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Remediation of arsenic contaminated soils by naturally grown weeds

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Abstract: A remediation study was conducted to reduce arsenic from contaminated soils using three selected weeds during 2005-2006. Soils were collected from sadar upazila of Faridpur district. Water hyacinth, barnyard grass and water taro were used for this study. Arsenic uptake increased with increasing levels of As for three selected weeds and accumulation of As in root was always higher than the respective shoot. The highest As concentration was found in barnyard grass (56.93 and 26.50 mg As kg^{-1} root and shoot, respectively) followed by water taro (46.40 and 19.77 mg As kg^{-1} root and shoot, respectively) and water hyacinth (45.50 and 17.03 mg As kg^{-1} root and shoot, respectively) at soil-1 (116 mg As kg^{-1} soil). In soil-2 and soil-3, the higher arsenic was also obtained in barnyard grass. The highest recovery was recorded in water hyacinth due to higher biomass production.
Key words: Weed arsenic, Contamination, Arsenic accumulators, Phytoremediation, Soil arsenic

Introduction

Eighty million of people are threatened by arsenic poisoning in 61 districts of Bangladesh. The affected areas of Faridpur district have more than 20 mg As kg^{-1} soils. The presence of high concentration arsenic in surface soil due to irrigation with As contaminated ground water may result in high concentration of arsenic in cereal, vegetables and agricultural products that may contaminate food chain. Phytoremediation is a low cost and ecofriendly technology that employs the use of plants for cleaning the contaminated sites. Arsenic accumulators like barnyard grass (*Echinochloa crussgalli*), water hyacinth (*Eichhornia crassipes*), water taro (*Monochoria hastata*), dog grass (*Cynodon dectylon*), *azolla*, topapana *(Pistia stratiotes*), malancha (*Alternenthera phyloxeroides*), water cress (*Enhydra fluctuans*) accumulate arsenic (Zaman *et al.*, 2005; Sultana *et al.,* 2005). Most of the research workers conducted their research on severity of As contamination, either in ground water or in soil or in plant. But very few research groups concentrated their thoughts on the remediation of As from contaminated soil. This technique is ecofriendly and economically feasible for the reduction of excess As from arsenic contaminated soil of Bangladesh. Considering the above facts, this research work was undertaken to remediate arsenic contaminated soils by naturally grown weeds and to assess arsenic accumulation pattern in root and shoot of three weeds.

Materials and Methods

A pot culture experiment was conducted in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh from May to September, 2006 and the laboratory analysis was completed in November 2006. Soils were collected from the three arsenic contaminated sites of Sadar Upazila of Faridpur district, which were known as severely arsenic contaminated area. Exactly 5 kg soil was taken in a series of plastic pots. Proper spacing was maintained among the pots for convenience of cultural operations. The experiment was laid out in a Completely Randomized Design (CRD) with four replications. Exactly 20 mg N and 20 mg P kg^{-1} soil were added from urea and TSP, respectively. Weed seedlings were collected from Agronomy Field of Bangladesh Agricultural University, Mymensingh, known as arsenic contamination free areas. The criteria used for selecting weeds for As remediation were high As tolerance, high bioaccumulation factor, short life cycle, high propagation rate, wide distribution and large shoot biomass (Mitra, 2004; Zaman *et al.*, 2005; Sultana *et al.*, 2006). Three seedlings were transplanted in each pot.

Weeds were uprooted carefully at 45 days after transplanting. The collected plant sample was digested by wet oxidation method using diacid mixture (HNO_3: $HClO_4$= 2:1) following the method as outlined by Singh *et al.* (1999). Arsenic content of soil and plant extracts was determined by hydride generator atomic absorption spectrophotometer as per Welsch *et al.* (1990). The data generated out of the experiment were statistically analyzed (Gomez and Gomez, 1984).

Table 1. Arsenic, pH and EC of experimental soils

Soil samples	Location	As (mg kg-1 soil)	pH	EC (µS cm-1)
Soil -1 (S1)	Paranpur	116.0	7.50	177
Soil - 2 (S2)	Kamorpur	47.3	7.42	159
Soil - 3 (S3)	Dholdi	19.0	7.53	164

Table 2. Local, english, scientific names and family of weeds

Local name	English name	Scientific name	Family
Kachuripana	Water hyacinth	Eichhornia crassipes	Pontederiaceae
Bara Shama	Barnyard grass	Echinochloa crusgalli	Graminae
Panikachu/kechur	Water taro	Monochoria hastata	Ponderaceae

Results and Discussion

Biomass production

Biomass production significantly decreased with increasing As levels (Table 3). The highest biomass (48.43 g) was found in water hyacinth at soil-3 (19 mg As kg^{-1} soil) and the lowest (7.98 g) was in barnyard grass at soil-1 (116 mg As kg^{-1} soil) as shown in Fig. 1. The respective biomass production due to increased level of arsenic ranged from 32.80 to 48.43, 7.90 to 12.90 and 24.46 to 36.11 g for root and shoot of water hyacinth, barnyard grass and water taro combinedly.

