Arsenic Accumulation by Rice from Different Concentration of Arsenic Contaminated Soil

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Abstract: An experiment was conducted at the Horticultural farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to evaluate the arsenic accumulation by the rice plant during the period from July 2012 to October 2012 following Complete Randomized Design (CRD) with three replications each. Rice plant (BRRI dhan-29) grown at soil treated with different arsenic concentrations viz. A₀: 0 ppm, A₁: 500 ppm, A₂: 1000 ppm and A₃: 2000 ppm. Number of leaves, plant height, leaf area, tiller number, number of panicle, number of filled grain, plant biomass and grain biomass were decreased significantly while the arsenic contamination level in soil increased. Rice plant biomass accumulated 206.0, 195.0, 82.9, 54.5 ppm and grain accumulated 61.6, 36.5, 29.9, 14.9 ppm arsenic respectively from 2000, 1000, 500 and 0 ppm arsenic contaminated soil.

Key words: Rice · Arsenic and accumulation

INTRODUCTION

Arsenic contamination of groundwater is a serious problem in Bangladesh. Use of groundwater for irrigation is a route of arsenic which enters the food chain and indirectly affects human health. Duxbury et al. [1] mentioned the presence of arsenic in food chain. Food could be a way of arsenic entry into human body through water-soil-plant transfer [1, 2]. Some of our foodstuffs are also contaminated with arsenic [3-5]. It might be due to the high concentrations of arsenic in the soil and irrigation water. Arsenic-contaminated water used in irrigation contaminates soils and then uptake by plants cause arsenic contamination of the edible portions of rice grains that consumed by humans. Most groundwater used for irrigation in Bangladesh is contaminated with arsenic [6]. Beside the natural occurrence of arsenic, indiscriminate use of arsenical pesticides worldwide has led to extensive contamination of agricultural soils [7]. As the plant uptake water and nutrient, so this arsenic has come to the leaves, flowers as well as grains of the food and after consuming the arsenic contaminated food peoples are affected severely. High arsenic irrigated water and soil appears to result in higher concentration of arsenic in root, stem and leaf of rice plants [8, 9]. Rice is very efficient in arsenic accumulation, thus posing a potential health risk to people who eat lot of rice. Available form of arsenic in soil and groundwater is uptake by rice plant root with other nutrient which indirectly enter to rice grain that rice have sold in Agora, Nandon, Minabazar and so many big shops. Keeping the above point in view, current research was mainly conducted on the arsenic accumulation from soil by rice plants.

MATERIALS AND METHODS

The experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Bangladesh during the period from July 2012 to October 2012. Rice seedlings (Oryza sativa; BRRI Dhan 29) of 30 days ages were used on the experiment. The experiment was carried out in a Completely Randomized Design (CRD) where soil treated with four level of arsenic viz. A₀: Control (0 ppm); A₁: 500 ppm; A₂: 1000 ppm; A₃: 2000 ppm following three replications. Arsenic was applied in the form of Arsenic trioxide (As₂O₃). A ratio of 1:1 well rotten cow dung and soil were mixed and pots were filled 15 days before
transplanting. The pot was hand-weeded and watered as needed. No additional fertilizers or soil amendments were added during the growing seasons. About 30 days rice seedlings were transplanted on the pot. Data were collected on leaf number, plant height, leaf area, number of tiller, number of panicle, grain number (filled and unfilled), plant biomass, arsenic accumulation on 0.5 mg tested sample of plant biomass, total arsenic accumulation of arsenic on plant biomass, grain biomass, arsenic accumulation on 0.5 mg tested sample of grain biomass and total accumulation of arsenic on grain biomass. Leaf area was measured by non-destructive method using CL-202 Leaf Area Meter, (USA). Plant biomass was measured by using precision balance after drying. After growing plants were collected and dried. After drying leaves become smash by mortar and pastel machine. The chemical analysis was performed in Bangladesh Council of Scientific Research Institute (BCSRI) by using “Atomic Absorption Spectrometer”.

Statistical Analysis: Collected data were statistically analyzed using MSTAT-C computer package programmed. Mean for every treatments were calculated and the analysis of variance (ANOVA) for each one of the characters was performed by F–test (Variance Ratio). Difference between treatments was evaluated by Least Significance Difference (LSD) test at 5% level of significance [10].

RESULTS

Leaf Number: Leaf number showed statistically significant differences among control, 500, 1000 and 2000 ppm at 15, 30, 45 and 60 DAT (Fig. 1a). Maximum leaf number was recorded from A (51.3) whereas the minimum from A (2.6) at 60 DAT (Fig. 1a). Leaf number was reduced when arsenic concentration in soil was increased.

Plant Height: Plant height was reduced with the increase of arsenic concentration in soil (Plate 1). Plant height showed statistically significant differences among control, 500, 1000 and 2000 ppm at 15, 30, 45 and 60 DAT (Fig. 1b). Longest plant was observed from A (92.3 cm) whereas shortest from A (6.7 cm) at 60 DAT (Fig. 1b).

