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VARIATION IN SALINITY THROUGH THE SOIL PROFILE IN SOUTH COASTAL REGION OF BANGLADESH

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ABSTRACT

The spatial variability of salt accumulation through the soil profile was studied at Latachapali union of Kalapara upazila, Patuakhali district, Bangladesh. The soil samples were collected from 30 locations covering six villages of the union: Kuakata, Malapara, Fashipara, Khajura, Mothaopara and Tajepara. Five locations were randomly selected from each village. From each location soil samples were collected from three soil depths at 0-2 cm, 2.1-4 cm and 4.1-6 cm. Electrical conductivity of top 0-2 cm soil depth was 20.49 dS/m, in 2.1-4 cm soil depth was 7.14 dS/m and in 4.1-6 cm soil depth 4.15 dS/m. The study soils were strongly acidic having pH value 4.73, 4.99 and 5.20 in 0-2, 2.1-4 and 4.1-6 cm soil depth, respectively. The highest of 8.8 Na:K ratio was found in 0-2 cm soil depth. The Na:K ratio gradually decreased with the increase of soil depth, having 6.59 in 2.1-4 cm and 5.42. in 4.1-6 cm soil depth. The results clearly reveal that the top soil is very much sensitive to salt stress. Based on the electrical conductivity and Na:K ratio the Fashipara, Kuakata and Tajepara village were found seriously affected by salinity.

Key words: Coastal region, Patuakhali district, electrical conductivity, Na:K ratio, saline soil

INTRODUCTION

Land salinization and water resource deterioration negatively affect irrigated agriculture in arid and semiarid areas by limiting the area of arable land and reducing crop yields worldwide (Munns *et al*., 2015). About 600 million people currently inhabit low-elevation coastal zones that will be affected by progressive salinization (Payo *et al.,* 2017). Soil salinity is a global problem that affects approximately 20 % of irrigated land and reduces crop yields significantly (Qadir *et al*., 2014). Bangladesh is a low-lying flat delta at the confluence of the Ganges-Brahmaputra-Meghna rivers system. The country is crisscrossed with an intricate network of rivers and also has a long coast line in its southern side which is about 710 km long and runs parallel to the Bay of Bengal through 19 districts and 151 upazillas (CZPo., 2005). The coastal region occupies 20% area of the country. A number of environmental issues and problems are hindering the development of coastal livelihood of Bangladesh. Salinity is one of the most important issue of them, which is expected to aggravate by climate change and sea level rise and eventually affect crop production (Hossain *et al.*, 2015). The southern region of Bangladesh is recognized as an agro

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ecologically disadvantaged region. Soil salinity, water salinity and water-logging are major constraints for higher crop productivity in the south coastal region of Bangladesh (MoA and FAO, 2013). Over 400 million hectares of soils are affected by salinity in which electrical conductivity of the root zone exceeds 4 dSm^{-1} at 25°C (Martinez *et al.,* 2012). In addition, climate change could result in increased soil surface salinity due to long periods of drought (Yeo *et al*., 2017).

A recent study indicates that the salinity affected area has increased from 8,330 km^2 in 1973 to 10,560 km^2 in 2009 (Soil Resource Development Institute (SRDI, 2010) in Bangladesh. However, the level of salt accumulation in different depths of soil is not adequately investigated. Through this research attention has been paid to evaluate the spatial variability of salt accumulation through the soil profile.

MATERIALS AND METHODS

The study was conducted at Latachapali union of Kalapara upazila, Patuakhali district, Bangladesh. This union is the south most union of Patuakhali district and attached with Bay of Bengal. The experimental area belongs to the agro ecological Zone of AEZ-13 (Ganges Tidal Flood Plain). The soil samples were collected from 30 locations covering six villages of Latachapali union: Kuakata, Malapara, Fashipara, Khajura, Mothaopara and Tajepara. Five locations were randomly selected from each village. From each location soil samples were collected from three soil depths at 0-2 cm, 2.1-4 cm and 4.1-6 cm. Thus total 90 soil samples (6 village × 5 locations per village × 3 depths per location) were collected in the study. Geographic positioning system (GPS) reading of the sampling location is given in Table 1. Soil samples were collected from each location by means of an auger on 16 April 2017. The collected soil samples were carried to the laboratory, air dried, broken down large macro aggregates, ground and passed through a 2-mm sieve to remove weeds and stubbles from the soil. Chemical analysis of the soil sample was done in the laboratory of the Department of Soil Science, Patuakhali Science and Technology

Table 1. GPS reading of the soil sampling locations.

