EFFECTS OF ARSENIC CONTAMINATION IN SPRINKLING WATER ON THE ARSENIC CONTENT OF LETTUCE IN HYDROCULTURE

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ABSTRACT

Horticulture, and mainly vegetable growing, is one of the most important sectors of agriculture in Hungary. The production area of indoor and outdoor vegetable growing exceeds 60 000 ha per year. About 80 percent of this area is located in the southeast region of the country. The average precipitation of this area is 380-450 mm per year, therefore intensive vegetable growing can't avoid irrigation. However, sprinkling water is relatively available in this territory. Underground water for irrigation between 30 and 200 m is obtainable in good quality and quantity for all agricultural production. In some cases higher salt content and iron level appear in underground waters, and beyond these, higher arsenic concentration can be observed probably from geological origin. Main arsenic ion form is arsenate, which was concentrated in living water residues in Pleistocene and Holocene. In these waters arsenic concentration is 20 to 200 μg/L. In Faculty of Horticulture, Kecskemét College, we started our investigations in order to study the arsenic uptake and accumulating properties of different vegetables, grown under the influence of arsenic polluted sprinkling water. Our methods were indoor and outdoor growing, rainfall and trickle irrigation, soil and hydroculture manner as well. This paper summarizes our results on hydroculture lettuce grown with 0-25-50-75-100-200 μg/L (natural As dose) and 400-600-800 μg/L (provoked As dose) arsenic polluted sprinkling water.

Keywords: arsenic pollution, lettuce, greenhouse, hydroculture, hidroponically, ICP-AES

INTRODUCTION

Arsenic (As) is a well known toxic element found in Hungarian well waters due to natural geological conditions (FÜGEDI ET AL., 2004). In the EU-countries as well as in Hungary government decrees [201/2001 (X.25.)] determine the acceptable concentration of arsenic in drinking water (10μg/L, at most) and food of vegetable origin (vegetables, 200 μg/kg) [17/1999 (IV.16.) EüM]. Serious problems in the water supply of Hungary are caused by wells bored in some parts of the country which yield polluted water of 30-150 μg/L As concentration (BARTHA, 2004).

Due to these measures the impact of polluted water on the population can be reduced, but it must not be forgotten, that in the southern and south-eastern parts of the country fresh vegetables irrigated with arsenic water can threat the consumers directly.

It is clearly known from geological research (BARTHA, 2004), that underground waters in southern and south-eastern parts of the Great Plain contain arsenic in high concentration (30-200 μg/l). This area represents 80% of the irrigated vegetables territory.

The inorganic forms of arsenic are dangerous poisons noxious to the whole human body, reducing the activity of the nervous system, kidneys, respiratory organs and the liver, also resulting in reproductive and genetically anomalies and cancer (FERGUSSON, 1991).

Trial series were started in cooperation between the Ornamental Plant and Vegetable Crops Institute and Soil and Plant Analysis Laboratory of the College for Horticulture (Hungary, Kecskemét) to determine the concentration of this toxic element in some important vegetables irrigated with polluted water. Leaf-vegetables, pepper, tomato, carrot and parsley have been tested from 2006 onwards followed by hydroponic lettuce in 2009, 2010 and 2011. Lettuce is grown on about 2000 ha, half in the open and half in forcing-house. The water used for irrigation or for nutrient solutions is obtained from wells, 30-100 m deep (BARTHA, 2004).

Aim of trials to analyze the effect of water with arsenic content characteristic for the region on lettuce leaves grown in hydroculture, when polluted water is used for the nutrient solution. Arsenic doses of 25, 50, 75, 100, 200, 400, 600, 800 μg/L were tested. The first five doses represent concentrations found in nature, the extreme values (400-600 μg/L) served for scientific observations or modelled extreme conditions.

MATERIAL AND METHOD

Trials included lettuce in hydroponic culture in the greenhouse of the Ornamental Plant and Vegetable Crops Institute. There were three tables each containing three nutrient channels made of plastic plates, 4.3 m long, 15 cm high and 30 cm large.

In each channel 25 l standard solution was circulated by a pump controlled by a time switch. An upper container (feeder) and a bottom container (collecting) facilitated the storage of the solution. The slight sloping of the channels furthered the solution flow. In the hydroculture roots developed in the solution and plants were fixed in a neutral agent, rock-wool, and cubes.

The hydroculture started 1st September 2009, 29th March 2010 and 11th April 2011. Two-four leaf lettuce was pricked into rock-wool cubes. The growing period lasted 6 weeks in each year.

