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Effect of Arsenic Contaminated Irrigation Water on the Cultivation of Red Amaranth

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Abstract: Arsenic (As) in excess of acceptable limit has been found in ground water in many parts of Bangladesh which is one of the densely populated countries in the world. Such kind of groundwater is extensively used for the purpose of irrigation mostly in rural areas of the country. Growth and overall yield of the crop can be affected by uptaking arsenic from this contaminated water. An experimental study was conducted to observe the effects of such water on the growth and yield of red amaranth vegetable plant (*amaranthus retroflexus L.*) and also check their rate of uptake from soil to the body of the plant. Different arsenic concentrations from 0 to 60 mg/L were mixed with water and applied to the plant in a controlled environment. The yield of amaranth was significantly reduced which was observed from the experiment. Arsenic content of root, stem and leaf was also examined with different doses and a relationship was established between doses and uptake rate.

Key words: Arsenic, Irrigation water, Red amaranth, Concentration, Yield, Uptake rate

INTRODUCTION

Arsenic and arsenical compounds are extremely toxic. They are found in effluents and leaches from metallurgic industries, glassware and ceramic industries, dye, pesticide and fertilizer manufacturing industries, petroleum refining and other chemical industries. In some part of the world arsenic occurs naturally in the soil from where it reaches to the ground water.

In Bangladesh, ground water which is free from pathogenic microorganisms and available in adequate quantity in shallow aquifers became a popular and effective source for drinking water as well as irrigation water for scattered rural population. Shallow tube wells were found to be the best option for rural water supply and Bangladesh achieved a remarkable success by providing 97% of the rural population with tube well water. Moreover, about 33% of total agricultural lands are brought under irrigation facilities [1]. Most of these lands are irrigated with ground water which comes from both deep as well as shallow tube wells.

Unfortunately, when the rural people have developed the habit of using ground water being aware of its importance to avoid pathogenic diseases, arsenic in excess of acceptable limit has been found in many parts of Bangladesh. Thousands of people are reported to have already shown symptoms of being poisoned by arsenic and several millions are at risk of arsenic contamination those who use tube well water mainly from shallow wells for drinking purposes. If arsenic contaminated water is used for irrigation, it may cause hazard for soil environment and crop quality as well. Like other heavy metals, arsenic is toxic to different kind of plants [2], hence its disposal into the environment must be carefully controlled and try to minimize adverse effects.

Objective of the Study: No physical evidence was found that arsenic is essential for plant growth; however it has phyto toxic effect on different crops. Arsenic is translated to many parts of the plants, most of which is found in old leaves and roots. Yield limit for arsenic concentration

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Table 1: Nutrient status of the experimental soil prior to fertilization

Texture	pH	OM%	Ca	Mg	K	Total N %	P	S	As	Cu	Fe	Mn	Zn
			meq/100g				µg/gm						
Clay loam	5.1	1.05	3.4	2.6	0.18	0.06	12	14	5.8	4	161	51	2.0
Critical level	-	-	2.0	0.8	0.20	-	14	14	-	1	10	5	2.0

in plant tissue are 4-5 mg/L in cotton and 1 mg/L in soybeans. In rice, the critical level in grains ranges from 20 to 100 mg/L and in roots 1000 mg/L. Wetland rice is known to be very susceptible to arsenic toxicity as compared to upland rice. Basically crops do not accumulate enough arsenic which may not toxic to human body. Instead, reduction of growth and total failure of crops are the main consequences due to arsenic contamination. It has been reported by Abedin *et al.* [3] that a reduction of 20% of crop (cereal) production from approximately 20 mg/L of arsenic in the plant body. Islam *et al.* [4] reported that plant height can be reduced by effect of arsenic. Heavy metal like arsenic has no beneficial effect but have toxic effect even at low concentration in plant [5]. The uptake and accumulation of arsenic by cereals, pulses and vegetable crops resulting in considerable reduction in the yields has been observed by Premlal, 1998. Similar findings were also reported in some other studies [6, 7].

Plants extract the required chemicals either from soil or irrigated water through their roots. If the arsenic concentration in an area is high, it is possible for plants to uptake the toxic element which ultimately can enter the food chain. The people of Bangladesh consider plants as cheap vital sources of vitamins and minerals. If the people consume arsenic contaminated plants or fruits, it might cause detrimental health hazards. Very few works has been done to check the uptaking rate of arsenic by plants. Also its effect on the growth, yield, uptaking capacity of various parts of the plants and other physical parameters etc has not been critically evaluated.

This study was conducted with a view to observe the overall yield and uptaking rate of arsenic from irrigated water by various parts of red amaranth plant (i.e., roots, leaves, stems) and also comparison between some variables i.e., number of leaves per plant, length and circumference of stem etc with respect to amaranth irrigated with arsenic contaminated water under controlled environment. Red amaranth was chosen as it is widely consumed in Bangladesh, cheap and its harvesting period is comparatively small. Moreover, it is easy to grow and has a reputation for its high nutritious value of various vitamins. In short, red amaranth is an important leafy vegetable in Bangladesh.

