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Effects of Salinity on Soil and Tomato Yield at Coastal Area of Bangladesh

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Abstract: Saline soil is an increasing threat to agriculture and a key factor in reducing plant productivity. A field study was carried out from different soil depths at Kalapara Upazila in Patuakhali district and tomato plant was grown to determine the effects of salinity on it. It was found that the soil was silty clay, average pH 6.65, cation exchange capacity varied from 12.80 to 21.0 meq/100 g soil venting medium to high status. The organic matter content was low (0.967%), total nitrogen was 0.071%, phosphorous and potassium were low but sulphur was high (47 mg/kg). Exchangeable sodium, potassium, calcium and magnesium existed at high levels. The present results revealed that salinity adversely affected the morphological and yield parameters of tomato. The tomato yield declined as salinity increased, and the reduction varied depending on the stage. The yield decreasing rate was the highest in BARI Tomato 14 (62%), but BARI Tomato 7 showed lower decreases due to salinity increases (47%). So, BARI Tomato-7 was the most salt tolerant and suitable variety for the Kalapara coastal region.

Keywords: Cation Exchange Capacity; Organic matter; Salinity; Soil; Tomato plant.

INTRODUCTION

Bangladesh is an agro-based country where a number of environmental issues and problems are obstructing its development. A huge area of about 24.5 million hectares in Bangladesh goes under problematic soils (Khan *et al.* 2008). These soils impose a severe limitation on successful crop production due to the unfavorable effects of certain chemical or physical properties of soils. The agricultural production has to be stepped up substantially either by multiple cropping on the existing cultivated lands or by bringing the additional area under cultivation. But the possibility to increase the food production by these two ways is seriously limited, particularly in Bangladesh. The probable feasible alternative is to increase the cultivated area by bringing the waste and barren lands under cultivation.

Soil salinity affects the chemical parameters in soil and it is one of the major reasons of decline in the organic matter and nitrogen level in the southwestern part of Bangladesh. The highlands of Barisal, Khulna and Patuakhali regions are mostly salt affected and local transplanted Aman rice is the principal crop where flooding depth ranges from 0.3-0.9 meter. This kind of land is suitable for at least two crops and sometimes three crops. The cropping patterns followed in the coastal regions are generally Fallow-Fallow-Transplanted Aman rice. The low land used in coastal area is largely difficult due to critical soil salinity in dry season and inaccessibility of quality irrigation water. In the coastal saline belt with short winter season, timely sowing/planting of rabi crops is crucial. Cropping intensity can be improved in slightly saline areas by adopting proper soil and water management practices with the introduction of salt stress tolerant crop varieties.

The cultivated tomato, *Lycopersicon esculentum* Mill., is moderately tolerant to salinity and is typically cultivated in regions that are exposed to soil salinization (Cuartero *et al* 1999). Salinity problem indicated very little attention in the past, but due to increased demand for growing more food to nourish the rising population of the country it has become imperative to explore the potentials of salt affected lands. The tomato production is inhibited in the coastal area of Kalapara due to appropriate knowledge of salt tolerant variety, developed technology and upward or lateral movement of saline groundwater during the dry season viz, November-May (Karim *et al*. 1990). Environmental conditions varies from year to year and region to region in the coastal areas so, phenotypically stable varieties are of great importance, Therefore the study was aimed to assess the effect of salinity on physico-chemical properties of soil and to explore the changes of morpho-physiological and yield parameters of tomato plant at different salinity levels.

MATERIALS AND METHODS

This experiment was conducted in two steps. In first step, soil sample collection, laboratory analysis and in the second step, tomato plant grown in pots with different salinity levels.

Location of the study area

A field survey was carried out at Kalapara upazila of Patuakhali district of Barisal Division in Bangladesh which is located at 21.9861^0N and 90.2422^0E (Figure 1). Topographically these parts are low lying and have elevations mostly less than 8 m above the mean sea level.

