SOIL SALINITY SURVEY IN RELATION TO PERFORMANCE OF TOMATO IN SATKHIRA DISTRICT OF BANGLADESH

N. Naher[1], M. K. Uddin[2], K. U. Ahamed[3], A. K. M. M. Alam[4] and R. M. Masum[5]

ABSTRACT

Bangladesh is highly vulnerable to sea level rise. Both water and soil salinity along the coast is increasing with the rise in sea level, destroying normal characteristics of coastal soil and water. A soil survey was conducted in Satkhira district on March to July 2009 and soils samples were collected from 30 sites at 0.5 km distance and 0-50 cm, 50-100 cm and 100-150 cm depth and analyzed to determine the effect of salinity on soil properties. A field experiment was conducted from December 2009 to March 2010 in Satkhira district to observe the yield performance of eight different tomato varieties for growing under saline area by RCBD with three replications. In the saline soils of Satkhira pH value of the surface horizon was slightly lower (5.37) than those of the subsoil (7.70). Cation exchange capacity (CEC) and organic matter was medium to high status, nutrient deficiencies of total nitrogen, phosphorous and potassium were quite dominant but sulphur was high (15.0 to 20 mg/100 kg). Exchangeable sodium, potassium, calcium and magnesium were in high level. The dominant water soluble cations were Na^+, Ca^{2+}, Mg^{2+} and K^+ and anions Cl^- and SO_4^{2-}. In the field experiment, each tomato varieties showed a special criterion among others, variety BARI Tomato7 gave the highest yield (100.33 t/ha) whereas BARI Tomato14 showed the highest size (17.0 cm) among others. The highest number of fruits/plant was recorded from BARI Tomato 11 (212.33) which was cherry type and the lowest number was recorded from BARI Tomato 4(23.66). So, soil salinity is the most dominant limiting factor in saline regions, especially during the dry season and cropping intensity will be increased by adopting proper soil and water management practices with the introduction of salt tolerant tomato varieties in saline areas.

Keywords: Coastal area, salinity, tomato, yield

INTRODUCTION

Climate change is a pressing development challenge for Bangladesh in view of the country's vulnerability to its impacts. Saline water intrusion is the main problem in the south-western zone. About 60 and 15 percent of arable land (total 1.0 mha croplands) of southwestern and southeastern respectively are affected by salinity in the dry period (Rahman and Bhattacharya 2014). The area lies at 0.9 to 2.1 metre above mean sea level (Iftekhar and Islam, 2004). Agricultural land use in these areas is very poor and the cropping patterns followed mainly Fallow-Fallow-Transplanted Aman rice (Petersen and Shireen, 2001). Maximum salinity occurs in Bangladesh in the month of March and April ((IWM, 2014; Sayma and Mashfiqus 2012). Bangladesh is an agro-based country where agriculture is considered as backbone of her economy. Tomato is a major vegetable crop that has achieved tremendous popularity over the last century. It is grown in practically every country in the world, in outdoor fields, greenhouses and net houses (Peralta *et al.,* 2005). It can contribute significantly to the nutrition of the people of this country as a source of vitamins and minerals.

Salinity in soil becomes a problem when the total amount of salts which accumulate in the root zone is high enough to negatively affect plant growth. Excess soluble salts in the root zone restrict plant roots from withdrawing water from the surrounding soil, effectively reducing the plant available water (Western Fertilizer Handbook, 1995; Bauder, 2001; USDA, Natural Resources Conservation Service, 2002). The plant response to salt stress is complex, since it varies with the salt concentration, the type of ions, other environmental factors, and the stage of plant development depending on the growth conditions. Salinity problem received very little attention in the past, but due to increased demand for

[1] Professor, [5] MS. Student, Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, [2] Professor, Department of Environmental Sciences, Jahangirnagar University, Dhaka 1342, [3] Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, [4] Senior Scientific Officer, PRC, BARI, Gazipur.

growing more food to feed the booming population of the country it has become imperative to explore the potentials of these lands. The production of tomato is constrained in the coastal area of Satkhira due to lack of knowledge of salt tolerant variety, improved technology and upward or lateral movement of saline groundwater during the dry season viz, November-May (Karim *et al.*, 1990). The main purpose of this study was to determine the salinity level of Satkhira saline area, to see the effect of salinity on soil physical and chemical properties and to evaluate the performanc of eight different tomato varieties for growing under present saline condition and screen them for salt tolerance.