At the end of the trial period the lettuce heads were removed from rock-wool cubes. Random samples were taken on the whole length of each channel, fully developed healthy leaves were taken from the middle of the heads in four repetitions.

Root samples were also collected by lifting the rock-wool cubes and disentangling the roots carefully.

The solids content in leaves and roots were determined by drying (70 ^{0}C) and homogenizing samples in a mill up to air dry stage. Samples were digested in a microwave device by means of concentrated nitric acid and hydrogen peroxide. Element contents were evaluated in an ICP-AES spectrometer.

RESULTS

According to classical analytical methods the arsenic content of samples was determined from the solids content. It must not be forgotten, however, that parts of vegetables (in lettuce the whole foliage) have very high water content. In our solids calculations the solids content of the samples varied between 3.05 and 5.82 m/m% with an average of 4.06 m/m%.

Relevant rules [17/1999 (IV.16.) EüM] allow 0.200 mg/kg arsenic in vegetables for fresh consumption at original water content. The value of arsenic concentration measured in lettuce solids should be divided by 25 to obtain the arsenic concentration of the plant at original water level.

Figures 1-3 represent arsenic concentrations in the three years and average of repetitions.

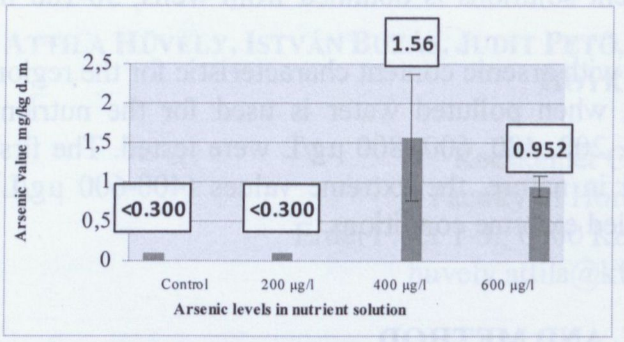

Figure 1. As levels in leaves referring to solids, mg/kg (2009)

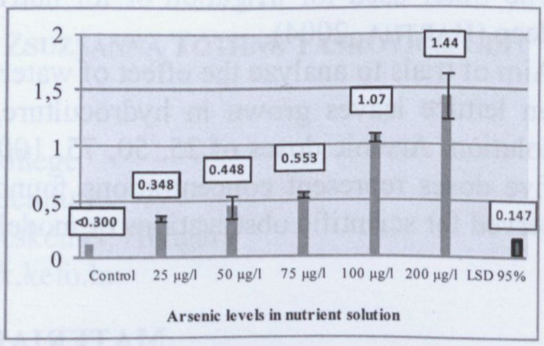

Figure 2. As levels in leaves referring to solids, mg/kg (2010)

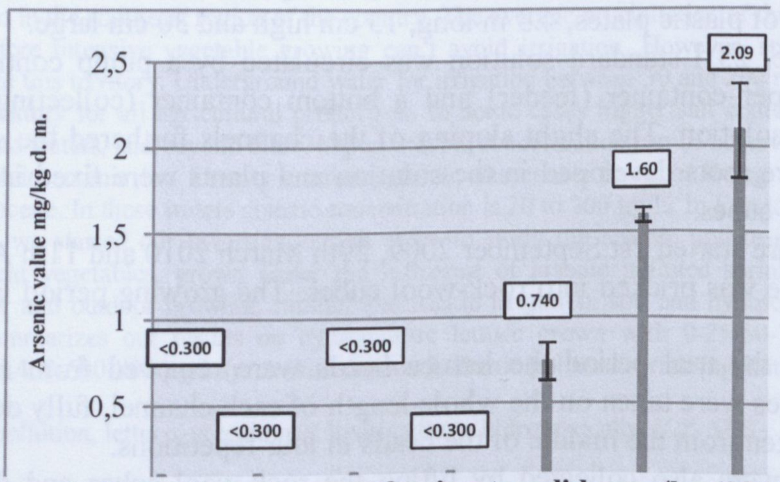

Figure 3. As levels in leaves referring to solids, mg/kg (2011)

As shown by *Figure 2* the 200 µg/L dose in 2009 did not result in measureable As-content in lettuce leaves. Doses 400 and 600 µg/L increased As-content in leaves referring to control and the 200 µg/L dose. Scattering among repetitions is high. The highest As value – 2.67 mg/kg - was found in the third repetition of the 400 µg/L dose. Repetition averages in 400 and 600 µg/L doses were contradictory as the mean of the 400 µg/L dose surpassed that of the 600 µg/L dose (1.56 and 0.952 mg/kg, respectively).