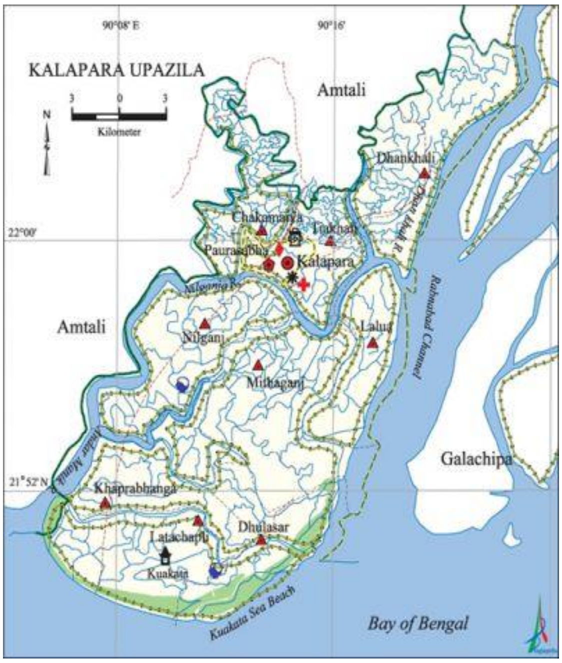

Figure 1. Study areas at Kalapara in Patuakhali district of Bangladesh (Source: Google Earth).

Soil data collection and analysis

Systematic random sampling techniques were used for sample collection from 30 sites at 0.5 km distance and 0-50, 50-100 and 100-150 cm depth by auger. Composite soil samples were analyzed for particle-size distribution, pH, electrical conductivity (EC), cation exchange capacity (CEC), organic carbon and total nitrogen. The available phosphorous was determined by Olsen *et al.* (1954) method and the available sulfur by calcium chloride (0.15%) extraction method. The non-exchangeable potassium content was obtained by boiling HNO_3 method. Exchangeable magnesium was extracted by Diethylene Triamine Penta Acitate solution and its concentration in the extract was measured directly by an atomic absorption spectrophotometer (AAS). Flame photometer was used to estimate the exchangeable calcium, sodium and potassium.

Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR) were assessed by using the formula of Richards (1954)

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

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

Pot experiment

To determine the growth and yield response of tomato to different salinity levels, four tomato varieties were grown in pot at Sher-e-Bangla Agricultural research field during the period from November 2020 to March 2021 by two factor randomized complete block design with three replications. The electrical conductivity of salt solutions was 2, 4, 6 and 8 dS/m and 0.3 dS/m for tap water (control). Tomato plants were subjected to salinity at the vegetative stage after seedling establishment at 30 days after transplanting.

The soil data obtained from survey was analyzed by Statistical Package for Social Science (SPSS 16.0) and plant data by MSTAT-C program. The treatment means were compared by using DMRT/ LSD at 5% level of probability.

RESULTS AND DISCUSSION

Physical properties of soil

The dominant soil textural classes in the study area were silty clay and the clay and silt particles were detected to increase with depth (Table 1).

Table 1. Textural classes of soil at different depths in studied area.

Location	Depth cm	Particle size distribution (%) Sand	Silt	Clay	Texture
Kalapara	0-50	11	53	36	Silty Clay
	50-100	10	50	40	Silty Clay
	100-150	5	57	38	Silty Clay

Soil chemical properties

It is observed from the Table 2 that soil pH in 0 –50 cm depth was 5.70 to 5.92 that was slightly acidic but in 50 -100 cm 6.30 to 7.0 and in 100 –150 cm it remained 7.0 – 7.9. The low organic matter content may be due to lower topographic position, to the rapid decomposition of organic matter because of tropical monsoon climate, rapid removal of mineralized products through leaching and crop removal (Karim and Iqbal, 2001). Acute deficiency of phosphorous observed here. Similar result was obtained by Karim *et al*. (1990). In 41% areas of Bangladesh, phosphorous was found

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beneath the critical level for most of the agricultural crop (SRDI, 2003). Total nitrogen decreased with depth that was 0.05 to 0.09%. The low nitrogen level of saline soil was due to high rates of decomposition of organic matter and insufficient application of organic matter and high volatilization of ammonium nitrogen (Islam *et al.* 2014). Cation exchange capacity of different horizons varied from 10.2 to 19.0 meq/100 gm soil expressing medium status and potassium varied from 0.75 to 1.78 meq/100 gm. Insufficient application of potash fertilizer, high cropping intensity, and limited scope of tidal water inundation may be the reason of lower potassium content in this area.