Experimental Setup: A green house experiment was conducted to examine the effect of different levels of arsenic on yield and nutrient uptake of red amaranth plant. Background level of arsenic was determined prior to start of the experiment. Thirteen different levels of arsenic concentration from 0 to 60 mg/L (i.e., 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 mg/L) mixed with water and red amaranth were then grown using the water. Arsenic was mixed with water as As_2O_3. Nutrient status of the initial soil has been checked and displayed in Table 1.

Soils for plantation of the red amaranth were collected from Soil Science Farm of Bangladesh Agricultural Research Institute (BARI) located at Dhaka, Bangladesh and then dried the soil by flowing air. Twelve kilograms dried soil was provided in 13 non porous earthen pots (Fig 1). Each pot was 30 cm in diameter and 32 cm in height. A blanket dose of 120 mg/L N (Nitrogen), 80 mg/L P (Phosphorous), 100 mg/L K (Potassium) and 40 mg/L S (Sulpher) was applied to each pot. Urea, triple super phosphate, potash and gypsum were used as a source of N, P, K and S, respectively. The fertilizers were mixed with the soil and then placed in the earthen pot. Equal amount of seeds of the red amaranth (variety BARI Lal Shak-1) were planted in each pot. The pots were then placed in the controlled environment.

Solution of arsenic (As_2O_3) mixed with distilled water for the above mentioned concentrations were applied to different pots whenever required. Pictures of the earthen pots with growing red amaranth plants are displayed in Fig 1. The pots were leveled for the experiment for different concentration of arsenic. Reduction of yield of the plants can be observed physically from the pots due to higher arsenic


(a) As @ 0 mg/L


(b) As @ 5 mg/L


(c) As @ 10 mg/L


(d) As @ 15 mg/L


(e) As @ 20 mg/L


(f) As @ 25 mg/L


(g) As @ 30 mg/L


(h) As @ 35 mg/L


(i) As @ 40 mg/L


(j) As @ 45 mg/L


(j) As @ 50 mg/L


(k) As @ 55 mg/L


(l) As @ 60 mg/L

Fig. 1: Snapshots of the red amaranth plantation in a controlled environment. White stickers are displaying the concentration of Arsenic (As) used in different pots

concentration. The plants were harvested after approximately one month. Different components of the plant (i.e., root, stem and leaf) from each pot were collected for checking yield and also for chemical analysis. Yields were estimated from fresh plant and arsenic concentrations were checked after drying the plants.

RESULTS AND DISCUSSION

The red amaranth plants were harvested and checked the yield with effect of arsenic on it. At first the yield of the plant was estimated by counting number of plants were grown in every pot with the variation of different arsenic concentration. Length of stem, stem circumference and number of leaves per plant were also counted and finally estimated the yield of the fresh plant per pot. The results of the effect of arsenic on red amaranth are summarized in Table 2. Every components of the plant were decreasing by increasing arsenic concentration which can be observed from the table. High arsenic concentration significantly reduces the number of plants per pot and other yield components. The plants can tolerate arsenic concentration up to 50 mg/L and not a single plant was observed with higher than this concentration. Highest number of leaf per plant was obtained from no arsenic (0 mg/L) treated pot and number of leaf per plant decrease with the increase of arsenic level. Figure 2 depicts the total yield of the fresh plant in percentage with different level of arsenic concentration which shows a decreasing tendency of yield with increasing arsenic concentration.

The plants were then dried for estimating arsenic concentration by chemical analysis. The concentration at different parts i.e., root, stem and leaf were estimated by spectrophotometer and statistically analyzed with software named IRRISTAT. Table 3 displays the dry weight per pot of the different components of the red

Table 2: Effect of different levels of arsenic (As) on yield of red amaranth

As level mg/L	No. of plants per pot	Stem length (cm)	Stem circumference (cm)	No. of leaves/plant	Fresh yield (gm per pot)	% yield decrease over control
0	48.0	22.33	2.27	8.53	134.2	-
5	46.3	21.07	2.20	8.20	122.1	9.02
10	45.0	20.20	2.03	8.07	109.1	18.70
15	44.0	19.40	1.90	7.80	102.1	23.92
20	42.3	18.13	1.87	7.60	83.2	38.00
25	39.3	17.13	1.77	7.27	69.7	48.06
30	34.0	14.30	1.70	7.27	50.3	62.52
35	27.7	13.13	1.63	6.80	43.8	67.36
40	20.0	12.47	1.57	6.67	32.0	76.15
45	14.0	10.93	1.47	6.53	20.8	84.50
50	8.3	9.00	1.40	6.47	14.5	89.20
55	-	-	-	-	-	100.00
60	-	-	-	-	-	100.00

Table 3: Yield variation of red amaranth plants and their Arsenic uptake rate with different levels of arsenic concentration.