MATERIALS AND METHODS

A field survey was carried out in the area at Asasuni upazila of Satkhira district located at 22.5500^0N 89.1681^0E. Topographically of this area is low lying and has elevations mostly less than 8 m above the mean sea level and subjected to flooding in the monsoon season. Soil samples were collected from 0-50 cm, 50-100 cm and 100-150 cm depth and were dried at room temperature, crushed, mixed thoroughly, sieved with 2mm sieve. Particle-size analysis was carried out by the hydrometer method as outlined by Bouyoucos (1927). The textural classes were then determined by plotting the results on a triangular diagram designed by Marshall (1947) following the U.S. Department of Agriculture classification system. The pH was determined by a glass-electrode pH meter in the soil suspension having a soil: water ratio of 1:2.5, after 30-min shaking. The electrical conductivity (EC) was measured by an EC meter in the soil suspension having a soil: water ratio of 1:5, after 30-min shaking. The organic carbon content was determined by the wet oxidation method as outlined by Nelson *et al.*, (1982) and total nitrogen content by the micro-Kleldhal digestion method. Cation exchange capacity (CEC) was determined by the sodium saturation method as described by Chapman (1965) and available phosphorous by the method as given by Olsen *et al.* (1954). The available sulfur was determined by the calcium chloride (0.15%) extraction method (Williams and Steinbergs, 1959). The non-exchangeable potassium content was determined by the boiling HNO_3 method (Knudsen *et al.*, 1982) and Exchangeable calcium, sodium and potassium were extracted from soil using 1M CH_3COONH_4 and their concentrations in the extract were directly determined by a flame photometer. Exchangeable magnesium was extracted by DTPA solution (Diethylene Triamine Penta Acitate) and its concentration in the extract was determined directly by an atomic absorption spectrophotometer (ASS). Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR) were determined by using the following formula

$$ESP = \frac{\text{Exchangeable } Na^+}{\text{CEC}} \times 100$$

$$SAR = (\text{sodium}^+ / \text{calcium}^+ + \text{magnesium}^+)/2)^{1/2}$$

The field experiment was conducted from December 2009 to March 2010. The experiment was laid out in a RCDB with three replications. Eight treatments were used in the study. These were V_1- BARI Tomato 2, V_2-BARI Tomato 3, V_3-BARI Tomato 4, V_4-BARI Tomato 7, V_5- BARI Tomato 8, V_6-BARI Tomato 9, V_7- BARI Tomato 11 and V_8-BARI Tomato 14, collected from HRC, BARI, Gazipur. Seeds were sown in seed bed and four week-old tomato plants were transplanted in the field on 15 December 2009. The unit plot size was 1 m × 3 m. with plant spacing 60cm × 60cm. Data on plant height, branches/plant, fruits/plant, weight of fruits, diameter/fruits and yield (t/ha) were recorded and analyzed statistically by using MSTAT-C program. The treatment means were compared by using DMRT/ LSD at 5% level of probability following Gomez and Gomez (1984).

