SALINITY IMPACTS ON EXPERIMENTAL FODDER SORGHUM PRODUCTION

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ABSTRACT

Field experiment was conducted at research station of Soil, Water & Environment Discipline, Khulna University, during the dry season to see the growth performance of sorghum (*Sorghum bicolor* L. cv. Morokoshi) irrigating with saline water. For irrigation, river water (RW) containing EC value of 14.04 dS m^{-1} was collected from the *Rupsha* river, Khulna and mixed with tap water [TW] containing EC value of 0.78 dS m^{-1} at three different ratios (3:1, 1:1 and 1:3 v/v). After mixing, water containing five different EC values (0.78, 4.19, 7.18, 10.79 and 14.04 dS m^{-1}) were obtained and considered as salinity treatment. Harvesting and sampling was done 83 days after transplanting (DAT) by cutting four sorghum plants randomly selected from each plot. Different morphological parameters such as plant height, leaf number, leaf length, leaf width, stem diameter and plant biomass were measured and recorded. Soil samples were also collected from each plot. Under water salinity stress, all the agronomic attributes and plant biomass showed a decreasing tendency with increasing salt concentration in irrigation water but the growth was not harmfully affected at lower levels of salinity. Plant height and biomass was significantly decreased irrigating with water containing salinity 10.79 dS m^{-1}. After harvest it was found that irrigation with saline water up to 10.79 dS m^{-1} did not show any increase of soil salinity. It was probably due to rainfall during the monsoon which was occurred at the later stage of the growing period. So, the fodder sorghum plant might be cultivated in the coastal regions of Bangladesh where fresh water irrigation is limited due to salinity problem as well as might be grown irrigating with saline water up to 10.79 dS m^{-1}.

Keywords: Biomass, coastal region, fodder, sorghum, morphology, salinity.

INTRODUCTION

Salinity is one of the major abiotic stress factors that affect plant growth and productivity, especially in arid and semi-arid tracts as well as coastal areas in tropical

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regions of the world (Hafsi et al., 2010). Salinity is the accumulation of salt in soil and water. Increasing both soil and water salinity decrease crop production through adversely affecting plant growth and development (Ahmed, 2009; Jahanzad et al., 2013, Qadir et al., 2014). Over 800 million hectares of land are salt affected throughout the world, either by salinity (397 million ha) or by the associated condition of sodicity (434 million ha) (FAO, 2000). More than 30% of the cultivable land in Bangladesh lies in the coastal area. Out of 2.86 million hectares of coastal and off-shore lands about 1.06 million ha of arable lands are affected by varying degrees of salinity (SRDI, 2010). Over the last 35 years, salinity has increased around 26 percent in the coastal region of Bangladesh (Mahmuduzzaman et al., 2014).

In fact, in arid and semi-arid regions saline soils are abundant due to intensity of evaporation and insufficient amount of rainfall for substantial leaching (Dai, 2011). Salinity problem in tropical region is quite different than in arid and semiarid region. Saline or salt affected soils are common problem in coastal area of tropical regions as well as in Bangladesh. The main source of salinity here is of marine origin. Sea water surrounds the south coast, intrudes northward and causes salinity (Brady & Weil, 2002).

Farmers in the coastal areas mostly cultivate low yielding, traditional rice varieties during wet season. Most of the land remains fallow in the dry season (January- May) because of soil salinity, lack of good quality irrigation water and late draining condition of the field (Karim et al., 1990). Livestock contributed around 14% to agriculture GDP (FPMU, 2014) in Bangladesh. The major constraints to dairy cattle production are the shortages of feeds and fodder. In case of coastal region in Bangladesh the problem is severe and diverse. Since plant growth and development are adversely affected by both soil and water salinity, these conditions are unsuitable for crop cultivation as like as livestock feeds and fodder which are dependent on supplemental irrigation during the season December–May. The scope of cow rearing is limited due to the shortage of grazing and fodder field. Besides, peoples have been using virgin land and water for shrimp production through allowing the intrusion of saline water, and increasing salinity in surrounding areas and damaging the grazing areas for livestock. The grazing land is decreased up to 64% over last twenty years (Ghafur et al., 1999; Anwar, 2005).

