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RESEARCH ARTICLE

ARSENIC TOLERANCE AND ASSIMILATION POTENTIALITY OF JUTE, KENAF AND MESTA AT EARLY GROWING STAGE

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ABSTRACT

Arsenic (As) is an environmentally hazardous toxic metalloid. To evaluate As tolerance and assimilation capacity, seedlings of jute (*Corchorus capsularis* L. var. BJC-7370 and CVE-3), kenaf (*Hibiscus cannabinus* L. var. HC-95 and HC-3) and mesta (*Hibiscus sabdariffa* L. var. Samu-93) were grown for 25 days in hydroponic nutrient solution containing four levels of As *viz* 0, 5, 10 and 15 mg L^{-1} with four replications. Results were showed that the seedlings of jute, kenaf and mesta were highly potential to tolerate As toxicity. Arsenic had no significant effects on survibility of kenaf, mesta and jute seedlings (var.CVE-3). Root and shoot length and dry biomass were decreased with the increasing levels of As. Values of bio-concentration factor indicated the varieties of kenaf, mesta and jute (var.CVE-3) were As accumulator. Arsenic accumulation was higher in root than shoot and translocation factor indicated that As is slowly translocated from root to shoot. The rate of translocation is increased with the increasing concentration of As in solution. Highest As contents in shoot (3636.10 mg kg^{-1}) and root (6350.38 mg kg^{-1}) were detected from kenaf HC-3. The highest amount (16.05 mg As pot^{-1}) of As accumulation was also calculated from the variety of kenaf HC-3 with the addition of 45 mg As pot^{-1}. The order of As tolerance and absorption potentiality were kenaf HC-3>mesta Samu-93>jute CVE- 3>kenaf HC-95>jute BJC-7370. These varieties are good cultivar for cultivation and/or phytoremediation of As contaminated environment.

KEYWORDS

Arsenic, environment, jute, kenaf, mesta.

1. INTRODUCTION

Arsenic (As) is a toxic metalloid which is not biologically essential element. Among the toxic metalloids it is one of the catastrophes for environmental and health hazards affecting 35-77 million people or 21-48% of total population in Bangladesh (Rahman et al., 2018). It exists in the environment especially in the soil and water and disseminate due to the anthropogenic activities. Arsenic occurs in soil and minerals and may enter air, water and land through wind-blown dust and water run-off. Arsenic in the atmosphere comes from various sources like volcanoes release about 3,000 tons per year and microorganisms release volatile methyl arsines to the extent of 20,000 tons per year, but human activity is responsible for much more 80,000 tons of arsenic per year are released by the burning of fossil fuels (Arora et al., 1985). The organic and inorganic forms of As present in the environment is harmful for biological system. Though some plant species have ability to uptake and accumulate As in their body from nutrient solution or soil. Actually all plants have the ability to accumulate "essential "metals (Ca, Cu, Fe, Mg, Mn, Mo, and Zn) from the soil solution. This ability also allows plants to accumulate other "non-essential" metals (Al, As, Cd, Cr, Hg, Pb, Pd, Pt, Sb, Te, Tl and U) which have no biological function at all (Chhotu and Fluekar, 2009). Islam et al. (2013) reported that plant species *Eichhornia crassipes*, *Echinochloa crusgalli* and *Monochoria hastata* can easily survive when growing these plants in artificially As contaminated (30, 50, 70 and 100 mg As kg^{-1}) and naturally As contaminated (22.00, 47.3 and 116.00 mg As kg^{-1}) soils. Some varieties of fibrous crops seed are capable to germinate against 50 mg As $L^{-1}$of As though the rate of germination and root shoot growth were decreased with the increasing concentrations (Nizam *et al*. 2013). Water lettuce (*Pistia stratiotes* L.) and water zinnia (*Wedelia trilobata* H.) can survive in As contaminated hydroponics solution up to 150 to 170 mg As kg^{-1}. *Micranthemum umbrosum* plants is a good As accumulator from both of organic and inorganic As contaminated water (1000 µg As L^{-1}) without showing any phytotoxicity (Islam *et al*. 2013a, 2015, 2017). After growing As contaminated hydroponics solution smooth cord grass (*Spartina alterniflora* L.) and smartweed (*Polygonum hydropiperoides* L.) uptake 100 and 120 mg As kg^{-1} in their root. Arsenic is translocated to many parts of the plants, most of it is found in old leaves and roots and uptake seems to be promoted by reduction processes (Chino, 1981).

Water hyacinths are very effective to remove As from contaminated water and the roots of water hyacinths removed 81% from a 400 ppb As solution (Misbauddin and Fariduddin, 2002). To evaluate the As tolerance and accumulation capability of plant species, researcher adopt different ways and means. Sometimes seeds of plants are sown in the contaminated medium for germination; and sometimes plants are raised in contaminated soil and nutrient solution containing As. Most of the

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researchers used non-crop species for phytoremediation and/or absorption of contaminants from the environment which might be not adopted by the farmers in the field level due to no income from this cultivation of non-crop species. So potential application of non-edible crop species (like different fibrous crop varieties) for remediation or absorption or assimilation of toxic contaminants (like As) in the field level which will be adopted by the farmers by increasing their income and as environmental decontamination technology. From this point of view, we are trying to evaluate As tolerance and absorption potentiality by different fibrous crop varieties of jute, kenaf and mesta in hydroponic nutrient solution containing different levels of As.