Leaf Area: Leaf area showed statistically significant differences among control, 500, 1000 and 2000 ppm at 15, 30, 45 and 60 DAT (Fig. 1c). Maximum leaf area was recorded from A (20.3 cm²) whereas minimum (8.1 cm²) was found from 2000 ppm (A) arsenic treated soil at 60 DAT (Fig. 1c).

Tiller Number at 30 DAT: Tiller number per hill ranged from 3.9 to 24.0 among the different arsenic concentration contaminated soil (Table 1). The maximum number of tiller per hill was found in A (24.0) while minimum from A (3.9) (Table 1).
Plate 1: Plant growth variation grown at different concentrated arsenic treated soil at 15 days after treating.

Table 1: Response of rice plant grown in different concentrated arsenic treated soil on different attributes.

<table>
<thead>
<tr>
<th>Arsenic concentrations</th>
<th>Tiller number at 30 DAT</th>
<th>Number of panicle</th>
<th>Filled</th>
<th>Unfilled</th>
<th>Plant biomass (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_0$</td>
<td>24.0a</td>
<td>21.4a</td>
<td>525.3a</td>
<td>39.3c</td>
<td>405.5a</td>
</tr>
<tr>
<td>$A_1$</td>
<td>11.7b</td>
<td>9.9b</td>
<td>369.7b</td>
<td>193.3a</td>
<td>233.0b</td>
</tr>
<tr>
<td>$A_2$</td>
<td>9.3c</td>
<td>7.1c</td>
<td>119.7c</td>
<td>214.0a</td>
<td>153.4c</td>
</tr>
<tr>
<td>$A_3$</td>
<td>3.9d</td>
<td>2.9d</td>
<td>43.67d</td>
<td>130.7b</td>
<td>101.8c</td>
</tr>
<tr>
<td>LSD</td>
<td>1.2</td>
<td>1.9</td>
<td>25.9</td>
<td>60.0</td>
<td>57.9</td>
</tr>
<tr>
<td>CV%</td>
<td>4.9</td>
<td>9.5</td>
<td>4.9</td>
<td>20.8</td>
<td>12.9</td>
</tr>
</tbody>
</table>

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

**Number of Panicle:** Number of panicle of rice plant ranged from 21.5 to 2.9 among the different arsenic concentration in soil (Table 1). The maximum number of panicle (21.5) was produced in control ($A_0$) while minimum from the plant grown in 2000 ppm arsenic treated soil ($A_3$; 2.9) (Table 1).

**Filled and Unfilled Grain Number:** The filled grain number ranged from 525.3 to 43.7 while unfilled 39.3 to 214.0 plant$^{-3}$ among the different arsenic concentration in soil (Table 1). The maximum number of filled grain was produced in control ($A_0$; 525.3) whereas minimum from plants grown in 2000 ppm arsenic treated soil ($A_3$; 43.7). Unfilled grain showed a statistically significant variation among the different concentrated arsenic treated soil. Maximum number of unfilled grain was obtained from $A_2$ (214.0) which was statistically similar with the $A_1$ (193.3) followed by $A_3$ (130.7) whereas minimum from $A_0$ (39.3) (Table 1).

**Plant Biomass:** Plant leaf biomass showed statistically significant differences among control, 500, 1000 and 200 ppm. Maximum plant leaf biomass was recorded from $A_0$ (405.5 mg) whereas the minimum from $A_3$ (57.9 mg) which was statistically similar with $A_2$ (153.4 mg).

**Arsenic Accumulation on 0.5 mg Tested Sample of Plant Biomass:** Plants from 2000 ppm ($A_3$) treated soil up took maximum amount of arsenic (1019.0 ppb) while minimum from $A_0$ (0.06 ppb) (Table 2).

**Total Arsenic Accumulation on Plant Biomass:** Rice plant accumulated maximum 206.0 ppm arsenic from $A_3$ (2000 ppm arsenic treated soil) which was statistically similar with the $A_1$ (195.0 ppm) followed by $A_3$ (82.9 ppm) whereas minimum from $A_6$ (0.03 ppm) (Table 2).

**Grain Biomass:** Maximum grain biomass was found from control ($A_0$; 310.1 mg) whereas minimum from $A_3$ (141.4 mg) (Table 2).

