Cadmium remediation potentials of jute, kenaf and mesta at early growing stage

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Abstract: Cadmium (Cd) remediation potentials of jute (*Corchorus capsularis* L. var. BJC-7370 & CVE-3), kenaf (*Hibiscus cannabinus* L. var. HC-95 & HC-3) and mesta (*Hibiscus sabdariffa* L. var. Samu-93) was studied at early growing stage. The seedlings of kenaf and mesta were normally survived up to 10 mg L^{-1} Cd contaminated hydroponic solution. At the highest level (10 mg L^{-1}) of Cd contamination shoot and root biomass production efficiency of the varieties were kenaf HC-3 > kenaf HC-95 > mesta Samu-93 > jute CVE-3 > jute BJC-7370. Values of bioconcentration factor indicated that the varieties of jute, kenaf and mesta were Cd accumulator. Translocation factor indicated that Cd is slowly translocated from root to shoot in jute, kenaf and mesta plants, and the rate of translocation is decreased with the increasing of Cd concentration in nutrient solution. For kenaf and mesta, concentrations of Cd in root and shoots were increased with the increasing addition of Cd in nutrient solution. Root Cd contents were higher than shoot. At early growing period Cd remediation potentiality of the varieties were HC-3 > kenaf HC-95 > mesta Samu-93 > jute CVE-3 > jute BJC-7370.
Key words: Cadmium, remediation, jute, kenaf, mesta.

Introduction

Cadmium (Cd) is hazardous element because of its high toxicity to organism; it has greater capability of accumulation and retention in the body of organisms including humans (Goel, 2006). There are many ways of releasing Cd in the environment and it exists in the nature mainly in the form of sulphide. Large quantities of cadmium are often found with the ores of Zn and Pb in the form of impurities. The main source of cadmium is cladding industry, where it is used in protective metal coating, nuclear reactor, alkaline cells; and alloy industry. Human contribution of releasing Cd in the environment is 20 times more than the natural release Khopkar (2005). Excess concentrations of some heavy metals such as Cd (II), Cr (VI), Cu II), Ni (II), and Zn (II) in soils have caused the disruption of natural aquatic and terrestrial ecosystems (Meagher, 2000). Cadmium content of industrially contaminated soil was 10.30 mg kg^{-1} whereas its concentration was 0.53 mg kg^{-1} in uncontaminated soil (Nizam, 2014). Cadmium content of soils adjacent to the pharmaceutical, textile, tannery, battery and food and beverage industries and pond, *beel*, river, hand tubewell, shallow tubewell and deep tubewell of Bangladesh ranged from 0.10- 6.60 mg kg^{-1} (Begum, 2006). The mean level of Cd in the soils of China was greater than the Governmental standards and ranged from 0.45 to 1.04 mg kg^{-1} (Wang *et al*., 2001).

The mean Cd concentration, in the soils of arsenic affected area of Murshidabad district of West Bengal in India was 0.37 mg kg^{-1} (Chowdhury *et al*., 2003). Since Cd is a hazardous metal and can not be destroyed, so that it is necessary to remediate. Remediation of Cd by using plants is more convenient than other method of remediation.

Various plant species are used to mitigate metal contaminants. Kenaf (*Hibiscus cannabinus* L.) and corn (*Zea mays* L.) were used for phytoremediation of trace metal contaminated soils and shoot of these two plant varieties grown in Cd contaminated sludge contained 2.49 and 2.1 mg Cd kg^{-1}, respectively (Arbaoui *et al*., 2014). Tree plants, *Delonix regia* and *Thespesia populneoides* and *Leacaena leucocephala* can be successfully used for the phytoremediation of Pb and Cd contaminated soil (Sarwat *et al*., 2013). Corn (*Zea mays* L.) is a potential accumulator plants for phytoremediation of Pb and Cd polluted soils (Amin, 2011). *Phragmites communis, Typha angustifolia* and *Cyperus esculentus* were be used for heavy metals (Cd, Cr, Cu, Mn, Ni and Pb) phytoremediation from metal containing industrial wastewater (Chandra and Yadav, 2011). Kenaf was used for the remediation of artificially Cd contaminated soil (Bada and Raji, 2010).

