EXAMINATION OF THE ARSENIC ACCUMULATING CAPACITY OF TOMATO UNDER THE INFLUENCE OF ARSENIC TREATED IRRIGATION WATER

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Abstract: *The horticulture product, 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, sprinkler and drip irrigation, soil and hydroculture manner as well. This paper summarizes our results on field tomato grown with 0-50-100-200-400-800 µg/L (natural As dose) arsenic polluted sprinkling water, with sprinkler and drip irrigation.*

Keywords: *arsenic pollution, tomato, field experiment, berry weight, ICP-AES*

INTRODUCTION

Arsenic (As) element is known for a long time, it is an occurring toxic element in our ground water. It has been proved since the early 1980s that the arsenic content of drinking water in the water base areas of the southeastern counties (Bacs-Kiskun, Békés, Csongrad and Szolnok) exceeds the standards which was 50 µg/l in that time (BARTHA, 2004).

According to current legislation in Hungary the arsenic content of drinking water can be maximum 10 µg/l (201/2001th Government Decree). As for irrigation water the concentration must be below 100 or 200 µg/l (depending on direct or indirect consumption of plants) (MI-10-172/9-1990). If the food is derived from plant or it consumed as raw food the maximum concentration is 200 µg/ kg (17/1999th (VI.16) EüM). Arsenic is toxic to humans and animals alike, its inorganic forms are seriously toxic, and known as carcinogens. Arsenic causes disease of nervous system, kidney, hematopoietic system, the respiratory system, liver function decreases, reproductive and genetic anomalies also occur. The human body suffers as a whole (COLLECHI et al., 1986; KLIMENTNÉ and MUCSI, 1992).

This problem was recognized in 1981-83. Arsenic is the most severe problem in Hungarian groundwater supplies. Approximately 80% of domestic vegetable-growing area (an average of 50 to 60 thousand ha) that is located in the Southern Great Plain region is affected by arsenic contaminated water. Vegetables that are grown in forced and field conditions can contact arsenic contaminated irrigation water since they are irrigated with non purified water.

Arsenic accumulation in plant parts that are intended for consumption is not inevitable. Different plants react for toxic elements in different ways. It is very important to know which vegetable species that are produced in the area may have critical arsenic concentration which is 0.200 mg/kg As relative to the original moisture content of the product.

In this paper the aim of the experiments is

- to investigate the effect of arsenic-treated water on tomato,
- to know what extent this plant takes up arsenic and in what arsenic concentration accumulates in plant parts - leaves, roots, and generative organs - berry-plant parts,
- to know the effect of arsenic contaminated irrigation water on the change of the yield of the tomato berry weight,
- to know if there are visible symptoms on the tomato, due to the arsenic uptake.

MATERIAL AND METHOD

Tomato was analyzed in field. The experiments were set in the Demonstration Garden of the College Faculty of Horticulture of the Kecskemét College in 2011 and 2012. The samples were analyzed in the Soil and Plant Testing Laboratory of the Faculty.

The tomato experiment was performed under field conditions in 2011 and 2012. During the test, the plants were raised in ground containers of 0.3 m^2 surface. The soil of the containers is a fertile sand soil with good humus content. The planting of seedlings was carried out on May 18, 2011 and May 26, 2012. The plants were treated with arsenic treated irrigation water throughout the growing period, arsenic doses employed were the follows: 50, 100, 200, 400 and 800 mg/l. The arsenic was present in the water in forms of arsenic trioxide (As_2O_3) arsenite (H_2AsO_3-) and arsenate (H_2AsO_4-). The water for treatment was prepared in the laboratory.

Two different kinds of irrigation methods were used in the experiments. Sprinkler irrigation released the arsenic irrigation water over the entire surface of the plant, whereas arsenic drip irrigation water was applied only on the soil surface.

Treatments were performed in 4 replicates. In all arsenic dose of both irrigation methods two containers were selected, two tomato plants per container were grown, so the samples of 4-4 plants were constituted in four repetitions.

During the experiment leaf samples were collected several times according to ripeness. Upon the completion of testing root samples were collected.

In the experiments the yield of the plants was determined. In tomato the quantity of berries was weighed.

The dry matter content of the samples was determined in laboratory and after the nitric acid/ hydrogen peroxide digestion of the samples total arsenic content of the samples was analyzed. The measurement was carried out by ICP-AES technique (HÜVELY, 2005).

RESULTS

The arsenic content of tomato roots increased by the growing arsenic dosages in both study years and in each irrigation methods. In 2011 a significant difference existed between each successive dose by the effect of drip irrigation, and the maximum arsenic concentration reached 7.57 mg/kg dry matter. In sprinkler irrigation treatments, except from 2 treatments (100 and 400 mg/l), there was a significant difference between successive doses too, the maximum arsenic concentration reached 5.47 mg/kg. Regression analysis revealed that the „r” values were high (0.95 and 0.93, P = 1%). In 2012 the tendency was similar, but we measured different arsenic concentration values in the root. The highest measured value was 16.4 mg/kg (in drip irrigation) and 44.5 mg/kg (in sprinkler irrigation), that is there has been a considerable increase in compared to 2011. In the second year the higher concentration was due to the sprinkler irrigation method (*Table 1*).

