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Impacts of Salinity on Mineral Accumulations in Vegetables Grown in the South-Central Coastal Region of Bangladesh for Nutritional Security

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Abstract— Water and soil salinity is gradually increasing due to climate change and limits the production and quality of crops. Mineral contents of vegetable are one of the vital requirements for human nutrition and food security. The uptake and accumulation of minerals in vegetables are influenced by different degrees of soil salinity. Considering these factors, a research work was conducted in the Department of Agricultural Chemistry, Patuakhali Science and Technology University to find out the impacts of salinity on mineral contents and their quality. The vegetables papaya (Carica papaya), brinjal (Solanum melongena), radish (Raphanus sativus), tomato (Lycopersicon esculentum), yard long bean (Vigna unguiculata) and knolkhol (Brassica oleracea) were collected along with saline and non-saline soils from Sonakata of Barguna and Kadamtala of Patuakhali, respectively in the south-central coastal region of Bangladesh. Soil and vegetable were analyzed for P, K, Ca, Mg, S, Cu, Mn, Zn and B. Soil pH, EC and Na were also analyzed. Results indicated that pH and EC of the soils were 7.2-7.9 and 1.19-7.9 dSm-1, respectively. The saline soil contained comparatively higher amounts of Ca, Mg, Na, K, S, Mn and Zn and lower amounts of P, Cu and B. The accumulation of Ca, Mg, K, S, Mn and Zn were increased but P, Cu and B were decreased for almost all the vegetables in saline soil. Comparatively higher amount of Ca (24048.0 mgKg-1), Mg (16336.3 mgKg-1) were accumulated in papaya, K (117.0 mgKg-1), S (1380.0 mgKg-1) and Zn (40.0 mgKg-1) were accumulated in radish, Cu (18.0 mgKg-1) in knollkhol, Mn (60.0 mgKg-1) in tomato grown in saline soil of Sonakata at 7.9 dSm^{-1} EC level. Soil salinity decreases the yield of vegetables whereas it increased some mineral constituents. The vegetables could tolerate moderate soil salinity (soil EC up to 7.9) and might be recommended to grow in the saline soils of Bangladesh.

Index Terms— Coastal Region, Mineral Composition, Salinity, Vegetable.

1 Introduction

THE coastal area covers about 20% of the country and over thirty percent of the net cultivable area. It extends inside up to 150 km from the coast. Out of 2.85 million hectares of the coastal and offshore areas about 0.83 million hectares are arable lands, which cover over 30% of the total cultivable lands of Bangladesh. Most of the coastal areas of Patuakhali and Barguna are used in agriculture. The cultivable lands in these coastal areas are affected with varying degrees of soil salinity (SRDI, 2013). Among the saline area 25% of land (0.161 and 0.101 m ha land) is highly saline (EC 12-16 ds/m) and very highly saline (EC>16 ds/m) (SRDI, 2013). The coastal area of Bangladesh includes tidal, estuaries and river floodplains in the south along the Bay of Bengal. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen & Shireen, 2001). The farmers of these southern coastal belts mostly cultivate rice and at the same time they grow some indigenous vegetables like cucumber, tomato, cantaloupe/rockmelon, spinach, cabbage, broad bean, potato, sweet potato, capsicum, beans, carrot, radish, sweet gourd, bottle gourd, red amaranth, aroids etc.

The relations between salinity and mineral nutrition of vegetable crops are extremely complex and a complete understanding of the intricate interactions involved would require the input from a multidisciplinary team of scientists. Crop performance may be adversely affected by salinity-induced nutritional disorders. These disorders may result from the effect of salinity on nutrient availability, competitive uptake, transport or partitioning within the plant. Salinity can also cause a combination of complex interactions that affect plant metabolism, susceptibility to injury or internal nutrient requirement. Despite a large number of studies that demonstrate that salinity reduces nutrient uptake and accumulation or affects nutrient partitioning within the plant, little evidence exists that adding nutrients at levels above those considered optimal in non-saline environments, improves crop yield (Grattan and Grieve, 1999).

Salt tolerances are usually given in terms of the stage of plant growth over a range of electrical conductivity (EC) levels. Electrical conductivity is the ability of a solution to transmit an electrical current. Salinity levels vary widely across a saline seep. Salinity also varies from spring to fall. Salinity usually appears on the soil surface just after spring thaw. A high salt level interferes with the germination of new seeds. Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of low concentration into an area of high

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concentration. Therefore, because of the salt levels in the soil, water and nutrients cannot move into the plant roots. As soil salinity levels increase, the stress on germinating seedlings also increases. In some cases, salinity also has a toxic effect on plants because of the high concentration of certain salts in the soil. Salinity prevents the plants from taking up the proper balance of nutrients they require for healthy growth (Agdex, 2001).

