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Research Article

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Phytoremediation Potential of Kenaf (*Hibiscus cannabinus* L.), Mesta (*Hibiscus sabdariffa* L.), and Jute (*Corchorus capsularis* L.) in Arsenic-contaminated Soil

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Abstract

BACKGROUND: Arsenic (As)-contaminated groundwater used for long-term irrigation has emerged as a serious problem by adding As to soils. Phytoremediation potential of fiber crops viz., kenaf (*Hibiscus cannabinus* L.), mesta (*Hibiscus sabdariffa* L.), and jute (*Corchorus capsularis* L.) was studied to clean up As-contaminated soil.

METHODS AND RESULTS: Varieties of three fiber crops were selected in this study. Seeds of kenaf, mesta, and jute varieties were germinated in As-contaminated soil. Uptake of As by shoot was significantly higher than that by root in the contaminated soil. In As-contaminated soil, kenaf and mesta varieties accumulated more As, than did jute varieties. In the plant parts above ground, mainly the shoots, the highest As absorption was recorded in kenaf cv. HC-3, followed by kenaf cv. HC-95. Kenaf varieties produced more biomass. In terms of higher plant biomass production, and As absorption, kenaf varieties showed considerable potential to remediate As-contaminated soil.

CONCLUSION: The overall As absorption and phytoremediation potentiality of plant varieties were in the order of kenaf cv. HC-3 > kenaf cv. HC-95 > mesta cv. Samu-93 > jute cv. CVE-3 > jute cv. BJC-7370. All varieties of kenaf, mesta, and jute could be considered for an appropriate green plant-based remediation technology in As-contaminated soil.

Key words: Arsenic, Contaminated soil, Jute (*Corchorus capsularis* L.), Kenaf (*Hibiscus cannabinus* L.), Mesta (*Hibiscus sabdariffa* L.), Phytoremediation

Introduction

Phytoremediation is an effective, low-cost, and promising new method that uses green plants to clean up metal contaminated soils. It is a relatively inexpensive form of ecological engineering that has proven effective. Plants that accumulate metals in high concentrations are sometimes referred to as hyperaccumulators. Hyperaccumulator plants possess highly efficient mechanisms to acquire and concentrate As in their tissues (Ma *et al.*, 2001; Visoottivisetha *et al.*, 2002; Tu and Ma, 2002; Mahimairaja *et al.*, 2005; Gonzaga *et al.*, 2008). Ideal hyperaccumulators should have the ability to absorb large amounts of As, and continuously accumulate, translocate, and tolerate high concentrations of As, over the entire growth cycle

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(Garbisu and Alkorta, 2001; Murakami and Ae, 2009). In addition, the phytoremediation of metal pollutants from the contaminated soil also requires rapidly growing plant species that have high biomass. The concentration of metal in the harvestable part of a hyperaccumulator plant must be significantly higher than that in the soil, in order to ensure that the volume of contaminated plant material generated by phytoremediation is less than the original volume of the contaminated soil (Salt, 2000).

Bangladesh has considerable plant biodiversity, and hence, has the potential to provide suitable species for phytoremediation of As-contaminated soil. The problems arising from As contamination in groundwater are major concerns in many countries, especially in Bangladesh, owing to high levels of environmental toxicity to living organisms. Recently, it has become apparent that As-contaminated groundwater used for irrigation is further compounding the problem by adding As to soils, thus posing a serious threat to plants, human health, and environment health, through food chain pathways (Bruce *et al.*, 2003; Duxbury *et al.*, 2003; Williams *et al.*, 2006; Zhu *et al.*, 2008). In irrigated areas, researchers found that soil samples collected from Dholdi, Komorpur, and Paranpur areas of Faridpur district in Bangladesh contained 22.0, 47.3, and 116.0 mg/kg As, respectively (Islam *et al.*, 2013). Specifically, in areas with As-enriched groundwater-irrigated soil, As level detected up to 57.0 mg/kg (Alam and Sattar, 2000). In Bangladesh, contaminated groundwater is used for the irrigation of rice, which is the staple food. With regards to food safety, accumulation of As in the contaminated soil can cause toxicity to rice plants and subsequently a significant reduction in yield, thus threatening long-term sustainability of rice cropping systems in the affected areas (Panaullah *et al.*, 2009; Khan *et al.*, 2010). As-contaminated soil has emerged as a serious problem, because of As accumulation in rice grains, its toxic and carcinogenic properties (Tripathi *et al.*, 2007), and its effects on both human and animal health. It is important to remediate As-contaminated soil to adequately protect animal and human health.

