American-Eurasian Journal of Scientific Research 3 (1): 48-53, 2008
ISSN 1818-6785

Effects of Arsenic on Red Amaranth (*Amaranthus retroflexus* L.)

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Abstract: For the past few decades, ground water has been extensively used for the purpose of irrigation in rural areas of Bangladesh. In areas where the ground water contaminated with arsenic (As) is used for irrigation, crops can uptake them along with other metallic nutrients. This can negatively affect the growth and overall yield of the crops which can consequently be detrimental to human health. A greenhouse study was conducted to examine the effects of arsenic-contaminated irrigation water on the growth of red amaranth (*Amaranthus retroflexus* L.) and uptake of arsenic. There were 13 levels of arsenic treatments (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 mg L^{-1}) mixed in irrigation water and red amaranth was grown using these irrigation water. The experiment was set in RCB design with 3 replications. It has been observed that addition of arsenic with irrigation water significantly reduced the yield and yield components of red amaranth. The fresh weight of red amaranth was also reduced drastically due to the addition of more than 15 mg L^{-1} level of arsenic containing water. This Fresh weight decreases with the increase of arsenic concentration and the reduction ranges from 9.02 to 100.00%. Arsenic content in root, stem and leaf increases with the increase of arsenic level used. Transfer coefficient (transfer of Arsenic from soil to above ground part of plant) is highest in native arsenic (0 mg L^{-1}) added red amaranth (1.60) and decrease thereafter up to 50 mg L^{-1} As added red amaranth (0.35).

Key words: Arsenic (As) · Yield · Red Amaranth · Concentration · Uptake

INTRODUCTION

About 33 percent of total arable lands of Bangladesh are now brought under irrigation facilities [1]. Most of the lands are irrigated with ground water which comes from deep tube well and shallow tube well. Most of ground waters of irrigated areas of Bangladesh are contaminated with arsenic [2]. If arsenic contaminated water is used for irrigation, it may create hazard both in soil environment and in crop quality. Like other heavy metals arsenic is toxic to plant [3] and its discharge into the environment must be carefully controlled and minimized.

There is no evidence that arsenic is essential for plant growth but 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. The yield limiting arsenic concentrations in plant tissue are 4-5 ppm in cotton and 1 ppm in soybeans. In rice, the critical level in grains ranges from 20 to 100 ppm As; and in roots 1000 ppm As. Tillering is also severely depressed with high concentration of As [4]. Wetland rice is known to be very susceptible to As toxicity as compared to upland rice, since As (III) would be more prevalent under reducing conditions [5]. In general, ordinary crop plants do not accumulate enough As to be toxic to man. Instead, growth reductions and crop failure are the main consequences. Twenty percent loss of crop (cereal) production due to high concentration (20 ppm) of arsenic in plant body was reported in a research study [6].

Plants extract the required chemicals either from ground or irrigated water from the soils through their roots. If the arsenic (As) concentration in an area is high, it is possible for plants to uptake the toxic As element which ultimately can enter the animal food chain. The

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people of Bangladesh, as like other parts of the world, consider plants as cheap vital sources of vitamins and minerals. If the people consume As contaminated plants or fruits, it might cause detrimental health hazards. Red amaranth is an important leafy vegetable in Bangladesh. This plant is easy to grow within short harvesting period and has a reputation for its high value of various vitamins. There has been limited work on the arsenic uptake by plants which are mainly consumed by the people of Bangladesh. Also its effect on the plant's growth, yield, uptake capacity of various parts of the plants and other physical parameters, the effect on the consumer haven't been thoroughly studied scientifically.

This study was conducted with a view to observe the arsenic uptake from irrigated water by various parts (Roots, leaves, stem) of red amaranth and compare some variables (number of leaves per plant, length and circumference of stem) with respect to amaranth irrigated under controlled environment.

MATERIALS AND METHODS

A green house experiment was conducted to study the effect of different levels of arsenic on the yield and nutrient uptake of red amaranth (*Amaranthus retroflexus* L.) at BARI during August-September of 2006. Background level of As was determined prior to experimentation. Nutrient status of initial soil has been given in Table 1.

