Arsenic uptake in bean and cabbage grown in silty and sandy soil and irrigated with arsenic containing water

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Abstract
The uptake of arsenic was studied in bean (*Phaseolus vulgaris* L.) and cabbage (*Brassica oleracea* L. var. *capitata* L.) in an open greenhouse pot culture with sand and silt soil as substrate. The plants were irrigated with water containing sodium arsenate at concentrations 0.05 and 0.2 mg As L^{-1}. The total arsenic concentration of the different plants parts was determined by ICP-MS, following microwave-assisted acid digestion. The As concentration in the bean was in the order: root>shoot>bean pod and in cabbage: root>leaves. Increasing As concentration in the irrigation water resulted in decreased edible biomass production in bean, while in cabbage the edible biomass production increased. At the highest dose (0.2 mg As L^{-1}) if a person consumes about 450g of bean then their As intake will be: 0.9 µg from bean grown in sand and 0.72 µg from bean grown in silt. If 450g of cabbage is consumed then the As intake would be: 22.5 µg from cabbage grown in sand and 12.15 µg from cabbage grown in silt.
Considering the WHO recommended MTDI limit of 2 µg kg^{-1} body weight, both bean and cabbage can be consumed at the highest As treatment level of 0.2 mg L^{-1}.
Keywords: irrigation, arsenic uptake, sandy soil, vegetables

1. Introduction

Arsenic (As) is a highly toxic element found ubiquitously in nature that represents a potential environmental threat to human, animal and plant health (Rosas-castor et al., 2014). Arsenic can enter terrestrial and aquatic environments through both natural processes and anthropological sources (Quanji et al., 2008).
Aquifers in the Pannonian basin contain naturally occurring arsenic (1-174 µg L^{-1}), and the water from these aquifers is utilized for drinking and irrigation purpose. This As affects one million people, at levels greater than the recommended 10 µg L^{-1} WHO standards (Varsanyi et al., 2006). As is recognized as a toxic element and has been classified as a human carcinogen which at chronic levels adversely affects skin, lungs and overall human health (Rahman et al., 2009).

The transfer of arsenic in soil–plant systems represents one of the principal pathways for human exposure to arsenic (Lu et al., 2010). As uptake by vegetables depends on its availability in soil and the ability of the crop to take up As and translocate it. The main chemical forms of As available for uptake by plant is As(V), found in aerobic soils and As(III), predominant in anaerobic soils. Presence of clay, organic matter, P and S in the soil influences As uptake. Due to low soil As availability the arsenic concentration in plants varies from less than 0.01 to about 5µg g^{-1} (DW) (Huang et al., 2006).

2. Title

2.1 Objective

The aim of this study was to (1) Investigate the plant biomass production in two soil types (sand and silt), with two different arsenic concentrations using groundwater for irrigation, (2) Determine the uptake of arsenic by the various plant parts, especially the edible part and (3) Compare the As uptake by bean (*Phaseolus vulgaris* L.) and cabbage (*Brassica oleracea* L. var. *capitata* L.)

2.2. Materials and methods

Arsenic uptake by bean and cabbage was studied in sand [Top soil: 0-30 cm, Őrbottyán (47°40'N, 19°14'E)] and silt soil [Top soil: 0-60 cm, Hatvan (47.670356°, 19.644652°)] by applying irrigation water containing As, mimicking the groundwater As concentration.
Arsenic accumulation in root, shoot, and fruit was analyzed at the fruiting or mature stage. Plants were grown in a pot-soil system in open greenhouse. Plants were supplied with Hoagland's nutrient solution (Hoagland and Arnon, 1938) and irrigated once a week with tap water. Arsenic was supplied in the form of sodium arsenate, at concentrations 0, 0.05 and 0.2 mg L^{-1}.
Separated plant samples were thoroughly washed with Milli-Q water and oven dried at 40°C for 48hrs. The dry homogenized samples were digested in a microwave-assisted acidic digestion system using 7 cm^3 67 % nitric acid and 3 cm^3 30 % hydrogen-peroxide. The resultant solutions were diluted with deionized water up to 25 cm^3. Concentration of As and certain nutrients (P, K, Mg, Fe,

Mn, Cu, Zn) were determined by inductively-coupled plasma mass spectrometer. (Analytik Jena, Germany).