2. Materials and Methods

2.1 Seedling Raising, Transplanting and Treatments

Uniform textured healthy seeds of jute (*Corchorus capsularies* L. var. BJC-7370 and CVE-3), Kenaf (*Hibiscus cannabinus L*. Var. HC–95 and HC–3) and mesta (*Hibiscus sabdariffa L*. Var. Samu–93) were separated from collected seeds. Seeds were surface sterilized by dipping 95% ethanol for 3 minutes and washed with deionized water to prevent fungal attack. Seedlings were raised in petridish at room temperature. Five days old normal and healthy seedlings were transplanted in nutrient solution (Full strength Hoagland solution). The nutrient solution was prepared following procedure outlined by Hoagland and Arnon (1950). Cylindrical shape 3.5 liters size plastic pots were used as nutrient solution containing pot. The circular shaped non-reactive styrofoam sheets having 20 cm diameter in size were used as lids to cover the plastic pots containing nutrient solution. Thirty-five circular holes were made on the lids of styrofoam, the size of each hole was 1 cm in diameter. Thirty seedlings were planted through thirty separate holes on the lid of the plastic pots containing 3 liters of nutrient solution and five holes was left open for adding distilled water and maintaining aeration. Seedlings were fixed properly in the holes with the help of small pieces of foam. Constant volume of the nutrient solution was maintained by adding required amount of deionized water every day. After planting the pots were placed in the net house and after two days of planting four different levels of As *viz.* 0.0 (control), 5.0, 10.0, and 15.0 mg L^{-1} of As from analytical grade sodium arsenite ($NaAsO_2$) were applied maintaining four replications following completely randomized design (CRD). The hydroponic pots were shaded with transparent polyethylene sheet to protect rain water. The pH of the nutrient solution was maintained at 5.5-6.0.

2.2 Harvesting, Data Recording, Plant Sampling, Processing and Chemical Analyses

The plants were growing for 25 days. Plants were harvested after 25 days of planting. Shoots and roots were separated and cleaned thoroughly with tap water and rinsed with 0.1 M HCl solution, followed by several rinses with deionized water. Data were recorded in terms of percent seedling survivability, root and shoot lengths (cm) in the day of harvesting and dry weights of shoots and roots (g pot^{-1}) were recorded. After air drying, samples were oven dried at 75^{0}C for 48 hours. To determine As, finely ground plant samples were digested with 65% HNO_3 (MERCK, Germany) and 30% H_2O_2 (Scharlau, Spain) following procedure outlined by Cai *et al*. (2000) and Islam *et al*. (2015). After extraction, As contents in plants were directly determined with atomic absorption spectrophotometer (Shimadzu AA 7000) at the wavelength of 193.7 nm following method described by Sparks (1996) and Singh *et al.* (1999). Arsenic standard, blank, triplicate and continuing calibration verification was included in elemental analysis.

2.3 Bio-concentration Factor (BCF) and Translocation Factor (TF)

The bioconcentration factor or bioaccumulation factor (BCF or BAF) and translocation factor (TF) were calculated following formulae outlined by Ho *et al.* (2008).

BCF (root) = $C_{root}/C_{solution}$, where C_{root} is the concentration of element in root and $C_{solution}$ is the concentration of element in solution.

BCF (shoot) = $C_{shoot}/C_{solution}$, where C_{shoot} is the concentration of element in shoot and $C_{solution}$ is the concentration of element in solution. TF (from root to shoot) = C_{shoot} / C_{root}, where C_{shoot} is the concentration of element in shoot and C_{root} is the concentration of element in root.

2.4 Statistical Analysis

The analyses of variance (ANOVA) of various characters and As contents of shoot and root of different varieties were done following the principle of statistics (Gomez and Gomez, 1984). Least significant difference (LSD) and Duncan's multiple range (DMRT) tests were performed to determine the statistical significance.

3. Results and Discussion

3.1 Seedling Survibility

The application of As up to 15 mg L^{-1} had no significant effect on the seedling survibility of kenaf HC-95, kenaf HC-3, mesta -samu93 and jute CVE-3 varieties, but the seedlings of jute BJC-7370 were affected. Out of five varieties four varieties (kenaf HC-95 & HC-3, mesta Samu-93 and jute CVE-3) showed the highest (100%) seedling survibility at all concentrations and the lowest (0.00%) was in jute variety BJC-7370 at 10 and 15 mg As L^{-1} treatment (Table 1 & Photo 1-5). The seedlings of jute BJC-7370 was survived only up to 5 mg As L^{-1}. The degeneration of all seedlings of BJC-7370 at 10 and 15 mg AsL^{-1} indicated their less As tolerant potentiality. The maximum survibility of seedlings of kenaf HC-95, kenaf HC-3, mesta Samu-93 and jute CVE-3 indicated their more tolerant potentiality to As toxicity (Table 1 and Photo 1-5).

Photo -1 Photo -2 Photo -3

Photo - 4 Photo - 5

Photo 1-5: Effects of increased concentrations of As (mg As L^{-1}) on kenaf, mesta and jute at early growth stage in solution culture.