Location	GPS reading	Location	GPS reading
Kuakata 1	Latitude- 21.82416 Longitude- 90.11748	Khajura 1	Latitude- 21.82650 Longitude- 90.11032
Kuakata 2	Latitude- 21.82571 Longitude- 90.1164	Khajura 2	Latitude- 21.82752 Longitude- 90.10905
Kuakata 3	Latitude- 21.82553 Longitude- 90.11542	Khajura 3	Latitude- 21.82937 Longitude- 90.11008
Kuakata 4	Latitude- 21.81891 Longitude- 90.11555	Khajura 4	Latitude- 21.83052 Longitude- 90.10978
Kuakata 5	Latitude- 21.82107 Longitude- 90.11504	Khajura 5	Latitude- 21.83208 Longitude- 90.11110
Malapara 1	Latitude- 21.82428 Longitude- 90.11059	Mothaopara 1	Latitude- 21.83609 Longitude- 90.11087
Malapara 2	Latitude- 21.82664 Longitude- 90.11094	Mothaopara 2	Latitude- 21.83489 Longitude- 90.1094
Malapara 3	Latitude- 21.82987 Longitude- 90.11238	Mothaopara 3	Latitude- 21.83587 Longitude- 90.10846
Malapara 4	Latitude- 21.83108 Longitude- 90.11141	Mothaopara 4	Latitude- 21.83794 Longitude- 90.10905
Malapara 5	Latitude- 21.83288 Longitude- 90.11134	Mothaopara 5	Latitude- 21.83742 Longitude- 90.11064
Fashipara 1	Latitude- 21.83666 Longitude- 90.11633	Tajepara 1	Latitude- 21.82505 Longitude- 90.15861
Fashipara 2	Latitude- 21.83788 Longitude- 90.11617	Tajepara 2	Latitude- 21.82434 Longitude- 90.15854
Fashipara 3	Latitude- 21.83928 Longitude- 90.11873	Tajepara 3	Latitude- 21.82511 Longitude- 90.16088
Fashipara 4	Latitude- 21.84241 Longitude- 90.11941	Tajepara 4	Latitude- 21.82618 Longitude- 90.15931
Fashipara 5	Latitude- 21.84553 Longitude- 90.12071	Tajepara 5	Latitude- 21.82647 Longitude- 90.1579

University, Dumki, Patuakhali. Chemical analysis was done for electrical conductivity, pH, and potassium and sodium contents following standard methods. Soil electrical conductivity (EC) was measured in 1:5 soil-water suspensions and multiplied by 5 and then match with tabulated value as described by Soil Resource Development Institute, Bangladesh (Petersen, 2002).

The recorded data on various soil parameters were statistically analyzed using 'Analysis of variance technique' with the help of STAR (Statistical Tool for Agricultural Research; 2013) computer program developed by International Rice Research Institute and the mean difference were adjusted by Duncan's Multiple Range Test at 5% level of significance.

For statistical interpretation, both soil depth effect and spatial effect/variation in villages were determined. To determine the soil depth effect each of 30 samples collected from respective soil depth of six villages were considered as replication. Accordingly for calculation of spatial effect (village effect) 15 soil samples collected from each village were considered as replication. The primary and mean data are presented in the following tables. The last row of each table exhibits the statistical interpretation of soil depth effect and similarly last column shows the statistical interpretation of spatial/village effect. The soil test value interpretation values in applicable cases are given at the bottom of each table.

RESULTS AND DISCUSSION

Electrical conductivity of soil

Electrical conductivity (EC) of soil was significantly influenced by soil depth. In the 0-2 cm soil depth, the EC value was 20.49 dS/m (Table 2). The EC value was drastically reduced to 7.14 dS/m in 2.1-4 cm soil depth. The EC value recorded in 4.1-6 cm soil depth (4.15 dS/m) was statistically similar with EC value found in 2.1-4 cm depth. Table 2 clearly evidenced that soil salinity developed within a very thin top layer of the soil, below which the salinity level is relatively comfortable for crop growth. Salts generally are transported from a salt laden water table to soil surface by capillary rise due to evaporation. When the water table rises close to the soil surface, the net rate of water movement to the surface by capillary action may exceed the downward flow of water. Thus, salts are carried toward the soil surface where the water evaporates and salts accumulate (Ghosh *et al*. 2016).