There were 13 levels of Arsenic (0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 mg L^{-1}) mixed in irrigation water and red amaranth were grown using these irrigation water and appropriate figures have been shown in Fig. 1 and 2. Arsenic was applied as As_2O_3. The experiment was set in a RCB design with three replications.

Top soils (0-15 cm) were collected from Soil Science Farm to Green house. Collected soils were cleaned and dried. Twelve kilogram (dry weight basis) of soil was taken in a series of non porous earthen pots. Each pot was 30 cm in diameter and 32 cm in height. A blanket dose of 120 ppm N, 80 ppm P, 100 ppm K and 40 ppm S was applied to each pot. Urea, triple super phosphate, muriate of potash and gypsum were used as a source of N, P, K and S, respectively. Whole amount of N, P, K and S were mixed with soil. Arsenic was applied through irrigation water. Seeds of red amaranth (var. BARI Lal Shak-1) were sown on 10 August. An equal amount of distilled water (in control treatment) and Arsenic solution (treatment wise) was added to each pot, whenever required. The crop was harvested on 16 September. The yield and yield components were recorded. Red amaranth root, shoot and leaf and post harvest soil from each pot were collected for chemical analysis. Arsenic was determined by AAS (Perkin Elmer-Analyst 200) with hydride generator and other element were determined with AAS (GBC-903), spectrophotometer (Spectronic 21) and Flame photometer. Collected data were analyzed statistically with IRRISTAT software package program. The mean effects were adjudged by Duncun's Multiple Range Test [7].

RESULTS AND DISCUSSION

Effects of different levels of arsenic on yield components and yield of red amaranth (*Amaranthus retroflexus* L.) are summarized in Table 2. Different levels of arsenic significantly reduce number of plants/pot and other yield components of red amaranth. The highest number of plants/pot (48.0) was obtained from no arsenic treated pot which was statistically similar to As_5 (46.3), As_{10} (45.0), As_{15} (44.0) and As_{20} (42.3) and superior to all other treatments. No plants were grown in 55 and 60 mg L^{-1} As irrigated pot. Similarly highest number of leaf/plant (8.53) was obtained from no arsenic treated pot and number of leaf/plant decrease with the increase of Arsenic level. Numbers of leaf/plant were nil in 55 and 60 mg L^{-1} As irrigated pot and lowest in 50 mg L^{-1} As (6.47) irrigated pot. Heavy metals like Arsenic uptake and accumulation in plants result in negative effects in plant growth [8]. Similarly highest stem length (22.33 cm) was obtained from no arsenic treated pot which was similar to As_5 (21.33), As_{10} (20.20) and As_{15} (19.40) and superior to all other treatments. The lowest stem length (9.00 cm) was obtained from As_{50} treatment. Reduced plant heights by adding various As concentrations were reported in an earlier study (As on rice) [9]. 23% plant height of rice was reduced by applying As @ 40 ppm was reported during that study. Stem circumference decrease with increase level of Arsenic. Highest stem circumference (2.27 cm)

Table 1: Nutrient status of experimental soil prior to fertilization

Texture	pH	OM (%)	Ca	Mg	K	Total N (%)	P	S	As	Cu	Fe	Mn	Zn
			meq/100g				µg/g						
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