Table 1: Effects of As on the seedling survibility of jute, kenaf and mesta varieties at early growing stage

As levels (mg L^{-1})	% Seedling survibility				
	Jute (BJC-7370)	Jute (CVE-3)	Kenaf (HC-95)	Kenaf (HC-3)	Mesta (Samu-93)
0	100.00a	100.00	100.00	100.00	100.00
5	31.67b	100.00	100.00	100.00	100.00
10	0.00c	100.00	100.00	100.00	100.00
15	0.00c	100.00	100.00	100.00	100.00
Range	0.00-100.00	100.00-100.00	100.00-100.00	100.00-100.00	100.00-100.00
Mean	65.83	100.00	100.00	100.00	100.00
SE±	10.82	0.00	0.00	0.00	0.00
LSD	2.67	0.00	0.00	0.00	0.00
Sig. levels	**	NS	NS	NS	NS

** = Significant at 1% level of probability and NS = Not significant. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

3.2 Shoot Length of Plants

The shoot lengths of plants were significantly decreased with the application of As in the solution at the levels of 5.00-15.00 mg As L^{-1}. Most of the varieties showed gradual decreasing trend but drastic decreasing trend was found in jute variety BJC-7370 (Table 2 & Figure 1-5). The highest shoot lengths 57.30, 51.27, 42.10, 38.41 and 16.67 cm were recorded in jute CVE-3, kenaf HC-3, HC-95, mesta Samu-93 and jute BJC-7370, respectively at control. The lowest 0.00, 15.62, 21.72, 21.73, and 22.97 cm were in the variety of jute BJC-7370, mesta Samu-93, kenaf HC-3, kenaf HC-95 and jute CVE-3, respectively at 15 mg As L^{-1}. All the seedlings of BJC-7370 were degenerated at 10 and 15 mg As L^{-1} due to the toxicity of As. In case of kenaf HC-95 statistically no variations were found in shoot growth at 5 to 15 mg L^{-1} As treatment. Except jute variety BJC-7370, almost all the varieties were survived with sufficient shoot growth up to 15 mg As L^{-1} (Table 2 & Figure 1-5).

Table 2: Effects of As on the shoot length of jute, kenaf and mesta varieties at early growing stage

As levels (mg L^{-1})	Shoot length (cm)				
	Jute (BJC-7370)	Jute (CVE-3)	Kenaf (HC-95)	Kenaf (HC-3)	Mesta (Samu-93)
0	15.67a	57.30a	42.10a	51.27a	38.41a
5	11.30b	45.00b	23.57b	35.57b	30.66b
10	0.00c	41.00c	22.67b	26.47c	22.13c
15	0.00c	22.97d	21.73b	21.72c	15.62d
Range	0.00-15.67	22.97-57.30	21.73-42.10	21.72-51.27	15.62-38.41
Mean	13.48	41.57	27.52	33.75	26.71
SE±	0.75	3.74	2.57	3.52	2.62
LSD	1.20	2.13	1.42	3.98	1.70
Sig. levels	**	**	**	**	**

** = Significant at 1% level of probability and NS = Not significant. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

Present findings are in line with the findings of Islam et al. (2013), from an experiment they revealed that increasing dose of As significantly decreased the height of three plant species namely water hyacinth (*Eichhornia crassipes*) barnyard grass (*Echinochloa crusgalli*) and water taro (*Monochoria hastata*) when growing these plants in artificially contaminated soil with the concentrations of 30, 50, 70 and 100 mg As kg^{-1} and naturally contaminated soils of 22.00, 47.30 and 116.00 mg As kg^{-1}. Effect of As on the growth of barnyard grass and rice were studied by Sultana (2011) and observed gradual and slight growth reduction when barnyard grass and rice seedlings were grown in nutrient solution containing 1 to 10 mg As L^{-1}. Chun et al. (2007) also reported that the shoot growth of wheat seedlings decreased gradually at high concentrations (5-20 mg As kg^{-1}) of As. The reduction of shoot growth of present study also consensus with the statement of Azpiazu (1989), who stated that growth reduction of above ground plant parts occurred due to the addition of As at 100 mg L^{-1}. Growth reduction also supported by Jiang and Singh (2003) in case of barley (cv. Spartan) plant due to receive As containing irrigation water. In the present study the growing capability of kenaf HC-95, kenaf HC-3, mesta Samu-93 and jute CVE-3 were found up to the application of 15 mg As L^{-1}, indicates their tolerant capability to As contaminated medium, though the toxic effect of As reduced their gradual shoot growth with the increasing of As concentration. At 10 and 15 mg As L^{-1}.The growth of jute variety BJC-7370 were totally stopped and all the seedlings were fall into death and rotted before harvest which indicates it susceptibility or less tolerance to As contaminated medium of the variety. The result of BJC-7370 was consented with the results of Zaman et al. (2001), they stated that rice plants grown on soil irrigated with > 30 mg As L^{-1} died before flowering, > 20 mg As L^{-1} showed 80% death rate but < 10 mg As L^{-1} irrigated soil plants survived up to harvest with normal growth and yield.

3.3 Root Length of Plants

Like shoot lengths the root lengths of plants were also significantly decreased with the application of As in the solution at the levels of 5-15 mg As L^{-1} (Table 3). Most of the varieties showed gradual decreasing trend but drastic decreasing trend was found in jute variety BJC-7370. The highest root lengths 34.19, 29.03, 25.50, 22.27 and 7.37 cm were recorded in the variety of kenaf HC-95, kenaf HC-3, jute CVE-3, mesta Samu-93 and jute BJC-7370, respectively at control. The lowest 0.00, 9.61, 10.40, 20.93 and 21.00 cm in the variety of jute BJC-7370, mesta Samu-93, jute CVE-3, kenaf HC-3 and kenaf HC-95, respectively at 15 mg As L^{-1}. The seedlings of BJC-7370 degenerated with of 10 mg As L^{-1}. In case of kenaf HC-95 & HC-3 statistically no variations were found in root growth at control to 5 mg As L^{-1} and 10 to 15 mg As L^{-1} (Table 3). Except jute variety BJC-7370, almost all the varieties were grown with sufficient root growth up to 15 mg As L^{-1} in nutrient solution.