Early growing stage of remediator plant species in contaminated media is crucial to grow it as phytoremediator in contaminated soil. Early growing stage is the second step for further growth and development of plants in contaminated soil. If the seedlings of a species fail to grow in contaminated medium then the later stages they are fail to establish as a complete plant. Plant species usually have more tolerance in soil containing more toxic metal concentration compared to direct toxic metals containing solution in lab condition, because a lot of diversified factors including microbes are activated in soil medium that are commonly absent in artificial medium in lab condition (Nizam *et al*., 2013). It is considered that plant species which are able to grow in artificial contaminated medium at early growing period they might be able to established a mature plant on contaminated soil. These characteristics are helps to grow a plant species on contaminated soil and reducing toxic metals from the soil. Considering above thinking in mind, the present study was carried out to evaluate the Cd remediation potentialities of jute, kenaf and mesta at early growing stage.

Materials and Methods

Uniform textured seeds of jute (var. BJC-7370 & CVE-3), kenaf (var. HC-3 & HC-95) and mesta (var. Samu-93) were separated from collected seeds and surface sterilized by dipping 95% ethanol for 3 minutes and washed with deionized water to prevent fungal attack. Seedlings were raised in petridish. Five days old seedlings were transplanted in nutrient solution (Full strength Hogland solution). The nutrient solution was prepared following procedure outlined by Hogland and Arnon (1950). Cylindrical shape 3.5 liters size coloured plastic pots were used as solution containing pot. The circular shaped lids of the plastic pots having 20 cm diameter in size were prepared with non-reactive styrofoam sheet to cover the 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 and 0 (control), 1, 5 and 10 mg Cd L^{-1} were applied maintaining 3 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 5.5. The plants were growing for 25 days. After 25 days of planting, plants were harvested. 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. After that, data were recorded. Percent seedling survivability, root & shoot lengths (cm) were recorded in the day of harvesting. Dry weights of shoots and roots (g pot^{-1}) were recorded after air drying followed by oven dried at 75^0C for 48 hours. For the determination of Cd, finely ground samples were digested following procedure outlined by Cai *et al*. (2000) and Cd contents from the extracts were directly determined with atomic absorption spectrophotometer (Model: Shimadzu AA 7000) at the wavelength of 228.8 nm following method described by Sparks (1996) and Singh *et al.* (1999). The bioconcentration factor or bioaccumulation factor (BCF or BAF) and translocation factor (TF) were calculated following formulae outlined by Ho *et al.* (2008). Statistical analyses were done following method as described by Gomez and Gomez (1984).

Results and Discussion

Seedling survibility: The application of Cd up to 10 mg L^{-1} had no significant effect on the seedling survibility of varieties of kenaf and mesta (Table1). Cadmium showed significant effect only on the seedlings of jute BJC-7370 and CVE-3 varieties. The degeneration of all seedlings of jute BJC-7370 and CVE-3 varieties at 10 mg Cd L^{-1} indicated their less Cd tolerant potentiality. The seedlings of this variety tolerated only up to 5 mg Cd L^{-1} in solution culture. Kenaf and mesta varieties showed maximum seedling survibility to Cd toxicity. The degeneration of all the seedlings of jute BJC-7370 and CVE-3 varieties with higher concentration of Cd was similar to the findings of Skorzynska- Polit and Baszynski (1997), who reported that the plants of *Phaseolus coccineus* L. affected by the toxicity of Cd.

