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On

A Comparative Financial Evaluation of Selected Vegetables Production in Bangladesh

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Mitigation of Salinity Stress on Growth and Yield of Crops

ABSTRACT

Salinity is a major abiotic stress that limited the growth and productivity of plants in many areas of the world. A systematic study was conducted from secondary information about salinity to know the effect of salinity on seed germination, seedling growth, plant growth and yield with mitigation and management practices. Salinity reduces germination and seedling growth of different crops. Salt tolerance screening at germination provides little basis for assessing crop salt tolerance. High levels of soil salinity reduce plant growth and photosynthesis resulting low yield. Though response of different crops are not same at various degrees of salinity. Wheat is more tolerant than rice in salinity where maize occupies moderate between these crops. With the increase of salinity Na+, Ca++, Cl- decrease and increase K+ causing nutritional imbalance in plants resulting ion toxicity. So, the developments of methods and strategies to ameliorate deleterious effects of salt stress on plants have received considerable attention. Effect of salinity can be hindered by using rhizobium inoculums combination with tryptophan and arginine solutions in mungbean. Drip irrigation and manual pump irrigations in raised bed with mulch would be found more effective for the production of different vegetables in saline soil. Development and use of salt tolerant varieties can increase the possibility of cultivation of different crops in saline areas.

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Chapter I

INTRODUCTION

Salinity is the saltiness or dissolved salt content of a body of water. It may also refer to the salt content of soil. A saline soil is defined as having a high concentration of soluble salts, high enough to affect plant growth. Salinity occurs through natural or human-induced processes that result in the accumulation of dissolved salts in the soil water to an extent that inhibits plant growth. Sodicity is a secondary result of salinity in clay soils, where leaching through either natural or human-induced processes has washed soluble salts into the subsoil, and left sodium bound to the negative charges of the clay. Salinity in a given land area depends upon various factors like amount of evaporation which leads to increase in salt concentration and amount of rain that leads to decrease in salts. Salinity may occur when there is irregular irrigation, inadequate drainage, wrong fertilizer application, and it extremely increases particularly in protected cultivation.

Salinity adversely affects plant growth and development (Lazof and Bernstein, 1997). Salinity drastically affects photosynthesis (Seeman and Sharkey, (1986); Soussi *et al*., 1998), nitrogen (Cordovilla *et al*., (1995); Mansour, 2012) and carbon metabolism (Delgado *et al*., (1994); Soussi *et al*., (1999); Balibrea *et al*., 2000). Salinity causes nutritional disorders in plants which may lead to deficiencies of several nutrients and drastically increasing in Na^+ levels (Cordovilla *et al*., (1995); Grattan and Grieve, (1999); Mengel and Kirkby, 2011). Such physiological changes will result in a decrease in plant growth (Mensah *et al*., 2013) and consequently in crop yield. Seed germination, seedling emergence, and their survival are particularly sensitive to substrate salinity (Mariko et al., (1992) and Baldwin et al.,(2012). High levels of soil salinity can significantly inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity (Grieve and Suarez, 1997).

Salt stress causes multifarious drastic effects in plants and among these factors production of reactive oxygen species (ROS) is a common phenomenon. These ROS are highly reactive because they can interact with a number of cellular molecules and metabolites and ultimately leads to cellular damage.

Salinity may also affect the physical and chemical properties of soil, resulting in surface soil compaction and erosion. High levels of salt can dehydrate soil bacteria and fungi and reduce soil health, which is depended on good microbial activity for the formation of organic matter and nutrient recycling. The breakdown in soil structure, together with the associated loss of plant cover, results in a greater exposure of the soil to erosion. Sheet, rill, gully and wind erosion is commonly caused by salinity.

Soil salinity is a worldwide problem. Bangladesh is no exception to it. In Bangladesh, salinization is one of the major natural hazards hampering crop production. The total area of Bangladesh is 147, 570 km2. The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. About 52.8 percent of the net cultivable land in the coastal area is affected by varying degrees of soil salinity (Begum *et al*., 2009). Fertility status of most saline soils ranges from low to very low in respect to organic matter content, nitrogen, phosphorus and micronutrients like zinc and copper. The crop yields obtained in these soils are also low. The vast land remains mostly uncultivated except some selected areas where T. aman is cultivated. Salinity problem received very little attention in the past. Nevertheless, symptoms of such land degradation with salinization are becoming too pronounced in recent years. Increased pressure of growing population demand more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops.

The ability of plants for tolerance and thrive in saline soil condition has a great importance in agriculture, which indicates the salinity tolerances capacity of plant as a desirable trait (Francois and Mass, (1994); Mahmood *et al*., 2000). Hence selection and breeding of cultivars that can grow and provide economical yield under saline conditions may be an efficient tool in resolving the salinity problems (Ashraf and McNeilly, 2013).

Considering the above facts, the following objectives were undertaken:

- to understand the effect of salinity on crop growth and yield.
- to review the mitigation and management for minimizing salinity problem

Chapter II

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. Therefore, all the information were collected from secondary sources with a view to prepare this paper. Various relevant books and journals, which were available in the library of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) and BARI were used for the preparation of this paper. For collecting recent information internet browsing was also be practiced. Good suggestions, valuable information and kind consideration from my honorable major professor, course instructors and other resources personnel were taken to enrich this paper. After collecting necessary information, it has compiled and arranged chronologically for better understanding and clarification.