Table 2. Chemical properties of soils collected from Kalapara of Patuakhali.

Sample No	Soil Layer Depth (cm)	pH	Total N (%)	CEC meq/100 gm soil	Organic Matter (%)	P mg/kg	K mg/100 gm soil	S mg/kg
1	0-50	5.70	0.09	10.2	1.20	1.50	0.09	65.00
	50-100	6.30	0.08	19.0	0.67	0.95	0.17	43.00
	100-150	7.00	0.06	18.2	0.58	0.75	0.10	39.00
2	0-50	5.92	0.08	12.2	1.75	1.78	0.07	62.00
	50-100	6.35	0.07	18.5	0.60	1.00	0.40	40.00
	100-150	7.80	0.06	17.0	0.59	0.90	0.10	40.00
3	0-50	5.90	0.09	12.8	1.75	1.60	0.08	63.00
	50-100	7.00	0.07	19.0	0.70	0.90	0.13	40.00
	100-150	7.90	0.05	17.2	0.50	0.75	0.11	38.00
Average		6.652	0.071	16.011	0.967	1.125	0.138	47.777
STD		0.817	0.013	3.351	0.527	0.391	0.102	11.766
CV (%)		12.28	19.18	20.93	54.55	34.75	33.20	24.62

The range of topsoil sulphur was 62.0 to 65.0 mg/g at Kalapara which was greater than the surrounding areas. Continuous inundation with tidal water may be the reason of higher sulphur content at this area. The critical limits of potassium and sulfur are 0.12 meq/100 g and 10 mg/kg though coastal soils usually have higher concentrations than the critical limit (Huq and Shoaib 2013). The greater ECe value found at the surface horizon followed by lessening with depth can be recognized to flooding with saline water or accumulation of salts through upward capillary movement of saline ground water. Soil salinity ranged from 3.5 to 4.4 (Table 3). But in dry season this ranges become 7 to 8.2 dS/m which belongs to saline category (SRDI, 2003).

Table 3. Salt characteristics of soils of study area at Kalapara, Patuakhali.

Location	Depth cm	ECe dS/m	CEC meq/ 100g soil	Exchangeable Cations (meq/100g soil)			
				Na	K	Ca	Mg
Kalapara	0-50	4.4	12.5	1.60	0.53	6.70	4.44
	50-100	3.8	20.90	2.10	1.10	10.7	7.71
	100-150	3.5	17.30	1.50	1.00	8.80	7.50
Average		3.9	16.9	1.73	0.87	8.70	6.53

Exchangeable Na, K, Ca and Mg

The exchangeable sodium of the soils of different depths found 1.60 to 2.1 meq/100 gm soils (Table 3). The exchangeable potassium varied mainly based on the clay content and it was 0.53 to 1.10 meq/100gm soil which was very high. The exchangeable calcium was 6.70 to 10.7 meq/100gm soil which was high to very high and exchangeable magnesium 4.44 to 7.71 meq/ 100gm soil that was in the very high level.

Water soluble ions

Na, K, Ca and Mg ions remained 0.7-1.5, 0.04 - 0.12, 0.05-0.12 and 0.08-0.2 meq/L respectively and the prominent anions were SO_4^{2-} and Cl^- in the study area. The amount of accumulated salt was observed higher at the surface horizon and increased with depth (Table 4).

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

At Kalapara the range of ESP was 9.50 to 13.05% that was intermediate and the SAR values varied from 1.90 to 3.30 which were acceptable. When the values of SAR and ESP in soils are greater than 13 and 15, respectively, the soils are said sodic soils and considered as problem soils (Osman, 2013).