Table 1. Effects of Cd on the seedling survibility of different varieties of jute, kenaf and mesta

Cd levels	%Seedling survibility				
(mg L^{-1})	Jute (BJC-7370)	Jute (CVE-3)	Kenaf (HC-95)	Kenaf (HC-3)	Mesta (Samu-93)
0	41.00a	78.33a	100.00	100.00	100.00
1	31.67b	50.00b	100.00	100.00	100.00
5	26.67c	40.00c	100.00	100.00	100.00
10	0.00d	0.00d	100.00	100.00	100.00
Range	0.00 - 41.00	0.00 - 78.33	100.00 -100.00	100.00 -100.00	100.00 -100.00
Mean	33.11	56.11	100.00	100.00	100.00
SE±	2.11	5.04	0.00	0.00	0.00
LSD	4.92	3.84	0.00	0.00	0.00
Sig. levels	*	**	NS	NS	NS

*= Significant at 5 % level of probability, ** = 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.

Table 2. Effects of Cd on the shoot length of different varieties of jute, kenaf and mesta

Cd levels	Shoot length (cm)				
(mg L^{-1})	Jute (BJC-7370)	Jute (CVE-3)	Kenaf (HC-95)	Kenaf (HC-3)	Mesta(Samu-93)
0	27.67a	41.50a	42.97a	42.90a	35.83a
1	10.23b	16.50b	22.73b	29.03b	25.83b
5	7.50c	7.50c	14.07c	25.07c	15.80c
10	0.00d	0.00d	10.57d	18.38d	14.17c
Range	0.00 - 27.67	0.00 - 41.50	10.57- 42.97	18.38 - 42.90	14.17-35.83
Mean	15.13	21.83	22.58	28.85	22.91
SE±	2.76	4.41	3.80	2.73	2.65
LSD	1.68	1.15	1.25	1.69	1.70
Sig. levels	**	**	**	**	**

** = 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.

Shoot length of plants: The shoot lengths of plants significantly decreased with the increasing concentrations of Cd in nutrient solution at the levels of 1 -10 mg Cd L^{-1}. The highest shoot lengths 42.97, 42.90, 41.50, 35.83 and 27.67 cm were recorded from HC-95, kenaf HC-3, jute CVE-3, mesta Samu-93, and jute BJC-7370, respectively at control. The lowest 0.00, 0.00, 10.57, 14.17 and 18.38 cm were in jute BJC-7370, jute CVE-3, kenaf HC-95, mesta Samu-93 and kenaf HC-3, respectively at 10 mg Cd L^{-1} (Table 2). Actually, at 10 mg Cd L^{-1} all the seedlings of jute BJC-7370 & CVE-3 were degenerated just after few days of planting. The varieties of kenaf and mesta showed gradual decreasing trend but drastic decreasing trends were found in jute variety BJC-7370 and CVE-3 from control to 10 mg Cd L^{-1} (Table 2). The retardation of plants growth might be due to the toxic effect of Cd. The reduction of shoot length of present study also supported by Bindu *et al.* (2010), they found significant decrease in the relative growth, biomass productivity and total chlorophyll content in the taro plant (*Colocasia esculenta*) with an increase in Cd concentration and exposure time. Effect of Cd on the growth of alfalfa plants were studied by Peralta *et al.* (2000) and observed that, Cd (II) at a 10 ppm- dose significantly reduced the shoot growth and when the concentration of was increased to 20 ppm, shoot growth was reduced and the size of shoot diminished by 63.0% and 40 ppm concentration showed lethal effects and was supported by Oncel *et al.* (2000). The decreasing trend of shoot growth of plants in the present study also consented with findings of (Midrar-Ul- Haq *et al.*, 2006), According to them the higher concentrations of Cd reduced growth and chlorophyll content of four vegetable species: *Pertoselinum crispum, Beta vulgaris, Porophyllum ruderale and Phaseolus vulgaris*, but they did not mentioned the concentrations in their report.

Root length of plants: The increasing levels (1-10 mg Cd L^-1) of Cd in the nutrient solution significantly reduced the root length of plants at early growing stage. For all the varieties, maximum root lengths were recorded at control treatment. The highest root length 34.40, 31.87, 29.30, 16.96 and 12.67 cm were recorded in HC-95, kenaf HC-3, mesta Samu-93, jute CVE-3 and jute BJC-7370, respectively at control and the lowest 0.00, 0.00, 5.23, 6.63 and 10.77 cm were in the variety of jute BJC-7370, jute CVE-3, mesta Samu-93, kenaf HC-95 and kenaf HC-3, respectively at 10 mg Cd L^{-1} (Table 3).