Chapter III
RESULTS AND DISCUSSION

Present soil salinity status in Bangladesh

The total area of Bangladesh is 147, 570 km2. The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. 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.. The cultivable areas in coastal districts are affected with varying degrees of soil salinity. The coastal and offshore 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).

It is anticipated that withdrawal of fresh river water from upstream, irregular rainfall, introduction of brackish water for shrimp cultivation, faulty management of the sluice gates and polders, regular saline tidal water flooding in unprotected area, capillary rise of soluble salts etc. are the main causes of increased soil salinity in the top soils of the coastal region. About 0.328, 0.274, 0.189, 0.161 and 0.101 million hectares of land are affected by very slight, slight, moderate, strong and very strong salinity respectively. A comparative study of soil salinity during last four decades (1973-2009) in coastal areas is shown in table 2. About 50% of the coastal lands face different degrees of inundation, thus limiting their effective use. This situation is expected to become worse further because of the effects of climate change. Cropping intensity may be increased in very slight and slightly saline areas by adopting proper soil and water management practices with the introduction of different salt tolerant varieties of crops.

Table 1. Extent of soil salinity during the last four decades (1973-2009) in coastal areas

Years	**Salinity class and Salt affected area (000'ha)**				**Total (000'ha)**
	S1 (2.0-4.0 dS/m)	**S2 (4.1.0-8.0 dS/m)**	**S3+S4 (8.1-16.0 dS/m)**	**S5 (>16.0 dS/m)**	
1973	287.37	426.43	79.75	39.9	833.45
2000	289.76	307.20	336.58	87.14	1020.75
2009	328.43	274.22	351.69	101.92	1056.26

Source: SRDI,(2010)

A comparative study of the salt affected area in between 1973 to 2009 showed that about 0.223 million ha (26.7%) new land is effected by various degrees of salinity during about the last four decades (Table 1&2). It was also found that about 0.0354 million hectares of new land is effected by various degrees of salinity during last 9 years only (2000-2009) and newly six districts were saline affected from 1973 to 2000 (Table 3).

Table 2. A comparative study of the salt affected area in between 1973 to 2009 in coastal areas

Salt affected area (000'ha)			Salt affected area increased during last 9 years (000'ha) (2000-2009)	Salt affected area increased during last 36 years (000'ha) (1973-2009)
1973	**2000**	**2009**		
833.45	1020.75	1056.26	35.51 (3.5%)	222.81 (26.7%)

Source: SRDI,(2010)

Effect of salinity on seed germination and seedling growth

Although most plants are tolerant during germination, salinity stress delays this process even though there may be no difference in the percentage of germinated seeds from one treatment to another. It is this observation that categorizes this developmental stage for most crops as 'salt tolerant'.

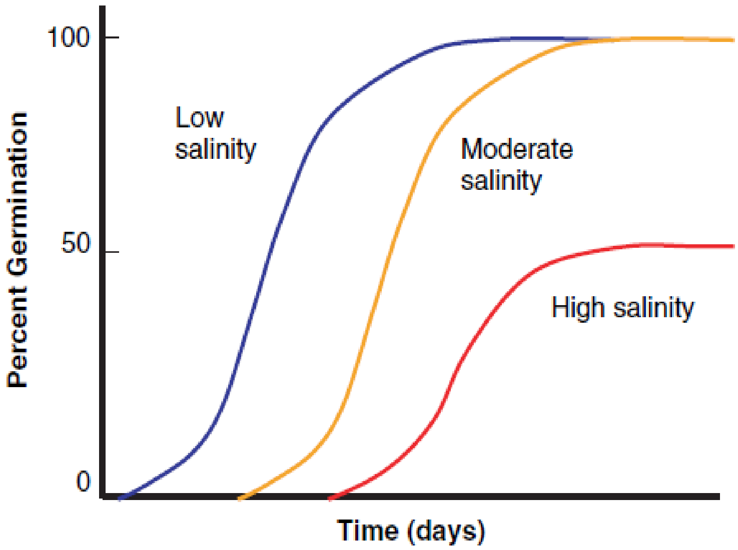

Figure 1. Generalized relationship between percent germination and time after water addition at low, moderate and high salinity. The germination rates and percentage of germinated seeds at a particular time various considerably among species and cultivars.

Source: Lauchli and Grattan,(2012)

Effect of salinity on plant growth and yield

Salinity affects plants in different ways such as osmotic effects, specific-ion toxicity and/or nutritional disorders. The extent by which one mechanism affects the plant over the others depends upon many factors including the species, genotype, plant age, ionic strength and composition of the salinizing solution, and the organ in question. Understanding these temporal differences in response to salinity, Munns (2012a, 2005) developed the concept of the 'two-phase growth response to salinity' (Figure 2). The first phase of growth reduction happens quickly (within minutes) after exposure to salinity.

