Early Stage Responses of Jute, Kenaf and Mesta in Arsenic Contamination Soil

ABSTRACT

A pot experiment conducted at BJRI (Bangladesh Jute Research Institute) in Dhaka from September to December 2023 assessed the responses of Jute, Kenaf, and Mesta to arsenic-contaminated soil. Arsenic (As) poses environmental hazards and toxicity. BJRI Deshi Pat 7, BJRI Kenaf-2 (HC-95) and BJRI Mesta-2 (VM-1) were grown for 42 days in 36 pots with four treatment levels of As (0 ml/L, 10 ml/L, 20 ml/L, and 30 ml/L) with four replications each. Results indicate Kenaf and Mesta demonstrated high potential to tolerate As toxicity with no significant effects on survivability. However, root length, shoot length, dry weight, fresh weight and bio-concentration factor decreased with increasing As treatment levels. The translocation factor indicated slow translocation from root to shoot, increasing with As concentration. BJRI Kenaf-2 (HC-95) accumulated the highest As (16.5 ml/L) at 30 ml/L As. BJRI Deshi Pat 7 and BJRI Mesta-2 (VM-1) showed good biomass production and low phytotoxicity to As making them suitable for cultivation in As-prone areas. BJRI Kenaf-2 (HC-95) exhibited the highest response to As at early growth stages, with the order of As absorption and tolerance potentiality being BJRI Kenaf-2 (HC-95) > BJRI Mesta-2 (VM-1) >BJRI Deshi Pat 7. These varieties are recommended for cultivation in As-contaminated soil.

Keywords: As-contaminated soil, irrigation, environmental hazards, metabolic processes

1. INTRODUCTION

Arsenic, a metalloid, has long been infamous for its historical association with poisonings, evoking sinister connotations. Arsenic contamination has escalated into a significant global environmental concern, jeopardizing not only our nation but the entire world. Arsenic poisoning poses a significant and grave challenge in Bangladesh, severely impacting the well-being of its population. It stems from the utilization of arsenic-laden groundwater for drinking, domestic, and irrigation purposes. Arsenic can infiltrate the human body through the consumption of groundwater contaminated with this toxic element and through the ingestion of foods cultivated in fields irrigated with arsenic-contaminated water. Over time, arsenic accumulates within the body, leading to the development of various debilitating health conditions and diseases in affected individuals [14,15]. At higher concentrations, arsenic has been documented to disrupt metabolic processes and hinder plant growth, occasionally resulting in fatality (Nahar et al., 2022). Bangladesh is currently grappling with a significant issue of elevated arsenic levels in groundwater. Roughly 27% of shallow tube wells (STWs) and 1% of deep tube wells (DTWs) in 270 upazillas (sub-districts) across the country are contaminated with arsenic levels exceeding Bangladesh's standards. Additionally, approximately 46% of STWs exceed the World Health Organization (WHO) standards for arsenic concentration (Howard *et. al*., 2006). In addition to domestic use, substantial volumes of water from shallow aquifers are employed for irrigation purposes during the dry Season (Nahar et al., 2022).

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). 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.

Arsenic naturally exists in soil and minerals, and it can enter the environment through processes such as wind-blown dust and water run-off. The atmosphere contains arsenic from multiple origins: approximately 3,000 tons annually from volcanic emissions and approximately 20,000 tons annually from microorganisms releasing volatile methyl arsines. However, human activities are the predominant source, contributing a significant 80,000 tons of arsenic per year through the combustion of fossil fuels (Uddin et al., 2020). The presence of both organic and inorganic forms of arsenic (As) in the environment poses a significant risk to biological systems. While certain plant species can effectively absorb and store arsenic from their surrounding nutrient solutions or soil, it's essential to note that all plants possess the capability to accumulate "essential" metals such as calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), and zinc (Zn) from the soil solution. This inherent ability also extends to the accumulation of other "non-essential" metals, including aluminum (Al), cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb), palladium (Pd), platinum (Pt), antimony (Sb), tellurium (Te), thallium (Tl), and uranium (U), despite the fact that these metals lack any discernible biological function (Uddin et al., 2020). In a study conducted by (Islam et al. in 2013), it was observed that certain plant species, namely *Eichhornia crassipes*, *Echinochloa crusgalli,* and *Monochoria hastata,* exhibited robust survival when cultivated in soils contaminated with artificial As at concentrations of 30, 50, 70, and 100 mg As per kilogram (kg-1), as well as naturally As-contaminated soils with concentrations of 22.00, 47.3, and 116.00 mg As per kilogram (kg-1). Moreover, specific fibrous crop seeds demonstrated the ability to germinate even in the presence of 50 mg As per liter (L-1) of arsenic. However, it's important to note that the rate of germination and the growth of both roots and shoots were adversely affected as the arsenic concentrations increased

(Nizam et al., 2020). Researchers employ various methods to assess the arsenic (As) tolerance and accumulation capabilities of different plant species. These methods often involve either germinating plant seeds in a contaminated medium or cultivating plants in soil and nutrient solutions that contain As. Many studies, including "Arsenic Tolerance and Assimilation Potentiality of Jute, Kenaf, and Mesta at the Early Growing Stage focus on non-crop species for phytoremediation, which may not be practical for farmers due to the lack of income generated from cultivating these non-edible species. Consequently, there is growing interest in exploring the potential of non-edible crop varieties, such as different fibrous crops, for the remediation, absorption, or assimilation of toxic contaminants like arsenic in field-level settings. This approach aims to not only address environmental contamination but also increase farmers' income by making it more economically viable. To this end, I aim to evaluate the arsenic tolerance and absorption potential of various fibrous crop varieties, specifically jute, kenaf, and mesta, by subjecting them to hydroponic nutrient solutions containing different levels of arsenic.