The shortage of feeds and fodder in the coastal areas of Bangladesh, often affect livestock production and productivity, needs immediate attention, especially, in searching of salt tolerant fodder crops. Farmers either can use salt tolerant fodder species or can grow plant irrigating with available fresh water mixing with saline water to increase livestock productivity.

Sorghum bicolor, a highly productive crop, grown for fodder, fiber and/or biofuel, ranks fifth in global cereal production and it shows a strong environmental stress tolerance to drought, heat, salinity and flooding (Igartua et al., 1994; Marambe & Ando, 1995; Belton et al., 2004; Netonda et al., 2004). The tillering characteristics

enable sorghum to completely regenerate the above-ground portions of the plant. Thus, sorghum plants have been kept alive for as long as 6 to 7 years where the climate is mild enough to avoid winterkill and when disease and insect protection have been provided (Saberi & Aishah, 2014). In the present research, we cultivated fodder sorghum in the south-west coastal region of Bangladesh under irrigation with saline water.

The objective of the present study was to see the growth performance of fodder sorghum under irrigation water salt stress.

MATERIALS AND METHODS

Description of the site

The experiment was carried out at the experimental field of Soil, Water and Environment Discipline, Khulna University, Bangladesh. The field was medium high land. The location lies in the agro-ecological zones (AEZ) 13, i.e. *Ganges Tidal Floodplain*. The experimental site is characterized by hot humid subtropical climate with abundant rainfall during monsoon.

Growing season

The experiment was conducted during the dry season (February–May).

Test plant

Forage sorghum (*Sorghum bicolor* L. cv. Morokoshi) was used as the test plant. The sorghum seeds were collected from the Plant Nutrition and Physiology Laboratory, Iwate University, Morioka, Japan.

Seed bed preparation

A seed bed (1m×1m) was prepared for seed germination and growing seedlings. The seed bed was ploughed and leveled properly by using traditional country spade. Weeds and stubbles were removed from the bed manually. The bed was kept moist through irrigation as and when required.

Seed sowing in seed bed

Before seed sowing, sorghum seeds were soaked in water for 6h then the seeds were sown on the seed bed by broadcasting method. After seeds sowing due care was taken to ensure no damage by birds and to raise healthy and strong seedling. Proper irrigation was done as and when required.

Experimental plot preparation

In the present experiment, there were four treatment combinations along with control. So, five experimental plots of equal size (1m×1m) were prepared by ploughing and leveling properly by using traditional country spade. All weeds, stubble, and crop residues were removed manually. During plot preparation the soil was well fertilized by applying chemical fertilizer (NPK) following the fertilizer recommendation guide (FRG, 2012) in Bangladesh. Then the field was made ready for transplanting.

Seedling transplantation

Fifteen days aged young seedlings were uprooted from the seed bed for transplanting. Before that the seed bed was moistened by the application of water so that the root system was not damaged. There were twelve plants in each plot. Since the experimental plot was small in size, transplantation method was followed to maintain equal space between and within the rows and columns to reduce the spacing effect.

Weeding

The experimental plot was kept free from weeds. Manual weeding was done on regular interval.

Collection of saline water for irrigation

The saline water was collected from the *Rupsha* river situated beside the Khulna city and the bulk water was immediately transported to the field laboratory of Soil, Water and Environment Discipline, Khulna University and stored in plastic container. Natural tide occur in this river and the river water (RW) was collected during high tide.

Treatments combination

Tap water (TW) containing EC value of 0.78 dS m^{-1} was mixed with collected saline RW containing EC value of 14.04 dS m^{-1}at three different ratios (3:1, 1:1 and 1:3)to change the salinity levels as different treatments. Treatment combinations are presented in Table 1.The table describes that control plants received irrigation water containing 0.78 dS m^{-1} of EC. Whereas different salinity treated plants received irrigation water containing 4.19, 7.18. 10.79 and 14.04 dS m^{-1} of EC, respectively.