In order to analyze the growth and yield characteristics of tomato in response to salinity were tested with different NaCl concentrations and the findings have been discussed below:

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Table 4. Water soluble ions, ESP and SAR of the study area at Kalapara, Patuakhali.

Location	Depth cm	Water soluble ions meq/L						ESP (%)	SAR
		Na	K	Ca	Mg	Cl	SO_4		
Kalapara	0-50	0.70	0.04	0.05	0.08	1.5	3.5	13.05	1.90
	50-100	1.30	0.12	0.12	0.20	1.6	3.80	10.58	2.30
	100-150	1.50	0.10	0.10	0.11	2.3	4.20	9.50	3.30
Average		1.66	0.08	0.09	0.13	1.8	3.5	11.19	2.5

Plant height (cm)

Plant height reduced significantly due to salinity increase and the reduction was quite incremental in tomato. At maturity stage plant height of the varieties was significantly different from each other and it was (90 cm) in BARI Tomato 7 in control. The difference of plant height among the varieties might be due to diverse genetic makeup of the varieties. The inhibitory effect of salinity on plant growth was well documented and a common phenomenon due to a combination of osmotic ion effects of Cl- and Na+ (Masud, 2018; Bakht *et al.* 2011)

Table 5. Effects of tomato varieties and salinity levels on plant height at vegetative and maturity stages.

Salinity Levels	BARI Tomato 2		BARI Tomato 7		BARI Tomato 9		BARI Tomato 14	
	V	M	V	M	V	M	V	M
Control	37.33	67.67	43.00	90.00	33.33	60.67	38.67	74.00
2dS/m	36.67	65.33	39.00	86.67	30.67	56.33	34.33	68.00
4dS/m	32.33	60.67	35.00	81.00	30.00	51.00	31.67	63.33
6S/m	29.67	55.33	30.00	76.00	26.00	48.00	29.67	58.00
8dS/m	26.67	50.33	27.30	70.60	23.00	43.00	36.33	54.00
SE	1.23	1.40	1.23	1.40	1.23	1.40	1.23	1.40
LSD (5%)	2.48	2.82	2.48	2.84	2.48	2.84	2.48	2.84

Number of leaves per plant

Salinity adversely influenced the production of leaf number in Tomato plants. At vegetative stage, the highest (20.33) number was found at control from BARI Tomato 7 which was statistically different from others and the lowest (8) in BARI Tomato 14 at 8 dS/m (Table 6).

Similar observation was also found by Naher *et al.* (2020) and Nizam *et al.* (2019) in tomato. This lessening in internodal distance and number of leaves may be due to the decrease in turgor potential, essential for cell elongation (Iqbal and Ashraf 2005) and turgor pressure, which were reduced under salt stress (Ashraf and Harris 2004).

Table 6. Effects of tomato varieties and salinity levels on number of leaf (at vegetative and maturity stages).

Salinity Levels	BARI Tomato 2		BARI Tomato 7		BARI Tomato 9		BARI Tomato 14	
	V	M	V	M	V	M	V	M
Control	13.00	18.67	20.33	26.00	13.00	15.00	14.00	14.67
2 dS/m	12.67	16.67	19.67	23.67	12.33	12.00	13.33	13.33
4 dS/m	11.00	14.00	17.33	19.33	10.33	11.00	11.67	12.00
6 dS/m	9.33	12.00	15.33	18.00	9.33	9.33	10.00	10.00
8 dS/m	8.33	9.33	13.00	14.00	8.33	8.67	8.00	9.33
SE	0.63	0.69	0.63	0.69	0.63	0.69	0.63	0.69
LSD (5%)	1.29	1.39	1.29	1.39	1.29	1.39	1.29	1.39

Here, V- Vegetative stage and M- Maturity stage

Chlorophyll (SPAD value)

Salinity caused reduction in SPAD value of leaf which was statistically significant (Figure. 2, 3, 4, 5). The highest SPAD value in leaves was observed in the control plants and then decreased with rising salinity levels. At vegetative stage BARI Tomato 7 exhibited the maximum chlorophyll content (49.05 SPAD units) and BARI Tomato 9 presented the lowest (41.5 SPAD units). At maturity stage the SPAD value was the lowest. The reduction is higher in vegetative stage than in maturity stage which is in agreement with (Naher *et al.* 2011) for tomato.