Fig. 1: As@0ppm

Fig. 2: As@5ppm

Fig. 3: As@10ppm

Fig. 4: As@15ppm

Fig. 5: As@20ppm

Fig. 6: As@25ppm

Fig. 7: As@30ppm

Fig. 8: As@35ppm

Fig. 9: As@40ppm

Fig. 10: As@45ppm

Fig. 11: As@50ppm

Fig. 12: As@55ppm

Fig. 13: As@60ppm

Fig. 2: Replication of samples

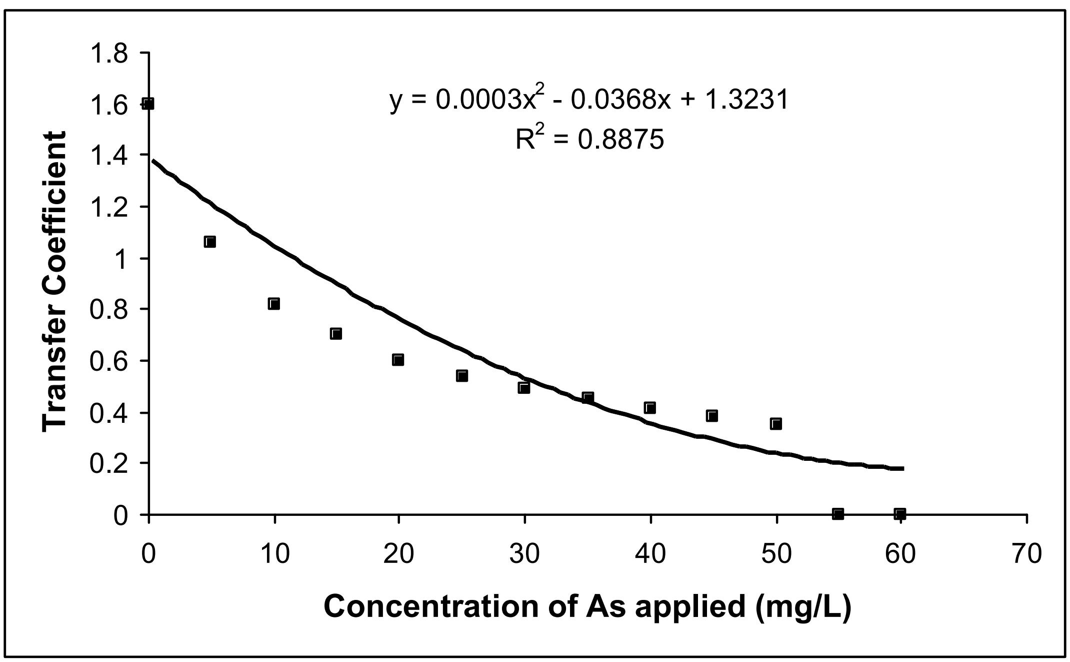

Fig. 3: Relation between concentration of as applied and transfer coefficient curve

Table 2: Effects of different levels of arsenic on yield and yield components of red amaranth

As level mg L^{-1}	No. of plants/pot	Stem length (cm)	Stem circumference (cm)	No. of leaves/plant	Fresh yield (g/pot)	Yield decrease over control (%)
0	48.0a	22.33a	2.27a	8.53a	134.2a	-
5	46.3a	21.07ab	2.20ab	8.20ab	122.1b	9.02
10	45.0ab	20.20abc	2.03abc	8.07ab	109.1c	18.70
15	44.0ab	19.40abc	1.90bcd	7.80ab	102.1c	23.92
20	42.3ab	18.13bc	1.87cd	7.60ab	83.2d	38.00
25	39.3bc	17.13cd	1.77cde	7.27ab	69.7e	48.06
30	34.0c	14.30de	1.70def	7.27ab	50.3f	62.52
35	27.7d	13.13e	1.63def	6.80ab	43.8f	67.36
40	20.0e	12.47ef	1.57def	6.67ab	32.0g	76.15
45	14.0f	10.93ef	1.47ef	6.53ab	20.8h	84.50
50	8.3g	9.00f	1.40f	6.47b	14.5h	89.20
55	-	-	-	-	-	100.00
60	-	-	-	-	-	100.00
SE (±)	2.7	1.60	0.143	0.84	4.66	-
CV (%)	9.8	12.1	9.7	14.0	8.0	-

Table 3: Dry matter yield, arsenic content and uptake of red amaranth treated with different levels of arsenic