Table 3: Effects of As on the root length of jute, kenaf and mesta varieties at early growing stage

As levels (mg L^{-1})	Root length (cm)				
	Jute (BJC-7370)	Jute (CVE-3)	Kenaf(HC-95)	Kenaf (HC-3)	Mesta (Samu-93)
0	7.37a	25.50a	34.19a	29.03a	22.27a
5	0.82b	22.43b	31.93a	27.13a	18.50b
10	0.00c	14.43c	21.93b	23.30ab	15.32c
15	0.00c	10.40d	21.00b	20.93b	9.61d
Range	0.00-7.37	10.40-25.50	21.02-34.19	20.93-29.03	9.61-22.27
Mean	4.09	18.19	27.26	25.10	16.42
SE±	1.06	1.85	1.83	1.21	1.46
LSD	1.07	1.32	2.08	3.31	1.76
Sig. levels	**	**	**	*	**

** = Significant at 1% level of probability and * = Significant at 5% level of probability. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

Gradual and slight growth reduction of barnyard grass and rice observed by Sultana (2011) when barnyard grass and rice seedlings were grown in nutrient solution containing 1.0 to 10.0 mg As L^{-1}. Similar had been the findings of Chun *et al*. (2007) in case of root growth of wheat seedlings at high concentrations (5-20 mg kg^{-1}) of As and supported by Xiaoli et al. (2005), they revealed that the root length of wheat seedlings were decreased with increasing concentrations of arsenate and arsenite. In the present study the growing capability of roots of kenaf HC-95, kenaf HC-3, mesta-samu93 and jute CVE-3 were found up to the application of 15 mg As L^{-1}, indicates their tolerant capability to As contaminated medium, though the toxic effect of As reduced their root growth gradually with the increasing of As concentration. The decreases of root growth were minimum at the increasing levels of As in the solution. At 10 and 15 mg As L^{-1} the growth of jute variety BJC-7370 were totally stopped and all the seedlings were fall into death and rotted before harvest which indicates it susceptibility or less tolerance to As contaminated medium. It was agreed with the findings of Zaman et al. (2001), they reported that rice seedlings were died due to the application of higher (20 to 30 mg L^{-1}) concentration of As. In the present study the growth reduction of roots of jute, kenaf and mesta plants were significant. The growth reduction was more in root than in shoot due to the direct contact of root with toxic metal containing solution.

3.4 Dry Weight of Shoot

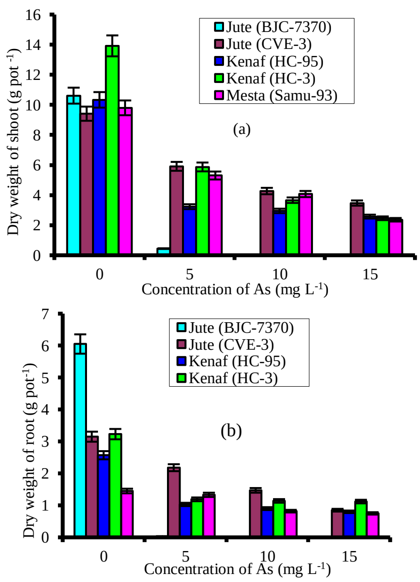


Figure 1: Effects of increased levels of As on the dry weight of shoot (a) and root (b) of jute, kenaf and mesta at early growing stage. Error bars indicates Mean ± SE.