Fruit and vegetables are the richest natural sources of micronutrients. But in developing countries, daily fruit and vegetable consumption is just 20-50 percent of FAO/World Health Organization (WHO) recommendations. Urban meals rich in low-cost fats and sugars are also responsible for rising levels of obesity and overweight. In India, diet-related chronic diseases, such as diabetes, are a growing health problem, and mainly in urban areas.

Considering the importance of vegetable in alleviating the problem of micronutrient deficiencies the best nutrient containing vegetable should be selected. In coastal saline area micronutrient content is hampered due to salinity but it is unclear how salinity affects the uptake of micronutrients. The objectives of the present study were to analyze the impacts of salinity on mineral compositions of vegetable grown in the south-central coastal region of Bangladesh and to determine the macro and micronutrients status in soil.

2 Materials and Methods

2.1 Sampling Sites

Vegetable and soils were collected from three locations of Patuakhali and single location of Barguna district. The samples were brought to the laboratory, processed and preserved accordingly. Six different vegetables and soil from each vegetable field were collected and composite samples were made. The samples were brought to the laboratory, processed and preserved accordingly.

Vegetables and soils were collected from following locations

1. Sonakata (Barguna)
2. Panjupara (Patuakhali)
3. Nilgonj (Patuakhali)
4. Kadamtala (Patuakhali)

List of vegetables collected

1. Papaya (*Carica papaya*)
2. Brinjal (*Solanum melongena*)
3. Radish (*Raphanus sativus*)
4. Tomato (*Lycopersicon esculentum*)
5. Yard long bean (*Vigna unguiculata*)
6. Knol khol (*Brassica oleracea*)

2.2 Analytical Methods for soil and vegetable samples

TABLE 1 ANALYTICAL METHODS OF SOIL AND VEGETABLE SAMPLES FOR pH, EC AND MINERAL COMPOSITIONS

Parameter	Extraction method/ Reagent		Instrument	Reference
	Vegetables	Soil		
pH	-	1:2.5 (Soil: Distilled water)	pH meter	Jackson (1973)
EC (dSm^{-1})	-	1:5 (Soil: Distilled water)	EC meter	Ghosh *et al.* (1983)
P ($mg\ kg^{-1}$)	Di acid mixture	0.5M NaHCO3 solution (pH 8.5)	Spectrophotometer	Olsen *et al.*, 1954; (Page *et al.*, 1982); Jackson (1973)
K and Na ($mg\ kg^{-1}$)	Di acid mixture	1N NH4OAc (pH 7.0)	Flame emission spectrophotometer	(Page *et al.*,1982); Golterman & Clymo (1971); Ghosh *et al.* (1983)
Ca and Mg ($mg\ kg^{-1}$)	Di acid mixture	1N NH4OAc (pH 7.0)	Complexometric titrarion	Page *et al.* (1982); APHA (2005)
S ($mg\ kg^{-1}$)	Di acid mixture	CaCl2 (0.15%)	Spectrophotometer	Tandon (1995)
Cu ($mg\ kg^{-1}$)	Di acid mixture	DTPA extraction	Atomic Absorption Spectrophotometer (AAS)	Hunter (1994); Tam and Yao (1999)
Mn ($mg\ kg^{-1}$)	Di acid mixture	DTPA extraction	Atomic Absorption Spectrophotometer (AAS)	Hunter (1994); Tam and Yao (1999)
Zn ($mg\ kg^{-1}$)	Di acid mixture	DTPA extraction	Atomic Absorption Spectrophotometer (AAS)	Hunter (1994); Tam and Yao (1999)
B ($mg\ kg^{-1}$)	Di acid mixture	DTPA extraction	Atomic Absorption Spectrophotometer (AAS)	Hunter (1994); Tam and Yao (1999)

kg = kilogram, mg = milligram, EC = electrical conductivity.

2.2 Statistical Analyses

The statistical analyses of the data obtained from chemical analyses of vegetables and soil samples will be performed. Correlation studies will be done following the statistical package for agricultural research as described by Gomez and Gomez (1984).

3 Results and Discussssions

3.1 Soil Physicochemical Properties

The pH and EC of soils ranged from 5.2-7.9 and 1.19-7.90 dSm^{-1}, respectively (Table 2). This result strongly agrees with that of Azam *et al.* (2018), Polara *et al.* (2006) and Kumar *et al.* (2018). The high pH in Sonakata soils might be due to presence of sodium carbonate and bi-carbonates, which precipitated as calcium and magnesium carbonates during evaporation, Bhaskar and Nagaraju (1998). Higher salinity at Sonakata soils may be due to the presence of higher chlorides which contribute to higher EC values. Higher evaporation during summer months also brings the soluble salts to the surface by capillary rise. Similar results were reported by Mandal and Sharma (2001) and Sharma *et al.* (2004). According to the standard of SRDI (2003), BARC (2005) and Chowdhury *et al.* (2011), only Sonakata soil was reported as medium saline and others were below the low salinity level.