2. MATERIALS AND METHODS

The experiment was conducted between September to December 2023. It was carried out in the central Research field of Bangladesh Jute Research Institute (BJRI), Dhaka. Throughout the experiment's time frame, the average maximum temperature was 32 °C and the average minimum temperature was 15 °C. The materials are BJRI Kenaf-2 (HC-95), BJRI Deshi Pat 7, BJRI Mesta-2 (VM-1). In the experiment, various doses of arsenic (As) were applied to the soil at rates of 0, 10, 20, and 30 ml/L (Milliliters per liter) of soil. The soil's initial arsenic content was 4.2. ml/L. Sodium meta-arsenite ($NaAsO_2$) was used as the source of arsenic, and all experiments were conducted in triplicate. The 36 pots were randomly arranged in the BJRI Research Field, following a completely randomized design (CRD) approach. Each pot was filled with 8 kg of air-dried soil, and the arsenic salt was applied to the pots using water based on the specified treatments. The experiment was done in 36 pots with the ideal size (12 inch or 30.48cm) of plastic pot. Among the 36 pots, soil pH was found in different parameter. pH value 5.8 was found in 2 pots, pH value 6.1 was found in 4 pots, pH value 6.2 was found in 6 pots, pH value 6.4 was found in 10 pots, pH value 6.5 was found in 14 pots according to the pH meter.

Among the 36 pots, soil moisture was found in different parameter according to the measurement method. The ideal soil moisture content for crop cultivation is between 20%– 60%. By using Soil Moisture Probe, it was calculated. The moisture content was found nearly 35%, 40%, 41%, 47%, 60% in 5 pots, 7 pots, 6 pots, 10 pots, 8 pots respectively. After preparing the Sodium–arsenite solution, it was applied on all the 36 pots. All the 36 pots were distributed among BJRI Kenaf-2 (HC-95), BJRI Deshi Pat 7, BJRI Mesta-2 (VM-1) by 12 pots, 12 pots, and 12 pots, respectively. Four treatments (T_0=0, T_1=10ml, T_2=20ml, T_3=30ml) were done with 3 replications of each pot on the V_1, V_2, and V_3 and mixed well with the soil. For each variety 180ml Sodium–arsenite solution was used on the soil and for all the three varieties 540ml solution was used in total amount. Before Sowing Seeds, seeds were dipped in 95% ethanol for a duration of 3 minutes as ethanol is an important compound that promotes numerous plant development processes including seed germination and seedling establishment. Seed germination increases due to the uses of 95% ethanol solution. The 3 varieties BJRI Kenaf-2 (HC-95), BJRI Deshi Pat 7, BJRI Mesta-2 (VM-1) were distributed into 36 pots and 12 pots for each variety. For each variety, 25 seeds were used for each pot. For the better growth and development of the plants, several intercultural activities such as thinning, irrigation, weeding, etc. were implemented. The plants in the pots were harvested at the 45th days after sowing. It was done manually by uprooting the plants from each pot very carefully. Data was recorded from each pot's plant with following parameters like Plant Fresh Weight, Shoot length, Root length, Dry weight, Bio-concentration factor (BCF) and Translocation factor (TF).

3.RESULTS AND DISCUSSION

3.1 Soil Properties

The soil sample that was collected for the experiment was analyzed in the laboratory before setup the experiment to know the nutrient and some elements presence in the soil. The values of elements of the initial analysis of the soil are presented in the Table 1.

Table 1: Some physical, physio-chemical and chemical properties of soil sample.

Properties	Soil values
pH	6.5-7.5
Sand	56%
Silt	24%
Clay	20%
Texture	Sandy loam
Moisture content	8.64%
Organic carbon	0.7%
Organic matter	1.20%
Available-N	504mg/kg
Available-P	30mg/kg
Available-K	63.33mg/kg
Arsenic	3.2mg/kg
Arsenic (water soluble)	Below detection level
Iron	1.6%
Manganese	372mg/kg

3.2 Seedling Survivability

The application of As up to 20 ml/L had no significant effect on the seedling survivability of BJRI Kenaf-2 (HC-95), BJRI Mesta-2(VM-1) but in BJRI Deshi Pat -7 some plants died. But the application of As range between 20ml/L to 30 ml/L has great effect on BJRI Deshi Pat 7 many seedlings were died and it indicated that Jute has less As tolerant potentiality. The seedling survivability in total 36 pots is presented in Table 2.

Table 2: Effects of As on the seedling survivability of Jute, Kenaf and Mesta varieties at early growing stage

As levels(ml/L)	% Seedling survivability		
	BJRI Kenaf-2 (HC-95)	BJRI Deshi Pat 7 (BJC-2142)	BJRI Mesta-2 (VM 1)
0	100.00	100.00	100.00
	100.00	100.00	100.00
	100.00	100.00	100.00
10	100.00	100.00	100.00
	100.00	100.00	100.00
	100.00	100.00	100.00
20	100.00	92.00a	100.00
	100.00	92.00a	100.00
	100.00	84.00b	100.00
30	100.00	80.00c	100.00
	100.00	72.00d	100.00
	100.00	60.00e	100.00
Range	100.00-100.00	60.00-100.00	100.00-100.00
Mean	100.00	90.00	100.00
SE	00.00		00.00
Sig. levels	Not significant		Not significant

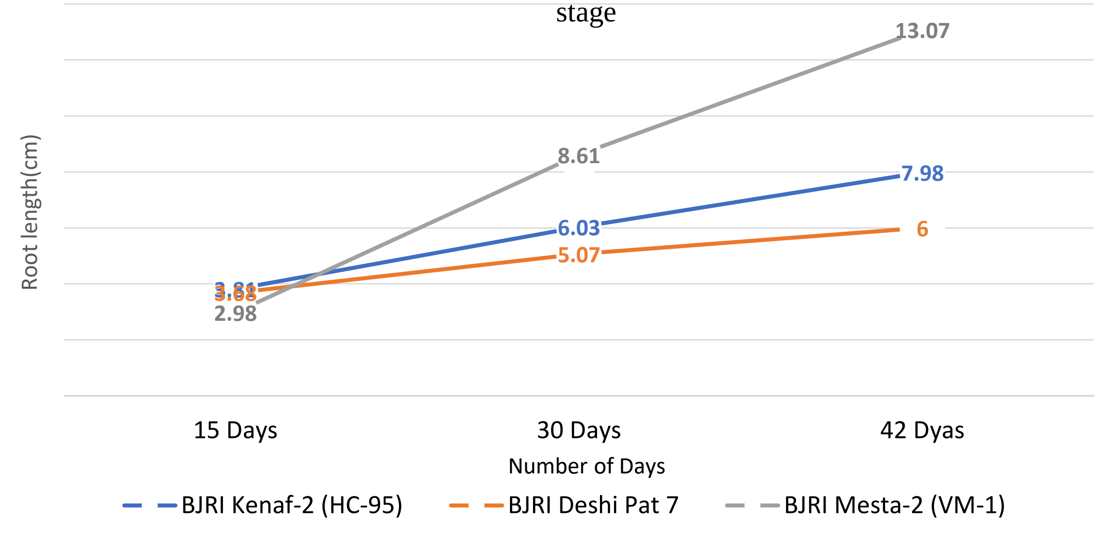
3.3 Root Length (at 15,30,42 days)