Over the locations the soils at 0-2 cm soil depth was highly saline (>12 dS/m) (Table 2). However, there was found a big variation among the samples. Out of 30 samples at 0-2.0 cm soil depth, only 1 was non-saline (3.3% of total samples), 2 slightly saline (6.7%), 4 moderately saline (13.3%), 3 saline (10.0%) and 20 was highly saline (66.7%). These results are consistent with Ceuppens *et al*. (1997) on paddy fields in the Senegal River delta showing that soil salinity progressively decreased with the increase in soil depth of rice cropping.

When soil depth effect is considered between different villages it was found that in 0-2 cm soil depth highest of 31.8 dS/m was recorded in Fashipara village which was followed by Kuakata (25.20 dS/m), Tajepara (25.11 dS/m), Mothaopara (16.32 dS/m), Malapara (13.56 dS/m) and Khajura (11.72 dS/m)

Table 2. Soil electrical conductivity (dS/m) as influenced by soil depths and locations

Locations	Soil depths			Location mean EC value (n=3)	Village mean (n=15)
	0-2 cm	2.1-4 cm	4.1-6 cm		
Kuakata 1	21.15	8.62	6.97	12.25	12.67
Kuakata 2	46.06	12.04	5.89	21.33	
Kuakata 3	28.26	5.45	5.89	13.20	
Kuakata 4	28.38	11.47	5.58	15.14	
Kuakata 5	2.17	1.31	0.78	1.42	
Kuakata mean	25.20	7.78	5.02		
Malapara 1	28.12	9.44	6.02	14.53	7.46
Malapara 2	5.07	1.45	0.92	2.48	
Malapara 3	6.97	4.88	0.85	4.23	
Malapara 4	5.45	1.58	1.38	2.80	
Malapara 5	22.17	9.31	8.24	13.24	
Malapara mean	13.56	5.33	3.48		
Fashipara 1	2.50	1.45	0.98	1.64	16.52
Fashipara 2	35.90	15.65	4.06	18.54	
Fashipara 3	9.69	4.37	1.64	5.23	
Fashipara 4	35.79	11.09	9.44	18.77	
Fashipara 5	75.10	28.38	11.72	38.40	
Fashipara mean	31.80	12.19	5.57		
Khajura 1	16.47	9.31	4.63	10.14	6.19
Khajura 2	11.79	4.37	1.25	5.80	
Khajura 3	13.81	1.97	1.58	5.79	
Khajura 4	1.78	0.59	0.65	1.01	
Khajura 5	14.76	5.83	4.12	8.24	
Khajura mean	11.72	4.41	2.45		
Mothaopara 1	5.96	1.45	1.11	2.84	8.35
Mothaopara 2	14.07	4.37	2.04	6.83	
Mothaopara 3	25.72	9.25	4.5	13.16	
Mothaopara 4	26.4	10.2	4.44	13.68	
Mothaopara 5	9.44	3.93	2.3	5.22	
Mothaopara mean	16.32	5.84	2.88		
Tajepara 1	35.7	12.67	9.63	19.33	12.74
Tajepara 2	36.9	6.34	4.5	15.91	
Tajepara 3	16.79	4.12	2.3	7.74	
Tajepara 4	15.21	4.31	5.64	8.39	
Tajepara 5	20.97	9	6.97	12.31	
Tajepara mean	25.11	7.29	5.81	12.74	
Grand depth mean	**20.49 A**	**7.14 B**	**4.15 B**		

Interpretation of EC value: Non saline 0-2, Slightly saline 2-4, Moderately saline 4-8, Saline 8-12, Highly saline >12 dS/m

Means with the same letter in column or row are not significantly different at 5% level by DMRT

Depth effect: Significant at 0.1 % level of probability, Standard error (±): 2.54

Village effect: Not significant, Standard error (±): 4.34

village (Fig. 1). Over the villages the EC value varied from 1.78 in Khajura Village to 75.10 in Fashipara village which indicates extreme variability in soil salinity. In agreement SRDI (2012) reported salinity from 0.3 to 70.0 dS/m in Ganges Tidal Flood plain soils.

Considering 2.1-4.0 cm soil depth highest mean EC (12.19 dS/m) was further recorded at Fashipara village (Fig. 1). The 2nd, 3rd, 4th, 5th and 6th position was obtained in the villages Khajura (11.72 dS/m), Kuakata (7.78 dS/m), Tajepara (7.29 dS/m), Mothaopara (5.84 dS/m) and Malapara (5.33 dS/m), respectively. At 4.1-6 cm soil depth Tajepara village (5.81 dS/m) had the highest EC value. The villages Fashipara, Kuakata, Malapara, Mothaopara and Khajura had EC value of 5.57, 5.02, 3.48, 2.88 and 2.45 dS/m, respectively (Fig. 1).