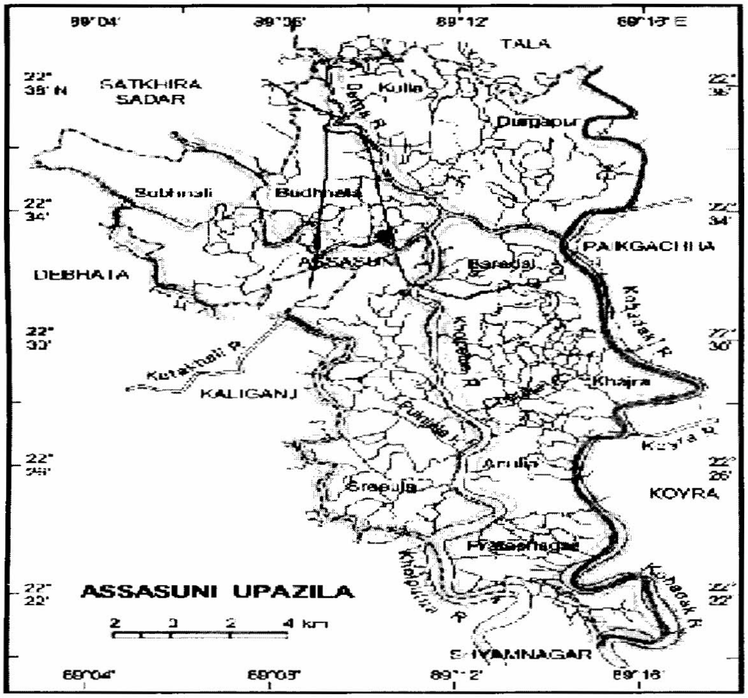

Fig. 1. Study area Assasuni upazila in the district of Satkhira of Bangladesh

RESULTS AND DISCUSSION

Soil physical and chemical properties

Data on the particle-size distribution and the USDA textural class of the soil is presented in the Table 1 indicated that the dominant soil textural class that occurs in the saline area of this region was silty clay. Physico-chemical properties of soils are presented in Table 2. The pH value of the top soil was 5.37 and at 100-150 cm depth it was 7.70 cm. The higher pH values of the soils are likely to create micronutrient deficiency and phosphate fixation problem. Uddin and Hossain (2013) reported that the soil pH and salinity varied at different depths in different land strips from 7.6 to 8.1 which also support the findings of Siddiqi (2001). It was shown that total nitrogen level in the soil was low and varied from 0.05 to 0.27 %. Nitrogen content of the surface horizon was higher than that of subsoil. Portch and Islam (1984) also found that 100% of the soils studied in saline areas were deficient in available nitrogen, which was similar to the present findings. CEC of all these soils varies from 14.80 to 27.2 cmol/kg soil expressing medium to high status. The high CEC values of these soils denote the comparatively high chemical activity of soil. Haque (2006) found pH range from 6.0-8.4 and organic matter content (1.0-1.5%) of the soils in coastal regions which was also pretty low. Most of the soils were found deficient in phosphorous (3.76 mg/kg). Potassium status from 0.09 to 0.17 meq/100 gm soil indicated very low to low but sulphur content was high (15.0 to 20 mg/100 kg).

Table 1. Physical properties of soils at Asasuni upazila of Satkhira district

Date of collection	Sample	Depth Cm	Particle size Distribution (%)			Texture
			Sand	Silt	Clay	
15-12-2010	Composite sample	0-50	8	52	40	Silty Clay
		50-150	10	57	42	Silty Clay
		100-150	11	59	25	Silty Clay

Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR)

Exchangeable Sodium Percentage has been used as a parameter for assessing the severity of salinity problem. It ranged from 2.31 % to 3.04% which is acceptable (< 10%). The sodium hazard is denoted by the sodium adsorption ratio. The SAR of a soil extract gives an indication of the level of exchangeable Na^+ in comparison with those of Ca^+ and Mg^+ in soil. The SAR values varied from 1.72-2.22 which was in acceptable range (Table 3).