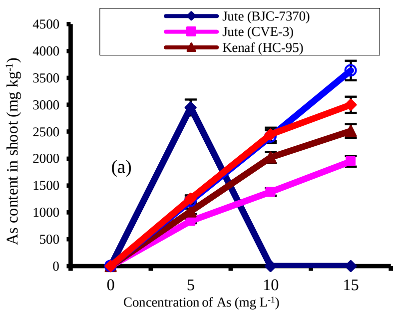
As shown in Figure 1(a) the dry weight of shoot of jute, kenaf and mesta plants were significantly decreased with the application of increasing levels (5-15 mg As L^{-1}) of As in the nutrient solution. Most of the varieties showed gradual decreasing trend but drastic decreasing trend was found in jute variety BJC-7370. For all the varieties, maximum dry weights recorded at control. The highest dry weights 13.92, 10.61, 10.33, 9.80 and 9.41 g pot $^{-1}$ were recorded in kenaf HC-3, jute BJC-7370, kenaf HC-95, mesta Samu- 93 and jute CVE-3, respectively, at control. The lowest dry weights 0.00, 2.36, 2.46, 2.57 and 3.47 g pot $^{-1}$ were in mesta Samu- 93, kenaf HC-3, kenaf HC-95 and jute CVE-3 at 15 mg As L^{-1} [Figure1(a)]. Except jute variety BJC-7370, almost all the varieties were able to produce sufficient dry biomass of shoot up to the application of 15 mg As L^{-1}. Similar had been the findings of Islam et al. (2013), they revealed significant decreasing trend of shoot biomass of barnyard grass (*Echinochloa crusgalli*) and water taro (*Monochoria hastata*) with the increasing concentration of As in artificial (30, 50, 70 and 100 mg As kg^{-1}) and natural (22.00, 47.30 and 116.00 mg As kg^{-1}) contaminated soils. Significant decrease in shoot dry weight was also observed by Sultana (2011) when barnyard grass and rice seedlings were grown in nutrient solution containing 5 to 10 mg As L^{-1}. In spite of gradual reduction of dry biomass production with the increasing of As concentration the ability of producing dry biomass of shoot at a satisfactory levels by the variety of kenaf HC-95, kenaf HC-3, mesta -samu93 and jute CVE-3 with the application of 5 to 15 mg As L^{-1}, indicates their growing potentiality to As contaminated medium, However, in the present study the reduction of fresh biomass production of kenaf HC-95, kenaf HC-3, mesta Samu-93 and jute CVE-3 plants were significant. It is assuming that higher concentration As in the growing solution had adverse effect on the growth and development of plants that influence the biomass production. This is corresponded with the view of Chun et al. (2007), they observed that the growth and biomass production of wheat seedlings were stimulated with the application of low concentration (0 to 1 mg kg^{-1}) of As but all these factors decreased gradually at high concentrations (5 -20 mg kg^{-1}) of As. Reduction of crop yield was observed by Abedin et al. (2002) but they did not mention any numerical value in relation to As concentration and crop yield.

3.5 Dry Weight of Root

The dry biomass of root were significantly decreased with the application of increasing levels (5 -15 mg As L^{-1}) of As in the nutrient solution. Most of the varieties showed gradual decreasing trend but drastic decreasing trend was found in jute variety BJC-7370.

In the present study, the ability of producing dry biomass of root at a satisfactory levels by the variety of kenaf HC-95, kenaf HC-3, mesta Samu-93 and jute CVE-3 up to the application of 15 mg As L^{-1}, indicated their tolerance potentiality to As contaminated medium, though the toxic effect of As gradually reduced the production of dry biomass of root, with the increasing of As concentration [Figure1 (b)]. All the varieties produced maximum dry weight at control treatment. The highest dry weights 6.05, 3.23, 3.15, 2.57 and 1.45 g were measured in jute BJC-7370, kenaf HC-3, jute CVE-3, kenaf HC-95 and mesta Samu-93, respectively at control. The lowest dry weights 0.00, 0.75, 0.80, 0.85 and 1.12 g pot^{-1} were in jute BJC-7370, mesta Samu-93, kenaf HC-95, jute CVE-3 and kenaf HC-3, respectively at 15.00 mg As L^{-1} [Figure 1 (b)]. Except jute variety BJC-7370, almost all the varieties were able to produce sufficient dry biomass of root up to 15 mg As L^{-1} in nutrient solution. Sultana and Kobayashi (2011) reported the little growth inhibition and biomass production of barnyard grass with increasing As concentration in growth medium. For most of the varieties the decreasing rates of dry biomass production of the present study were minimum at the increasing levels of As in the solution. Root biomass production of jute variety BJC-7370 was totally stopped at 10 and 15 mg As L^{-1} which indicates it susceptibility or less potentiality to As contaminated medium.

3.6 Effects of Applied As on the Concentration of As in Shoot of Jute, Kenaf and Mesta



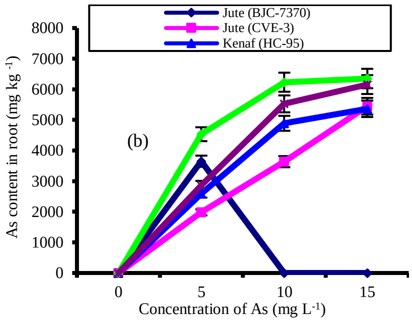


Figure 2: Effects of increased levels of As on the As content in shoot (a) and root (b) of jute, kenaf and mesta at early growing stage. Error bars indicates Mean ± SE.

Figure2 (a) reflected that, the concentrations of As in shoot of jute, kenaf and mesta were increased by the application of As in nutrient solution with increasing As (5-15 mg L^{-1}) levels. Except jute variety BJC-7370, maximum concentrations of As were detected at the highest treatment for almost all the varieties. At the highest level of As in the solution (15 mg As L^{-1}), As concentrations in the shoot were 3636.10 mg kg^{-1}, 2999.49 mg kg^{-1}, 2512.58 mg kg^{-1} and 1946.83 mg kg^{-1} for kenaf HC-3, mesta Samu-93, kenaf HC-95 and jute CVE-3, respectively. Similar increasing concentration of As in shoot was observed by Sultana (2011) when barnyard grass and rice seedlings were grown in nutrient solution containing 1 to 10 mg As L^{-1}.