The EC value was not significantly influenced by villages (Table 2). Over the villages EC value varied from 6.19 to 16.52 dS/m. The lowest was in Khajura and highest was in Fashipara village. The second highest EC was found in Tajepara village (12.74 dS/m) although it was very closer to Kuakata village (12.67 dS/m).

Soil reaction (pH)

Considering soil depth effect, the lowest of 4.73 pH value was found in 0-2 cm soil depth. The pH value gradually increased with the increase of the soil depth. However, the rate of rise was not significant. The pH value in 2.1 to 4 cm and 4.1 to 6 cm soil depth was 4.99 and 5.20 which was 5.5 and 9.9% higher than the pH value found in 0-2 cm soil depth (4.73). All the soil depth mean pH value was strongly acidic. It was probably due to the accumulation of sulphate

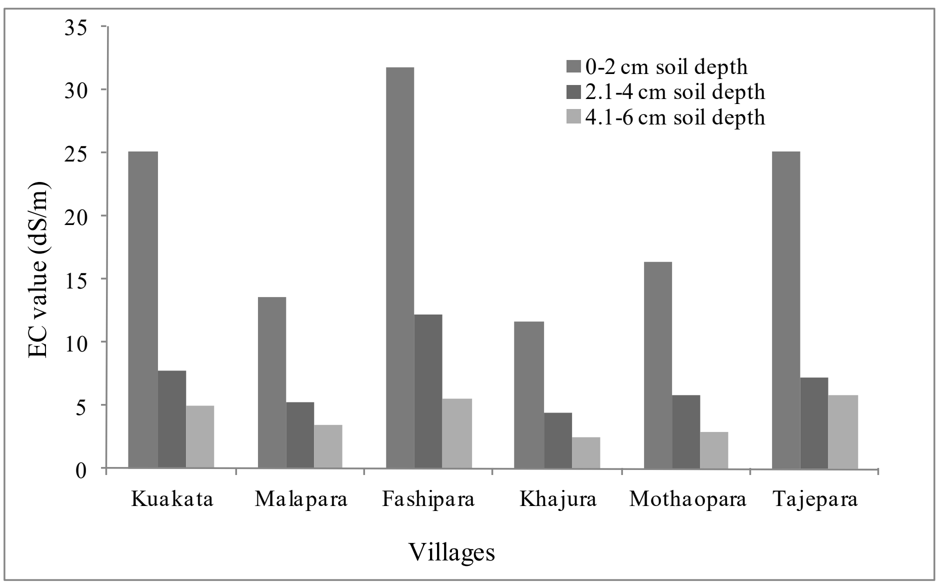

Fig. 1. Soil electrical conductivity (dS/m) in different depths at different villages of Kalapara upazila, Patuakhali, Bangladesh

Table 3. Soil pH as influenced by soil depths and locations

Locations	Soil depths			Location mean pH value (n=3)	Village mean (n=15)
	0-2cm	2.1-4 cm	4.1-6 cm		
Kuakata 1	4.6	4.75	4.81	4.72	5.23 a
Kuakata 2	5.17	5.06	6.09	5.44	
Kuakata 3	4.9	5.41	5.35	5.22	
Kuakata 4	4.42	4.83	5.55	4.93	
Kuakata 5	5.45	6.04	6.08	5.86	
Kuakata mean	**4.91**	**5.22**	**5.58**		
Malapara 1	4.28	4.63	4.63	4.51	4.87 ab
Malapara 2	4.42	4.75	4.81	4.66	
Malapara 3	4.5	4.95	5.35	4.93	
Malapara 4	5.01	4.89	5.2	5.03	
Malapara 5	5.03	5.69	4.88	5.20	
Malapara mean	**4.65**	**4.98**	**4.97**		
Fashipara 1	5.22	5.57	6.21	5.67	5.37 a
Fashipara 2	4.41	4.46	4.84	4.57	
Fashipara 3	5.1	5.3	4.89	5.10	
Fashipara 4	5.17	5.27	5.17	5.20	
Fashipara 5	5.8	6.46	6.75	6.34	
Fashipara mean	**5.14**	**5.41**	**5.57**		
Khajura 1	4.74	5.22	5.13	5.03	5.06 ab
Khajura 2	4.29	4.51	4.97	4.59	
Khajura 3	4.41	4.78	4.85	4.68	
Khajura 4	5.38	5.26	5.08	5.24	
Khajura 5	6.34	5.24	5.63	5.74	
Khajura mean	**5.03**	**5.00**	**5.13**		
Mothaopara 1	4.41	4.65	4.77	4.61	4.61 b
Mothaopara 2	4.4	4.68	4.8	4.63	
Mothaopara 3	4.21	4.41	4.96	4.53	
Mothaopara 4	4.65	4.34	4.62	4.54	
Mothaopara 5	4.57	4.71	4.91	4.73	
Mothaopara mean	**4.45**	**4.56**	**4.81**		
Tajepara 1	4.2	4.44	4.83	4.49	4.71 b
Tajepara 2	4.25	4.95	5.27	4.82	
Tajepara 3	4.1	4.64	5.58	4.77	
Tajepara 4	4.3	5.13	4.9	4.78	
Tajepara 5	4.11	4.78	5.19	4.69	
Tajepara mean	**4.19**	**4.79**	**5.15**		
Grand depth mean	**4.73 B**	**4.99 A**	**5.20 A**		