Table 2 pH, EC and ionic constituents of macro and micronutrient elements at different soils of vegetable field of south central coastal region of Bangladesh

SL No.	Locations	Soil pH	Soil EC (dSm^{-1})	P	K	Ca	Mg
				mg kg^{-1}			
01	Sonakata	7.90	7.90	18.07	198.9	1700.0	769.2
02	Panjupara	6.60	1.36	21.91	144.3	408.0	570.0
03	Nilgonj	5.20	1.23	27.86	159.9	230.0	188.4
04	Kadamtala	7.20	1.19	27.93	85.8	214.0	146.4
	Range	5.2-7.9	1.19-7.90	18.07-27.93	85.8-198.9	214.0-1700.0	146.4-769.2
	Mean	6.73	2.92	23.94	147.23	638.0	418.5
	SD value	1.15	3.32	4.83	46.95	713.44	301.62
	CV%	17.06	113.73	20.16	31.89	111.82	72.07

kg = kilogram, mg = milligram, EC = electrical conductivity, dS = decisiemens.

3.2 Macro and Micro Nutrient Status of Soil

Soil P, K, Ca, Mg, S, Cu, Mn, Zn and B concentration ranged from 18.07-27.93, 85.8-198.9, 214.0-1700.0, 146.4-769.2, 9.70-106.85, 1.03-5.67, 10.10-46.70, 0.78-3.31 and 0.21-0.98 mg kg^{-1}, respectively (Table 2). Soil P, Cu and B content decreased gradually with the increase of salinity. This reveals an antagonistic relationship of these nutrients with soil EC. Contradictory result was obtained by Saleque *et al.* (2010) and Hossain *et al.* (2015) reporting higher P content in the saline than non saline soils. They explained that coastal saline soils are generally replenished with phosphorus through tidal sediments which can contain considerable amounts of total and available P (763 mg/kg total and 28 mg/kg available P). On the other side, K, Ca, Mg, S, Mn and Zn content was found to increase with the increase of soil salinity indicating a salinity-nutrient synergistic relationship. Similar result was observed by Ravi Kumar *et al.* (2007), Hirekurabar *et al.* (2000), Kour and Jalali (2008) and Nega *et al.* (2001). The higher content in salty soils might be due to the presence of soluble salts and upward translocation of ions from lower depth along with capillary rise of ground water (Basavaraju *et al.*, 2005).

Table 3 Ionic constituents of macro and micronutrient elements at different soils of vegetable field of south central coastal region of Bangladesh

SL No.	Locations	Na	S	Cu	Mn	Zn	B
		mg kg^{-1}					
01	Sonakata	3660	106.85	1.03	46.70	3.31	00.21
02	Panjupara	2775	103.29	3.02	26.00	2.91	00.42
03	Nilgonj	2490	27.01	3.84	16.49	1.99	00.93
04	Kadamtala	2280	9.70	5.67	10.10	00.78	00.98
Range		1880-3660	9.70-106.85	1.03-5.67	10.10-46.70	0.78-3.31	00.21-00.98
Mean		2801.3	61.71	3.39	24.82	2.25	0.64
SD value		607.38	50.58	1.92	15.98	1.12	0.38
CV%		21.68	81.96	56.76	64.38	49.99	59.82

kg = kilogram, mg = milligram.

3.3 Accumulation of Macro Nutrients (P, K, Ca, Mg and S) in Different Vegetables

The limits of P in different vegetables ranged from 3525.64-6555.3 mg kg^{-1} (Figure 1). Higher accumulation of P was estimated in brinjal at Kadamtala (EC 1.19 dSm^{-1}) with the highest mean value of 6432.49 mg kg^{-1} P and lower accumulation was found in tomato at Sonakata (EC 7.90 dSm^{-1}) with the lowest mean value of 3867.18 mg kg^{-1} P. Results indicated that the concentration of P in all the vegetables decreased with the increase of soil EC levels. Phosphorus below 1500 mg kg^{-1} is considered a deficiency level. All the vegetables in this study were above the deficiency level. Coefficient of variance analysis showed that the degree of variations in P concentration in the vegetables at different locations was higher in papaya and tomato than that of other vegetables. This proves that soil salinity had greater influence on P uptake by papaya and tomato. According to Azam *et al.* (2018), the soils of both Sonakata (EC 7.90 dSm^{-1}) and Kadamtala (EC 1.19 dSm^{-1}) contained almost the same amount of P (27.93 and 27.86 mg kg^{-1}, respectively). As per Grattan & Grieve (1992), the interaction between salinity and P is very complex and there is no clear cut mechanistic explanation for decreased, increased or unchanged P uptake in response to salinisation in different species. On the other hand, Cramer *et al.*, (1991) and Grattan & Grieve, (1999) stated that, high soil salinity acts antagonistically to the uptake of the other nutrients, such as K^+, Ca^{2+}, N, P. So, the diminishing concentrations of P in the vegetables at higher EC levels signified that soil salinity acted as a barrier for the vegetables against the accumulation of this element from soil.