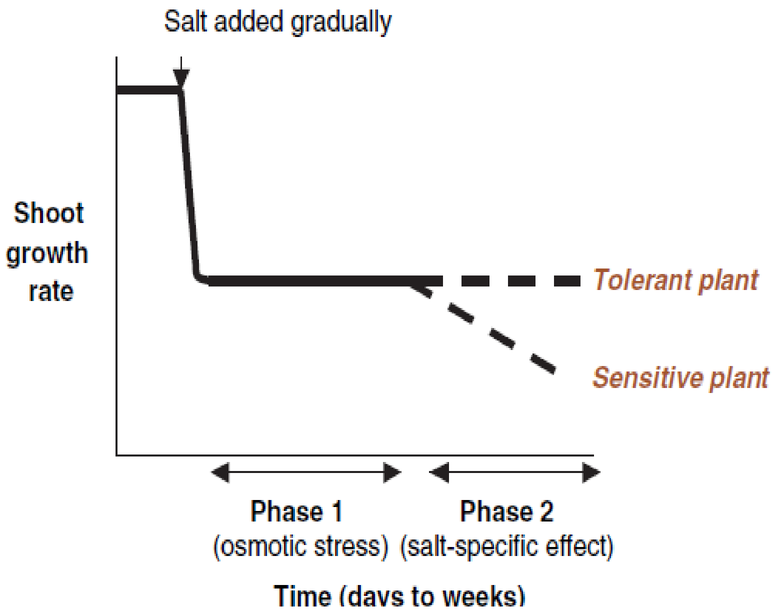

Fig. 2. Schematic illustration of the two-phase growth response to salinity for genotypes that differ in the rate at which salt reaches toxic levels in leaves.

Source: Munns, (2012)

This response is due to the osmotic changes outside the root causing changes in cell-water relations (osmotic effect). The osmotic effect initially reduces the ability of the plant to absorb water. This effect is similar to water stress and shows little genotypic differences. Several minutes after the initial decrease in leaf growth, there is a gradual recovery of the growth rate until a new steady state is reached, dependent upon the salt concentration outside the root (Munns, 2012a). The second much slower effect, taking days, weeks or months is the result of salt accumulation in leaves, leading to salt toxicity in the plant, primarily in the older leaves (i.e. salt-specific effect). This salt toxicity can result in the death of leaves and reduce the total photosynthetic leaf area. As a result, there is a reduction in the supply of photosynthate to the plant, affecting the overall carbon balance necessary to sustain growth (Munns, 2012a).

Effect of salinity on photosynthesis

High salt content can influence physiological processes of plants. In saline areas or areas irrigated with saline waters most crop plant species exhibit marked decrease in growth, photosynthesis and yield.

Salinity stress limits the uptake of CO2 (J. Zhang et al., 2006),resulting in decreasing carbon reduction by Calvin cycle which leads to non-availability of NADP+ for acceptance of electrons during photosynthesis. In this situation, photosynthetic reducing power, NADPH2, is used for proline biosynthesis and consequently NADP+ is regenerated (Z. Q.Wang et al., 2007) .These reactions are summarized in Figure 3. The excess accumulation of proline may therefore be a result of metabolic changes induced by high salinity. The present results also agrees with the observations of Delauney and Verma(1993) who stated that excess proline accumulation in response to high salinity functions by other than osmotic adjustment. The excess accumulation of proline may therefore be a result of metabolic changes induced by high salinity.

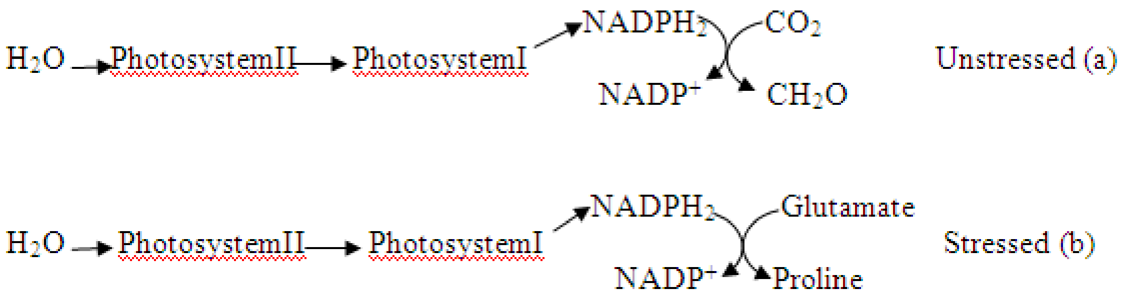

Fig. 3. Schematic illustration of electron flow in : (a) normal physiological condition and (b)high-salinity stress condition, which can lead to inhibition of photosynthesis by diverting the flow of photoreductant (e-) from the CO2 reducing system to proline biosynthesis, leading to reduced growth and productivity of the plants.