Table 3. Effects of Cd on the root length of different varieties of jute, kenaf and mesta

Cd levels	Root length (cm)				
(mg L^{-1})	Jute (BJC-7370)	Jute (CVE-3)	Kenaf (HC-95)	Kenaf (HC-3)	Mesta (Samu-93)
0	12.67a	16.96a	34.40a	31.87a	29.30a
1	10.30b	14.23b	28.47b	26.67b	22.03b
5	7.43c	12.78c	19.83c	20.17c	12.58c
10	0.00d	0.00d	6.63d	10.77d	5.23d
Range	0.00– 12.67	0.00- 16.96	6.63-34.40	10.77- 31.87	5.23d-29.30
Min	6.80	12.50	4.90	9.80	4.50
Mean	10.13	14.66	22.33	22.37	17.29
SE±	0.71	0.55	3.17	2.42	2.77
LSD	1.27	0.73	1.83	2.10	1.18
Sig. levels	**	**	**	**	**

** = 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.

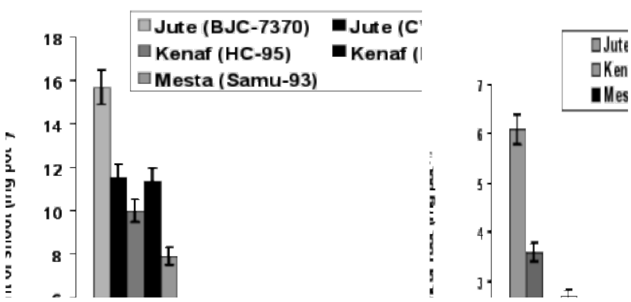

Fig. 1. Effects of increased levels of Cd on the dry weight of shoot (a) and root (b) of jute, kenaf and mesta dry at early growing stage. Bars indicate SE±.

The varieties of kenaf and mesta showed gradual decreasing trend but drastic decreasing trends were found in jute variety BJC-7370 and CVE-3 from control to 10 mg Cd L^{-1} (Table 3). The root growth was comparatively more adversely affected than that of shoot, such findings are in line with Al-Yemeni (2001), as stated that seedling growth was more sensitive to Cd and radicals were more affected than shoot. Present study showed that the root growth of jute variety BJC-7370 and CVE-3 were completely stopped at 10 mg Cd L^{-1}. It was similar to the results o of Peralta *et al.* (2000), they studied the effect of Cd on the growth of alfalfa plants and observed that Cd (II) at a 10 ppm-dose reduced the root size by 6.0% as compared to control root elongation and 40 ppm concentration showed lethal effects. The work of Oncel *et al.,* (2000) also supported it.

Dry weight of shoot: The dry weights also reduced with increased concentrations (1 -10 mg Cd L^{-1}) of Cd. For all the varieties, maximum dry weights were measured at control treatment. The highest dry weights 15.67,11.55,11.39, 10 and 7.91 g pot^{-1} were recorded from jute BJC-7370, jute CVE-3, kenaf HC-3, kenaf HC-95, and mesta Samu-93, respectively at control.