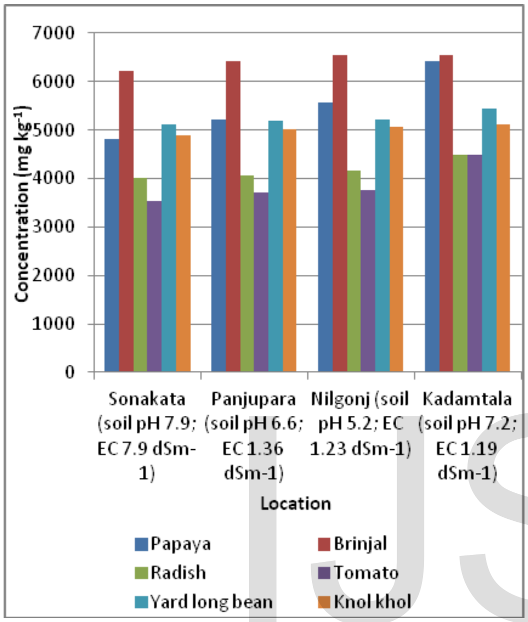

Fig. 1. Accumulation of P in different vegetables

Potassium content in different vegetables varied from 44.0 mg kg^{-1} (papaya) to 117.0 mg kg^{-1} (radish) at Kadamtala (EC 1.19 dSm^{-1}) and Sonakata (EC 7.90 dSm^{-1}), respectively (Figure 2). Results indicated a 3-fold variation in K content among different plants. This result differs from that of Alshammary, 2007 where he found a variation of 6-fold. Knol khol showed the maximum mean concentration of K (111.0 mg kg^{-1}) even though radish was the highest accumulator of this element. Yard long bean was the lowest average accumulator (55.75 mg kg^{-1}) of K. Bayuelo-Jimenez *et al.*, 2003 stated that soil salinity reduces the concentrations of K^+ in many plant species but results exhibited an increase in almost all the vegetables with the increase of soil salinity except radish. Hirpara *et al.*, 2005 reported that, K content exhibited a significant increase in leaves, stems and lateral roots with the increase of salt concentration in soil. Momayezi *et al.*, 2010 also explained that, the amounts of K^+ and Mg^{2+} of shoot and root tissues in Iranian rice (*Oryza sativa* L.) increased at high salt levels. Conversely, the experiment of Yousif *et al.* (2010) in Japan showed a gradual decrease in K uptake by vegetable plant due to salt stress. Findings of this investigation support that of Maksimovic and Ilin (2012) where the concentration of K was increased in pods and grains due to elevated salinity levels in Serbia. On the other hand, K concentrations in radish exposed an undulating trend at different EC levels. Moreover, degree of variations of K content in this vegetable was higher than that of other vegetables revealing an intense but disorderly impact of salinity on uptake by radish. Saline soil might have acted as a good reservoir of K which had aided in increased uptake of this element. Potassium content in brinjal was the least affected by salinity variations.