Source: Hossain *et al.*,(2012)

RICE

Salinity effects on seedling growth: Salinity caused a significant reduction in seedling growth with varying degree of variability among these lines. The fresh weight of all lines decreased as the level of salinity increased from 50 to 75mM NaCl. At 50mM NaCl the highest reduction (50%) was observed in L-2 at the exposure of one week salinity, while other lines exhibited comparatively less reduction at this time (Fig. 4). In salt sensitive lines, this reduction in growth became more pronounced with the passage of time even at the lower level of salinity. After 14 days of salinity treatment, the higher salinity level (75mM NaCl) resulted in a significant reduction in seedling growth when compared with control (Fig. 5) where L. No. 12, L. No. 2 and L. No. 64 exhibited 55, 65 and 62% reduction, respectively, while the least reduction in fresh weight was observed in L. No96 (7%). At lower level (i.e. 50mM NaCl) of salt, the comparatively less reduction in their fresh weights were observed even at the exposure of two weeks salinity. This has indicated that plants affected by salts at lower concentration can tolerate salt stress for longer duration before significant reduction of seedling growth occurs .Salinity reduces the growth of plant through osmotic effects, reduces the ability of plants to take up water and this causes reduction in growth. There may be salt specific effects. If excessive amount of salt enter the plant, the concentration of salt will eventually rise to a toxic level in older transpiring leaves causing premature senescence, and reduced the photosynthetic leaf area of a plant to a level that cannot sustain growth .

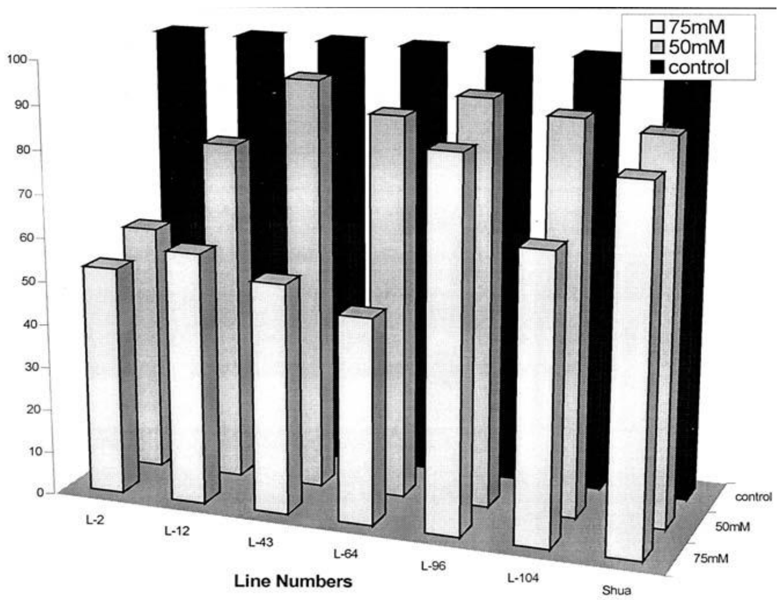

Fig. 4. Shoot growth of different rice lines at the exposure of one week salinity.

Source: Shereen *et al.*,(2015)

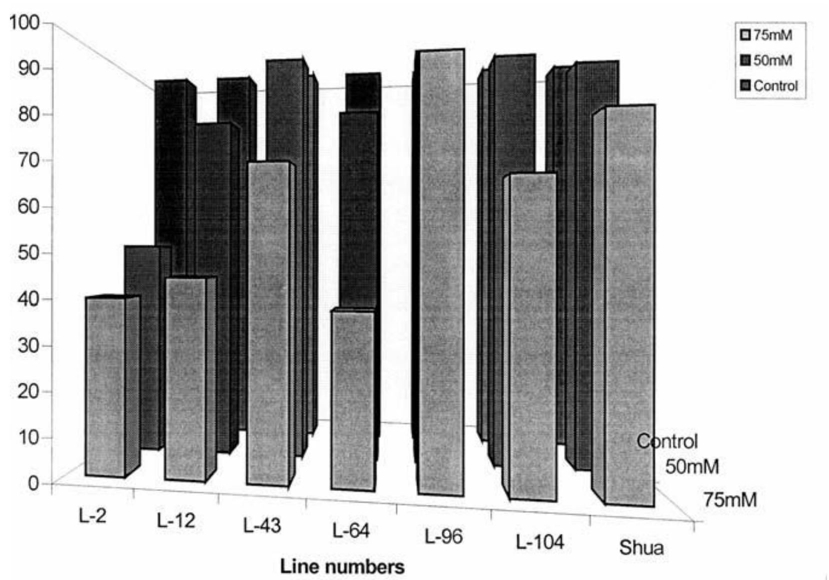

Fig. 5. Shoot growth of different rice lines at the exposure of two week salinity.

Source: Shereen *et al.*,(2015)

Sugarcane

CP-77-400 was less productive as compared to COJ-84 under non-saline conditions because its average length of culm (125.1 cm) was less as compared to that of COJ-84 (191.8 cm) (Table. 5) The length of leaves in CP-77-400 was higher than that in COJ-84, which was 143.08 and 108.2 cm, respectively. The average internodes length and culm diameter in both cultivars were almost the same and equal to 7.4 and 2.3 cm, respectively.The salinity tolerance was evaluated in terms of percent residual growth.