In order to expand the frontiers of phytoremediation technologies, much focus is now being placed on the increased use of plants that have the potential to accumulate As. There are some problems associated with the application of hyperaccumulators to the contaminated soil, such as small biomass and a limited adaptation capacity to growth conditions and cultivation. The selection of plants having metal-accumulating ability and compatibility with local weather conditions is an important issue. Some plant species such as *Agrostis castellana* L. and *Agrostis delicatula* L. (De Koe, 1994), *Bidens cynapiifolia* L. (Bech *et al.*, 1997), *Pteris vittata* L. (Ma *et al.*, 2001; Tu *et al.*, 2002; Ye *et al.*, 2011), *Mimosa pudica* L. and *Melastoma malabrathricum* L. (Visoottivisetha *et al.*, 2002), *Pityrogramma calomelanos* L. (Gulz *et al.*, 2005), *Sesuvium portulacastrum* L. (Lokhande *et al.*, 2011), *Hibiscus cannabinus* L. (Meera and Agamuthu, 2011) and *Echinochloa crusgalli* L. (Islam *et al.*, 2013), have been reported to accumulate As from soils. Three plant species such as kenaf (*Hibiscus cannabinus* L.), mesta (*Hibiscus sabdariffa* L.), and jute (*Corchorus capsularis* L.), which were used in the present study, are common fiber crops in Bangladesh and are easily cultivated in the contaminated soil. However, no systematic research has been conducted on remediation of As-contaminated soil, using these plants. It is therefore of utmost importance to investigate the use of these plants as an ecofriendly plant-based green method of cleaning up As-contaminated soil. The present study was conducted to evaluate the phytoremediation potential of kenaf, mesta, and jute in As-contaminated soil.

Materials and Methods

Experimental site and set up

The net house experiment was carried out in the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, located at 24.75°N latitude and 90.4°E longitude. In this investigation, As-contaminated and uncontaminated soils were collected from the selected area of Mymensingh district in Bangladesh, in the agroecological zone (AEZ)-28. Ten kilograms of processed and air-dried soil was taken in a plastic pot (30 cm × 20 cm × 25 cm), and moistened at 70% of the field capacity level, with As-free deionized water. The experiment was performed using a completely randomized design (CRD) with 4 replications. To assess phytoremediation potentiality of kenaf (*Hibiscus cannabinus* L. cvs. HC-3 and HC-95), mesta (*Hibiscus sabdariffa* L. cv. Samu-93) and jute (*Corchorus capsularis* L. cvs. CVE-3 and BJC-7370), 10 uniform textured surface seeds of

Table 1. Characteristics of As-contaminated and uncontaminated soils

Characteristics	As-contaminated soil	Uncontaminated soil
A. Physical characteristics:		
Sand (%)	38.00	41.00
Silt (%)	34.00	30.00
Clay (%)	28.00	29.00
Textural class (USDA)	Clay loam	Clay loam
Particle density (g/cm^3)	2.42	2.70
Bulk density (g/cm^3)	1.32	1.68
B. Chemical characteristics:		
pH	6.65	6.50
EC (μS/cm)	460.00	101.00
OC (%)	2.24	0.62
OM (%)	3.86	1.06
As (mg/kg)	98.25	11.84

each variety under test, were sterilized (by dipping in 95% ethanol), sown in each pot, and thinned to 6 seedlings per pot a week after germination. Nitrogen (N), phosphorus (P), and potassium (K) were applied to soil at rates of 60, 12, and 15 kg ha^{-1}, from urea, triple superphosphate (TSP), and muriate of potash (MOP), respectively. Whole amounts of P and K, and 50% of N fertilizers were applied as a basal dose, and the rest of N fertilizer was top dressed at 45 days after sowing (DAS). From sowing to harvest, all pots were kept under a polyethylene shaded net house for protection from rainwater. Weeding and irrigation with As-free water were performed. For each variety, data were recorded on seed germination, seedling survivability, plant height at 30, 60, 90, and 120 DAS, and stem girth at the harvesting stage. At 120 DAS, root samples of each variety was collected, cleaned thoroughly with tap water, and rinsed with 0.1M HCl solution, followed by several rinses with deionized water. After harvesting, shoot and root biomass of each dried plant variety, was also measured.