Interpretation of pH value: Very strongly acid <4.5, strongly acid 4.5-5.5, slightly acid 5.6-6.5, neutral 6.6-7.3, slightly alkaline 7.4-8.4, strongly alkaline 8.5-9.0
Means with the same letter in column or row are not significantly different at 5% level by DMRT
Depth effect: Significant at 1.0 % level of probability, Standard error (±)- 0.1333
Village effect: Significant at 0.1 % level of probability, Standard error (±)- 0.1775

containing materials, decomposition of organic matter and subsequent formation of carbonic acid (Islam *et al*., 2014). The increased acidity has many other negative effects on plant growth along with reduced availability of many essential plant nutrient elements. For example, when pH drops from 5 to 4 severe Al and Fe toxicity and phosphorus deficiency appears in plant (Brady and Weil, 2013). Acid soils possess toxic concentration of Al^{3+}, Fe^{3+}, and Mn^{2+} and lower concentration of available P, Mo, Ca and Mg (FRG 2012). Alam (2004) found pH value of saline soils of Bangladesh were 6.25 to 8.07 and 6.44 to 8.34 at 0-15 cm and 15-30 cm soil depth, respectively.

When soil depth effect was considered on village basis at 0-2 cm soil depth the Tajepara village had the highest acidity (4.19; lowest pH value). Based on the severity of acidity the villages were ranked as Tajepara (4.19) > Mothaopara (4.45) > Malapara (4.65) > Kuakata (4.91) > Khajura (5.03) > Fashipara (5.14). At 2.1-4 cm soil depth this ranking was as follows: Mothaopara (4.56) > Tajepara (4.79) > Malapara (4.98) > Khajura (5.00 > Kuakata (5.22) > Fashipara (5.41). Similarly in 4.1-6 cm soil depth the Mothaopara (4.81), Malapara (4.97), Khajura (5.13), Tajepara (5.15), Fashipara (5.57) and Kuakata (5.58) had the 1st, 2nd, 3rd, 4th, 5th and 6th position in severity of acidity.

Spatial variability of soil pH among the villages was not significant. Lowest mean pH value was found in Mothaopara village (4.61). The 2nd, 3rd, 4th, 5th and 6th rank was found in Tajepara (4.71), Malapara (4.87), Khajura (5.06), Kuakata (5.23) and Fashipara (5.37). Based on the mean value the soil of all the villages were strongly acidic.

Exchangeable K content in soil

Potassium content was significantly influenced by both soil depth and villages. The ammonium acetate extractable K found in 0-2, 2.1 to 4 and 4.1 to 6 cm soil depth was 46.5, 41.0 and 39.2 ppm, respectively (Table 4). The significantly higher K was found in 0-2 cm soil depth. The K content found in 2.1 to 4 and 4.1 to 6 cm was statistically insignificant. The K content found in 2.1 to 4 and 4.1 to 6 cm soil depth was 11.8 and 15.7 % lower than that found in 0-2 cm soil depth.

When soil depth effect was considered on village basis it was found that at 0-2 cm soil depth the Kuakata, Malapara, Fashipara, Khajura, Mothaopara and Tajepara village had K content of 38.1, 51.7, 44.0, 50.1, 44.0 and 51.3 ppm and in 2.1- 4 cm soil depth it was 34.6, 45.0, 41.5, 37.7, 38.3 and 48.8 ppm, and that of 33.9, 42,1, 38.1, 34.2, 33.2 and 53.6 ppm, respectively in 4.1- 6 cm soil depth.