Arsenic accumulation by weeds

Arsenic concentration was significantly increased in As accumulating weed species with increasing levels of soil As. Highest amount of As accumulation was in the root of barnyard grass (56.93 mg As kg^{-1} root) at S_1 treatment (116 mg As kg^{-1} soil) and minimum uptake occurred at S_3 treatment (19 mg As kg^{-1} soil) in the shoot of water hyacinth (6.17 mg As kg^{-1} shoot). In both shoot and root, arsenic concentration increased significantly with increased levels of arsenic (Table 4). The highest concentration of As in shoot was found in case of barnyard grass (26.50 mg As kg^{-1} shoot) at S_1 treatment followed by water taro (19.77 mg As kg^{-1} shoot) and water hyacinth (17.03 mg As kg^{-1} shoot) as presented in Fig. 2. Root accumulated higher amount of As than shoot. Similar results were also observed by Tlustos *et al.* 1998), Ma *et al.* (2004); Mitra (2004); Sultana *et al.* (2005) and Zaman *et al.* (2006). Arif (2001) stated that with the increasing accumulation of As in soil, As uptake by plants also increased.

Arsenic retention in post harvest soil

The amount of As retained in soil after 45 days varied from 6.82 to 49.96, 4.52 to 35.49 and 3.99 to 47.60 mg As kg^{-1} soil for S_1, S_2 and S_3 soils, respectively (Table 5). The uptake of arsenic by weeds and the retention of As in the post harvest soil revealed that small amount of As was not recovered. Smith *et al.* (1998) was also found that a considerable amount of arsenic was not recovered and assumed that this amount of As might have lost from the soil due to methylation or accidentally overflow of water from pots due to unprecedented rain that was out of control.

The increasing level of arsenic in soil increased the uptake of As by three weeds. Barnyard grass absorbed more As than others. In entire cases, root contained more As than shoot. Biomass production significantly decreased with increasing As levels. The highest recovery was recorded in water hyacinth due to higher biomass production. Barnyard grass, water hyacinth and water taro may be used for the remediation of arsenic contaminated soils according to their intensity of infestation in rice fields.