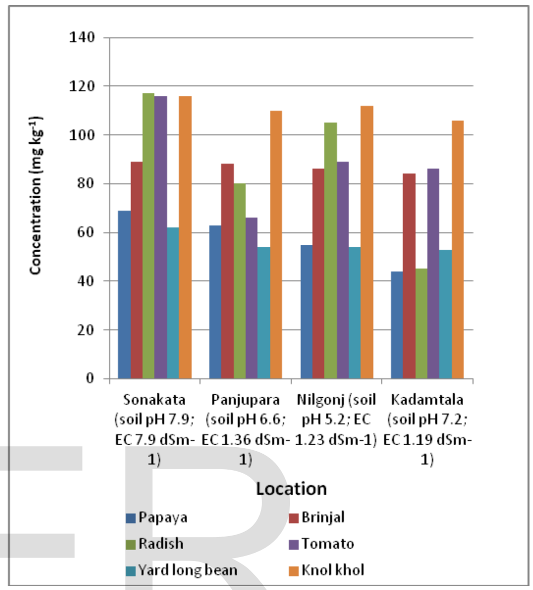

Fig. 2. Accumulation of K in different vegetables

Elevated Ca concentration was observed in the vegetables grown at higher EC levels. Sea water is a majestic source of Ca mineral which ultimately contributes to high soil content. This Ca might finally be translocated in the vegetable plants. Higher uptake of Ca occurred in papaya (24048.0 mg kg^{-1}) at Sonakata (EC 7.90 dSm^{-1}) and lower uptake occurred in tomato (3847.68 mg kg^{-1}) at Kadamtala (EC 1.19 dSm^{-1}) (Figure 3). This exposed a variation up to 6-fold, indicating that there was a significant unbalanced distribution pattern of Ca in the vegetables. Highest and lowest mean concentrations were observed in papaya (12279.83 mg kg^{-1}) and brinjal (4566.5 mg kg^{-1}), respectively. Since 0-3500 mg kg^{-1} Ca level is associated with plant deficiency (Haarenen, 1963), so none of the vegetable plants were in the deficient range. Donald, 2003 stated that saline soil naturally contains Ca, Mg and S. As an evidence of this, widespread increment of Ca content in papaya was found in saline soil. The concentration climbed up to about eight times more in saline soil than that of non saline soil. Koksal *et al.*, 2016 also observed that Ca concentration in marigold plant grew up to 15.64 g kg^{-1} from 8.04 g kg^{-1} as NaCl treatment increased from 0.0 to 150 mM. A suitable ration between calcium and phosphorus is considered a better index as compare to their absolute concentration (Singh and Mishra, 1987). A Ca-P ratio of about 1.5:1 was observed in all the vegetables except

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papaya. The study of Alshammary, 2007 also showed plant Ca-P ratio as 2.4:1 for most of the plants.

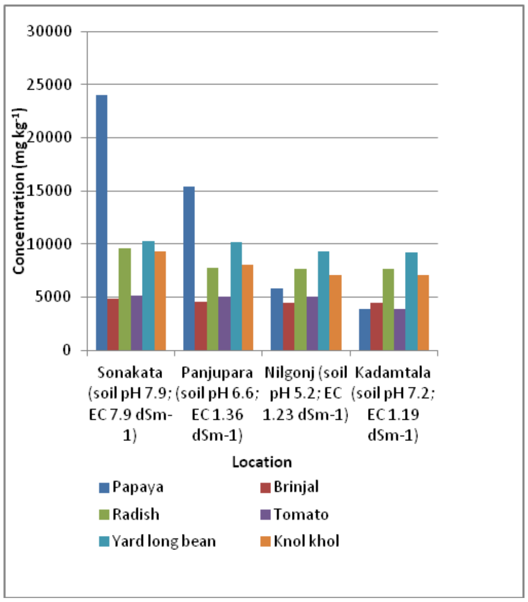

Fig. 3. Accumulation of Ca in different vegetables

Higher accumulation of Mg was found in papaya (16336.3 mg kg^{-1}) at Sonakata (EC 7.90 dSm^{-1}) and lower accumulation in tomato (3624.0 mg kg^{-1}) at Kadamtala (EC 1.19 dSm^{-1}) (Figure 4). Plant growth is adversely affected by salinity induced nutritional disorders (Greenway & Munns, 1980). Musyimi (2007) reported that, Mg content in avocado decreased from 6550 mg kg^{-1} to 3950 mg kg^{-1} in a study in Kenya. But in present study, Mg content in papaya and yard long bean increased with the increment of soil EC levels. This result accompanies with that of Koksal *et al.*, 2016. He also quantified an increase of Mg content in marigold plant from 1340 to 4640 mg kg^{-1} due to increasing of NaCl treatment from 0.0 to 150 mM. Higher mineral content of saline soil might have favored the higher uptake as Azam *et al.*, 2018 quantified that Sonakata soil (EC 7.90 dSm^{-1}) contained almost 8 and 3-fold of Ca and Mg, respectively than Kadamtala soil (EC 1.19 dSm^{-1}). In addition, increased Mg uptake can be occurred in S predominant soil. As per Momayezi *et al.*, 2010, salt treatment of Iranian rice (*Oryza sativa* L.) with SO_4^{2-} dominance caused an increase of Mg^{2+} content in root tissue. About 4 times higher S was observed in Sonakata soil than Kadamtala (Azam *et al.*, 2018). In radish, Mg concentration was almost unchangeable in all locations indicating the weightless effect of soil salinity on Mg uptake. The highest and lowest mean Mg content were observed in yard long bean (11210.25 mg kg^{-1}) and tomato (4225.15 mg kg^{-1}), respectively. Magnesium concentration of 2000 mg kg^{-1} in plants is commonly regarded as the minimum dietary concentration for adequate health (Kemp, 1960). None of the vegetables were deficient in Mg. The investigation demonstrated a 3-fold increment of Mg concentration in papaya due to increased salinity.