At 15 days, root length significantly decreased when plants were exposed to arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat 7 showed less reduction, while BJRI Mesta-2 (VM-1) had a higher reduction in root length. For BJRI Kenaf-2 (HC-95), root length ranged from 6.3cm (0 ml/L arsenic) to 2.0cm (30 ml/L arsenic). BJRI Deshi Pat 7 showed root lengths from 5.9cm (0 ml/L arsenic) to 2.1cm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) exhibited root lengths from 5.0cm (10 ml/L arsenic) to 2.0cm (30 ml/L arsenic). At day 30, root length significantly decreased with arsenic solutions at 20-30 ml/L, except for BJRI Mesta-2 (VM-1) which showed an increase. BJRI Deshi Pat-7 exhibited a higher decreasing trend, while BJRI Mesta-2 (VM-1) showed a lesser decrease. For BJRI Kenaf-2 (HC-95), root length ranged from 8.7cm (0 ml/L arsenic) to 3.6cm (30 ml/L arsenic). BJRI Deshi Pat-7 showed root lengths from 6.55cm (0 ml/L arsenic) to 3.2cm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) exhibited root lengths from 12.8cm (30 ml/L arsenic) to 6cm (10 ml/L arsenic). At day 42, root length significantly decreased with arsenic solutions at 20-30 ml/L, except for

BJRI Mesta-2 (VM-1) which showed an increase. BJRI Deshi Pat-7 exhibited a higher decreasing trend, while BJRI Mesta-2 (VM-1) showed a lesser decrease. For BJRI Kenaf-2 (HC-95), root length ranged from 10cm (0 ml/L arsenic) to 5.5cm (30 ml/L arsenic). BJRI Deshi Pat-7 showed root lengths from 7.2cm (0 ml/L arsenic) to 4.1cm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) exhibited root lengths from 19cm (20 ml/L arsenic) to 8cm (10 ml/L arsenic).

Comparison between root length among different varieties at different periods:

Figure-1: effect of as on root length of different varieties at early growing stage

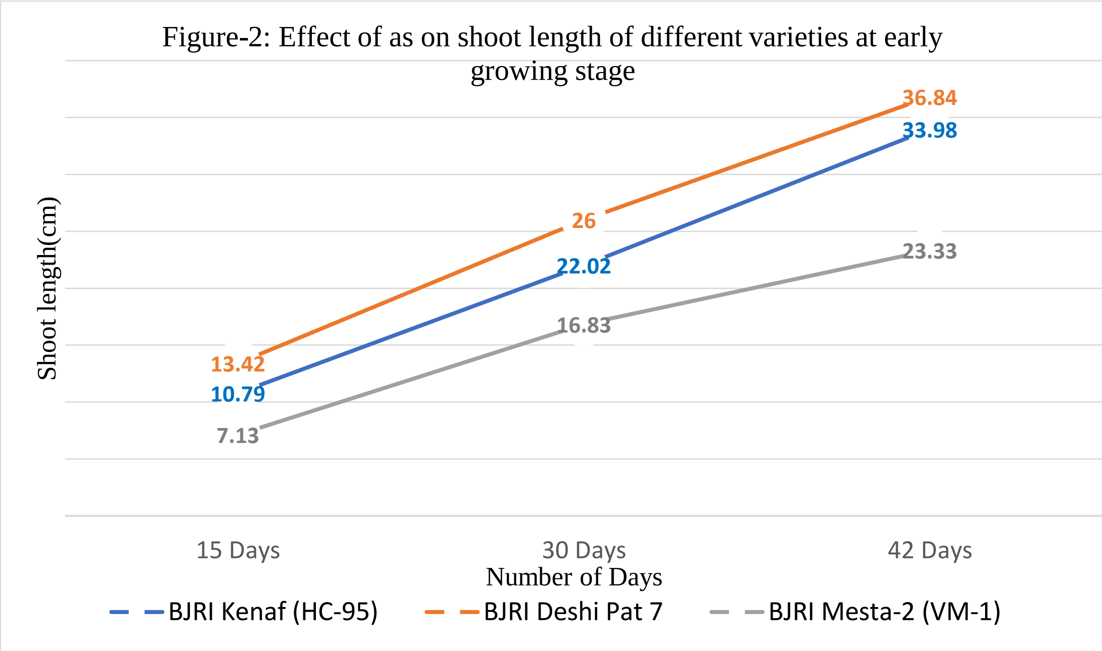


From the above graph, after the final harvesting at the 42 days, the order of root length growth on different varieties at early growing stage in As contaminated soil is BJRI Mesta-2 (VM-1) >BJRI Kenaf-2 (HC-95) > BJRI Deshi Pat 7. In the As contaminated soil, BJRI Mesta-2 (VM-1) can show the highest root length among the other varieties.