Both cultivars performed differently at different salt levels with respect to control. It was observed that COJ-84, known for high sugar production, was less salt tolerant as compared to CP-77-400. There was an increasing and decreasing trend in the average culm length in CP-77

400 with an increase in salt concentration of the growth medium as compared to control. A maximum decrease was found at 200 mM NaCl treatment, where the remaining culm length was only 71%. Moreover, maximum increase in culm length occurred at 50 mM NaCl level. On the other hand, culm length in COJ-84 also showed same increasing and decreasing trend at different salinity treatments, but with the difference that its values decreased at all salinity levels as compared to control. Maximum decrease (residual culm length = 61%) was at 150 and 200 mM NaCl concentrations (Table 3). The behavior of leaf length to salinity was also interesting and again both varieties behaved differently at different salinity levels.

Table 3. Growth of sugarcane cultivars CP-77-400 and COJ-84 grown under saline conditions

Cultivar	NaCl levels (mM)				
	(Control)	50	100	150	200
			Culm length (cm)		
CP-77-400	125.1	130 (104)	126.6 (101)	101.5 (81)	89.3 (71)
COJ-84	191.8	145 (76)	161.9 (84)	116.5 (61)	116 (61)
			Leaf length (cm)		
CP-77-400	143.08	134.1 (94)	118.4 (83)	120.5 (84)	112 (78)
COJ-84	108.2	138 (128)	107 (99)	111.8 (103)	99 (92)
			Internode length (cm)		
CP-77-400	7.4	7.4 (100)	8 (108)	7.2 (97)	6.6 (89)
COJ-84	7.4	6.0 (81)	7.0 (95)	5.72 (77)	5.74 (78)
			Culm diameter (cm)		
CP-77-400	2.3	2.1 (91)	2.3 (100)	2.00 (87)	2.1 (91)
COJ-84	2.2	2.31 (105)	2.2 (100)	2.11 (96)	2.11 (96)

Values in parantheses are per cent of control

Source: Hussain *et al.* , (2014)

The average leaf length in CP-77- 400 decreased at all salinity levels and maximum decrease was at 200 mM NaCl treatment,whereas leaf length in COJ-84 remained almost unchanged at 100, 150 and 200 mM NaCl levels, while an increase was observed at 50 mM NaCl concentration (Table 8).The average percent residual internode length in CP-77-400 remained unchanged at 50 mM, it increased to a maximum of 108% at 100 mM and decreased to 89% at 200 mM NaCl treatments. On the other hand, internode length in COJ-84 decreased at all salinity levels and maximum decrease was at 150 and 200 mM levels (Table 8).The effect of salinity on culm diameter in CP-77-400 was prominent. Culm diameter decreased at all salt treatments except at 100 mM salt concentration where it remained unchanged. Maximum decrease was observed at 150 mM NaCl treatment. On the other hand, COJ-84 showed an increase in culm diameter at 50 mM, remained unchanged at 100 mM and decreased at 150 and 200 mM NaCl concentrations (Table 5).

Groundnut

The five genotypes responded differentially to the different levels of salinity. As the concentration increases, there were corresponding decreases in the percentage germination and seedling emergence. The most effective concentrations, which depressed the germination counts, were saline solutions with electrical conductivities of 8.90 and 17.00 ms/cm(Table 4).

Table 4. Effect of salinity on germination and seedling development of five groundnut genotypes

Parameter	Cultivar	Salinity measured as electrical conductivity (mS/cm)					
		0.015	**1.50**	**2.60**	**4.68**	**8.90**	**17.0**
Germination (%)	Esan Local	70.0	68.5	55.2	50.4	48.4	46.4
	RRB 12	56.0	56.0	51.0	47.6	45.1	42.6
	RMP 91	57.0	50.0	37.0	33.7	30.8	27.8
	Ex-Dakar	80.0	80.0	75.2	70.4	67.6	64.8
	RMP 12	50.0	48.0	42.5	37.5	36.3	35.0
Emergence (%)	Esan Local	70.0	67.3	55.0	48.0	44.0	38.0
	RRB 12	55.0	54.0	49.0	45.0	41.0	36.4
	RMP 91	57.0	49.0	35.0	30.0	29.0	21.0
	Ex-Dakar	79.0	78.0	74.0	68.0	60.0	54.0
	RMP 12	50.0	48.0	40.0	36.0	35.0	30.0
Root length (mm) at 10 DAP	Esan Local	14.3	15.8	12.6	10.2	9.8	9.0
	RRB12	12.5	12.0	10.3	9.9	9.3	8.7
	RMP91	11.1	12.0	9.0	8.4	8.1	7.9
	Ex-Dakar	12.0	12.0	10.4	8.5	8.3	8.0
	RMP12	8.5	8.5	6.4	5.9	5.2	5.0
Plant height (cm) at 56 DAP	Esan Local	32.4	34.0	27.2	24.0	22.1	20.1
	RRB12	22.6	22.2	24.2	20.9	19.2	17.4
	RMP91	22.7	23.4	19.8	18.7	16.0	13.2
	Ex-Dakar	36.8	33.7	32.4	29.1	25.6	22.0
	RMP12	23.2	23.5	16.4	14.6	13.7	12.7
Number of Leaves/ plant at 56 DAP	Esan local	50.3	49.4	41.5	38.5	36.4	34.3
	RRB12	43.6	43.0	40.5	33.5	32.9	32.3
	RMP91	42.7	42.0	37.0	26.5	22.9	19.3
	Ex-Darkar	42.4	40.6	35.0	31.1	29.4	27.7
	RMP12	40.1	40.2	37.2	38.1	30.5	24.9
Primary Branches / plant at 56 DAP	Esan local	6.1	6.0	5.9	5.6	5.1	4.6
	RRB12	5.7	5.9	5.6	5.1	4.6	4.5
	RMP91	5.6	5.6	5.4	5.0	4.7	4.4
	Ex-Dakar	5.6	5.6	5.3	5.0	4.8	4.6
	RMP12	4.9	5.4	5.0	4.0	3.9	3.8