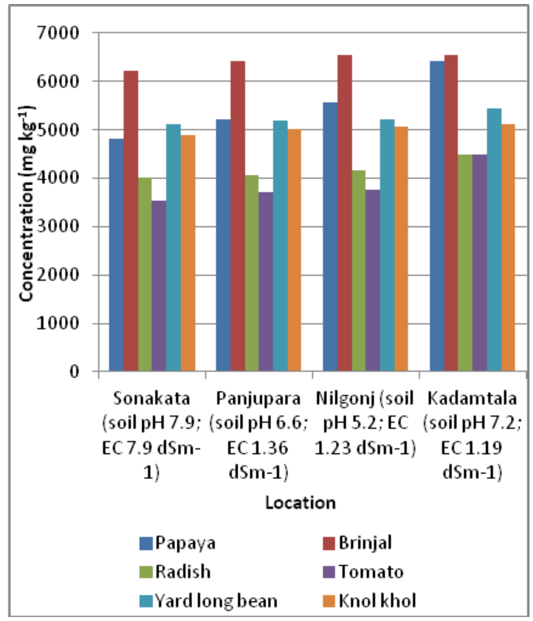

Fig. 4. Accumulation of Mg in different vegetables

Higher uptake of S was observed in all the vegetables at higher EC levels. Maximum content of S was found in radish (1380.0 mg kg^{-1}) at Sonakata (EC 7.90 dSm^{-1}) and in papaya (700.0 mg kg^{-1}) at Kadamtala (EC 1.19 dSm^{-1}) (Figure 5).

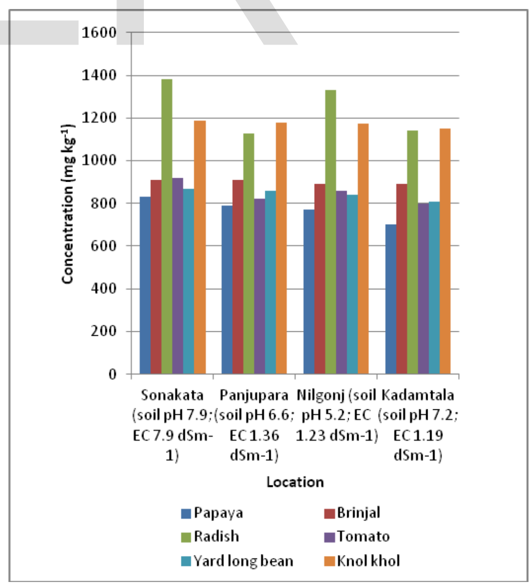

Fig. 5. Accumulation of S in different vegetables

Knol khol and radish contained almost twice amount of S than papaya. The mean concentration of S in radish, knol khol and papaya was 1245.0, 1173.3 and 772.5 mg kg^{-1}, respectively. It is reported that soil salinity suppresses shoot growth more than the root growth (Maas & Hoffman, 1977; Ramoliya *et al.*, 2004). So, radish, being a root crop, might have accumulated more S than other non root vegetables. Increased S accumulation at saline soil of Sonakata might have occurred due to higher S content of Sonakata soil (106.85 mg kg^{-1}) than non saline soil of Kadamtala (27.01 mg kg^{-1}) as stated by Azam *et al.*, 2018. Seawater contains more dissolved ions than all types of freshwater (Gale and Thomson, 2006). The most abundant dissolved ions in seawater are Na^+, Cl^-, Mg^{2+}, SO_4^{2-} and Ca^{2+} (Hogan and Michael, 2010). These SO_4^{2-}, Mg^{2+} and Ca^{2+} might have enriched the soils of Sonakata with S, Mg and Ca, respectively. Coefficient of variance analysis showed that, S uptake by the vegetable plants was less favored by elevated soil salinity levels than K, Ca and Mg.