Table 2. Physico-chemical properties of soils collected from Asasuni upazila of Satkhira district

Location	Sample No	Soil layer depth (cm)	pH	Total N (%)	CEC cmol/kg	Organic Matter (%)	Extractable P (mg/kg)	Extractable K (cmol/kg)	Extractable S (mg/kg)
Asasuni	1	0-50	5.37	0.07	16.00	2.23	3.50	0.17	20.00
		50-100	6.70	0.09	16.60	1.06	2.70	0.16	18.50
		100-150	7.70	0.08	14.80	1.37	1.35	0.09	16.20
	2	0-50	5.70	0.09	20.80	2.16	4.50	0.16	19.30
		50-100	6.88	0.05	27.20	0.85	3.75	0.14	18.00
		100-150	8.12	0.08	24.80	1.23	2.40	0.10	15.00
	3	0-50	6.00	0.14	18.60	2.80	3.50	0.17	19.00
		50-100	6.87	0.17	24.60	1.93	2.50	0.14	19.00
		100-150	7.90	0.27	17.60	1.47	1.35	0.13	15.00
Average			6.80	0.11	20.11	1.68	3.67	0.14	17.44
STD			1.000	0.077	4.805	0.638	2.580	0.033	2.025
CV (%)			14.69	68.85	23.90	38.08	70.47	23.96	11.62

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Table 3. Salt characteristics of soils of study area

Sample	Depth cm	EC dS/m	SAR	ESP	Exchangeable Cations meq/100g soil				Water soluble ions meq/L					
					Na	K	Ca	Mg	Na	K	Ca	Mg	Cl	SO_4
Composite sample	0-50	5.2	1.72	2.31	0.52	0.45	4.25	6.0	1.9	0.65	0.35	0.39	9.6	2.4
	50-100	4.3	2.0	2.573	0.54	0.60	6.80	4.0	1.7	0.38	0.38	0.42	10.7	2.8
	100-150	2.9	2.22	3.04	0.56	1.45	10.75	4.2	1.5	0.35	0.35	0.40	11.3	3.0

Correlation matrix

The correlation matrix for physical and chemical properties determined in the present study area is given in Table 4. Significant and negative correlation observed between pH and micronutrients. It is observed that a positive significant correlation found with K to P and S. ECe showed positive correlation with OM, P K and S. From the result it was understood that the clay content was the most fundamental properties to control chemical properties of soils. Interaction of micronutrients to each other are also showed positive relationship indicated that one nutrient content effect another nutrient content.

Table 4. Correlation matrix between physical and chemical properties of the soils

	Clay	pH	N	CEC	OM	P	K	S	Ec	Ex Na	Ex K	Ex Ca	Ex Mg
Clay	1												
pH	-0.892**	1											
N	-0.162	-0.45	1										
CEC	-0.142	0.573	-0.989**	1									
OM	0.235	-0.647*	0.971**	-0.995**	1								
P	0.655*	-0.925**	0.754*	-0.840**	0.888**	1							
K	0.821**	-0.990**	0.569	-0.681*	0.747*	0.968**	1						
S	0.866**	-0.998**	0.5	-0.618*	0.689*	0.945**	0.996**	1					
Ec	0.693*	-0.943**	0.720*	-0.812**	0.863**	0.998**	0.980**	0.960**	1				
Ex Na	-0.866**	0.998**	-0.5	0.618*	-0.689*	-0.945**	-0.996**	-1.00**	-0.960**	1			
Ex K	-0.990**	0.946**	-0.139	0.279	-0.368	-0.754*	-0.893**	-0.927**	-.786**	0.927**	1		
Ex Ca	-0.921**	0.997**	-0.389	0.516	-0.595	-0.897**	-0.948**	-0.992**	-0.919**	0.992**	0.996**	1	
Ex Mg	0.419	-0.783**	0.907**	-0.958**	0.981**	0.960**	0.861**	0.817**	0.944**	-0.817**	-0.541	-0.739*	1

** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed).
Clay: clay percentage, N: total N content, CEC: cation exchange capacity, OM: organic matter content, P: available P determined by the Olsen method, K: available K content, S: Available S content, Ec: electrical conductivity, Ex Na : exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, Ex Mg: exchangeable Mg content

Salinity levels in the field experiment

In the field experiment, soil salinity range at the studied site at different times of the year 2009 and 2010 are shown in figure 2. Lowest salinity was recorded at the transplanting time 5.2 dS/m and the highest salinity was recorded 18.32 dS/m. Salinity increases after January. Rain water decreased salinity from 5.2 dS/m to 18.32dS/m. This range support the report Zaman and Bakri, (2003).They reported that Bangladesh has 3 million hectares of land is affected by salinity, mainly in the coastal and south-east districts, with ECe values ranging between 4 and 16 dS/m.