In case of jute variety BJC-7370, As detection was not possible with the application of 10 and 15 mg As L^{-1} because at these concentration all the seedlings were died just after few days of planting. But in this variety, As concentration was 2948.98 mg kg $^{-1}$ at 5 mg L^{-1}. Aerial plant parts of kenaf accumulates (<12% of total bioavailable metals) Fe and As Meera and Agamuthu (2012). This is also corresponded with the view of Zaman et al. (2001), they elucidated that higher amount of arsenic in soil and irrigated water tends to accumulate higher amounts of As in rice straw (0.5 to 72.0 mg As kg^{-1}) and grain (0.22 to 47 mg As kg^{-1}). In the present study all the varieties contained more than 1000 mg As kg^{-1}.Therefore, these varieties may be treated as hyperaccumulators of As, since Wei et al. (2004) stated that plants which are able to accumulate more than 1000 ppm As are considered as hyperaccumulators. Overall, the As concentrations were less in shoots than in roots due to the indirect contact of shoots with As contaminated nutrient medium.

3.7 Effects of Applied As on the Concentration of As in Root of Jute, Kenaf and Mesta

Like shoot the concentrations of As in root of jute, kenaf and mesta were increased by the application of As in nutrient solution with increasing As (5-15 mg L^{-1}) levels Figure 2 (b). Except jute variety BJC-7370, maximum concentrations of As were detected at the highest treatment for almost all the varieties. At the highest level of applied As in the solution (15 mg As L^{-1}), As concentrations in the root were 6350.38, 6153.00, 5445.75 and 5362.17 and mg kg^{-1} in kenaf HC-3, mesta Samu-93, jute CVE-3 and kenaf HC-95, respectively. In jute variety BJC-7370 As detection was not possible at 10 and 15 mg As L^{-1} because in these concentrations all the seedlings died just few days after planting. Meera and Agamuthu (2012) observed roots of kenaf absorbed 0.06-0.58 mg As per gram dry weight, which implies that kenaf root can be a bioavailable sink for toxic metals. Sultana (2011) also detected higher levels of As in the root of barnyard grass (1033.83 mg As kg^{-1}) and rice seedlings (832.83 mg As kg^{-1}) at higher levels of applied As (10 mg As L^{-1}).

3.8 Bio-concentration Factors (BCF) of As for Root and Shoot of Jute, Kenaf and Mesta

The bio-concentration factor or bioaccumulation factor of a plant for a given metal is the ratio of the metal in the plant parts (root or shoot) in

relation to the amount of metal in the growth medium. BCF or BAF is a crucial parameter to evaluate the potentiality of a plant in accumulating metals and the values were calculated on dry weight basis. The bio-concentration factors of root and shoot of each plant variety had been calculated separately against concentration of metal in contaminated and uncontaminated medium with that of concentration of metal concentrations in shoot and root. This factor was calculated to identify a plant species whether it is accumulator or excluder.

Both for roots and shoots the BCF values of most of the varieties were gradually and significantly decreased with the increasing of As concentration in the solution at the levels of 5 -15 mg As L^{-1}. These trends were in line with the results of Islam *et al.* (2013), they observed the decreasing trends of BCF in the roots and shoots of water hyacinth (*Eichhornia crassipes*), barnyard grass (*Echinochloa crusgalli*) and water taro (*Monochoria hastata*) with the increasing of As concentration in the artificially contaminated soil in the range of 30 -100 mg As kg^{-1}. Bio-concentration factors >1.00 indicate the plant is an "accumulator", < 1 indicate the plant is an "excluder" Baker (1981). In the present study with the application of As in the growing solution the BCF values of roots and shoots of all the varieties were found within the range of 357.48 - 906.60 and 129.79 - 589.80, respectively (Table 4). The maximum BCF value (906.60) of the present study was lower as par the result of Islam et al. (2013), where they calculated maximum BCF value (2300) in the roots of barnyard grass with the application of 22 ppm arsenite (As-III) from $NaAsO_2$ in artificially contaminated soil. Though the BCF value of their study was higher than that of present value, but such type of result was supported the current research. Since all the BCF values were higher than 1.00; therefore, it can be suggested that all the studied varieties of jute, kenaf and mesta are accumulators of As and have the As remediation potentiality from As contaminated medium.

Table 4: Bio-concentration factors (BCF) of As for root and shoot of jute, kenaf and mesta varieties at early growing stage

As levels of solution (mg L^{-1})	Bio-concentration Factors (BCF) for root					Bio-concentration Factors (BCF) for Shoot				
	Jute BJC-7370	Jute CVE-3	Kenaf HC-95	Kenaf HC-3	Mesta Samu-93	Jute BJC-7370	Jute CVE-3	Kenaf HC-95	Kenaf HC-3	Mesta Samu-93
0	0.00b	0.00c	0.00d	0.00d	0.00d	0.00b	0.00d	0.00d	0.00d	0.00d
5	730.01a	396.05a	518.39a	906.60a	572.95a	589.8a	168.15a	203.83a	352.90a	250.53a
10	#	363.60b	488.82b	623.04b	552.40b	#	137.91b	201.79b	240.83b	245.13b
15	#	363.03b	357.48c	423.36c	410.20c	#	129.79c	167.50c	172.08c	199.97c
Range	0.00–730.01	0.00–396.05	0.00–518.39	0.00–906.60	0.00–572.95	0.00–589.80	0.00–168.15	0.00–203.83	0.00–352.90	0.00–250.53
Mean	365.01	280.67	341.17	488.25	383.89	294.90	108.96	143.28	191.45	173.91
SE±	115.43	49.03	62.14	99.53	69.46	93.26	19.46	25.32	38.63	30.85
LSD	3.79	3.57	1.78	6.41	5.92	2.43	1.82	0.54	7.33	2.66
Sig. levels	**	**	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability and NS = Not significant. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

Plants died after few days of planting; ** = Significant at 1% level of probability. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

3.9 Translocation Factor (TF) of As from Root to Shoot for Jute, Kenaf and Mesta

Translocation factor or mobilization ratio of a plant for a given metal is the ratio of the metal concentration in the plant parts in relation to the concentration of metal in the growth medium or ratio of the metal concentration in relation to one part to another part (i.e., from root to shoot). The TF from root to shoot had been calculated to evaluate the mobilization of absorbed metals from root to shoot.