3.4 Accumulation of Micro Nutrients (Cu, Mn, Zn And B) in Different Vegetables

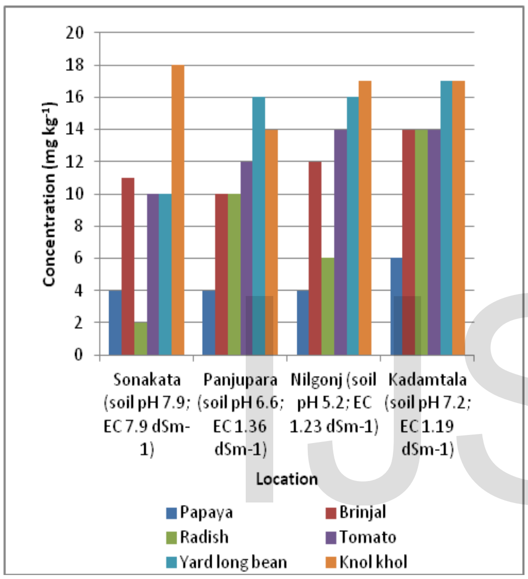

Fig. 6. Accumulation of Cu in different vegetables

Like P, the uptake of Cu by vegetables was adversely affected by higher EC levels of soil. The mean concentration of Cu in all the vegetables at Kadamtala (EC 1.19 dSm^{-1}) and Sonakata (EC 7.90 dSm^{-1}) was 13.66 and 9.16 mg kg^{-1}, respectively (Figure 6). This depicts a significant reduction (about 33%) in Cu accumulation by vegetable plants due to increased soil salinity. Most of the researchers indicated that in saline and saline sodic soils, the solubility of Cu is particularly low, and plants grown in such soils often experience deficiency of Cu, but not in all cases. Therefore, the Cu status of present study is in conformity with the results obtained by Page *et al.*, (1990); Izzo *et al.*, (1991) and Rahman *et al.*, (1993). They stated that leaf and stem Cu concentrations were found to decrease in salt-stressed maize grown both in solution cultures and soil. Knol khol was an exception in this regard. Higher EC level favored the uptake (increased up to 29%) of Cu in knol khol. Higher accumulation (18 mg kg^{-1}) of Cu was observed in knol khol at Sonakata (EC 7.90 dSm^{-1}) and lower accumulation (2 mg kg^{-1}) in radish at the same location. Knol khol was marked as the most efficient accumulator of Cu among the six vegetables (highest mean concentration of 16.5 mg kg-1). Few researchers revealed that, the uptake of Cu generally increased in crop plants subjected to salinity stress. Therefore, present findings in term of Cu uptake by knol khol are in accordance with the results obtained by Alam (1994).

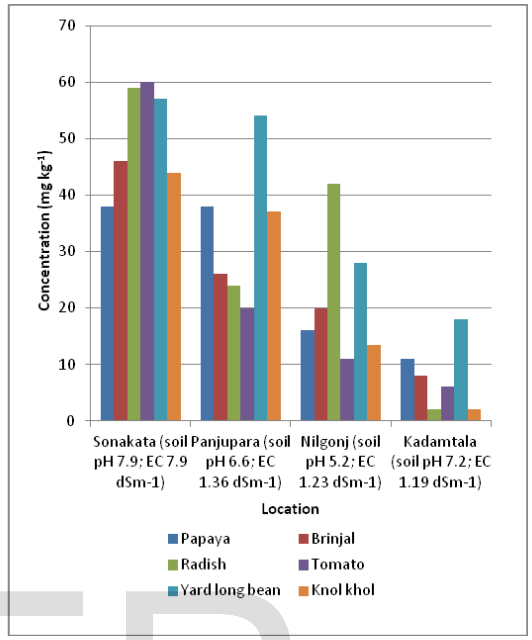

Fig. 7. Accumulation of Mn in different vegetables

The amount of Mn in the vegetables ranged from 2-60 mg kg^{-1} (Figure 7). The lowest amount was observed in both radish and knol khol at Kadamtala (EC 1.19 dSm^{-1}) and the highest in tomato at Sonakata (EC 7.90 dSm^{-1}). The content of Mn increased by leaps and bounds from non saline to saline area in all the vegetables. Similar findings have been reported by very few researchers (Niazi & Ahmed, 1984; Alam, 1994). They noted that Mn generally increases in crop plants under salinity stress. Whereas most other researchers revealed that salt stress (particularly NaCl) either reduced or had non-significant effect on the Mn concentration. Therefore, present results in term of Mn uptake are not in agreement with the results obtained by most of the researchers (Alam *et al.*, 1989; Izzo *et al.*, 1991; Rahman *et al.*, 1993; Al-Harbi, 1995; Lutts *et al.*, 1999; Mohamedin *et al.*, 2006; Huang *et al.*, 2007). Results further implied that only seven times increase in the soil EC level increased Mn content up to ten times in case of tomato (6 mg kg^{-1} at EC 1.19 dSm^{-1} and 60 mg kg^{-1} at EC 7.90 dSm^{-1}). These findings are contradictory with those obtained by Tunçturk *et al.*, (2008). Yard long bean exhibited the highest mean accumulation of Mn among six vegetables.