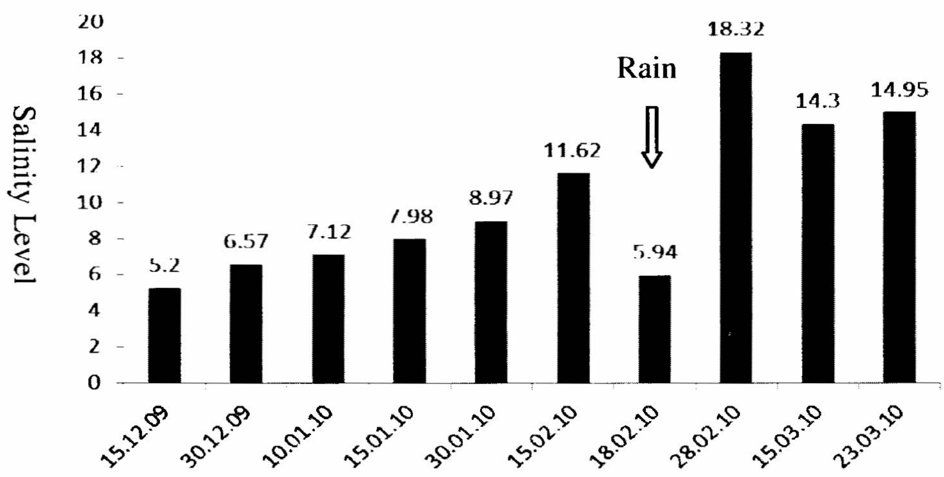

Fig. 2. Salinity levels of different treatments of tomato throughout the growing season

Plant growth parameters

Saline stress leads to changes in growth, morphology and physiology of the plant parts that will in turn change water and ion uptake. Plant growth was significantly affected (at 5% level) by salinity in this saline area. The results of the effect of varieties on the yield contributing characters of tomato plant have been presented in Table 5.

Plant height
Significant difference among the different treatments of tomato plant was observed in case of plant height. The variety BARI Tomato7 showed the highest plant height (114.67cm) and second highest (96 cm) differ from BARI Tomato14. Salinity stress resulted in a clear stunting of plant growth in BARI Tomato 8, so it showed the lowest plant height (60 cm). This result was similar to the annual research report of BARI (2007). The reduction of the plant height due to reduction in internodal distance with increased salinity may be a result of a combination of osmotic ion effects of Cl^- and Na^+ (Al- Rwahy, 1989; Zhu, 2001).