Source: Menash *et al.*, (2013)

The cultivar, Ex-Dakar recorded the highest percentage germination while RMP 91 recorded the least in the different saline solutions. The percentage seeding emergence in the field was however lower than what was recorded for the germination percentages. The ability of a seed to germinate and emerge under salt stress indicates that it has genetic potential for salt tolerance. The effect of the saline conditions was more on number of days to achieve germination (speed of germination) and percentage seedling emergence than percentage germination (Table 5).

Table5. Summary of the effects of saline conditions on five germination characteristics of groundnut genotypes

Conductivity of saline solution (ms/cm	No. of days to germination	Germination		Radicle length at 10 DAP (cm)
		Germination (%)	Emergence (%)	
0.015	3	72.4	62.6	11.0
1.50	3	72.0	60.5	11.5
2.60	3	70.8	52.1	9.1
4.68	4	70.0	47.9	8.2
8.90	5	69.6	45.6	7.7
17.7	**>6**	**60.8**	**40.0**	**7.3**

Source: Menash *et al.*, (2013)

The radicle length of the five groundnut genotypes differed under the different salinity levels as shown in Table 7. The Esan Local genotype had the longest radicle length (9.0 mm) and hence the least affected by the saline conditions and this was followed by RRB 12 (8.7 mm) while RMP12 (5.0 mm) was the most adversely affected by the saline solutions. The trends observed in the germination and shoot emergence studies as well as radicle length determinations were similar; that is, increasing salinity (measured by the electrical conductivity of the irrigation water) led to reductions in the value of the specific parameter.

VEGETABLES

The germination of sugar beet, cabbage, amaranth and pak-choi was strongly affected by all salt treatments. Increased salt concentration caused a decrease in germination. Strong reduction was observed mainly at the higher level of salt concentration compared to control. Lowest germination was observed in case of pak-choi at high salinity treatments (Figure 6) while the highest germination was measured in sugar beet.

The data presented in Figure 6 indicated that .the germination response of the four vegetables species under observation showed marked differences in the timing of initiation and completion of germination. Germination started within 36 hours and was complete on the 8th day. Germination delayed as the level of salinity increased. Figure 4 indicated that sugar beet and cabbage completed their germination nearly in same time but sugar beet took comparatively less time to complete germination. On the other side pak-choi took more time to complete germination then sugar beet, cabbage and amaranth.The studies were laid to investigate the influence of salinity on seedling growth of germinating seeds of sugar beet, cabbage, amaranth and pak-choi. The results indicated that emergence of root and shoot continuous increase in length of root and shoot was observed in frequent hours of germination in four vegetable species in control as well as salt treatments. The data on the average length (Figure 5) of root and shoot shows that sugar beet, cabbage, amaranth and pak-choi showed a strong inhibition with the increasing level of salt solution particularly at high salt levels (9.4 dS m^{-1} and 14.1 dS m). The results presented in Figure 7 indicated that great reduction of shoot growth and particularly in root growth occurred with NaCl treatments. Decrease in length of root was more pronounced as compared to shoot in all NaCl salt treatments in sugar beet, cabbage, amaranth and pak-choi. However this decrease was more prominent in pak-choi then sugar beet, cabbage and amaranth. Cabbage, sugar beet and amaranth also showed sign of great affects on root length. On the other hand, great inhibition in shoot length was recorded in amaranth. In contrast, shoot growth of sugar beet was less affected (Figure 7). Non significant difference was observed in shoot length of sugar beet at 4.7 dS m^{-1} then control Shoot and root fresh weight was significantly reduced in all accessions at all salinity levels (4.7–14.1 dS m^{-1} NaCl), whereas fresh shoot weight was reduced more as compared to fresh root weight.

This trend was more prominent in cabbage then sugar beet, amaranth and Pak-choi at all salt levels (Figure 6). However amaranth showed less reduction. On the other hand fresh root weight of Pak-choi was strongly inhibited by all salinity treatments as compared to sugar beet, cabbage and amaranth. But this decrease was less in amaranth (Figure 8).