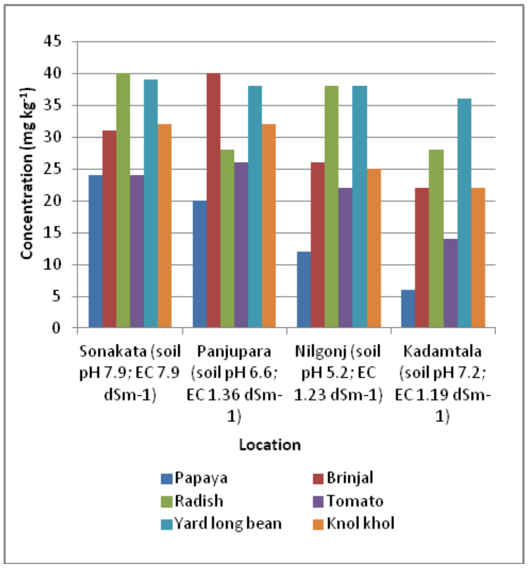

Fig. 8. Accumulation of Zn in different vegetables

The accumulation of Zn in vegetables ranged from 6.0-40.0 mg kg^{-1} (Figure 8). Higher and lower accumulation of Zn was observed in radish at Sonakata (EC 7.90 dSm^{-1}) and papaya at Kadamtala (EC 1.19 dSm^{-1}), respectively. Yard long bean seemed to be the most consistent accumulator of Zn among the vegetables. The mean content of Zn in yard long bean amounted 37.75 mg kg^{-1} which is more than twice of that of papaya (15.5 mg kg^{-1}). On an average, the concentration of Zn climbed up to 48% from non saline to saline area. Therefore, our findings are strongly in line with the results obtained by Hirpara *et al.*, 2005 (a significant increase in the concentration of Zn in leaves, stems, tap roots and lateral roots ($p < 0.01$) in response to increase in salt-stress) and Achakzai *et al.*, 2010 (a maximum uptake of Zn by roots (54.17 mg kg^{-1}) and shoots (59.17 mg kg^{-1}) was recorded in salinity doses having EC 1.19 and 22.38 $mscm^{-1}$, respectively). This means that the plants were benefitted by saltiness of the soil while accumulating Zn. The majority of studies have shown salinity to increase Zn concentration in plant tissue such as in citrus (Ruiz *et al.*, 1997), maize (Rahman *et al.*, 1993) and tomato (Knight *et al.*, 1992), but in other studies it was not affected (Izzo *et al.*, 1991) or actually decreased Zn concentration as in case of cucumber leaves (Al- Harbi, 1995). Uddin *et al.*, 2012 also investigated a 2-fold decrease of Zn content with the increase of soil EC level from 0-264 mM in purslane (*P. oleracae*) stems and leaves in Malaysia.

Ions can interact with the soil and the plant in different ways, which can lead to deficiency or toxicity phenomena that affect growth and development (Nilsen and Orcutt, 2000; Zhu, 2003). The ionic uptake by the cell is affected by the environmental salinity, which affects the relative availability of the ions in the area surrounding the root (Nilsen and Orcutt, 2000; Grattan and Grieve, 1999). Likewise, B uptake by vegetable plants was suppressed by salty soil in the study area. Exalted EC levels in the saline soil might have reduced the availability of B in the rhizophere of vegetable plants. Higher uptake (82.0 mg kg^{-1}) of B was observed in brinjal at Kadamtala (EC 1.19 dSm^{-1}) and lower uptake (20.0 mg kg^{-1}) in tomato at Sonakata (EC 7.90 dSm^{-1}) (Figure 8).

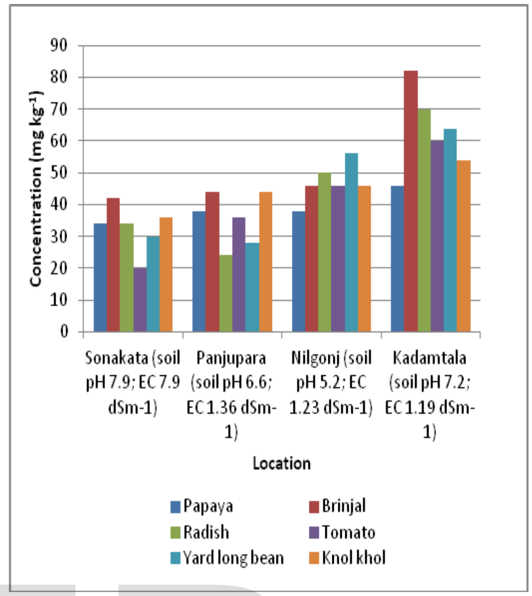

Fig. 9. Accumulation of B in different vegetables

The mean content of B ranged from 39.0-53.5 mg kg^{-1} in papaya and brinjal, respectively. Micro nutrient analysis of vegetables depicted that B uptake by plants reduced up to 47% as the soil EC grew up from 1.19 to 7.9 dSm^{-1}. This result is in good agreement with that of Alpaslan and Gunes (2001). They observed that, B concentrations of tomato decreased under saline conditions compared to non saline conditions. They also concluded that, B uptake was decreased by reduced transpiration flow rate in tomato as a result of salinity.

4 Conclusion

Soil K, Ca, Mg, S, Zn and Mn contents were synergistic and P, Cu and B were antagonistic with salinity. The accumulations of K, Ca, Mg, S, Zn and Mn in vegetable were positively related to soil salinity. Papaya grown in saline soil accumulated extremely highest amount of Ca and Mg. Vegetable grown in non-saline soil accumulated comparatively higher amount of Cu than saline soil, but knolkhol was the exception. Almost all the vegetables grown in saline soils accumulated higher amount of Mn. Therefore, the above-mentioned vegetables can tolerate moderate salinity and might be grown in the south-central coastal region of Bangladesh for nutritional security.

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