Soil sampling and analysis

After collection of both contaminated and uncontaminated soils, the physical and chemical characteristics of each soil were recorded (Table 1). Uncontaminated soil typically contains 10.0–12.0 mg/kg As (Smedley and Kinniburgh, 2002; Hossain, 2006; Henke, 2009), therefore, samples falling within this range, in the present study, were considered uncontaminated soil. Soil samples containing 98.25 mg/kg As, were treated as As-contaminated soil. Considering the intensity of soil As contamination, soil samples were collected separately prior to incorporation into each pot. Texture, bulk and particle densities of preharvest soil samples were determined following methods as outlined by Klute (1986). Electrical conductivity (EC) and pH values of preharvest soil samples were measured electrometrically in a 1:2.5 and 1:5 suspension of soil and water, respectively (Singh *et al.*, 1999; Gupta, 2013). Organic matter content of preharvest soil samples was determined by wet oxidation method (Singh *et al.*, 1999). For the determination of As levels, soil samples were extracted by HNO_3 (AR grade), and H_2O_2 (AR grade), following the method outlined by Loeppert and Biswas (2002). Total As content from the soil extract, was determined using a hydride generation atomic absorption spectrophotometer (HG-AAS, SHIMADZU AA-7000, Japan), as described by Welsch *et al.* (1990) and Sparks (1996).

Plant sampling and analysis

After collecting plant samples, finely ground plant samples were digested with HNO_3 (AR grade), and H_2O_2 (AR grade), for the determination of As (Cai *et al.*, 2000). After extraction of plant samples, As concentration was analyzed using the HG-AAS, as described by Welsch *et al.* (1990), and Sparks (1996).

Enrichment factor (EF)

Enrichment factor (EF) was calculated to determine the degree of heavy metal accumulation in plants grown on the contaminated soil, in comparison to plants grown on the uncontaminated soil, using the following formula (Kisku *et al.*, 2000):

$$\text{EF (plant parts)} = C_{\text{plant parts (CS)}} / C_{\text{plant parts (UCS)}}$$

Where, $C_{\text{plant parts (CS)}}$ is the concentration of metal

Table 2. Effect of arsenic on plant growth in As-contaminated and uncontaminated soils

Plant variety	Germination (%)		Seedling survivability (%)		Stem girth (cm)	
	ACS	UCS	ACS	UCS	ACS	UCS
Kenaf cv. HC-3	93.33a	100.00	100.00a	100.00	5.02a	3.66a
Kenaf cv. HC-95	90.00a	100.00	93.33ab	96.67	4.49b	2.68c
Mesta cv. Samu-93	96.67a	100.00	93.33ab	96.67	2.98c	3.61a
Jute cv. CVE-3	80.00b	100.00	90.00b	96.67	2.05d	3.61a
Jute cv. BJC-7370	73.33b	90.00	90.00b	96.67	1.63d	3.45b
Min.	73.33	90.00	90.00	96.67	1.63	2.68
Max.	96.67	100.00	100.00	100.00	5.02	3.66
Mean	86.67	98.00	93.33	97.33	3.23	3.40
SE±	2.56	1.45	1.26	1.18	0.36	0.10
Significance level	**	NS	*	NS	**	**

ACS = Arsenic-contaminated soil; UCS = Uncontaminated soil
**Significant at 1% level of probability; *Significant at 5% level of probability and ^{NS}Not significant.
Values with same letter or without letter in a given column did not differ significantly, whereas values with dissimilar letters differed significantly, as per DMRT.

in plant parts (root or shoot) at the contaminated soil, and $C_{\text{plant parts (UCS)}}$ is the concentration of metal in plant parts (root or shoot) at the uncontaminated soil.

Bioconcentration factor (BCF)

Bioconcentration factor (BCF) provides an index of the ability of the plant to accumulate metal, with respect to metal concentration in the substrate. BCF was calculated from the following formula, as outlined by Ho *et al.* (2008).

$$\text{BCF (plant parts)} = C_{\text{plant parts}}/C_{\text{soil}}$$

Where, $C_{\text{plant parts}}$ is the concentration of metal in plant parts (root or shoot) and C_{soil} is the concentration of metal in soil.