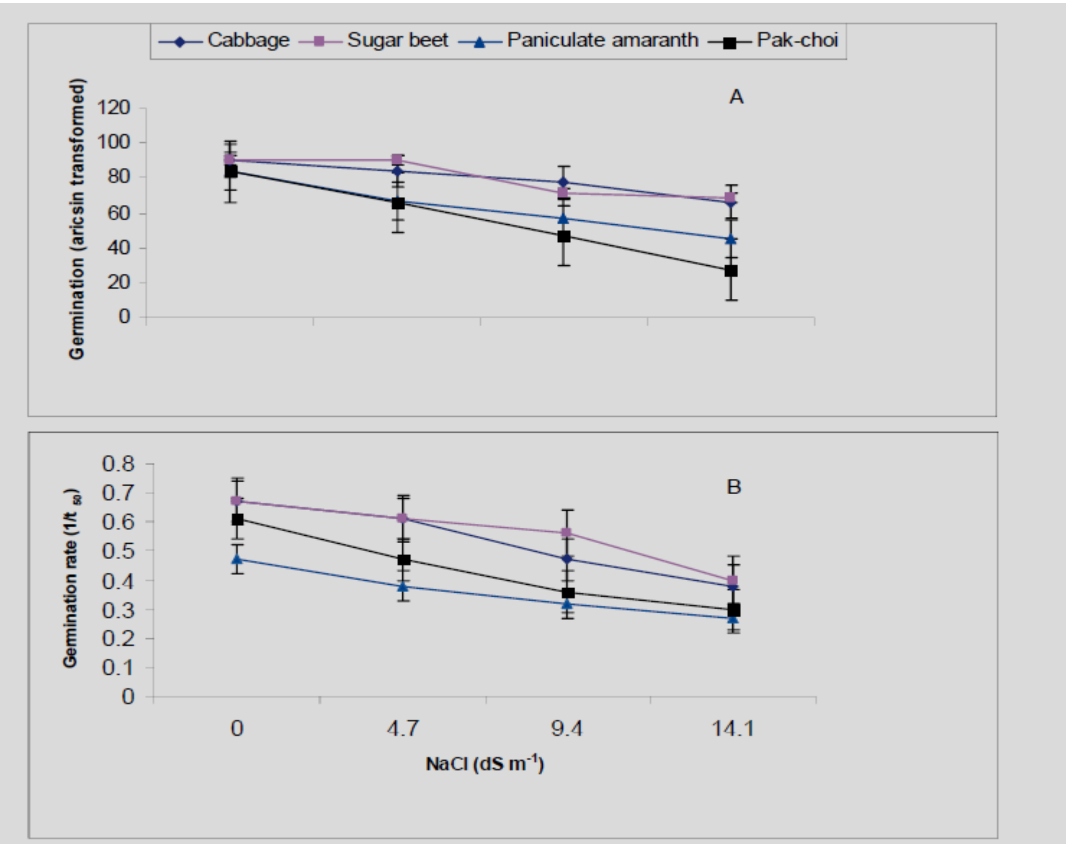

Fig.6. Effect of salt (NaCl) stress on the germination and the germination rate of four different vegetables. Error bars are not shown if similar than symbols.

Source: Jamil *et al.*, (2016)

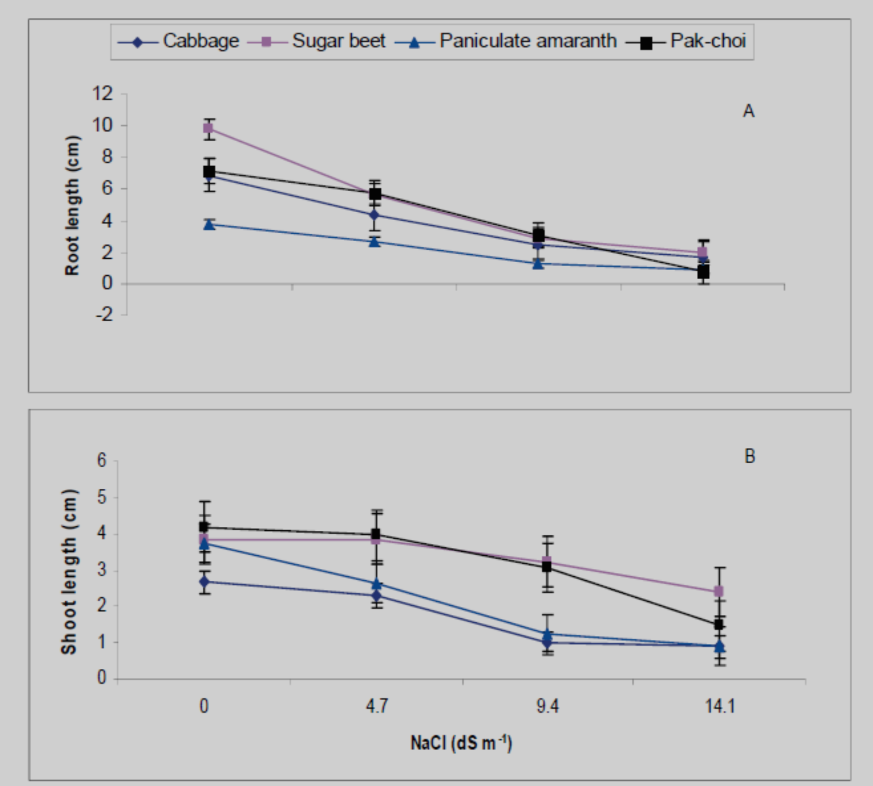

Fig. 7. Effect of salt(NaCl) stress on the root length and the shoot length of four different vegetables. Error bars are not shown if similar than symbols.