Irrigation

For seedlings establishment on experimental field normal tap water (0.78 dS m^{-1}) was used for irrigation when required. Fifteen days after transplanting (DAT), irrigation was done with treated water i.e. saline water and tap water combination according to treatment (Table 1). For each experimental plot same volume of water was irrigated irrespective to treatment.

Harvesting and sampling

Harvesting was done 83 days after transplanting. Four plants were selected as sample from each experimental plot through random selection. The selected plants were separated from the plot carefully by cutting the stems 3cm above the soil surface. Different morphological parameters *viz.* plant height, leaf number, leaf length, leaf width, and stem diameter, and plant biomass i.e. the fresh weight of the whole plant were measured and recorded. The soil sample was also collected from each plot.

Table 1. Treatment combination and EC values after mixing

Treatment	Water mixing combination	EC (dS m^{-1})
T0	Control (100% TW)	0.78
T1	75% TW + 25% RW (TW:RW, 3:1)	4.19
T2	50% TW + 50% RW (TW:RW, 1:1)	7.18
T3	25% TW + 75% RW (TW:RW, 1:3)	10.79
T4	100% RW	14.04

TW=Tap water; RW=River water

Data collection

For convenience of agronomic observation on the plant characters data were collected from four randomly selected plants from each of the plots. Data on plant characters were then collected as follows:

- Plant height (m): Plant height of the harvested plant samples was measured with the help of a meter scale from the ground level to the tip of the uppermost leaf. So, the height of four plant samples from each plot was measured.

- Leaf number: Leaf number was manually counted. All the leaves in each plant were considered for counting leaf number.

- Leaf length (cm): Two mature leaves from each plant were selected to measure leaf length. So, total eight leaf length from each plot was measured with the help of a meter scale to measure the leaf length.

- Leaf width (cm): The leaves that were considered for measuring leaf length were also considered for leaf width measurement and were measured with the help of a meter scale.

- Stem diameter (cm): The plant samples that were considered for plant height was also selected for the measurement of stem diameter. The circle sphere of the stem was measured at the point of 1m above from the ground with the help of a meter scale. Then the plant diameter was calculated.

- Plant biomass (kg): After measuring all the agronomic attributes of the plants, the plants were cut into small pieces and fresh weight was weighed with the help of an electric balance.

Measurement of electrical conductivity (EC)

The electrical conductivity of the soil was measured at a soil: water ratio of 1:5 with the help of EC meter (USDA, 2004) whereas the EC of water sample was measured by using the EC meter after filtering the sample.

Statistical analysis

The results were expressed as the averages of four replications. The data was subjected to ANOVA using computer built-in statistical software program Minitab-16. Differences between means were statistically analyzed following one-way analysis of variance and using Fisher's one way multiple comparison method (p=0.05). The association between water salinity and plant attributes was statistically tested by linear regression analysis. Graphs were prepared by using computer built-in Microsoft Excel-2010 program.

RESULTS

Morphological parameters

Plant height (m), Leaf number, Leaf length (cm), Leaf width (cm), Stem diameter (cm)

All the morphological parameters of the fodder sorghum plants measured after harvest are presented in table 2. The average plant height (n=4) varied from 1.83 ± 0.19 m to 2.51 ± 0.38 m among different concentrations of salinity in irrigation water. The tallest plant (2.93 m) was observed in 0.78 dS m^{-1} irrigated plot whereas the shortest plant (1.64 m) was observed in14.04 dS m^{-1} irrigated plot. Plant height was significantly (p=0.045) reduced only at the highest degree of irrigation water salinity at 14.04 dS m^{-1} (Table 2). The association between plant height and water salinity was statistically tested by linear regression analysis and it was found that the plant height was significantly (p=0.002, R-Sq=54.5%) reduced with increasing rate of water salinity. Increasing salinity levels from 0.78 to 14.04 dS m^{-1} reduced plant height by 3.98, 14.34, 14.34, and 27.09%, respectively, as compared with the control treatment.