Statistical analysis

Analysis of experimental data was performed statistically, following the procedure described by Gomez and Gomez (1984). Significance of difference between means was verified by Duncan's multiple range test (DMRT).

Results and discussion

Effect of As on plant growth

In general, germination of kenaf, mesta, and jute seeds was slightly higher in the uncontaminated soil than in As-contaminated soil. In As-contaminated soil, the highest germination (96.67%) was found in mesta cv. Samu-93, followed by kenaf cv. HC-3 (93.33%), and the lowest germination (73.33%) was recorded in jute cv. BJC-7370. Significant statistical variations existed in germination among all plant varieties; however, plant varieties germinated well on soil contaminated with As. Seed germinations of kenaf cv. HC-95 and mesta cv. Samu-93, were statistically identical. In the uncontaminated soil, maximum germination (100%) was observed in kenaf cv. HC-3 and HC-95, mesta cv. Samu-93, and jute cv. CVE-3, but minimum germination (90%) was recorded in jute cv. BJC-7370 (Table 2). No statistical variations were found in germination of different plant varieties.

Different plant species have different germination responses in the contaminated soil. The results of the present study, were supported by Mandal and Bhattacharyya (2007), who found that common pulses (*Vigna mungo* L., *Vigna radiata* L., *Pisum sativum* L., and *Lens culinaris* L.) germinated in the presence of As. The species *V. mungo*, and *V. radiata*, were more tolerant, as compared to *L. culinaris*, and *P. sativum*, although effective concentrations of As for certain degrees of inhibition, were different. Seed germination of jute, kenaf and mesta in the presence of As, was studied by Islam (2010), who reported that seeds of these plants were able to germinate in the presence of As, at certain contamination level. The germination of jute, kenaf, and mesta seeds, indicate their growing potentiality in As-contaminated soil.

Table 3. Effect of arsenic on plant height in As-contaminated and uncontaminated soils

Plant variety	Days after sowing (DAS)							
	30		60		90		120	
	ACS	UCS	ACS	UCS	ACS	UCS	ACS	UCS
Kenaf cv. HC-3	42.07a	43.63b	123.17a	143.18a	214.03a	215.47a	272.87a	224.87a
Kenaf cv. HC-95	35.57b	46.80a	105.53b	126.90b	181.07b	188.93b	234.27b	173.40b
Mesta cv. Samu-93	31.10b	45.67a	84.67c	125.30b	145.02c	161.53c	182.95c	219.48a
Jute cv. CVE-3	22.72c	23.55c	77.00c	126.83b	127.30d	199.08b	153.33d	224.92a
Jute cv. BJC-7370	22.17c	24.33c	79.93c	125.57b	92.05e	196.45b	92.05e	221.52a
Min.	22.17	23.55	77.00	125.30	92.05	161.53	92.05	173.40
Max.	42.07	46.80	123.17	143.18	214.03	215.47	272.87	224.92
Mean	30.72	36.80	94.06	129.56	151.89	192.29	187.09	212.84
SE±	2.13	2.83	4.98	1.93	11.44	5.04	17.05	5.40
Significance level	**	**	**	**	**	**	**	**

ACS = Arsenic-contaminated soil; UCS = Uncontaminated soil
**Significant at 1% level of probability. Values with same letter or without letter in a given column did not differ significantly, whereas values with dissimilar letters differed significantly, as per DMRT.

In both As-contaminated and uncontaminated soils, 100% seedling survivability was observed in kenaf cv. HC-3. Other plant varieties like kenaf cv. HC-95, mesta cv. Samu-93, and jute cvs. CVE-3 and BJC-7370 showed 96.67% seedling survivability in the uncontaminated soil. In As-contaminated soil, 93.33% of kenaf cv. HC-95 and mesta cv. Samu-93 seedlings survived. In As-contaminated soil, the lowest seedling survivability (90%) was detected in two jute varieties (Table 2). Seedling survivability is one of the most important characteristics of a plant that absorbs toxic metal from the contaminated soil. Significant effects were observed on seedling survivability in As-contaminated soil; however, the varieties under consideration easily survived in As-contaminated soil containing 98.25 mg/kg As. The observed survivability of the selected varieties of kenaf, mesta, and jute was consistent with the findings of Islam *et al.* (2013).