3.4 Shoot length (at 15,30,42 days)

At day 15, shoot length significantly decreased with arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat-7 showed a lesser decreasing trend, while BJRI Mesta-2 (VM-1) exhibited a higher decrease. The highest shoot length for BJRI Kenaf-2 (HC-95) was 14.5cm (0 ml/L arsenic) and lowest was 5.2cm (30 ml/L arsenic). BJRI Deshi Pat-7 had a range from 18.1cm (0 ml/L arsenic) to 6.9cm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) showed shoot lengths from 9.0cm (0 ml/L and 10 ml/L arsenic) to 4.1cm (30 ml/L arsenic). At day 30, shoot length continued to decrease significantly with arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat-7 exhibited a lesser decreasing trend, whereas BJRI Mesta-2 (VM-1) showed a higher decrease. The highest shoot length for BJRI Kenaf-2 (HC-95) was 30.64cm (0 ml/L arsenic) and lowest was 11.2cm (30 ml/L arsenic). BJRI Deshi Pat-7 ranged from 34.87cm (0 ml/L arsenic) to 14.67cm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) showed shoot lengths from 24.55cm (0 ml/L arsenic) to 10.6cm (30 ml/L arsenic). At day 42, shoot length significantly decreased with arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat-7 exhibited a lesser decreasing trend, while BJRI Mesta-2 (VM-1) showed a higher decrease. The highest shoot length for BJRI Kenaf-2 (HC-95) was 48cm (0 ml/L arsenic) and lowest was 16cm (30 ml/L arsenic). BJRI Deshi Pat-7 ranged from 52cm (0 ml/L arsenic) to 19cm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) showed shoot lengths from 32cm (0 ml/L arsenic) to 14cm (30 ml/L arsenic).

Comparison between shoot length among different varieties at different periods:



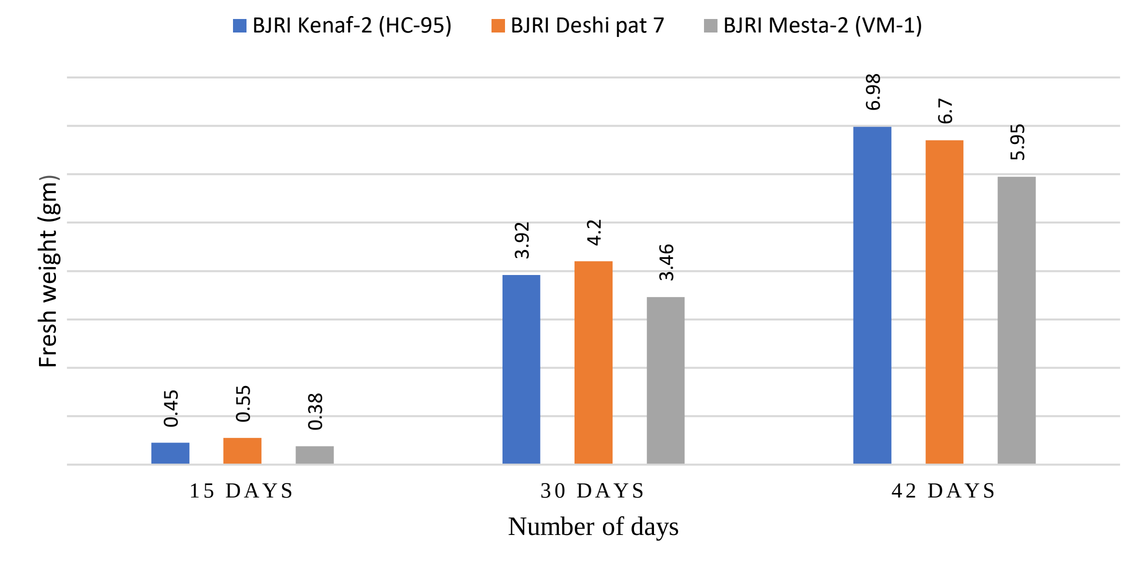
From the above graph, after the final harvesting at the 42 days, the order of shoot length growth on different varieties at early growing stage in As contaminated soil is BJRI Deshi Pat 7 > BJRI Kenaf-2 (HC-95) > BJRI Mesta-2 (VM-1). In the As contaminated soil, BJRI Deshi Pat 7 can show the highest shoot length among the other varieties.

3.5. Fresh weight (at 15, 30,42 days)

At day 15, fresh weight significantly decreased with arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat-7 showed a lesser decreasing trend, while BJRI Mesta-2 (VM-1) exhibited a higher decrease. The highest fresh weight for BJRI Kenaf-2 (HC-95) was 0.70gm (0 ml/L arsenic) and lowest was 0.19gm (30 ml/L arsenic). BJRI Deshi Pat-7 ranged from 0.90gm (0 ml/L arsenic) to 0.19gm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) showed fresh weights from 0.33gm (0 ml/L arsenic) to 0.16gm (20 ml/L arsenic). At day 30, fresh weight continued to decrease significantly with arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat-7 exhibited a lesser decreasing trend, whereas BJRI Mesta-2 (VM-1) showed a higher decrease. The highest fresh weight for BJRI Kenaf-2 (HC-95) was 7.45gm (0 ml/L arsenic) and lowest was 0.67gm (30 ml/L arsenic). BJRI Deshi Pat-7 ranged from 7.64gm (0 ml/L arsenic) to 0.8gm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) showed fresh weights from 6.57gm (0 ml/L arsenic) to 0.51gm (30 ml/L arsenic). At day 42, fresh weight significantly decreased with arsenic solutions at 20-30 ml/L. BJRI Kenaf-2 (HC-95) and BJRI Deshi Pat-7 exhibited a lesser decreasing trend, while BJRI Mesta-2 (VM-1) showed a higher decrease. The highest fresh weight for BJRI Kenaf-2 (HC-95) was 14.33gm (0 ml/L arsenic) and lowest was 1.53gm (30 ml/L arsenic). BJRI Deshi Pat-7 ranged from 13.19gm (0 ml/L arsenic) to 1.17gm (30 ml/L arsenic). BJRI Mesta-2 (VM-1) showed fresh weights from 12.96gm (0 ml/L arsenic) to 1.48gm (20 ml/L arsenic).