When K content was compared between different villages it was found that the Tajepara village had highest K content (51.2 ppm). The second highest K content was found in Malapara village (46.3 ppm). The Fashipara, Khajura, Mothaopara and Kuakata village had mean K content of 41.2, 40.7, 38.5 and 35.5 ppm.

Exchangeable Na content of soil

Significant variation was observed among the soil depths in relation to exchangeable Na content of soil (Table 5). Among the 30 sample data exchangeable Na content in 0-2, 2.1-4 and 4.1-6 cm soil depth ranged from 129.6 to 925.9, 74.1 to 634.3 and 78.7 to 444.4 ppm, respectively. In every soil depth lowest Na content was found at Mothaopara village.

Table 4. Soil exchangeable K content (ppm) as influenced by soil depths and locations

Locations	Soil depths			Location mean K content (n=3)	Village mean (n=15)
	0-2cm	2.1-4 cm	4.1-6.0 cm		
Kuakata 1	35.3	39.6	38.8	37.9	35.5 c
Kuakata 2	56.0	51.3	46.0	51.1	
Kuakata 3	43.4	43.7	44.3	43.8	
Kuakata 4	21.8	15.4	12.8	16.7	
Kuakata 5	34.1	22.8	27.7	28.2	
Diaramkhola mean	**38.1**	**34.6**	**33.9**		
Malapara 1	55.0	53.9	45.8	51.6	46.3 ab
Malapara 2	53.7	34.1	38.5	42.1	
Malapara 3	64.9	49.7	42.6	52.4	
Malapara 4	48.2	36.9	40.8	42.0	
Malapara 5	36.9	50.5	42.7	43.4	
Ghoramkhola mean	**51.7**	**45.0**	**42.1**		
Fashipara 1	33.3	27.7	25.9	29.0	41.2 abc
Fashipara 2	52.9	52.3	42.7	49.3	
Fashipara 3	40.8	39.8	37.7	39.4	
Fashipara 4	41.1	34.5	31.2	35.6	
Fashipara 5	51.9	53.1	53.1	52.7	
Fashipara mean	**44.0**	**41.5**	**38.1**		
Khajura 1	40.3	39.0	39.3	39.5	40.7 abc
Khajura 2	56.8	40.3	31.4	42.8	
Khajura 3	52.3	46.6	41.7	46.9	
Khajura 4	58.3	26.5	25.2	36.7	
Khajura 5	43.0	36.2	33.2	37.5	
Kuakata mean	**50.1**	**37.7**	**34.2**		
Mothaopara 1	43.9	33.0	41.1	39.3	38.5 bc
Mothaopara 2	25.1	33.7	22.0	26.9	
Mothaopara 3	42.6	42.7	37.1	40.8	
Mothaopara 4	56.8	45.5	38.5	46.9	
Mothaopara 5	51.8	36.9	27.3	38.7	
West Kuakata mean	**44.0**	**38.3**	**33.2**		
Tajepara 1	47.2	46.8	45.0	46.3	51.2 a
Tajepara 2	50.2	46.6	48.7	48.5	
Tajepara 3	37.4	38.0	51.0	42.1	
Tajepara 4	50.8	52.3	55.5	52.9	
Tajepara 5	70.7	60.2	67.6	66.2	
Tajepara mean	**51.3**	**48.8**	**53.6**		
Grand depth mean	**46.5 A**	**41.0 B**	**39.2 B**		

Interpretation of K content: Very low <0.075, low 0.076-0.15, medium 0.151-0.225, optimum 0.226-0.30, high 0.31-0.375, very high >0.375

Means with the same letter in last column or last row are not significantly different at 5% level by DMRT.

Depth effect: Significant at 5.0 % level of probability, Standard error (±)- 2.77

Village effect: Significant at 0.1 % level of probability, Standard error (±)- 3.67

When mean of 30 samples was considered highest of 390.1 ppm was recorded at 0-2 cm soil depth. The lowest value of 196.5 ppm was in 4.1 to 6 cm soil depth which was not statistically different with Na content of 2.1-4 cm soil depth (261.3 ppm). Table 5 indicated that with the increases of soil depth the Na content was reduced gradually.