The average leaf number varied from 11 ± 1.0 to 13 ± 2.7 (Table 2). There was no significant (p=0.51) difference in leaf number among the plants grown in different degrees of salinity in irrigation water (Table 2). While increasing salinity levels from 0.78 to 14.04 dS m^{-1} reduced leaf number by 0, 0, 7.69, and 15.38%, respectively as the salinity levels order compared with the control treatment.

The mean leaf length of the plant varied from 89.2 ± 11.0 cm to 107.2 ± 8.9 cm (Table 2). The longest plant leaf (114.5 cm) was observed when the plants were irrigated with water containing EC value of 4.19 dS m^{-1} whereas the shortest plant leaf (76.5 cm) was observed in treatment of 14.04 dS m^{-1}. There was no significant (p=0.18) change in leaf length among the treatments up to 10.79 dS m^{-1}. But the average plant leaf length was significantly reduced at 14.04 dSm^{-1}irrigated plot. Increasing salinity levels from 0.78 to 14.04 dS m^{-1} reduced leaf length by 0, 4.10, 3.64, and 16.79 %, respectively as the salinity levels order compared with the control treatment.

Table 2. Response of water salinity on morphological parameters of sorghum

EC (dS m^{-1}) in irrigation water	Plant height (m)	Leaf number	Leaf length (cm)	Leaf width (cm)	Stem diameter (cm)	Plant biomass (kg plant^{-1})
0.78	2.51±0.38^a	13±2.7^a	107.2±8.9^{ab}	8.02±0.53^{ab}	2.25±0.23^a	0.74±0.16^a
4.19	2.41±0.22^{ab}	13±0.6^a	108.7±5.4^{ab}	6.88±0.55^{ab}	2.11±0.21^a	0.54±0.11^{ab}
7.18	2.15±0.05^{ab}	13±1.0^a	102.8±2.4^{ab}	7.12±0.63^{ab}	2.19±0.15^a	0.51±0.05^{ab}
10.79	2.15±0.24^{ab}	12±1.5^a	103.3±1.0^{ab}	6.33±0.36^{bc}	1.80±0.10^a	0.34±0.07^b
14.04	1.83±0.19^b	11±1.0^a	89.2±11.0^b	5.55±0.69^c	1.72±0.25^a	0.32±0.08^b

Data indicates the average value ± standard deviation of four replications. Different letters indicate the significant differences.

The average leaf width of the fodder sorghum plant varied from 5.55±0.69 cm to 8.02 ± 0.53 cm. The widest leaf (8.6 cm) was observed in 0.78 dS m^{-1} irrigated plot whereas the narrowest leaf (4.75 cm) was observed in 14.04 dS m^{-1} irrigated plot. The leaf width was significantly (p=0.015) reduced only at 14.04 dS m^{-1}.Increasing salinity levels from 0.78 to 14.04 dSm^{-1} reduced leaf width by 14.21, 11.22, 21.07, and 30.80%, respectively as the salinity levels order compared with the control treatment.

The mean value of stem diameter of fodder sorghum plant varied from 1.72±0.25 cm to 2.25±0.23 cm. No significant (p=0.07) differences on stem diameter were observed among the plants irrigated with different levels of salinity. Increasing salinity levels from 0.78 to 14.04 dS m^{-1} reduced stem diameter by 6.22, 2.67, 20.0, and 23.56%, respectively as the salinity levels order compared with the control treatment.

Plant biomass (kg plant^{-1})

The average plant biomass varied from 0.32±0.09 kg to 0.74±0.16 kg (Table 2). The maximum plant biomass (0.91 kg) was observed in 0.78 dS m^{-1} irrigated plot whereas the minimum plant biomass (0.26 kg) was observed in 14.04 dSm^{-1} irrigated plot. The plant biomass was significantly (p=0.003) reduced at 10.79 and 14.04 dS m^{-1} irrigated plot. Increasing salinity levels from 0.78 to 14.04 dS m^{-1} reduced plant biomass by 27.03, 31.08, 54.05, and 56.76%, respectively as the salinity levels order compared with the control treatment. The association between plant biomass and water salinity was statistically tested by linear regression analysis and it was found that the plant height was significantly (p<0.001, R-Sq=71.2%) reduced with increasing rate of water salinity.