The lowest 0.00, 0.00, 1.35, 1.59 and 3.23 g pot^{-1} were in the variety of jute BJC-7370, jute CVE-3, mesta Samu-93, kenaf HC-95 and kenaf HC-3, respectively at 10 mg Cd L^{-1} [Fig. 1(a)] . The dry weights of shoot were significantly and drastically decreased with increased doses of Cd in the solution at the levels of 1 -10 mg Cd L^{-1} [Fig. 1(a)]. In case of jute BJC-7370 & CVE-3 statistically no variations were found in dry weight of shoot at 1 and 5 mg Cd L^{-1}. The decreasing tendency of dry biomass production might be due to the reduction of seedlings growth because of toxic effect of Cd. The reduction of chlorophyll of content reduced the photosynthetic ability of plants tends to decreased the biomass accumulation. Higher concentrations of Cd reduced growth and chlorophyll content of four vegetable species: *Pertoselinum crispum, Beta vulgaris, Porophyllum ruderale and Phaseolus vulgaris* (Midrar-Ul- Haq *et al.*, 2006). But they did not mentioned the concentrations in the abstract. Maiti *et al.* (2002) reported that Cd (at 3 and 10 ppm) affected germination, seedling growth and reduced chlorophyll contents of the vegetables. Among the studied varieties, due to the degeneration of seedlings the dry weights of shoot of jute varieties BJC-7370 and CVE-3 were turned in to zero at 10 mg Cd L^{-1}, which indicates their less tolerance to comparatively higher concentration of Cd in the growing medium. Such types of seedlings degeneration was described by Peralta *et al*. (2000), they stated that Cd (II) at 40 ppm concentration showed lethal effects over the alfalfa (*Medicago sativa*) plants and the data corresponded with those of Oncel *et al*. (2000). On the other hand comparatively higher dry biomass production ability of kenaf and mesta varieties showed their more tolerance to Cd contaminated medium than jute varieties.

Dry weight of root: The dry weights of root at early growing stage were decreased significantly by the application of increased concentrations (1 -10 mg Cd L^{-1}) of Cd in the nutrient solution. All the varieties produced maximum dry biomass at control treatment.

The highest dry weights 6.10, 3.59, 2.70, 2.46 and 1.19 g pot^{-1} were recorded from jute BJC-7370, jute CVE-3, kenaf HC-3, kenaf HC-95, and mesta Samu-93, respectively at control and the lowest 0.00, 0.00, 0.24, 0.68 and 0.72 g pot^{-1} were in the variety of jute BJC-7370, jute CVE-3, mesta Samu-93, kenaf HC-3 and kenaf HC-95, respectively at 10 mg Cd L^{-1} [Fig.1(b)]. Low photosynthetic ability due to the toxic effect of Cd would be responsible for the decreasing tendency of dry biomass in root and was supported by the results of Maiti *et al*. (2002), because they concurred that Cd (at 3 and 10 ppm) affected germination, seedling growth and reduced chlorophyll contents of the vegetables. Among the studied varieties, due to the degeneration of seedlings the fresh weights of root of jute varieties BJC-7370 and CVE-3 were turned in to zero at 10 mg Cd L^{-1}, which indicated their less potency to comparatively higher concentration of Cd in the growing medium [Fig. 1 (b)]. Such types of seedlings degeneration was described by Peralta *et al*. (2000), they stated that Cd (II) at 40 ppm concentration showed lethal effects over the alfalfa (*Medicago sativa*) plants and the data corresponded with those of Oncel *et al*. (2000). On the other hand, comparatively higher fresh weight of root showed the more tolerance of kenaf and mesta varieties to Cd contaminated medium than that of jute varieties.

Bioconcentration factors (BCF) of Cd for root and shoot of jute, kenaf and mesta: The bioconcentration 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. It is a useful parameter to evaluate the potential of a plant in accumulating metals and the values were calculated on dry weight basis. The bioconcentration factor of each plant variety was calculated separately against different levels of Cd in the nutrient solution.

Table 4. Bioconcentration Factors (BCF) of Cd for root and shoot of jute, kenaf and mesta

Cd levels of solution (mg L^{-1})	Bioconcentration Factors (BCF) for root					Bioconcentration 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	0.00c	0.00b	0.00d	0.00d	0.00d	0.00c	0.00c	0.00d	0.00d	0.00d
1	992.30a	312.84a	661.10a	597.50a	916.80a	217.08a	204.61a	251.12a	201.13a	162.17a
5	497.08b	311.52a	420.34b	410.41b	381.08b	76.65b	63.33b	69.26b	84.61b	52.04b
10	#	#	243.68c	262.69c	296.42c	#	#	40.15c	44.84c	38.02c
Range	0.00 - 992.30	0.00 - 312.84	0.00 - 661.10	0.00 - 597.50	0.00 - 916.80	0.00 - 217.08	0.00 - 204.61	0.00 - 251.12	0.00 - 201.13	0.00 - 162.17
Mean	496.46	208.12	331.28	317.65	398.58	97.91	89.31	90.13	82.65	63.06
SE±	124.09	45.17	73.19	65.94	99.98	27.81	26.27	29.05	22.52	18.21
CV (%)	25.00	21.70	22.09	20.76	25.09	28.41	29.41	32.23	27.25	28.88
LSD	16.90	14.65	26.08	13.60	27.46	18.48	9.30	8.04	3.00	4.44
Sig. levels	**	**	**	**	**	**	**	**	**	**

