>32.40</td>
<td>6.13</td>
<td>43.38</td>
<td>16.86</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Acknowledgements

RLFF thanks to CNPq for the research fellowship.

References