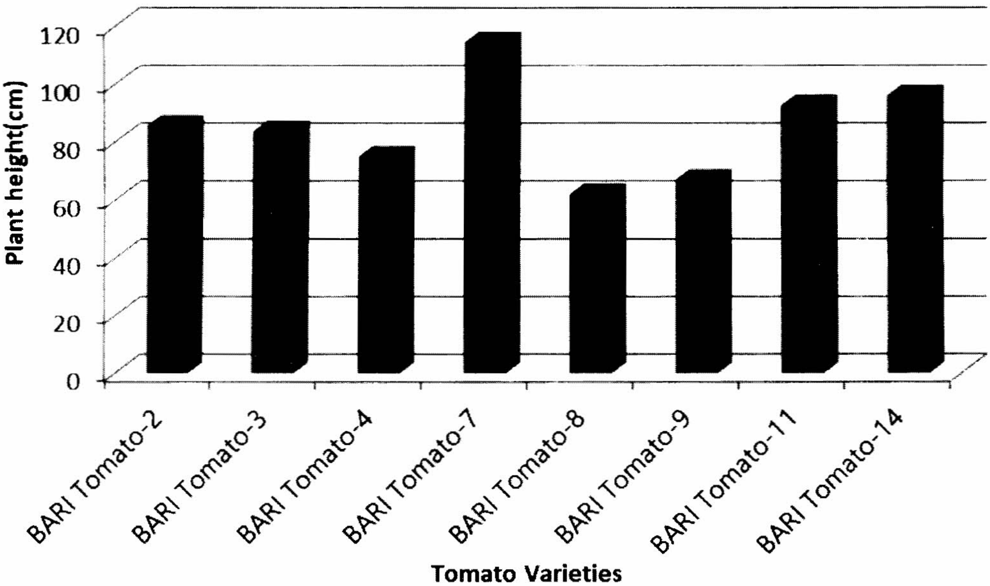

Fig. 3. Plant height of tomato varieties grown under study saline area

Branches/plant: The results presented in Table 5 indicate that there were no significant differences in respect of branches/plant between varieties. BARI Tomato 9 contained the highest number of branches/plant(5.00) and BARI Tomato 3, BARI Tomato 4 and BARI Tomato 11 showed statistically same number of branches/plant but BARI Tomato 8 showed the lowest number (3.67). Cuartero and Munoz (1999) reported the same result in tomato.

Days to flowering and days to harvest: Tomato varieties began to flowering at different dates after transplanting. BARI Tomato 3, BARI Tomato 8 and BARI Tomato 14 began to give flower at 53.67 days after transplanting but the date to harvest of BARI Tomato 2 and BARI Tomato 3 were statistically same and BARI Tomato 4, BARI Tomato 9 and BARI Tomato 11showed late harvest days. The differences in fruit number and size were larger with increasing duration of the harvesting period. This report was similar to other studies (Adams and Ho,1989) and Van leperen,1996).

Cluster/plant: BARI Tomato 11 gave the highest number of cluster/plant (13.33) and also the fruits/cluster (13.67). BARI Tomato 4 gave the lowest number of cluster/plant (8.33). The reduction in fruit number observed in the present study appeared to be related to a reduction in the average number of flowers per cluster and per plant. This is consistent with the hypothesis of Cuartero and Munoz (1999) that stress restricts the number of flowers per truss. The number of cluster/plant was reduced both with high salinity and with long salinisation periods. So this characteristic seems to show little response to salinity up to 8 dS/m ECe (Van leperen, 1996).

Fruits/plant: The highest number of fruits/plant was recorded from BARI Tomato11 (212.33) which was statistically different from other varieties. The lowest number was recorded from BARI Tomato

4(23.66). But BARI Tomato 2, BARI Tomato 3 and BARI Tomato 9 showed the same number of fruits/plant. The decrease of fruit number in the present study was affected by salinity and the duration of the harvesting period. Results of this study are consistent with Adams and Ho (1989); Cuartero and Munoz (1999) and Van-leperen (1996) who observed that the number of harvested fruits per plant in tomato decreased due to salinity. The reduction in fruit number observed in the study appeared to be related to a reduction in the average number of flowers per cluster and per plant. Grunberg *et al.* (1995) reported that fruit set could be decreased because of low number of pollen grains/flower in plants under salt stress; extra flower production would be inhibited (Saito and Ito, 1974).

Individual fruit weight: The highest individual fruit weight was noted from BARI Tomato 7 (85 gm) while lowest from BARI Tomato 11(3.33gm). The fruit fresh weight for variety BARI Tomato 7 was enhanced in this saline area could be a good sign for positive response of plants to salinity (Table 5).

Fruit diameter: Tomato fruit diameter decreased significantly at 5% level in different varieties. The highest fruit diameter was noted from BARI Tomato14 (17cm) while the lowest diameter was found in BARI Tomato11 (6 cm). BARI Tomato 3, BARI Tomato 7 and BARI Tomato 9 produced the second highest fruit diameter. In general, the smaller the fruit size, the less important its reduction in size by salt (Cruz and Cuartero, 1990).