At 120 DAS, the largest stem girth (5.02 cm) was measured in kenaf cv. HC-3, followed by kenaf cv. HC-95 (4.49 cm), in As-contaminated soil. In the uncontaminated soil, stem girth of different plant varieties was less than that of the same varieties in the contaminated soil. The highest stem girth value (3.66 cm) was found in kenaf cv. HC-3, followed by mesta cv. Samu-93 (3.61 cm) and jute cv. CVE-3 (3.61 cm). This result may be attributed to greater nutrient absorption potential of kenaf, even in As-contaminated conditions. In addition, stem girths of mesta cv. Samu-93 and jute cvs. CVE-3 and BJC-7370 in the uncontaminated soil were higher than those of the same varieties grown in As-contaminated soil (Table 2).

In both uncontaminated and As-contaminated soils, plant heights differed from variety to variety at different DAS. At 30 and 60 DAS, plant heights of all varieties were higher in the uncontaminated soil than in As-contaminated soil. At 30 DAS, maximum plant height (42.07 cm) was recorded for kenaf cv. HC-3, and minimum plant height (22.17 cm) was recorded for jute cv. BJC-7370 in As-contaminated soil. On the other hand, maximum plant height (46.80 cm) was recorded for kenaf cv. HC-95, in the uncontaminated soil, and the minimum value (23.55 cm) was recorded for jute cv. CVE-3 (Table 3). At 60 DAS, maximum plant height (123.17 cm) was recorded for kenaf cv. HC-3, and minimum plant height (77.00 cm) was recorded for jute cv. CVE-3, in As-contaminated soil. The highest value of plant height (143.18 cm) measured in the uncontaminated soil was recorded for kenaf cv. HC-3, and the lowest value (125.30 cm), for mesta cv. Samu-93 (Table 3).

At 90 DAS, heights of all plant varieties were higher in the uncontaminated soil than in As-contaminated soil. During this period, maximum plant height (214.03 cm) was recorded in As-contaminated soil for kenaf cv. HC-3, and minimum plant height (92.05 cm) was observed in jute cv. BJC-7370. On the other hand, the highest plant height (215.47 cm) was recorded in the uncontaminated soil from the variety of kenaf cv. HC-3, and the lowest plant height (161.53 cm) was recorded in mesta cv. Samu-93 (Table 3). At 120 DAS or harvesting stage, plant heights of kenaf cvs. HC-3 and HC-95 were higher in As-contaminated soil than in the uncontaminated soil. In this period, maximum plant height (272.87 cm) was recorded in the contaminated soil, from the variety of kenaf cv. HC-3, and minimum plant height (92.05 cm) was recorded in jute cv. BJC-7370. In the uncontaminated soil, maximum plant height (224.92 cm) was recorded in jute CVE-3, and minimum plant height (173.40 cm) was recorded in kenaf cv. HC-95 (Table 3).

The present study related to plant height agreed with the findings of Islam *et al.* (2013), who stated that plant height decreased naturally in As-contaminated soils having three As concentrations (22.00, 47.30, and 116.00 mg/kg). The observed plant heights of mesta cv. Samu-93, and jute cvs. BJC-7370 and CVE-3 were consistent with the results obtained by Bada and Kalejaiye (2010) and Bada and Raji (2010). At the harvesting stage, plant heights of some varieties grown on both As-contaminated and uncontaminated soils were close to the plant heights of jute, kenaf, and mesta (Islam and Rahman, 2008).

Effect of As on plant biomass production

The experimental results in Fig. 1 indicate that dry plant biomass production of roots and shoots varied from variety to variety. In As-contaminated soil, the highest dry biomass (589.39 g/pot) of shoot was measured in kenaf cv. HC-3, followed by kenaf cv. HC-95 (487.23 g/pot), and the lowest biomass (17.20 g/pot) was measured in jute cv. BJC-7370. Maximum dry biomass (133.70 g/pot) of root, was also measured in kenaf cv. HC-3, followed by kenaf cv. HC-95 (121.93 g/pot), and minimum biomass (16.59 g/pot) was obtained for the variety of jute cv. BJC-7370.

In phytoremediation, the uptake capability of toxic metals and biomass production capacity of plant species are very important considerations when cultivation is done on the contaminated soil. Among the plant species, kenaf varieties grown in As-contaminated soil produced a greater amount of shoot biomass, as compared to other varieties (Fig. 1). These results can be attributed to toxic metal tolerance of plant varieties. Meera and Agamuthu (2011) reported that kenaf was found to have higher biomass and subsequently recorded 11% higher bioaccumulation capacity, indicating its suitability for phytoextraction of As in the contaminated soil.