**Arsenic Accumulation on 0.5 mg Tested Grain Sample:** Grain obtained from 2000 ppm arsenic treated soil up took maximum (218.0 ppb) amount of arsenic while minimum by the plants from $A_0$ (0.02 ppb) (Table 2).
Table 2: Response of rice plant grown in different concentrated arsenic treated soil on arsenic accumulation attributes

<table>
<thead>
<tr>
<th>Arsenic concentrations</th>
<th>Arsenic accumulation on 0.5 mg tested plant biomass sample (ppb)</th>
<th>Total arsenic accumulation on plant biomass (ppm)</th>
<th>Grain biomass (mg)</th>
<th>Arsenic accumulation on 0.5 mg tested grain sample (ppb)</th>
<th>Arsenic accumulation on grain on total biomass (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A₀</td>
<td>0.06d</td>
<td>0.03b</td>
<td>310.1a</td>
<td>0.02d</td>
<td>0.01d</td>
</tr>
<tr>
<td>A₁</td>
<td>171.5c</td>
<td>82.9b</td>
<td>222.7b</td>
<td>67.1c</td>
<td>29.9c</td>
</tr>
<tr>
<td>A₂</td>
<td>626.2b</td>
<td>195.0a</td>
<td>165.5c</td>
<td>110.4b</td>
<td>36.5b</td>
</tr>
<tr>
<td>A₃</td>
<td>1019.0a</td>
<td>206.0a</td>
<td>141.1d</td>
<td>218.0a</td>
<td>61.6a</td>
</tr>
<tr>
<td>LSD</td>
<td>206.7</td>
<td>71.3</td>
<td>15.8</td>
<td>4.2</td>
<td>6.0</td>
</tr>
<tr>
<td>CV%</td>
<td>21.9</td>
<td>26.5</td>
<td>1.76</td>
<td>1.07</td>
<td>9.2</td>
</tr>
</tbody>
</table>

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

**Total Arsenic Accumulation on Rice Grain:** The total accumulation of arsenic on rice grain found a statistical significant variation among the plants grown in different concentrated arsenic treated soil. However, maximum amount was up taken by A₁ (61.6 ppm) whereas minimum by A₀ (0.01 ppm) (Table 2).

**DISCUSSION**

It was found from the present investigation that number of leaves, plant height, leaf area, tiller number, number of panicle was decreased significantly while the arsenic contamination level in soil increased. Arsenic concentration in irrigation water significantly declined plant height [8, 9], tiller number of BR-11 [11], leaf area at higher rates of dimethyl arsenic acid (DMAA) [12].

Plant biomass varied due to the variation of the concentration of arsenic [13]. Arsenate in irrigation water significantly decreased the number of filled grain [8, 9]. From the current experiment it was identified that rice plants grown in arsenic contaminated soil significantly reduced their grain biomass. Rice accumulated arsenic 1.55 ppm in grain, 5.57 ppm in rice husk and 39.78 ppm in straw from the 50 ppm arsenic contaminated soil [14].

The concentrations of arsenic in rice straw are up to 91.8 mg kg⁻¹ (91.8 ppm) for the highest arsenic treatment [8, 9] but the current experiment showed that rice plant biomass took up maximum 206.0 ppm arsenic. Result of the current experiment showed that rice grain accumulated 61.6 ppm i.e., 61.6 mg arsenic was up taken by per kilogram of rice grain sample. The arsenic concentrations ranged from 2.2 to 38.0 mg kg⁻¹ in root, 1.37 to 11.80 mg kg⁻¹ in straw, 0.28 to 1.76 mg kg⁻¹ in husk and 0.20 to 0.67 mg kg⁻¹ in grain of BRRI dhan-33 while in BR-11 cultivar, it ranged from 2.0 to 30.0 mg kg⁻¹ in root, 2.10 to 10.30 mg kg⁻¹ in straw, 0.35 to 1.87 mg kg⁻¹ in husk and 0.17 to 0.94 mg kg⁻¹ in grain [15]. Similarly, higher arsenic accumulation was found by Colocasia esculenta from different concentrations (500, 1000 and 2000 ppm) of arsenic contaminated soil [16]. The increased arsenic accumulation in plant biomass and grain of the rice might be due to the increase in soil arsenic concentrations. Xie and Huang [17] reported that arsenic absorption and accumulation is greatly influenced by arsenic concentration in the growth media and increases in higher arsenic levels. Arsenic by root can readily be transported to aerial parts, causing an elevated leaf and shoot concentrations [18]. This study showed that plant biomass had maximum arsenic content than the grain biomass. Arsenic concentration pattern in rice plant parts generally followed a trend as root>straw>husk>whole grain>husked rice [17]. It can be observed from the recent study that rice plant has relatively higher accumulation of arsenic on their plant biomass and grain if these were grown on highly arsenic contaminated soil. This plant biomass of rice plant could be eaten by cattle. Most of the population of Bangladesh used these cattle as readily available and cheap source of meat and milk. Thus there will be a risk to enter the arsenic on human body. On the other hand, rice grain was directly taken by human. So rice plant grown on the highly arsenic contaminated soil is a danger for the human health. Therefore, it is necessary to remove the arsenic from arsenic contaminated soil or stop to enter to the food crops.

**CONCLUSIONS**

Rice plant rapidly took up arsenic from soil. This arsenic was present on both plant biomass and rice grain. The presence of arsenic both on plant biomass and grain can enter to the human body directly or indirectly and cause harmful effect. Arsenic from soil should be removed from soil.

**REFERENCES**