Comparison between fresh weight among different varieties at different periods:

Figure-3:effect of as on fresh weight of different varieties at early growing stage



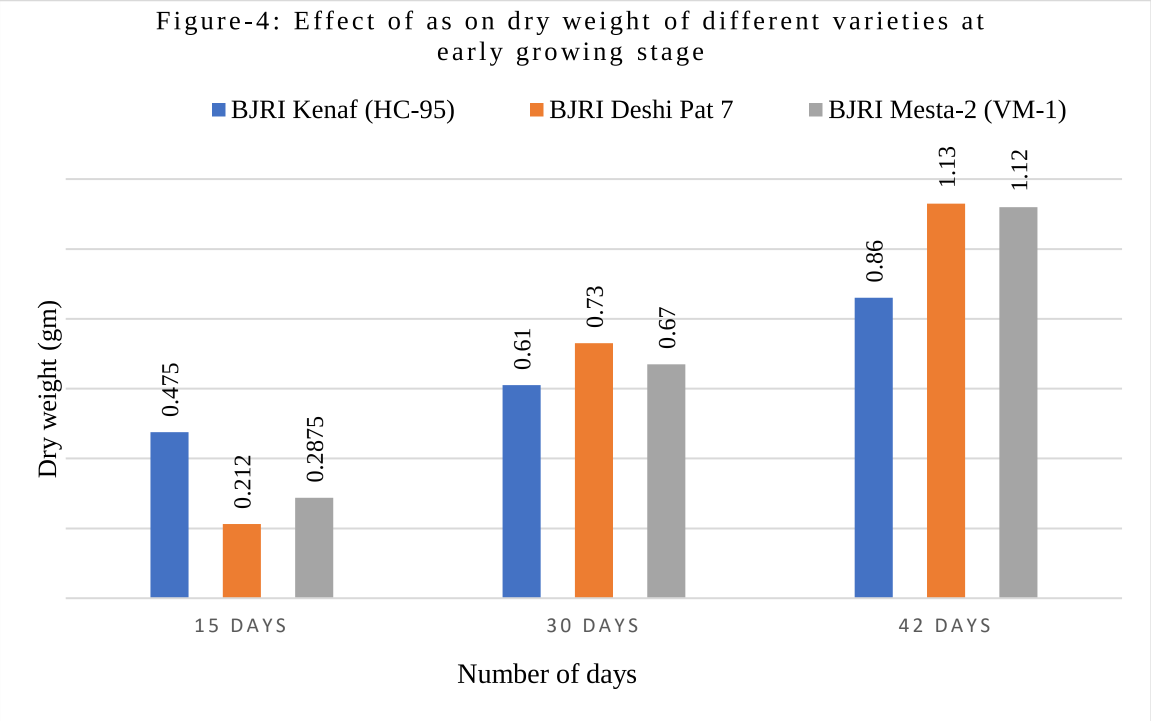
From the above graph, after the final harvesting at the 42 days, the order of fresh weight amount on different varieties at early growing stage in As contaminated soil is BJRI Kenaf-2 (HC-95) > BJRI Deshi Pat 7 > BJRI Mesta-2 (VM-1). In the As contaminated soil, BJRI Kenaf-2 (HC-95) can show the highest fresh weight amount among the other varieties.

3.6 Dry weight (at 15,30,42 days)

At 15 days, the dry weight of plants decreased significantly with 20-30 ml/L As solution. BJRI Kenaf-2 (HC-95) and BJRI Mesta-2(VM-1) showed lesser decreases, while BJRI Deshi Pat-7 had a higher decrease. BJRI Kenaf-2 had a highest dry weight of 0.9gm and lowest of 0.1gm at 0 ml/L As solution. BJRI Deshi Pat-7 recorded highest dry weight of 0.14gm and lowest fresh weight of 0.2gm at 0 ml/L As solution. BJRI Mesta-2 recorded highest dry weight of 0.5gm and lowest of 0.05gm at 0 ml/L As solution. At 30 days, the dry weight of plants decreased significantly with 20-30 ml/L As solution. BJRI Deshi Pat-7 and BJRI Mesta-2(VM-1) showed lesser decreases, while BJRI Kenaf-2 (HC-95) exhibited a higher decrease. The highest dry weight of BJRI Kenaf-2 was 1.25gm at 0 ml/L As solution and lowest was 0.14gm at 30ml/L. BJRI Deshi Pat-7 recorded highest dry weight of 1.45gm at 0 ml/L As solution and lowest fresh weight of 0.2gm at 30ml/L. BJRI Mesta-2's highest dry weight was 1.32gm at 0 ml/L As solution and lowest was 0.21gm at 30ml/L. At 42 days, the dry weight of plants significantly decreased with 20-30 ml/L As solution.

BJRI Deshi Pat-7 and BJRI Mesta-2(VM-1) exhibited lesser decreases, while BJRI Kenaf-2 (HC-95) showed a higher decrease. The highest dry weight of BJRI Kenaf-2 was 2.24gm at 0 ml/L As solution and lowest was 0.16gm at 30ml/L. BJRI Deshi Pat-7 recorded highest dry weight of 2.25gm at 0 ml/L As solution and lowest fresh weight of 0.16gm at 30ml/L. BJRI Mesta-2's highest dry weight was 2.08gm at 0 ml/L As solution and lowest was 0.28gm at 30ml/L.

Comparison between dry weight among different varieties at different periods:

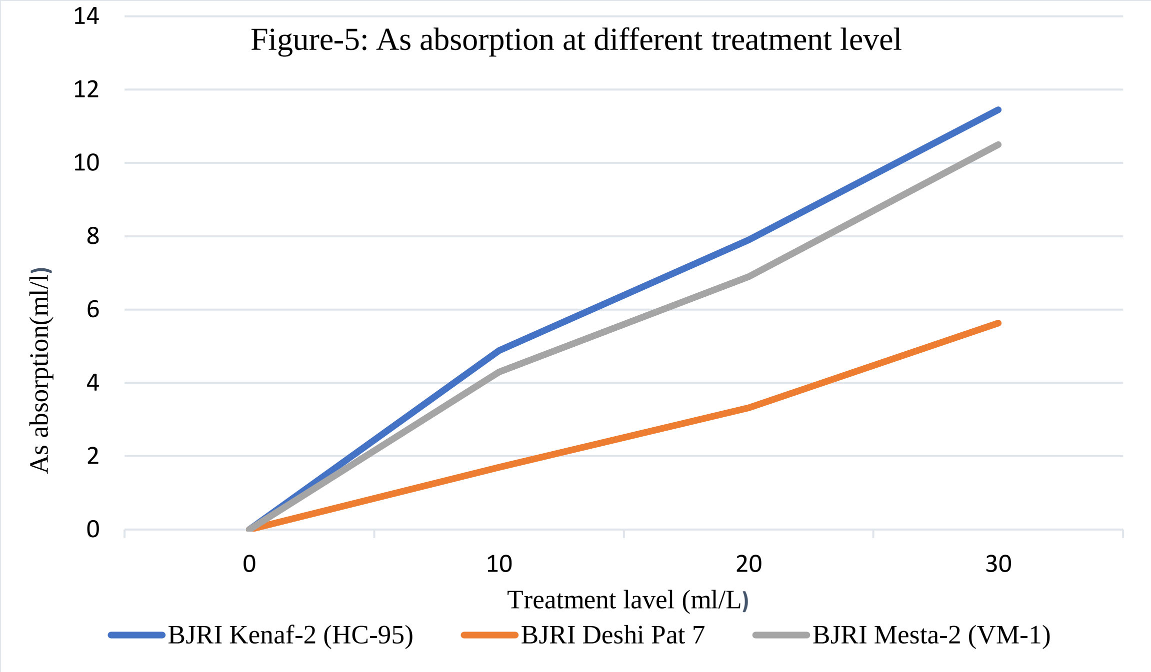


From the above graph, after the final harvesting at the 42 days, the order of dry weight amount on different varieties at early growing stage in As contaminated soil is BJRI Deshi Pat 7 > BJRI Mesta-2 (VM-1) > BJRI Kenaf-2 (HC-95). In the As contaminated soil, BJRI Deshi Pat 7 can show the highest fresh weight amount among the other varieties.

3.7.1 Total amount of As absorption by Kenaf, Mesta and Jute (at 15 days)

The values of total amount of As in BJRI Kenaf-2 (HC-95), BJRI Deshi Pat 7 and BJRI Mesta-2 (VM-1) were increased with the increasing of amount of As applied in the pots. The highest average As absorption was in BJRI Kenaf-2 (HC-95) at 6.07ml/L, then BJRI Mesta-2 (VM-1) at 5.45ml/L and less absorption was in BJRI Deshi Pat 7 at 2.66ml/L. Maximum As absorption were detected at the highest treatment for all the varieties. Highest total amount of As was calculated in BJRI Kenaf-2 (HC-95).

Comparison between As absorption among different varieties at different treatment levels at 15 days:

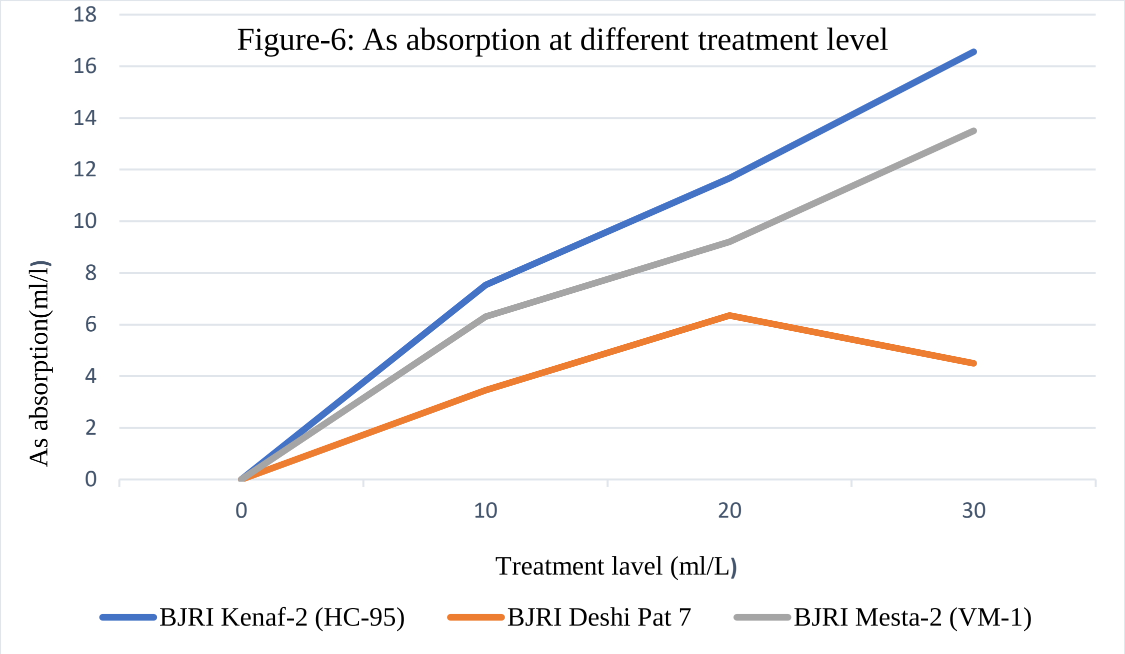


From the above graph, after the final harvesting at the 15 days, the order of As absorption on different varieties at early growing stage in As contaminated soil is BJRI Kenaf-2 (HC-95) > BJRI Mesta-2 (VM-1) > BJRI Deshi Pat 7. In the As contaminated soil, BJRI Kenaf-2 (HC-95) can absorb highest amount of As from the soil among the other varieties.

3.7.2. Total amount of As absorption by Kenaf, Mesta and Jute (at 42 days)

The values of total amount of As in Kenaf HC-95, BJRI Deshi pat Shak 7(BJC-2142) and BJRI Mesta-2 (VM-1) were increased with the increasing of amount of As applied in the pots. The highest average As absorption was in Kenaf HC-95 at 16.5ml/L, then BJRI Mesta-2 (VM-1) at 14.51ml/L and less absorption was in BJRI Deshi pat Shak 7(BJC-2142) at 7.51ml/L. Maximum As absorption were detected at the highest treatment for all the varieties. Highest total amount of As was calculated in Kenaf HC-95.

Comparison between As absorption among different varieties at different treatment levels at 42 days:



From the above graph, after the final harvesting at the 42 days, the order of As absorption on different varieties at early growing stage in As contaminated soil is BJRI Kenaf-2 (HC-95) > BJRI Mesta-2 (VM-1) > BJRI Deshi Pat 7 . In the As contaminated soil, BJRI Kenaf-2 (HC-95) can absorb highest amount of As from the soil among the other varieties.