Slight variations were found in the values of translocation factor from root to shoot with the increasing of applied As in the growth medium. TF become <1.00 indicate slow translocation.

The highest (0.81) TF was calculated from the variety of jute BJC-7370 at 5 mg As L^{-1} followed by 0.49 in mesta Samu-93 and the lower 0.39 in the variety of kenaf HC-3 and HC-95 with the application of 5 mg As L^{-1} followed by the lowest 0.00 for all the varieties at control (Table 5). In the present study the TF values for all the varieties were <1.00 (Table 5) indicated that in hydroponic solution As was slowly translocated from root to shoot. The root to shoot TFs of As ranged from 0.37-0.45, 0.47-0.61 and 0.43-0.55 for water hyacinth, barnyard grass and water taro when experimented with the growing of these plants species in naturally (22.00, 47.30 and 116.00 mg As kg^{-1}) and artificially (30, 50, 70 and 100 mg As kg^{-1}) contaminated soils (Islam *et al*. 2013). Meera and Agamuthu (2012) also reported similar type of TF (TF<1) for kenaf grown in soil polluted with landfill leachate containing As and Fe. Islam *et al*. (2013a, 2015) found that *Micranthemum umbrosum* plants is a good As accumulator from water due to the bio-concentration factor values and translocation factor values are always greater than 1.0.

Table 5: Translocation Factor (TF) of As from root to shoot for jute, kenaf and mesta varieties at early growing stage

As levels of solution (mg L^{-1})	Translocation Factor (TF)				
	Jute BJC-7370	Jute CVE-3	Kenaf HC-95	Kenaf HC-3	Mesta Samu-93
0	0.00b	0.00c	0.00c	0.00b	0.00c
5	0.81a	0.42a	0.39b	0.39a	0.44b
10	#	0.38b	0.41b	0.39a	0.44b
15	#	0.36b	0.47a	0.41a	0.49a
Range	0.00 - 0.81	0.00 - 0.42	0.00 - 0.47	0.00 - 0.41	0.00 - .49
Mean	0.41	0.29	0.32	0.30	0.34
SE±	0.13	0.05	0.06	0.05	0.06
LSD	0.01	0.01	0.01	0.01	0.01
Sig. levels	**	**	**	**	**

Plants died after few days of planting; ** = Significant at 1% level of probability. In a column figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

3.10 Effects of Applied As on the Absorption of As by the Shoot of Jute, Kenaf and Mesta in Solution Culture

The uptake of As by shoot of jute, kenaf and mesta plants were significantly increased with the application of increasing levels (15 - 45 mg As pot^{-1}) of As in the nutrient solution. At The highest level (45mg As pot^{-1}) of As in the solution, As absorption by the shoot were 10.08, 8.93, 6.75 and 6.46 mg pot^{-1} in mesta Samu-93, kenaf HC-3, jute CVE-3 and kenaf HC-95, respectively. On the other hand, the lowest quantity (0.00 mg pot^{-1}) of As uptakes were calculated at control [Figure 3 (a)]. But with the application of 30 and 45 mg As pot^{-1} all the seedlings of jute BJC-7370 were died.

Nizam *et al.* (2016) reported that kenaf and mesta plants are highly effective to absorbed As from As contaminated soil. In the present study, most of the varieties showed gradual increasing absorption trend [Figure 3 (a)]. The ability of significant increase in As uptake by the variety of jute, kenaf and mesta with the application of 15 to 45 mg As pot^{-1} indicates their As accumulating potentiality from As contaminated medium. It was assumed that higher application of As in the growing solution had adverse effect on the growth and development of plants that influence the biomass production although it promotes the As absorption. Islam et al., (2015) found that maximum absorption of As (1219±44.11 mg As g^{-1}) by the leaves of *Micranthemum umbrosum* and good biomass production.

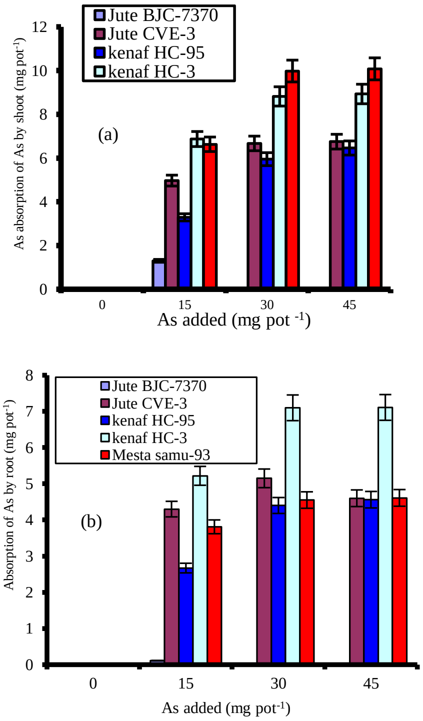


Figure 3: Effects of increased levels of total amount of applied As on the As absorption per pot by shoot (a) and root (b) of jute, kenaf and mesta at early growing stage. Error bars indicate mean±SE.