Soil EC (dS m^{-1}) after harvest

The initials soil EC value was 0.30±0.01dS m^{-1}. The soil EC values after plant harvest is shown in figure 1.It was found that soil EC value was lower than the initial EC value up to 10.79 dS m^{-1} irrigated plot. The soil EC value was higher only in case of where the irrigation water contained EC value of 14.04 dS m^{-1}.
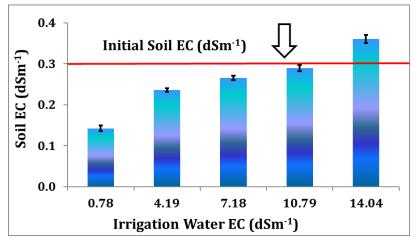
Figure 1. Soil EC values after harvest as compared to initial soil EC

DISCUSSION

Results in table 2 revealed that salinity concentrations had a significant effect on averages of plant height (m), leaf number, leaf length (cm), leaf width (cm), stem diameter (cm) and plant biomass (kg). Increasing salinity levels decreased all these characters. These findings are in agreement with other works (Bashir et al., 2011, El Naim et al., 2012, Haghighat et al., 2012) reported on sorghum. It was reported that salinity decreased leaf area of sorghum (Bashir et al., 2011; Jafari et al., 2009). Sadeghi & Shourijeh (2012) measured the number of leaves and found that the number of leaves was decreased. Increasing salinity levels decreased sorghum growth which is directly related to the amount of absorbed water by the roots and the toxic effects of Na+ at high salt concentrations might have caused physical damage to roots thereby decreasing their ability to absorb water and nutrient, which may resulted in poor growth (Iqbal et al., 2000). Excess of salt in growth medium restricts the availability of water to plant. This restriction causes in dehydration of cytoplasm which in turn affects the metabolism of the cells and ultimately reduces the growth of plant. Sorghum was classified as moderately salt tolerant plant (Krishnamurthy et al., 2007, Niu et al., 2012) which is confirmed in the present study. In the present study, sorghum was grown up to 7.18 dSm^{-1} EC without affecting its total biomass (Table 2). Some studies also reported variation in salinity tolerance between sorghum cultivars (Asfaw, 2011, El Naim et al., 2012). Salts in soil and water can reduce water availability to crops at all stages of plant development and affect physiological and biochemical processes via ion toxicity, osmotic stress and mineral deficiencies to such an extent that yields can be affected (Hasegawa et al., 2000; Munns, 2002).

Average salinity concentrations at the coast are higher in the dry season than in the monsoon, due to the lack of freshwater flows from upstream. The salinity normally builds up from October to the late May, and it remains higher during the dry season,

usually from February to May. At the end of May, salinity level drops sharply due to upstream flows and rainfall. Regarding the soil EC values after harvest, in the present study the authors stated that during the monsoon, due to rain water, soil salinity was decreased up to 10.79 dS m^{-1} from its initial value (Figure 1).Increasing salinity levels from 0.78 to 10.79 dS m^{-1} reduced soil EC by 53.33, 20, 10, and 3.33%, respectively as the salinity levels order compared with the control treatment whereas at 14.04 dS m^{-1}soil EC was increased by 20%.

CONCLUSION

The results of the present study revealed that the growth of the fodder sorghum was harmfully affected by the irrigation water salinity at higher salt concentrations. It was found that the plant height and plant biomass was significantly decreased when the plants were grown irrigating with water containing EC of 10.79 dS m^{-1}. So, the sorghum plants might be cultivated in the coastal regions of Bangladesh where fresh water is limited due to salinity problem as well as might be grown irrigating with saline water up to 10.79 dSm^{-1}.Moreover, it was found that the soil irrigating with saline water up to10.79 dSm^{-1} did not show any increase of soil salinity after harvest that might be due to heavy rainfall at the later stage of the plant's growth period during the monsoon. Further study on actual soil salinity with fodder sorghum should be necessary.

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