3.8.1. Bio-concentration factor (BCF) of As for root

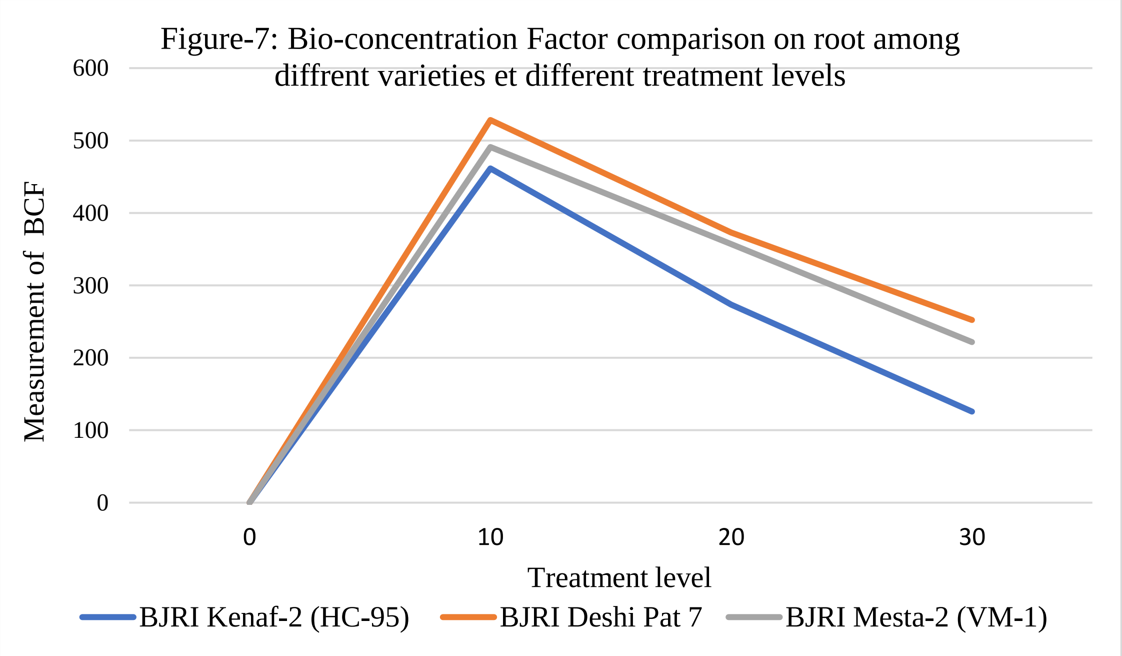
The bio-concentration factor of a plant for a given metal (As) is the ratio of the metal in the plant parts (root 0r shoot) in relation to the amount of metal in the growth medium. BCF is a crucial parameter to evaluate the potentiality of a plant in accumulating metals and the values were calculated on dry weight basis. BCF is higher in the root of BJRI Deshi Pat 7 and lower in BJRI Kenaf-2 (HC-95). BCF values of all varieties were gradually decreased with the increasing of As concentration.

$BCF= C_{root} / C_{medium}$

Here, C_{root} means concentration of heavy metal in plant parts(root) and

C_{medium} means Concentration of heavy metal in growth media

Comparison between Bio-concentration factor (BCF) of root among different varieties at different treatment levels at 42 days:



From the above graph, after the final harvesting at the 42 days, the order of bio-concentration factor of root on different varieties at early growing stage in As contaminated soil is BJRI Deshi Pat 7 > BJRI Mesta-2 (VM-1) > BJRI Kenaf-2 (HC-95). Here the bio-concentration factor was decreased as the treatment level of As was increased. In the As contaminated soil, BJRI Deshi Pat 7 can show highest amount of bio-concentration factor in root among the other varieties as BJRI Deshi Pat 7 absorbed less As.

3.8.2. Bio-concentration factor (BCF) of As for shoot

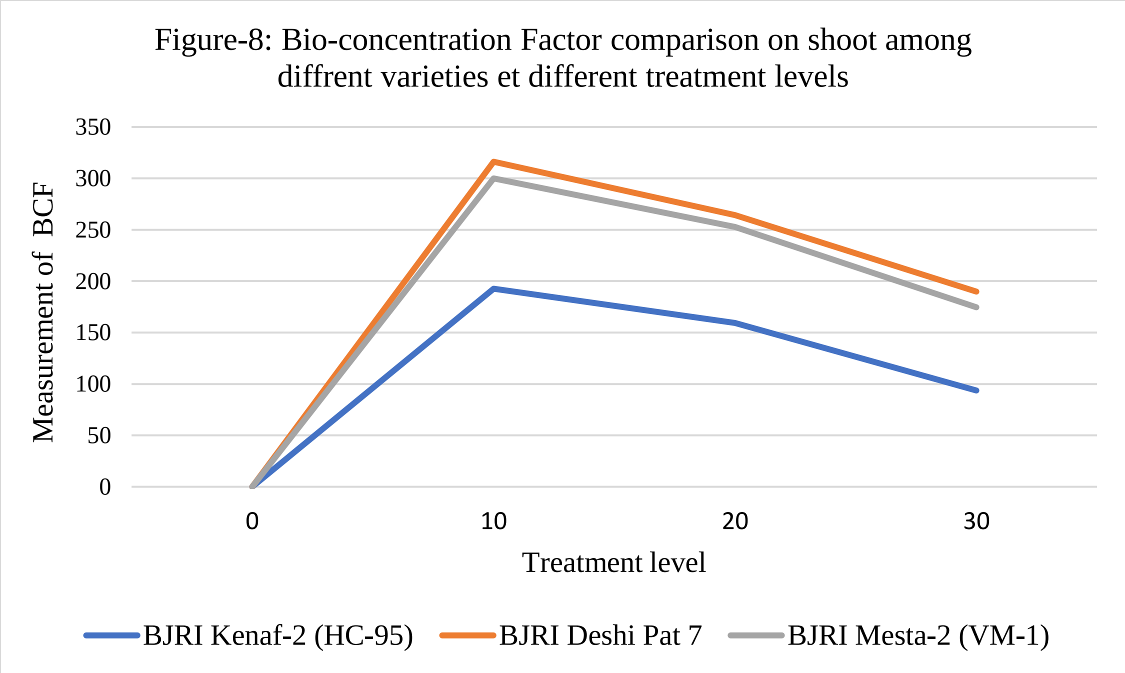
The bio-concentration factor of a plant for a given metal (As) is the ratio of the metal in the plant parts (root or shoot) in relation to the amount of metal in the growth medium. BCF is a crucial parameter to evaluate the potentiality of a plant in accumulating metals and the values were calculated on dry weight basis. BCF is higher in the shoot of BJRI Deshi Pat 7 and lower in BJRI Kenaf-2 (HC-95). BCF values of all varieties were gradually decreased with the increasing of As concentration.