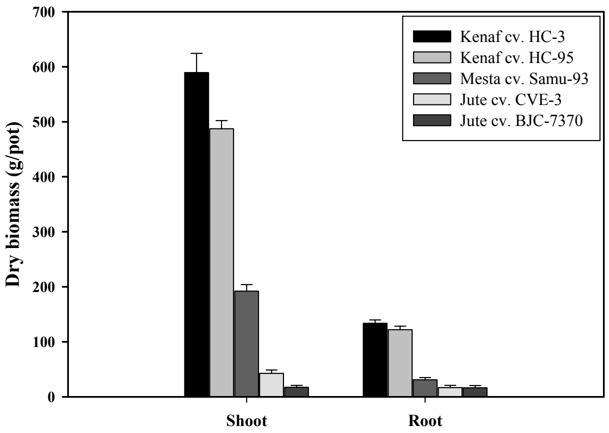

Fig. 1. Effect of arsenic on plant biomass production in the contaminated soil. Error bar indicates standard deviation of mean (n = 4).

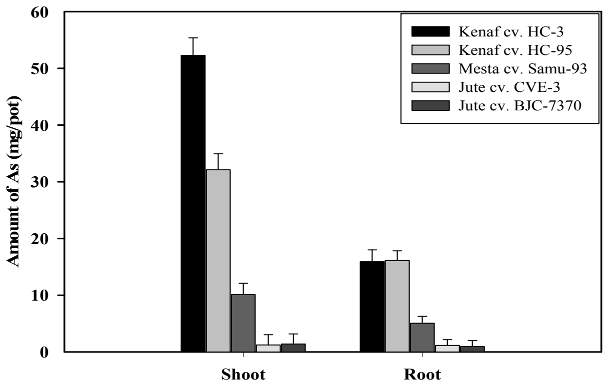

Fig. 2. Arsenic absorption by plant parts in the contaminated soil. Error bar indicates standard deviation of mean (n = 4).

As absorption by plant parts

In As-contaminated soil, As absorption by shoots and roots of plant species differed from variety to variety. In As-contaminated soil, maximum amount of As (52.29 mg/pot) was absorbed by shoots of kenaf cv. HC-3, followed by kenaf cv. HC-95 (32.12 mg/pot), whereas minimum amount (1.16 mg/pot) was absorbed by shoot of jute cv. CVE-3 (Fig. 2). In the case of roots, the highest amount of As (16.12 mg/pot) was absorbed by kenaf cv. HC-95, followed by kenaf cv. HC-3 (13.93 mg/pot), and the lowest amount (0.92 mg/pot), was observed in jute cv. BJC-7370 in the contaminated soil. As shown in Fig. 2, maximum As absorption by shoots and roots was found in kenaf varieties grown in the contaminated soil. In the present study, the aboveground plant parts (shoots) absorbed higher amount of As than belowground plant parts (roots), in all the plant varieties.

Table 4. Enrichment factor (EF) and bioconcentration factor (BCF) of arsenic for different plant varieties

Plant variety	Enrichment factor (EF)		Bioconcentration factor (BCF)	
	Root	Shoot	Root	Shoot
Kenaf cv. HC-3	2.66d	9.51b	1.06c	0.90a
Kenaf cv. HC-95	4.33c	5.86c	1.34b	0.67b
Mesta cv. Samu-93	2.68d	10.11a	1.67a	0.61b
Jute cv. CVE-3	5.15b	5.54c	1.41b	0.28c
Jute cv. BJC-7370	5.89a	10.52a	1.48b	0.84a
Min.	2.66	5.54	1.06	0.28
Max.	5.89	10.52	1.67	0.90
Mean	4.14	8.30	1.40	0.66
SE±	0.36	1.04	0.06	0.06
Significance level	**	**	**	**

**Significant at 1% level of probability. Values with same letter or without letter in a given column did not differ significantly, whereas values with dissimilar letters differed significantly, as per DMRT.

The present observations were similar to the findings of Sultana and Kobayashi (2011), who concluded that the uptake of As increased in roots and shoots, with increasing levels of As in soil. Other researchers also found that As uptake by plants increased, with increasing As concentration in the growth medium or soil (Ma *et al.*, 2001; Hoffmann *et al.*, 2004).