= Plants died before harvest and ** = 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.

Table 5. Translocation Factor (TF) of Cd from root to shoot for jute, kenaf and mesta

Cd 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	0.00c	0.00c	0.00c	0.00d	0.00c
1	0.22a	0.65a	0.38a	0.34a	0.18a
5	0.16b	0.20b	0.17b	0.21b	0.14b
10	#	#	0.16b	0.17c	0.13b
Range	0.00 - 0.22	0.00 - 0.65	0.00 - 0.38	0.00 - 0.34	0.00 - 0.18
Mean	0.12	0.29	0.18	0.18	0.11
SE±	0.03	0.08	0.04	0.04	0.02
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.

Both for root and shoot the bioconcentration factors of each plant varieties were decreased significantly with the increased of Cd concentration in the growing solution. The BCF values of roots were higher than that of roots. Bioconcentration factors >1 indicate the plant is an "accumulator", < 1 indicate the plant is an "excluder"

Baker (1981). In the present study, the BCF values of roots and shoots of all the varieties were found within the range of 243.68 - 992.30 and 38.02-243.68, respectively (Table 4). Therefore, it can be suggested that all the studied varieties of jute, kenaf and mesta are accumulators of Cd and have the Cd remediation potentiality from Cd contaminated medium.

Translocation factor (TF) of Cd 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 inthe 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 translocation factor from root to shoot decreased significantly with increasing of applied Cd at a levels of 1–10 mg Cd L^{-1} in the growing medium. The highest (0.65) TF was calculated from the variety of jute CVE-3 followed by 0.38 in kenaf HC-95 at 1 mg Cd L^{-1}. The lower TF 0.13 in mesta Samu-93 with the application of 10 mg Cd L^{-1} followed by the lowest (0.00) at control for all the varieties (Table 5). TF value < 1 indicates slow translocation, in the present study the. TF values for all the varieties were <1 indicated that in hydroponic solution Cd was slowly translocated from root to shoot (Table 5). Similar had been the findings of Ramesh *et al*. (2010), they observed average TF 0.82 for Cd in case of root to shoot when experimented with 11 plant species in a contaminated soil.

Effects of applied Cd on the concentrations of Cd in shoot of different varieties of jute, kenaf and mesta: At early growing stage the concentrations of Cd in shoot of jute, kenaf and mesta plants were positively influenced by the application of Cd in the nutrient solution with increasing levels (1 -10 mg Cd L^{-1}). At the highest Cd level (10 mg Cd L^{-1}) in the solution, Cd concentrations in shoot were 448.42, 401.50 and 380.21 mg kg^{-1} in kenaf HC-3, kenaf HC-95 and mesta Samu-93, respectively. For jute varieties, BJC-7370 & CVE-3 the respective highest concentrations 383.25 and 316.63 mg Cd kg^{-1} were detected in shoot at 5 mg Cd L^{-1} treatment. On the other hand, the lowest (0.00 mg kg^{-1}) Cd concentrations were detected at control for all the varieties. In case of kenaf HC-3, kenaf HC-95 and mesta Samu-93 gradual and significant variations were observed in increasing concentrations of Cd in shoot with the increase of Cd in nutrient solution [Fig. 2 (a)]. At 10 mg Cd L^{-1} all the seedlings of jute BJC-7370 and CVE-3 were fall into death within a few days after planting. The less tolerability of Cd toxicity of the seedlings of these two varieties might be the reasons for death. Al-Yemeni (2001) stated that the heavy metal (Cd) content of analysed *Vigna ambacensis* seedling parts increased with the increase (0.05 – 50 mM) of Cd concentration to a higher extent in the radicals than in the shoot. Such types of increasing trend also studied by Sridhar *et al*. (2005), they observed that the accumulation of Cd and Zn in all parts of the Indian mustard (*Brassica juncea*) plant increased significantly with an increase in applied metal concentration. The Cd content in shoot of the kenaf and mesta varieties indicates their Cd accumulating capability from the contaminated medium. In the present study, the Cd content in shoot of the jute, kenaf and mesta varieties indicated their Cd accumulating capability from the contaminated medium.