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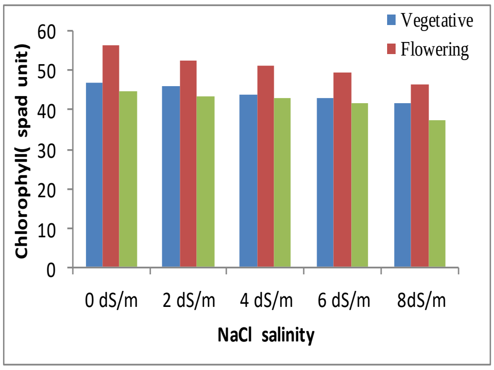

Figure 2. SPAD value of BARI Tomato 2 at different salinity level at 5% LSD.

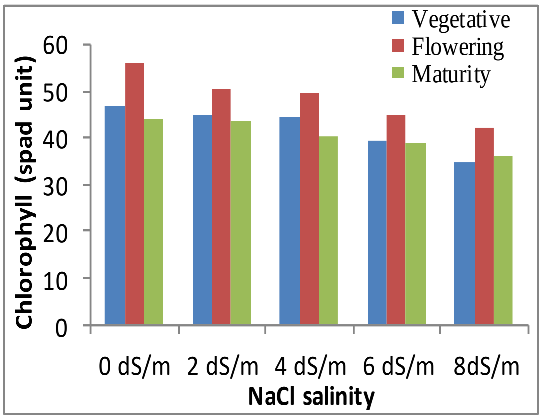

Figure 3. SPAD value of BARI Tomato 7 at different salinity level at 5% LSD.

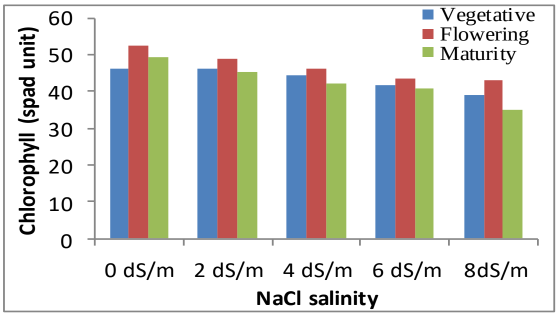

Figure 4. SPAD value of BARI Tomato 9 at different salinity level at 5% LSD.

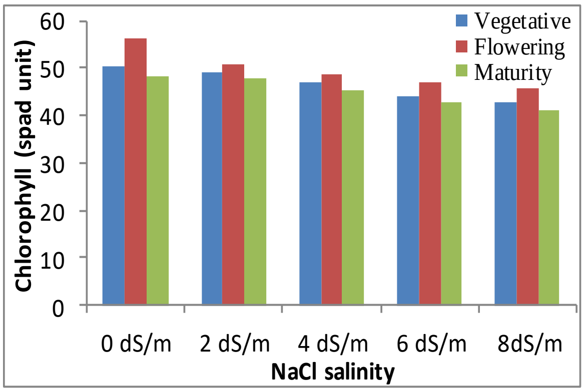

Figure 5. SPAD value of BARI Tomato 14 at different salinity level at 5% LSD.

The highest SPAD value in leaves was observed in the control plants and then decreased with rising salinity levels. At vegetative stage BARI Tomato 7 exhibited the maximum chlorophyll content (49.05 SPAD units) and BARI Tomato-9 presented the lowest (41.5 SPAD units). At maturity stage the SPAD value was the lowest. The reduction is higher in vegetative stage than in maturity stage which is in agreement with (Naher *et al.* 2011) for tomato.