Table 5. Soil exchangeable Na content (ppm) as influenced by soil depths and locations

Locations	Soil depths			Location mean Na content (n=3)	Village mean (n=15)
	0-2 cm	2.1-4 cm	4.1-6 cm		
Kuakata 1	333.3	310.2	296.3	313.3	341.7
Kuakata 2	773.1	435.2	287.0	498.5	
Kuakata 3	606.5	314.8	236.1	385.8	
Kuakata 4	560.2	333.3	217.6	370.4	
Kuakata 5	180.6	111.1	129.6	140.4	
Kuakata mean	**490.7**	**300.9**	**233.3**		
Malapara 1	601.9	393.5	263.9	419.8	245.1
Malapara 2	199.1	92.6	88.0	126.5	
Malapara 3	240.7	138.9	111.1	163.6	
Malapara 4	194.4	129.6	129.6	151.2	
Malapara 5	314.8	472.2	305.6	364.2	
Malapara mean	**310.2**	**245.4**	**179.6**		
Fashipara 1	180.6	138.9	148.1	155.9	354.9
Fashipara 2	588.0	430.6	222.2	413.6	
Fashipara 3	171.3	157.4	152.8	160.5	
Fashipara 4	537.0	319.4	273.1	376.5	
Fashipara 5	925.9	634.3	444.4	668.2	
Fashipara mean	**480.6**	**336.1**	**248.1**		
Khajura 1	375.0	282.4	203.7	287.0	230.2
Khajura 2	351.9	185.2	101.9	213.0	
Khajura 3	338.0	157.4	134.3	209.9	
Khajura 4	166.7	111.1	111.1	129.6	
Khajura 5	435.2	268.5	231.5	311.7	
Khajura mean	**333.3**	**200.9**	**156.5**		
Mothaopara 1	129.6	74.1	78.7	94.1	249.1
Mothaopara 2	185.2	351.9	157.4	231.5	
Mothaopara 3	504.6	342.6	203.7	350.3	
Mothaopara 4	532.4	333.3	199.1	354.9	
Mothaopara 5	314.8	171.3	157.4	214.5	
Mothaopara mean	**333.3**	**254.6**	**159.3**		
Tajepara 1	560.2	407.4	347.2	438.3	274.7
Tajepara 2	648.1	282.4	263.9	398.1	
Tajepara 3	356.5	148.1	92.6	199.1	
Tajepara 4	143.5	129.6	148.1	140.4	
Tajepara 5	254.6	180.6	157.4	197.5	
Tajepara mean	**392.6**	**229.6**	**201.9**		
Grand depth mean	**390.1 A**	**261.3 B**	**196.5 B**		

Means with the same letter in last column or last row are not significantly different at 5% level by DMRT

Depth effect: Significant at 0.1 % level of probability, Standard error (±) - 39.14

Village effect: Not significant, Standard error (±) - 6.35

Considering soil depth effect in different villages it was found that the Kuakata village had highest Na content (490.7 ppm) in 0-2 cm soil depth. The second and third rank in this depth was in Fashipara (mean 480.6 mmp, range 180.6-925.9 ppm) and Tajepara village (mean 392.6 ppm, range 143.5-648.1 ppm). In 2.1 to 4 cm soil depth the highest Na content was in Fashipara village (mean 300.9 ppm, range 111.1 to 435.2 ppm). Similar trend was also found in 4.1 to 6 cm soil depth. Among the six villages across the soil depths the Khajura village had the lowest Na content having mean 333.3, 200.9 and 156.5 ppm in 0-2, 2.1-4 and 4.1-6 cm soil depths, respectively.

The study villages were not statistically different in relation to exchangeable Na content of soil. The exchangeable Na content ranged from 230.2 ppm in Khajura village to 354.9 ppm in Fashipara village. The ranking of the villages in relation to Na content was as follows: Fashipara (354.9 ppm) > Kuakata (341.7 ppm) > Tajepara (274.7 ppm) > Mothaopara (249.1 ppm)> Malapara (245.1 ppm) > Khajura (230.2 ppm).

There was a significant positive strong correlation between Na and EC in the experiment ($r = 0.899$; $p > 0.1$; Table 7) which also a good agreement with Haque *et al*. (2008 and 2014). Excess sodium (Na^+) in the soil competes with Ca^{2+}, K^+, and other cations to reduce their availability to crops. Therefore, soils with high levels of exchangeable sodium (Na^+) may impact plant growth by dispersion of soil particles, nutrient deficiencies or imbalances, and specific toxicity to sodium sensitive plants (Machado *et al*. 2017).