As accumulation in plant varieties

Enrichment factor (EF) was used to evaluate the degree of accumulation of heavy metal in plant parts growing in the contaminated soil, as compared to plants parts growing in the uncontaminated soil. EF of heavy metals in plant parts is a crucial factor in the selection of phytoremediator species growing in heavily-contaminated soils (Barman and Bhargava, 1997). EF values of As for roots and shoots of kenaf, mesta, and jute varieties are presented in Table 4. In the case of EF values in roots, the highest value (5.89) was recorded for the variety of jute cv. BJC-7370 and the lowest value (2.66) was recorded for kenaf cv. HC-3. The highest EF value (10.52) for shoots was measured in the variety of jute cv. BJC-7370 and the lowest EF value (5.54) was recorded for jute cv. CVE-3. Significant variations were found in EF values of roots and shoots among the varieties of kenaf, mesta and jute (Table 4). In all plant varieties, the calculated EF values of roots and shoots were greater than 1. According to Kisku *et al.* (2000), EF values greater than 1.0 indicate that the accumulation of As in roots and shoots of plant species grown in the contaminated soil, may be due to irrigation of As-enriched groundwater, or discharge of industrial wastes into the soil environment. Singh *et al.* (2010) had similar findings for the accumulation of Cd, Zn, Cr, Pb, Cu, Ni, Mn, and Fe in 11 different plant species grown on naturally contaminated soil. Gupta *et al.* (2008) reported a similar trend in metal accumulation of plant species grown in the contaminated soil.

Bioconcentration factor (BCF) values of roots and shoots were calculated for As-contaminated soil. The highest BCF value (1.67) for roots was recorded for the variety of mesta cv. Samu-93, and the lowest BCF value (1.06) was recorded for kenaf cv. HC-3 (Table 4). In the case of shoots, the highest BCF value (0.90) was measured in kenaf cv. HC-3 and the lowest BCF value (0.28) was recorded in jute cv. CVE-3 (Table 4). In the case of BCF values in roots and shoots, significant differences existed between the varieties of kenaf, mesta and jute. Bioconcentration factors of roots were higher than that of shoots. Similar trends of observation were reported by Islam *et al.* (2013). According to Baker *et al.* (1981), all plant varieties in the present study are As accumulators in these soils, because BCFs of roots were more than 1, thereby indicating that these plants may have the potentiality for phytoremediation in As-contaminated soil.

As status in soils

After harvesting plant varieties, the content of As in postharvest soils was found to be less than that in preharvest soils, indicating As removal from soils (Table 5). Removal of As was dependent on plant

Table 5. Arsenic level in the contaminated soil

Plant variety	Preharvest soil (mg/kg)	Postharvest soil (mg/kg)	Removal (%)
Kenaf cv. HC-3	98.25	73.55	25.14
Kenaf cv. HC-95	98.25	68.35	30.43
Mesta cv. Samu-93	98.25	72.35	26.36
Jute cv. CVE-3	98.25	70.75	27.98
Jute cv. BJC-7370	98.25	75.92	22.72
Min.	-	68.35	22.72
Max.	-	75.92	30.43
Mean	-	72.18	26.52
SD	-	2.55	2.90
CV (%)	-	3.53	10.94

variety and As status in preharvest soils. In the contaminated soil, the highest As concentration (75.92 mg/kg) was detected in the postharvest soil cultivated with jute cv. BJC-7370, and the lowest As content (68.35 mg/kg) was recorded in the postharvest soil cultivated with kenaf cv. HC-95 (Table 5). Considering As status in the postharvest soil, all plant varieties under study have the capacity to absorb As from the contaminated soil. It is inferred from this investigation that plant varieties under consideration could be used to remediate As-contaminated soil.

Conclusion

All varieties of kenaf, mesta, and jute were able to germinate in As-contaminated soil, and were hence considered As accumulators, exhibiting remediation capability in the contaminated soil. However, kenaf varieties were more proficient than mesta and jute varieties in removing As from the contaminated soil. The overall As absorption and phytoremediation potentiality of plant varieties were in the order of kenaf cv. HC-3 > kenaf cv. HC-95 > mesta cv. Samu-93 > jute cv. CVE-3 > jute cv. BJC-7370. In conclusion, all varieties of kenaf, mesta, and jute can be considered for phytoremediation technology in As-contaminated soil.

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