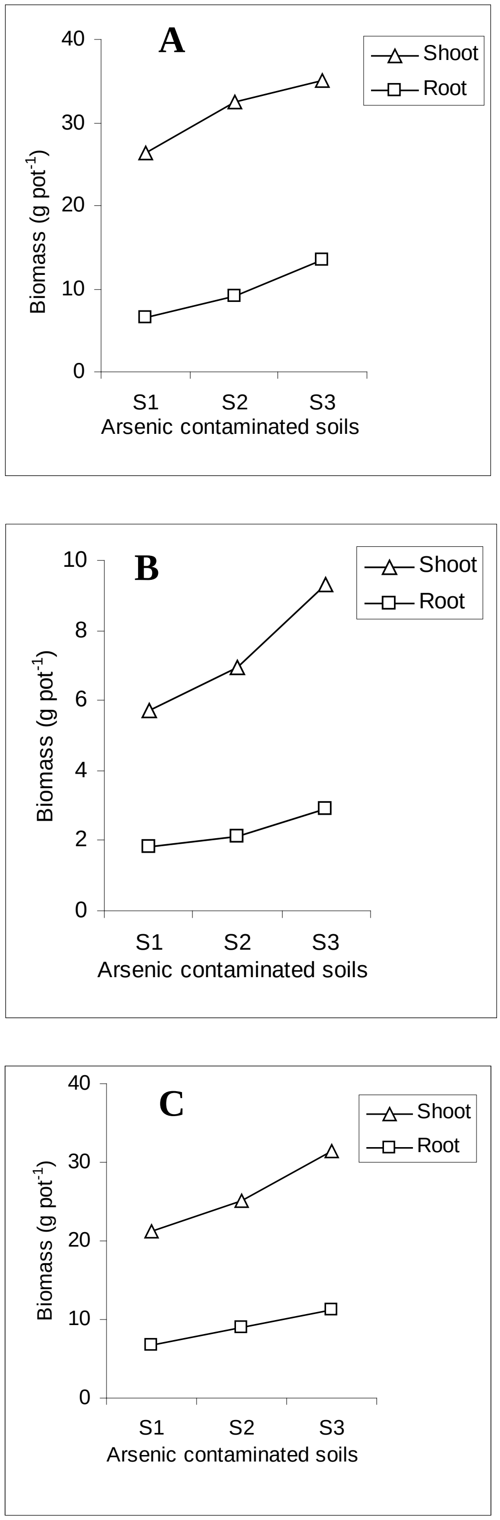

Fig. 1. Biomass production of water hyacinth (A), barnyard grass (B) and water taro (C) at different arsenic contaminated soils.

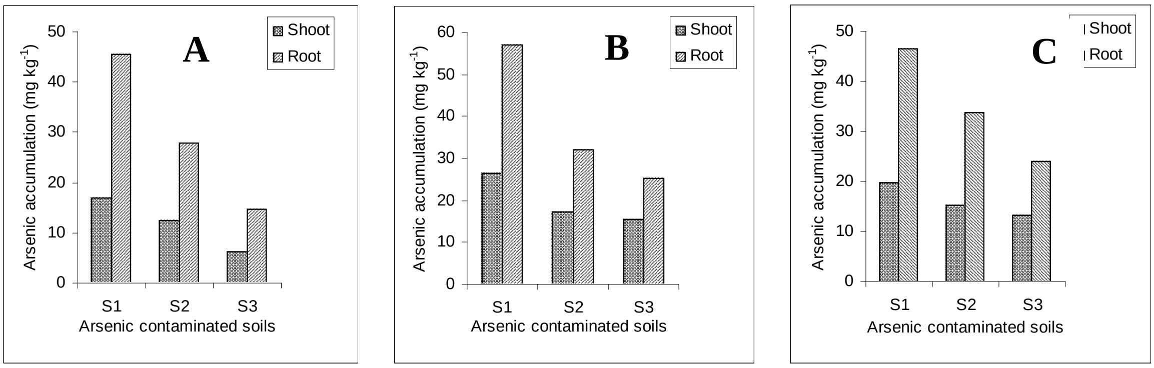

Fig. 2. Arsenic accumulation in shoot and root of water hyacinth (A), barnyard grass (B) and water taro (C)

Table 3. Biomass production of weeds at different soil arsenic levels

Treatment	Biomass production (g)					
	Water hyacinth		Barnyard grass		Water taro	
	Shoot	Root	Shoot	Root	Shoot	Root
S_1	26.30b	6.50c	5.70c	1.82b	21.20c	6.81c
S_2	32.47a	9.12b	6.95b	2.13b	25.06b	8.90b
S_3	35.03a	13.40a	9.30a	2.90a	31.33a	11.24a
Level of significance	**	**	**	*	**	**
$LSD_{0.05}$	2.60	1.31	1.12	0.554	2.308	1.806

In a column the common letter did not differ at 5% level of probability as per DMRT.
** Significant at 1% level of probability; * Significant at 5% level of probability

Table 4. Arsenic uptake by weeds

Treatment	As uptake (mg kg^{-1})					
	Water hyacinth		Barnyard grass		Water taro	
	Shoot	Root	Shoot	Root	Shoot	Root
S_1	17.03a	45.50a	26.50a	56.93a	19.77a	46.40a
S_2	12.53b	27.77b	17.27b	32.08b	15.17b	33.63b
S_3	6.17c	14.70c	15.40c	25.30c	13.27c	24.03c
Level of significance	* *	* *	* *	* *	* *	* *
$LSD_{0.05}$	2.18	2.31	1.90	2.52	1.33	1.92

In a column the common letter did not differ at 5% level of probability as per DMRT.
** Significant at 1% level of probability

Table 5. Arsenic retention in post harvest soil

Treatment	As (mg kg^{-1} soil)		
	Water hyacinth	Barnyard grass	Water taro
S_1	49.96a	35.49a	47.60a
S_2	25.01b	19.34b	26.73b
S_3	6.82c	4.52c	3.99c
Level of significance	* *	* *	* *
$LSD_{0.05}$	2.69	2.64	8.846

In a column the common letter did not differ at 5% level of probability as per DMRT.
** Significant at 1% level of probability

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