Table 5. Yield and yield contributing characters of tomato varieties at study area during rabi season

Varieties	Branches /Plant no.	Days to flowering	Days to harvest	Cluster /plant no.	Fruits/ cluster no.	Fruits/ Plant no.	Individual fruit wt (g)	Diameter /Fruits (cm)	Fruit length (cm)	Yield ton/ha
BARI Tomato-2	4.00cd	53ab	101a	9.33b	4.3bc	34.67c	54.67d	15.00c	4.33b	64.0bc
BARI Tomato-3	4.33bc	53.67a	103a	10.67b	3.67bc	32.33c	47.67g	16.00b	4.33b	65.67bc
BARI Tomato-4	4.33bc	53ab	91.33d	8.33c	3.33c	23.67e	20.33h	11.00d	3.0c	29.67d
BARI Tomato-7	4.00cd	52b	95.67c	9.67b	4.67b	31.00cd	85.00a	16.00b	5.0ab	100.33a
BARI Tomato-8	3.67d	53.67a	99b	9.33b	4.67b	27.33de	64.67c	15.00c	5.33a	83.67ab
BARI Tomato-9	5.00a	50.67c	91.33d	9.67b	4.0bc	34.00c	55.00d	16.00b	5.67a	56.33d
BARI Tomato-11	4.33bc	52b	91.67d	13.33a	13.67a	212.33a	3.67i	6.00e	2.33d	20.33c
BARI Tomato-14	4.67ab	53.67a	93.67c	10.67b	4.67b	40.00b	51.00f	17.00a	5.67a	74.0bc
CV (%)	8.81	1.31	0.89	6.29	12.69	3.98	2.07	0.00	5.36	1.838

Yield (ton/ha): BARI Tomato 7 gave the highest yield (90 t/ha) which was significantly different from all other varieties. The second highest fruit yield was obtained from the variety BARI Tomato 8(83.67 t/ha). The lowest was obtained from BARI Tomato 11(20.33 t/ha) due to its very small size. But BARI Tomato 4 was inferior to all other varieties 9 (Table 5). The yield of some varieties was less typically due to higher amount of salt depositions in the rhizosphere. However, BARI Tomato 14 was the second tallest but the fruits production in this variety was low may be due to its higher value for green matter under high salinity. This result was similar to Annual research report of BARI (2007) and BARI and ICBA (2007) in the saline areas of Bangladesh. Generally, the incorporation of salinity stress and weakness to tolerate salinity could lead to higher loss of plant production in some varieties (Daoud *et al.*, 2001).

CONCLUSION

Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degree of salinity. In this area electrical conductivity was slightly saline to saline (2.9 to 5.2 dS/m). The higher pH values of the soils are likely to create micronutrient deficiency problem. Cation exchange capacity varied from 12.5 to 19.1 meq/100 gm soil expressing medium to high status. The dominant water soluble cations were Na^+, Ca^{2+}, Mg^{2+} and K^+ and anions Cl^- and SO_4^{2-}. Hence, soil fertility should be improved based on the results obtained in the present study. In the field experiment, salinity range was 5.2 dS/m and 14.32 dS/m during transplanting and harvesting time at Satkhira. Plant growth was significantly affected by salinity in this saline area. Variety BARI Tomato7 gave the highest plant height (114.67 cm) and yield (100.33 t/ha). BARI Tomato 4, BARI Tomato 9 and BARI Tomato11 showed early harvest days. The highest number of fruits/plant was recorded from BARI Tomato 11 which was cherry type and the lowest number was recorded from BARI Tomato 4. Some varieties showed an optimistic response to salinity by producing more yield. The people in the coastal saline belt can grow short winter season and timely sowing/planting of rabi (winter) crops like tomato to increase the cropping intensity.

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