Figure 3 shows our results in 2010. Repetitions showed much less scattering than in 2009. Trials in 2010 indicated a more precise execution of trials. Between the same doses of the two years (200 µg/L) there was considerable difference despite similar conditions. To clear up the situation trial was repeated in 2011 involving all the doses.

The results of our study in 2011 confirmed the experiences of 2010 year. Arsenic content in leaves increased significantly with As doses elevating from 75 to 400 µg/L. in a concentration dependent manner. Arsenic concentration in leaves due to 100 and 200 µg/L concentration were similar. Arsenic doses higher than 400 µg/L did not cause further increase in leaf arsenic concentration, in 2009 and 2011 either.

Analysis of variance showed significant differences in arsenic concentration in leaves after arsenic contamination in sprinkling water in 2010 and 2011. Statistically significant differences (SD<5%) appeared after 75 and 100 µg/L treatments.

Similar trends were observed in the increase of As content in roots in the study years. *Figures 4-6* represent As values in root samples.

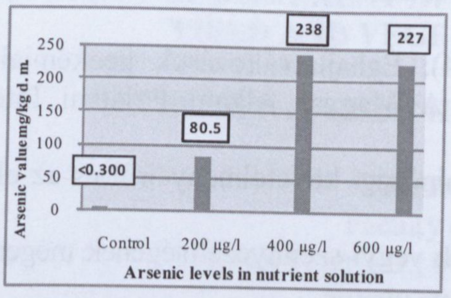

Figure 4. As levels in roots referring to solids (2009)

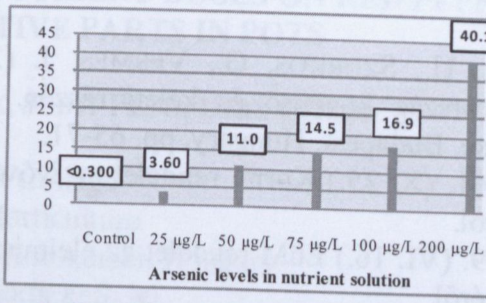

Figure 5. As levels in roots referring to solids (2010)

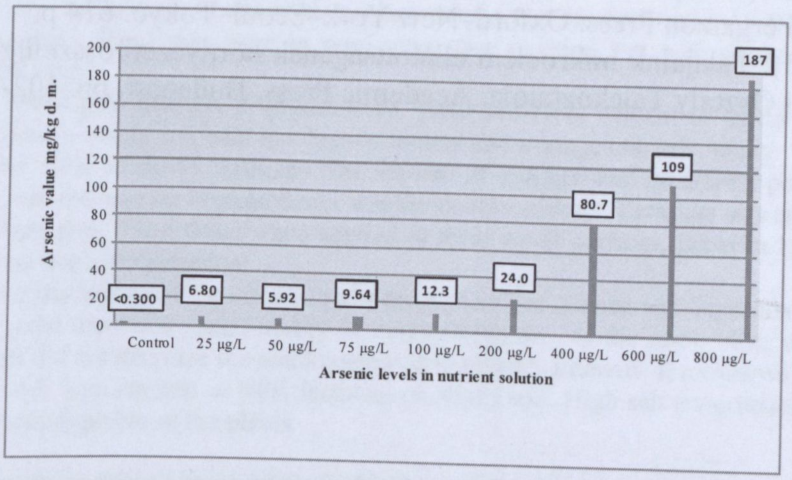

Figure 6. As levels in roots referring to solids (2011)

Increasing As doses increased As concentration in the roots. Low quantities of root samples did not allow repetitions and statistical analysis, yet the physiological filtration effect of the roots is well expressed.

CONCLUSIONS

Trials show that the arsenic concentration of the nutrient solution affects the As content in the vegetative parts of lettuce. Even slight doses (200µg/L) increased As level in the test plant.

Increasing As doses increased As concentration in the roots as well but the accumulation was more accentuated. In some doses As content in roots was 16-89 times higher than in leaves. Results are parallel to those of KÁDÁR (1993) who found 30 mg/kg in roots and 1-5 mg/kg in stems and leaves of the test plants, as affected by As doses. Summarizing it can be stated that the arsenic content of lettuce in original moisture content, grown in hydroculture, increases as affected by As application but it does not surpass the 0.2 mg/kg limit. According to our results even three times higher values than 200 µg/L found in natural well water do not increase the As level above the limit in lettuce.

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