3.11 Effects of Applied As on the Absorption of As by the Root of Jute, Kenaf and Mesta

As shown in Figure 4 the uptake of As by root of jute, kenaf and mesta plants were increased with the increasing levels (15 - 45 mg As pot^{-1}) of As application of in the nutrient solution. Maximum amount of As absorption were detected at the highest treatment for all the varieties. At the highest level (45 mg As pot^{-1}) of As in the solution, As absorption by the roots were 7.11, 4.61, 4.60 and 4.56 mg pot^{-1} for kenaf HC-3, mesta Samu-93, jute CVE-3 and kenaf HC-95, respectively. On the other hand, the lowest amount (0.00 mg pot^{-1}) of As absorption was at control. Most of the varieties showed gradual increasing absorption trend [Figure 3 (b)] and it is might be due the special affinity to As of these varieties (Islam et al. 2013). In the present study the ability of significant increase in As absorption by the variety of jute, kenaf and mesta with the application of 15 to 45 mg As pot^{-1} indicates their As accumulating potentiality to As contaminated medium, though the toxic effect of As gradually reduced their root biomass production with the increasing of applied As.

3.12 Total Amount of As Absorbed by Jute, Kenaf and Mesta

The values of total amount of As in kenaf and mesta varieties were increased with increasing of total amount of applied As pot^{-1} but the values were decreased for jute variety BJC-7370. The varieties of kenaf (HC-3 &HC-95) and mesta able to accumulate As with increasing rate up to 45 mg As pot^{-1}. The highest total amount (16.05 mg As pot^{-1}) of As was calculated from the variety of kenaf HC-3 with the addition of 45 mg As pot^{-1} followed by 15.92 mg As pot^{-1} in the same variety with the application of 30 mg As pot^{-1}. On the other hand, comparatively lower amount (1.41 mg As pot$^{-1)}$ of As in jute BJC-7370 with 15 mg As pot^{-1} and the lowest 0.00 mg As pot^{-1} for all the varieties at control (Table 6).

Table 6: Total amount of As in solution, plants and % recovery after harvesting of jute, kenaf and mesta at early growing stage

Total amount of As added to initial solution (mg pot-1)	Total amount of As remain in post harvest solution (mg pot-1)					Total amount of As absorbed by plant (mg pot-1)					Recovery of As (%)				
	Jute BJC-7370	Jute CVE-3	Kenaf HC-95	Kenaf HC-3	Mesta Samu-93	Jute BJC-7370	Jute CVE-3	Kenaf HC-95	Kenaf HC-3	Mesta Samu-93	Jute BJC-7370	Jute CVE-3	Kenaf HC-95	Kenaf HC-3	Mesta Samu-93
0.00	0.00d	0.00d	0.00d	0.00d	0.00d	0.00b	0.00c	0.00c	0.00d	0.00c	0.00b	0.00b	0.00c	0.00b	0.00c
15.00	12.09c	3.48c	7.69c	1.71c	2.10c	1.41a	9.27b	5.96b	12.09c	10.44b	90.00a	85.00a	91.00a	92.00ab	83.65b
30.00	28.50b	15.02b	15.18b	11.86b	12.32b	#	11.82a	10.35ab	15.92b	14.53a	#	89.47a	85.10b	93.03a	89.49a
45.00	42.60a	25.75a	28.02a	25.98a	25.49a	#	11.35a	10.91a	16.05a	14.69a	#	82.44ab	86.51b	93.40a	89.29a
Range	0.00-42.60	0.00-25.75	0.00-28.02	0.00-25.98	0.00–25.49	0.00-1.41	0.00–11.82	0.00–10.91	0.00–16.05	0.00–14.69	0.00–90.00	0.00-89.47	0.00–91.00	0.00–93.40	0.00–89.49
Mean	20.80	11.06	12.72	9.89	9.98	0.70	8.11	6.81	11.02	9.92	44.99	64.23	65.65	69.61	65.61
SE±	4.87	3.06	3.12	3.12	3.05	0.22	1.45	1.32	1.98	1.80	14.23	11.26	11.46	12.12	11.47
LSD	0.597	0.667	0.547	0.808	0.672	0.093	0.667	0.547	0.808	0.370	1.718	5.015	2.419	0.658	3.534
Sig. levels	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

Plants died few days after planting, ** = Significant at 1% level of probability. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

3.13 Recovery of As

Recovery of As for different varieties were calculated by following formula

%Recovery = Total amount of As absorbed by plants + Total amount of As remain in post harvest solution / Total amount of added As in initial solution × 100.

Maximum recovery (93.40%) was calculated for the variety of kenaf HC-3 with the addition of 45 mg As pot^{-1} followed by 93.30% in the same variety at 30 mg As pot^{-1}. Comparatively lower recovery 83.65% was found in mesta Samu-93 when 15 mg As pot^{-1} was applied followed by the lowest 0.00% for all the varieties at control.

4. Conclusions

It is concluded that mesta samu -93 and jute CVE-3 are good cultivar to cultivated in As prone areas due to good biomass production and showed low phytotoxicity to As. On the other hand, kenaf HC-3 is the best phytoremediator to As among the varieties due to high As absorption from the As contaminated medium.

Conflict of Interest

The authors declare that they have no conflict of interest.

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