Plants which are able to accumulate more than 100 ppm Cd, are considered as hyperaccumulators (Wei *et al*., 2004). According to their view, the varieties of jute, kenaf and mesta might be considered as hyperaccumulator of Cd.

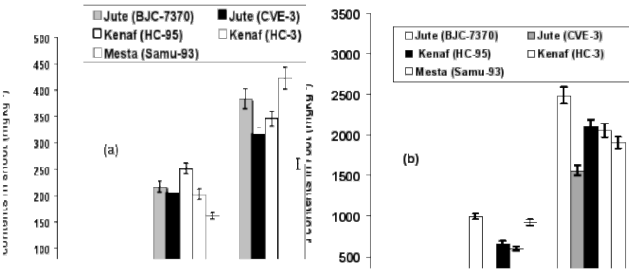

Fig. 2. Effects of increased levels of Cd on the Cd content in the shoot (a) and root (b) of jute, kenaf and mesta at early growing stage. Bars indicate SE±.

Effects of applied Cd on the concentrations of Cd in root of different varieties of jute, kenaf and mesta: The concentrations of Cd in root of jute, kenaf and mesta plants were increased by the application of Cd in the nutrient solution with increasing levels (1 -10 mg Cd L^{-1}). Fig. 13. & Appendix 28 reflected that, the concentrations of Cd were more in root than shoot. In case of kenaf HC-3, kenaf HC-95 and mesta Samu-93 rapid and significant variations were observed in increasing concentrations of Cd in root with the increase of Cd in nutrient solution. At the highest level (10 mg Cd L^{-1}) of Cd in solution, Cd concentrations in root were 2964.17, 2627.03 and 2436.78 mg kg^{-1} in mesta Samu-93, kenaf HC-3 and kenaf HC-95, respectively. The varieties BJC-7370 and CVE-3 showed the highest concentrations in root 2485.38 and 1557.61 mg Cd kg^{-1}, respectively at 5 mg Cd L^{-1}. The seedlings of jute BJC-7370 and CVE-3 were fall into death at 10 mg Cd L^{-1}. The less tolerability of Cd toxicity of the seedlings of these two varieties might be the reasons for death. On the other hand, the lowest (0.00 mg kg^{-1}) Cd concentrations were detected at control for all the varieties [Fig. 2(b)]. With the increasing (0.05 – 50 mM) of Cd concentration, higher amount of Cd accumulation in radicals (roots) of seedlings of *Vigna ambacensis* also found by Al-Yemeni (2001). Plants such as *Eichhornia crassipes* have shown potential to concentrate more than 6000 ppm of Cd and Pb in the whole plant, and more than 8000 mg L^{-1} of copper when grown with 5 mg L^{-1} of these heavy metals (Gardea-Torresdey *et al*., 2005). In the present study, the Cd content in root of the kenaf and mesta varieties indicates their Cd accumulating capability from the contaminated medium.

At early growing stage, the varieties of jute, kenaf and mesta were found potentials to remediate Cd from contaminated medium. Among the varieties the degrees of Cd accumulating potentialities were HC-3 > kenaf HC-95 > mesta Samu-93 > jute CVE-3 > jute BJC-7370. The findings of the present study would be help to grow these jute, kenaf and mesta varieties in Cd contaminated soil for the remediation of Cd.

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