As level mg L^{-1}	Dry weight (g/pot)			Arsenic concentration (µg/g)			Arsenic uptake (µg/pot)			Transfer coefficient
	Root	Stem	Leaf	Root	Stem	Leaf	Root	Stem	Leaf	
0	1.23a	6.14a	3.44a	5.11j	8.38j	10.19j	6.31cd	51.49c	35.11a-d	1.60
5	1.08b	5.82ab	3.21ab	6.85i	10.85i	12.02i	7.42bc	63.18ab	38.69abc	1.06
10	0.99bc	5.46b	3.01bc	8.38h	12.44h	13.55h	8.31ab	67.98a	40.84ab	0.82
15	0.91cd	5.02c	2.77cd	9.57g	13.87g	15.10g	8.72ab	69.70a	41.88a	0.70
20	0.85de	4.40d	2.42de	10.42f	14.95f	16.22f	8.86a	65.72a	39.34abc	0.60
25	0.78ef	3.87e	2.14ef	11.29e	16.02e	17.39e	8.82ab	61.93ab	37.27abc	0.54
30	0.71f	3.28f	1.83fg	10.02d	17.16d	18.20d	8.58ab	56.33bc	33.35bcd	0.49
35	0.60g	2.86g	1.69g	13.44c	17.73cd	18.72cd	8.07ab	50.77c	31.67cde	0.45
40	0.51g	2.32h	1.44gh	14.65b	18.14bc	19.16bc	7.48abc	42.10d	27.63de	0.41
45	0.40h	2.02hi	1.21hi	15.29a	18.71ab	19.77ab	6.12cd	37.86d	23.95ef	0.38
50	0.35h	1.83i	0.98i	15.83a	19.29a	20.24a	5.60d	35.33d	19.86f	0.35
55	-	-	-	-	-	-	-	-	-	-
60	-	-	-	-	-	-	-	-	-	-
SE ±	0.048	0.189	0.187	0.271	0.34	0.35	0.60	3.56	3.54	-
CV%	7.7	5.9	10.5	3.0	2.7	2.6	9.6	8.0	12.9	-

were recorded to no arsenic treated pot which were similar to As_5 (2.20 cm) and As_{10} (2.03 cm) and superior to all other treatments. Lowest stem circumference (1.40 cm) was obtained from As_{50} treatment.

Different arsenic levels significantly decreased fresh yield of red amaranth. Heavy metals like arsenic have no beneficial effect but have toxic effect even at low concentration in plant [10]. The uptake and accumulation of heavy metal like arsenic by cereals, pulses and vegetable crops resulting in considerable reduction in the yields has been very well documented [11]. The highest fresh yield (134.2 g/pot) was recorded from no arsenic treated pot which was significantly higher than all other treatment. The highest number of plants/pot, leaf/plant, stem length and stem circumference cumulatively increase the red amaranth yield. Due to addition of arsenic, fresh yield decreases with the increase of arsenic level and 100% yield reduction was obtained from As_{55} and As_{60} treated red amaranth. Similar findings were also reported earlier in other research studies [12,13]. Previous study revealed that rice grain yield drastically decreased with the application of As @ 40 ppm [9].

Dry weight, arsenic content and uptake of root, stem and leaf have been presented in Table 3. Root, stem and leaf weight decreased with the increase of arsenic level. The highest dry weight of root (1.23 g/pot), stem (6.14 g/pot) and leaf (3.44 g/pot) was obtained in the arsenic control treatment and decreased thereafter. Arsenic content of root, stem and leaf increased with the increase of Arsenic level. Addition of arsenic increased arsenic content in grain and straw of rice were also reported earlier [9]. Transfer coefficient (transfer of Arsenic from soil to above ground part of plant) is highest in native arsenic (0 mg L^{-1}) added red amaranth (1.60) and decrease thereafter up to 50 mg L^{-1} added arsenic treated red amaranth (0.35).

A relation between As concentration applied and transfer coefficient has been shown in Fig. 3 where the curve followed an equation (y = 0.0003x2 – 0.0368x + 1.3231) and R2 = 0.8875.

Uptake of arsenic from irrigation water by red amaranth showed no beneficial effect but have detrimental effect on their growth. Red amaranth can tolerate As up to 15 mg L^{-1} and drastic yield reduction was obtained thereafter. In dry matter yield, with increased As concentration, decreased As uptakes by roots, stems and leafs have been observed. The reason behind it is, with increased As concentration, the number of plants/pot and thereby mass of dry matter decreased significantly.

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