As levelmg/L	Dry weight (gm/pot)			Arsenic concentration (µg/gm)			Arsenic uptake (µg/pot)			Transfer coefficient
	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf	
0	1.23	6.14	3.44	5.11	8.38	10.19	6.31	51.49	35.11	1.60
5	1.08	5.82	3.21	6.85	10.85	12.02	7.42	63.18	38.69	1.06
10	0.99	5.46	3.01	8.38	12.44	13.55	8.31	67.98	40.84	0.82
15	0.91	5.02	2.77	9.57	13.87	15.10	8.72	69.70	41.88	0.70
20	0.85	4.40	2.42	10.42	14.95	16.22	8.86	65.72	39.34	0.60
25	0.78	3.87	2.14	11.29	16.02	17.39	8.82	61.93	37.27	0.54
30	0.71	3.28	1.83	10.02	17.16	18.20	8.58	56.33	33.35	0.49
35	0.60	2.86	1.69	13.44	17.73	18.72	8.07	50.77	31.67	0.45
40	0.51	2.32	1.44	14.65	18.14	19.16	7.48	42.10	27.63	0.41
45	0.40	2.02	1.21	15.29	18.71	19.77	6.12	37.86	23.95	0.38
50	0.35	1.83	0.98	15.83	19.29	20.24	5.60	35.33	19.86	0.35
55	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-

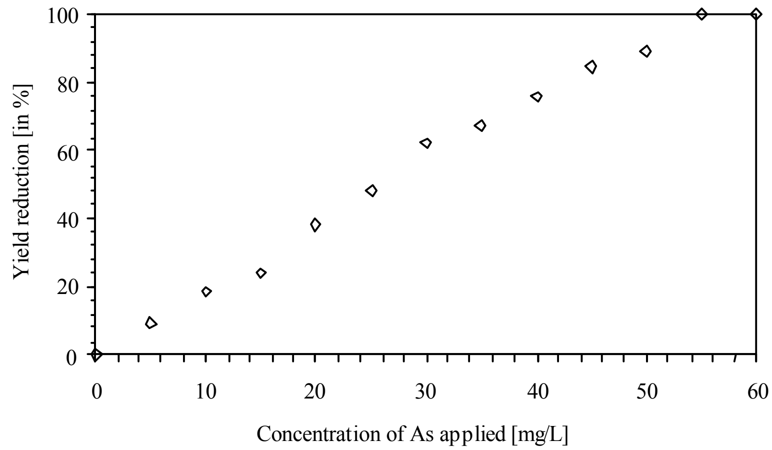

Fig. 2: Reduction of yield of the red amaranth plant due to different doses of arsenic

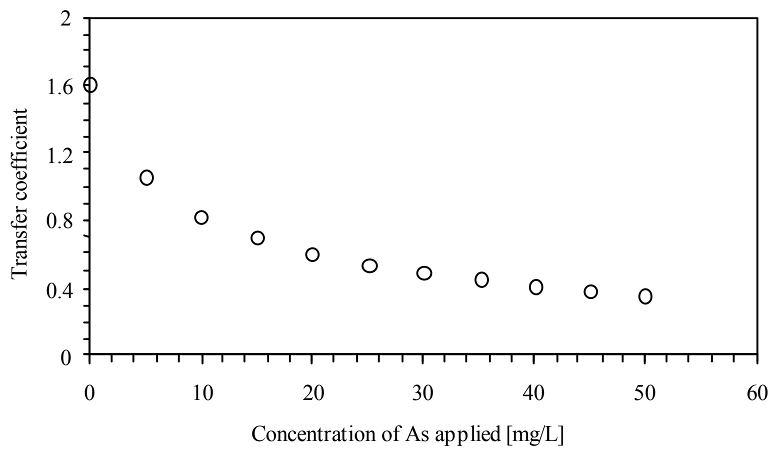

Fig. 3: Estimated transfer coefficient of arsenic by red amaranth for different arsenic concentration.

amaranth plant with the variation of arsenic concentration. The concentration in root, stem and leaf and their uptake rate also displays simultaneously in the table. The uptake rates of arsenic were observed increasing with increasing arsenic concentration up to approximately 15 mg/L and deceasing there after. The coefficient has a decreasing tendency as the gross yield was reduced with increasing arsenic concentration. Transfer coefficient of arsenic which defines as the rate of arsenic uptake from soil to different parts of the plant and is shown in Fig 3. The coefficient is highest in native arsenic concentration (0 mg/L) and decreases thereafter with additional concentration of arsenic.

Concluding Remarks: Arsenic contaminated ground water is used in many parts of Bangladesh for cultivation of food grain, vegetables, edible crops etc in the form of irrigation; however, the tolerable concentration level for different crops has yet to be evaluated. An experiment was conducted to check critically the yield and transfer rate of arsenic through soil to root, stem and leaf of red amaranth plant using arsenic contaminated water for irrigation of the plant, which is one of the cheapest vegetable and widely consumed by the people of Bangladesh. The experiment shows that gradual increase of arsenic decreases the yield of the red amaranth significantly. Due to addition of arsenic, fresh yield decreases with the increase of arsenic concentration and 100% yield reduction was obtained from As_{55} and As_{60} treated red amaranth. Basically the plant can tolerate arsenic upto 15 mg/L and drastic yield reduction was obtained with additional arsenic. The uptake rate of arsenic also found increases with the increase of arsenic concentration upto a certain limit, after that the rate decreases as the number of plants per pot reduced, which means the total reduction of yield of the red amaranth plant.

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