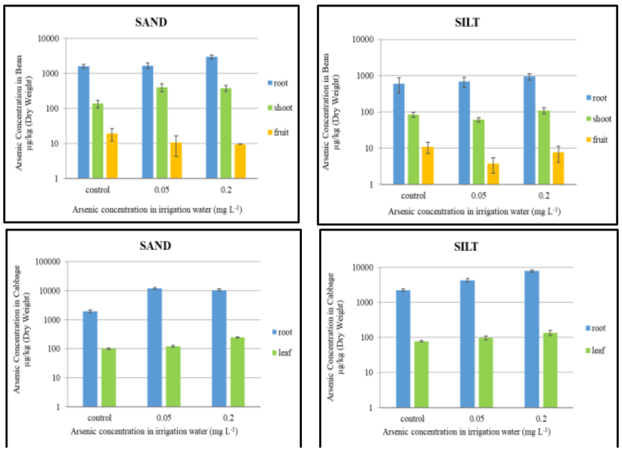

Fig.1. (A) As uptake in bean in sand, (B) As uptake in bean in silt, (C) As uptake in cabbage in sand, (D) As uptake in cabbage in silt

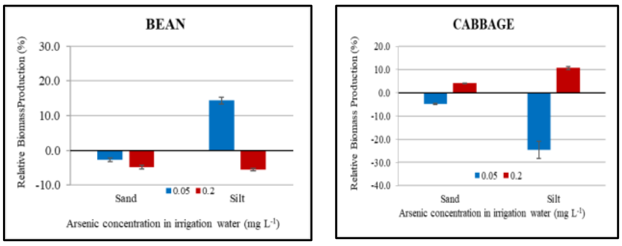

Fig.2. (A) Relative biomass production of bean fruit, (B) Relative biomass production of cabbage leaves

The soil samples were digested in aqua regia and the concentrations of elements were measured.

3. Result

- The As content of the sand and silt soil was 4.32 mg kg $^{-1}$ and 9.02 mg kg $^{-1}$, respectively.
- Neither of the plants exhibited any visible toxicity symptoms at any treatment.
- Increase in As concentration of the irrigation water caused an increase in the As accumulation in the plant, and in both plants maximum As concentration was found in the roots and minimum in the fruit or leaves. (Fig.1).
- As accumulation in edible part is higher in cabbage as compared to bean. Leafy vegetables accumulate more As than fruit bearing vegetables.
- The maximum As concentration in both vegetables occurred in those grown on sandy soil and they also had lower biomass productivity. Vegetables grown on silt soil had better biomass productivity (Fig.2).
- At 0.2 mg As L^{-1} treatment, bean displayed a negative biomass production in both soil types, but cabbage displayed positive biomass productivity in both soil types.

  Arsenic intake for a person consuming 450g (FW) of bean would be 0.9 µg from bean grown in sand and 0.72 µg from bean grown in silt. İn case of cabbage the intake would be 22.5 µg from cabbage grown in sand and 12.15 µg from cabbage grown in silt.
- Considering the maximum tolerable daily intake value of 2 µg As kg−1 body weight (WHO), both bean and cabbage grown in irrigation water containing up to 0.2 mg As L-1 are safe to consume. But we need to consider the As intake from other sources like water, cereals and meat.
- The transfer factor for As is the amount of As translocated from the roots to edible part. The TF from root to fruit or leaves was found to increase with increase in the As treatment applied. The transfer factor range for bean from root to fruit in sand was 0.012-0.003, and in silt was between 0.018-0.008.
- In cabbage the T.F from root to leaves was between 0.051-0.024 and 0.035-0.017 in sand and silt, respectively.

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