Days to flowering, number of cluster/plant and number of fruits per plant

BARI Tomato 7 began to give flower at 53.6 days after transplanting which was significantly different from others (Table 7). BARI Tomato7 and BARI Tomato 14 gave the maximum number of cluster per plant (6.0) at control and at 8 dS/m. At 8 dS/m it was observed that BARI Tomato 7 presented the highest number of fruits per plant (24) and BARI Tomato 2 produced the lowest. Naher *et al.* (2020) reported the similar results in case of tomato. Grunberg *et al.* (1995) stated that fruit set could be reduced due to low number of pollen grains per flower in plants under saline condition and additional flower production would be repressed.

Table 7. Effects of NaCl salinity on days to flowering, number of cluster/plant and number of fruits/plant of tomato varieties.

Salinity Level	BARI Tomato 2			BARI Tomato 7			BARI Tomato 9			BARI Tomato 14		
	DF	Cl/P	F/P	DF	Cl/P	F/P	DF	Cl/P	F/P	DF	Cl/P	F/P
Control	52.67	5.00	21.00	53.6	6.00	29.67	52.0	5.00	25.67	50.6	6.00	29.00
2 dS/m	52.33	4.67	19.67	52.3	5.67	28.33	50.6	5.00	24.33	49.0	6.00	28.60
4 dS/m	49.33	4.00	17.33	50.0	5.33	26.33	49.0	4.00	21.67	48.6	5.00	25.33
6 dS/m	46.67	3.67	16.33	49.3	4.67	24.67	46.3	4.00	19.67	46.3	4.67	22.67
8 dS/m	45.67	3.00	15.00	49.0	4.33	24.00	46.3	3.67	19.00	45.3	4.33	20.67
SE	1.01	1.03	1.17	1.01	1.03	1.17	1.03	1.01	1.17	1.01	1.03	1.17
$LSD_{(5\%)}$	0.65	0.61	2.38	0.65	0.61	2.38	0.65	0.61	2.38	0.65	0.61	2.38

Here, DF- days to flowering and Cl/P - No. of cluster/plant and F/P – No. of fruit /plant

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Yield (kg/plant)

Among the varieties BARI Tomato 7 provided the highest yield and BARI Tomato 2 the lowest (Table 8). The decreasing rate was highest in BARI Tomato 14 (62%) and BARI Tomato 7 showed lower decreases due to salinity increase (47%). Tomato yield can be reduced by decreased average fruit weight and/or the lowering in the number of fruits produced by the plant. At relatively low ECe, the yield reduction observed is caused mainly by a reduction in the average fruit weight whilst the fruit number remains unchanged; the declining number of fruits explains the main portion of yield reduction at higher ECe (VanIeperen 1996; Cuartero and Soria 1997). Salinity negatively affects the yield of crop plants by reducing the availability of soil moisture, and due to the toxicity effects of sodium and chloride ions at high concentrations to the plant (Munns and Tester, 2008).

Table 8. Yield (kg/plant) of four tomato varieties as affected by NaCl salinity.

Tomato varieties	NaCl salinity				
	Control	2 dS/m	4 dS/m	6 dS/m	8 dS/m
BARI Tomato 2	0.79 (100)	0.75 (95)	0.58 (73)	0.47 (62)	0.39 (49)
BARI Tomato 7	1.35 (100)	1.27 (94)	1.05 (78)	0.86 (64)	0.72 (53)
BARI Tomato 9	1.0 (100)	0.90 (90)	0.63 (63)	0.47 (47)	0.39 (39)
BARI Tomato 14	1.25 (100)	1.18 (94)	0.78 (62)	0.58 (46)	0.47 (38)
CV (%)			11.94		
$LSD_{(0.05)}$			0.125		

Values presented in parenthesis indicate percent values to the control

CONCLUSION

Soil physico-chemical properties were changed due to salinity at Kalapara Upazilla. The organic matter was low, nutrient deficiencies of total nitrogen, phosphorous and potassium of these soils was quite dominant but sulphur was high. Exchangeable sodium, potassium, calcium and magnesium were in high level. It was found that salinity adversely affected the morphological and yield parameters of tomato plant. Among the varieties BARI Tomato 7 showed the best performance, so it can be added in cropping pattern to increase the cropping intensity at the coastal region of Bangladesh.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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