Na:K ratio of soil

The Na:K ratio is an important determinant for achieving tolerance capacity of plant to salt stress. Although Na is the most hazardous element in saline soil, but even its higher concentration could not be harmful until K concentration remain in lower concentration. In fact there is a competition among Na and K in saline soil for plant uptake. Thus higher the Na:K ratio is more detrimental than lower Na:K ratio. In the experiment Na:K ratio was found significantly influenced by soil depth. Table 6 indicated that highest Na:K ratio (8.80) was found in 0-2 cm soil depth. It was reduced to 6.59 in 2.1-4 cm soil depth. The Na:K ratio found in 2.1-4 cm and 4.1-6 cm (5.42) was statistically insignificant. The results are therefore clearly evidenced that top soil is very much sensitive to sodium toxicity.

The village effect on Na:K ratio was also significant. The highest Na:K ratio of 10.61 was found in Kuakata village. The second highest Na:K ratio was found in Fashipara village (8.14) which was statistically similar with Kuakata village. The lowest Na:K ratio was found in Malapara village (5.17) which was statistically similar with Khajura (5.65), Tajepara (5.66) and Mothaopara village (6.39). The results further indicated that based on mean value the village Fashipara and Kuakata are the most sensitive to Na toxicity in soil. The high K/Na ratios are essential for normal plant functioning (Chinnusamy *et al*. 2005). The salt tolerant varieties show a lower Na:K ratio throughout a wide range of saline conditions (Hussain and Khattak 2005).

Table 6. Soil Na:K ratio as influenced by soil depths and locations

Locations	Soil depths			Location mean Na:K ratio (n=3)	Village mean (n=15)
	0-2cm	2.1-4 cm	4.1-6 cm		
Kuakata 1	9.45	7.82	7.63	8.30	10.61 a
Kuakata 2	13.81	8.48	6.25	9.51	
Kuakata 3	13.99	7.21	5.33	8.84	
Kuakata 4	25.64	21.68	17.02	21.45	
Kuakata 5	5.29	4.87	4.68	4.95	
Kuakata mean	**13.64**	**10.01**	**8.18**		
Malapara 1	10.94	7.30	5.76	8.00	5.17 b
Malapara 2	3.71	2.71	2.28	2.90	
Malapara 3	3.71	2.80	2.61	3.04	
Malapara 4	4.03	3.51	3.18	3.58	
Malapara 5	8.53	9.35	7.15	8.35	
Malapara mean	**6.18**	**5.14**	**4.20**		
Fashipara 1	5.42	5.02	5.72	5.39	8.14 ab
Fashipara 2	11.11	8.24	5.20	8.18	
Fashipara 3	4.20	3.95	4.05	4.07	
Fashipara 4	13.07	9.27	8.75	10.36	
Fashipara 5	17.83	11.95	8.37	12.72	
Fashipara mean	**10.32**	**7.69**	**6.42**		
Khajura 1	9.31	7.24	5.18	7.24	5.65 b
Khajura 2	6.19	4.60	3.24	4.68	
Khajura 3	6.47	3.38	3.22	4.35	
Khajura 4	2.86	4.19	4.40	3.82	
Khajura 5	10.11	7.41	6.98	8.17	
Khajura mean	**6.99**	**5.36**	**4.60**	**5.65**	
Mothaopara 1	2.96	2.24	1.91	2.37	6.39 b
Mothaopara 2	7.38	10.45	7.15	8.33	
Mothaopara 3	11.86	8.02	5.50	8.46	
Mothaopara 4	9.37	7.33	5.17	7.29	
Mothaopara 5	6.08	4.64	5.76	5.49	
Mothaopara mean	**7.53**	**6.54**	**5.10**		
Tajepara 1	11.86	8.71	7.72	9.43	5.66 b
Tajepara 2	12.92	6.06	5.42	8.13	
Tajepara 3	9.54	3.90	1.82	5.08	
Tajepara 4	2.82	2.48	2.67	2.66	
Tajepara 5	3.60	3.00	2.33	2.98	
Tajepara mean	**8.15**	**4.83**	**3.99**		
Grand depth mean	**8.80 A**	**6.59 B**	**5.42 B**		

Means with the same letter in last column or last row are not significantly different.
Depth effect: Significant at1 % level of probability, Standard error (±)- 1.05
Village effect: Significant at 1 % level of probability, Standard error (±)- 1.44

Table 7. Correlation between different soil parameters

Parameters	pH	EC	K	Na
pH	1.000			
EC	-0.123	1.000		
K	-0.179	0.303**	1.000	
Na	-0.041	0.899***	0.309**	1.000
Na:K ratio	-0.012	0.682***	-0.222*	0.778***

*=Significant at 5% level, **=Significant at 1% level, ***=Significant at 0.1% level

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