BCF= C_{shoot} / C_{medium}

Here, C_{shoot} means concentration of heavy metal in plant parts(shoot) and

C_{medium} means Concentration of heavy metal in growth media

Comparison between Bio-concentration factor (BCF) of shoot among different varieties at different treatment levels at 42 days:



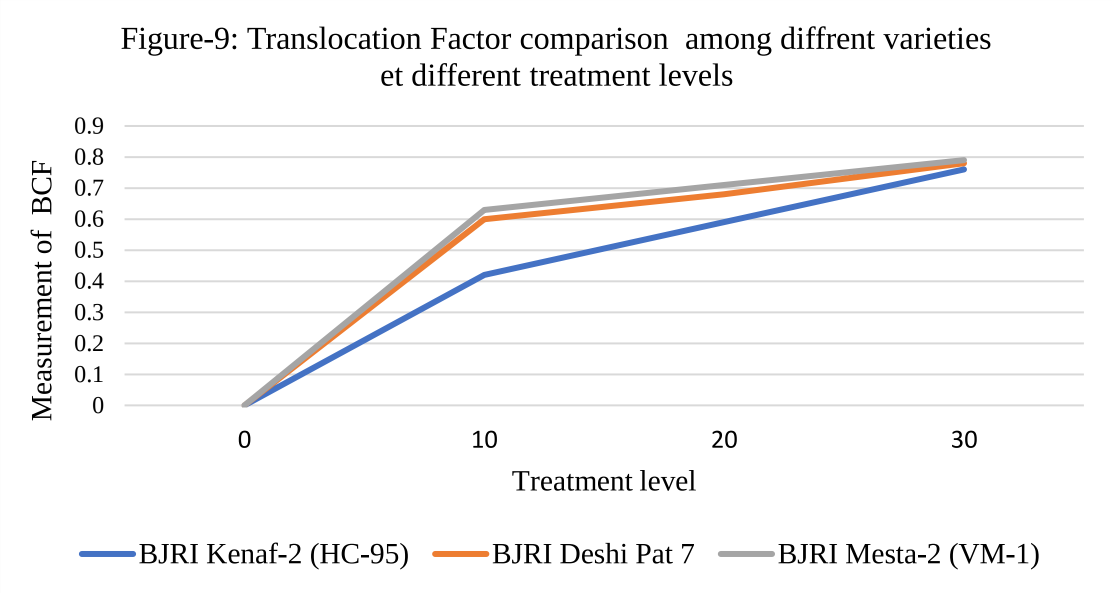
From the above graph, after the final harvesting at the 42 days, the order of bio-concentration factor of shoot on different varieties at early growing stage in As contaminated soil is BJRI Deshi Pat 7 > BJRI Mesta-2 (VM-1) > BJRI Kenaf-2 (HC-95). Here the bio-concentration factor was decreased as the treatment level of As was increased. In the As contaminated soil, BJRI Deshi Pat 7 can show highest amount of bio-concentration factor in root among the other varieties as BJRI Deshi Pat 7 absorbed less As.

3.9. Translocation factor (TF) of As from root to shoot

The translocation factor has been calculated to evaluate the mobilization of absorbed metal from root to shoot. Translocation factor is the ration of Bio-concentration factor of shoot in relation to the Bio-concentration factor of root. It is also called Shoot-root quotient, explains an ability of a plant to translocate the metal from root to shoot. TF become < 1 means slow translocation. Most slow translocation was recorded in BJRI Kenaf-2 (HC-95) and higher translocation was recorded in BJRI Deshi Pat 7.

TF = BCF of shoot/BCF of root

Comparison between Translocation factor (TF) of As from root to shoot among different varieties at different treatment levels at 42 days:



From the data analysis, after the final harvesting at the 42 days, the order of translocation factor from root to shoot of on different varieties at early growing stage in As contaminated soil is BJRI Deshi Pat 7 > BJRI Mesta-2 (VM-1) > BJRI Kenaf-2 (HC-95). At the treatment level of 30ml/L, the translocation factor of BJRI Mesta-2 (VM-1) is little bit higher than BJRI Deshi Pat 7. Translocation factor was increased with the increased of treatment level but slowly as the translocation factor is less than 1.

4. Conclusion

All the varieties BJRI Kenaf-2 (HC-95), BJRI Deshi pat 7 and BJRI Mesta-2 (VM-1) were able to germinate in As contaminated soil. It is concluded that BJRI Deshi Pat 7 and BJRI Mesta-2 (VM-1) are good cultivator to As prone areas due to good biomass production and showed low phytotoxicity to As. On the other hand, BJRI Kenaf-2 (HC-95) is the best phytoremediator to As among the other varieties because in the As contaminated soil BJRI Kenaf-2 (HC-95) absorbed high amount of As compared to the other varieties. In the As contaminated soil, BJRI Kenaf-2 (HC-95) and BJRI Mesta-2 (VM-1) showed 100% seedling survivability that means these two varieties are capable to survive in the As contaminated soil at different As level. BJRI Kenaf-2 (HC-95) showed the highest response to As at the early growth stages. The order of As tolerance and response of these three varieties are BJRI Kenaf-2 (HC-95) > BJRI Mesta-2 (VM-1) > BJRI Deshi Pat 7.

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