Table 1

Arsenic concentration in roots and leaves of tomato in 2011 an 2012

As doses	2011				2012			
	Drip irr.		Sprinkler irr.		Drip irr.		Sprinkler irr.	
	Roots	Leaves	Roots	Leaves	Roots	Leaves	Roots	Leaves
Control	0.449	<0.300	0.406	<0.300	<0.300	<0.300	<0.300	<0.300
50 μg/l	1.54	5.62	1.59	5.51	3.03	7.18	2.98	5.78
100 μg/l	2.64	5.77	2.04	7.48	3.59	7.43	5.73	6.74
200 μg/l	3.51	5.25	3.53	10.3	4.92	8.31	11.4	8.49
400 μg/l	6.22	5.83	3.79	11.4	6.88	8.05	18.9	12.0
800 μg/l	7.57	7.05	5.47	16.0	16.4	8.69	44.5	16.5
$SD_{5\%}$	*0.563*	*0.613*	*0.460*	*1.26*	*1.18*	*1.34*	*1.98*	*1.05*
								mg/kg d. m.

In most of the samples the arsenic concentration of tomato leaves increased by the increasing arsenic doses and there were large differences between the results of the irrigation methods.

In drip irrigation, variance analysis justified significant differences only between control treatment and other dose in both study years. The values were between 5.25 and 8,69 mg/kg in dry matter. As the growing season progressed, the leaf arsenic concentration increased steadily in both years according to the difference between control and treatments. The calculated regression coefficient values were between 0.521 and 0.608. It shows that the correlation is not statistically strong. The results of two years are parallel with each other, the highest measured value is 8.69 mg/kg in dry matter.

When sprinkler irrigation method was applied the arsenic content of tomato leaves increased linearly with the increasing dose. In each test periods significant differences ($SD_{5\%}$) existed between the control and the lowest dose, and between 2, 3 and 4 successive dose. R-values of the regression analysis were between 0.843 and 0.951. This proved to be significantly different in four out of the five periods, at P = 1-2% error likelihood. In both years arsenic concentration increased by the effect of sprinkler irrigation too in individual dose, as the season progressed by. It can also be stated that arsenic concentrations of the leaves were generally higher in of sprinkler irrigation then in drip irrigation in both years. The results of the two years were parallel to each other. The maximum arsenic concentration was at sprinkler irrigation, 16.5 mg/kg in dry matter.

The arsenic concentrations of tomato berries were very low. In the processing of the sample, the dry matter content of the berry crop was determined, which allowed the calculation of berry arsenic concentrations in initial moisture content. In the two study years, the arsenic content of the berry changed from 0.022 to 0.080 mg/kg, in the entire dose range. This value is 11-40 % of the existing food legislation authorized limit.

In 2011 treatments did not change tomato yield. In 2012, in case of drip irrigation there was no change in the yield too. However, the average berry yield per container reduced significantly under sprinkler irrigation.

CONCLUSIONS

The results of the experiment showed that arsenic concentration grows in the vegetative parts of tomato in significant rate due to arsenic treated irrigation water. The highest concentration was measured in the root samples. In compared to this the concentration was one or two magnitudes lower in leaves and one magnitude lower in the berries.

Over the time, the test results in field growing conditions show that the arsenic concentration of the matured tomato leaves (the same age) grew increasingly in both drip and sprinkler irrigation by the arsenic treatments. In 2011, in drip irrigation, at 800 mg/l of arsenic concentration treatment, 4.11, 4.52, 7.05 mg/kg arsenic concentrations were measured in the leaves in the consecutive sampling periods. As for sprinkler irrigation, the measured values were 6.60, 13.1, 16.0 mg/kg, respectively. In 2012, in drip irrigation, applying the highest dosage level, the arsenic concentration was 6.28, 8.69 mg/kg in the leaves. In sprinkler irrigation these values were 14.4, and 16.5 mg/kg.

According to the results of this paper, in field experiments sprinkler irrigation - implementing contact arsenic charging – resulted a significantly higher arsenic concentration in tomato leaves than drip irrigation. In 2011, the biggest differences in tomato arsenic concentration, at 800 mg/l of arsenic dose, were 16 and 7.05 mg/kg and in 2012 the differences were 16.5 and 8.69 mg/kg.

On the Southern Great Plain region, either in humic sandy soil or in hydroponics the arsenic concentration in tomato plant parts for consumption does not accumulate over the legal safety limit value (0.200 mg/kg) if the arsenic concentration of irrigation water is about 200 μg/l.

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