Source: Jamil *et al.*, (2016)

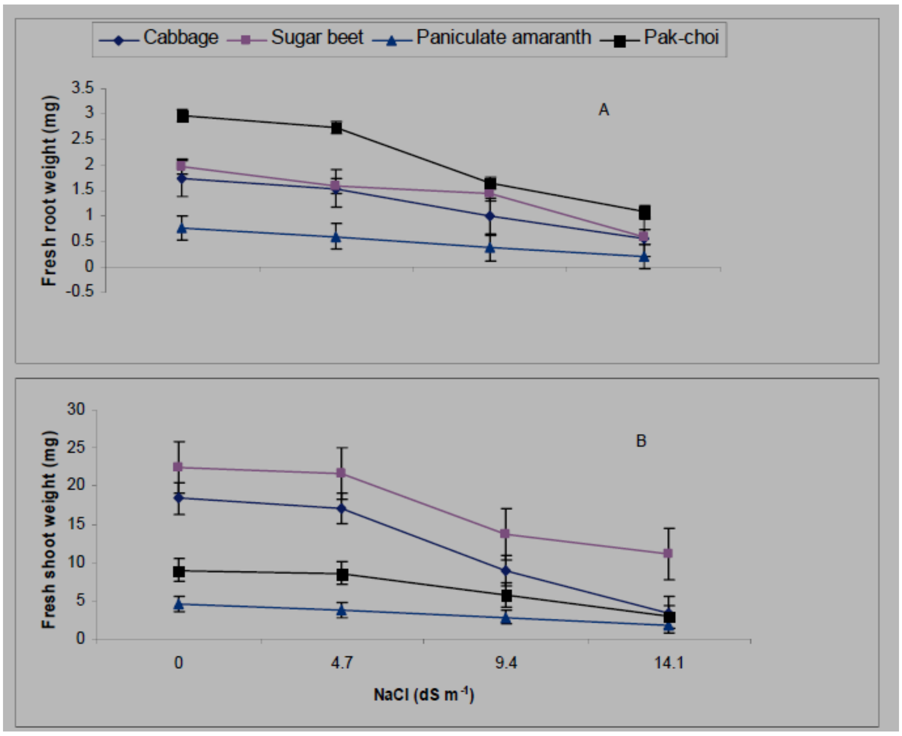

Fig. 8. Effect of salt (NaCl) stress on the fresh root weight and the fresh shoot weight of four different vegetables. Error bars are not shown if similar than symbols.

Source: Jamil *et al.*,(2016)

When the soil salinity exceeds a plant's tolerance, growth reductions occur. Salinity tolerance of a crop not only varies among crops/varieties but depends upon environment and cultural practices also. Therefore, to have more realistic assessment of salinity tolerance of a given crop, the value of soil salinity at which initial yield decline begins and % yield decline with per unit increase in salinity in for different vegetable crops (Table.6)

Table 6. Soil salinity (dS/m) at which initial yield decline begins and percent yield increase in salinity

Name of the crop	Soil salinity at which initial yield decline begins	Percent yield decline with per unit increase in salinity
Bean	.0	19.0
Broad bean	.6	9.6
Broccoli	2.8	9.2
Cabbage	.8	6.2
Carrot	.0	14.0
Celery	.8	6.2
Cucumber	2.5	13.0
Lettuce	1.3	13.0
Onion	1.2	16.0
Pepper	1.5	14.0
Potato	1.7	12.0
Radish	1.2	13.0
Spinach	2.0	7.6
Sweet corn	1.7	12.0
Squash	3.2	16.0
Tomato	2.5	9.9
Turnip	0.9	9.0

Source: Technical Bulletin-1, Hisar Agricultural University (SRDI,2013)

Mitigation of salinity

Many attempts have been made to reduce the drastic effect of salt stress on growth and productivity, most focusing on chemical amelioration, that involve developing salt-resistant cultivars, leaching excess soluble salts from upper to lower soil depths, flushing soils that contain salt crusts at the surface, reducing salt by harvesting salt-accumulating aerial plant parts in areas with negligible irrigation water or rainfall for leaching, and amelioration of saline soils under cropping and leaching. Breeding for tolerance to salinity in crops has usually been limited by a lack of reliable traits for selection. Therefore, the developments of methods and strategies to ameliorate deleterious effects of salt stress on plants have received considerable attention.

Data in Table 7 show that salinity affected plant height adversely, but the separate/combined application of L-TRP and Rhizobium increased the plant height significantly at all salinity levels, compared with respective uninoculated control. At original and medium salinities (2 and 4 dS/m), combined application (L-TRP and Rhizobium) showed significant increase of plant height by 13% and 18%, respectively, over uninoculated control, and differed nonsignificantly from Rhizobium inoculation alone. At high salinity (6 dS/m), L- TRP application enhanced the effectiveness of Rhizobium and gave the maximum increase (28% higher than respective uninoculated control) in plant height compared with their separate application and uninoculted control.

Data regarding root length of mung bean (Table 7) indicated that the integrated application of L-TRP and Rhizobium has more pronounced effects than their separate application, and showed maximum increase in root length that was up to 71% more than untreated control at all salinity levels. Rhizobium inoculation was the next effective treatment that was at par with L-TRP application at 6 dS/m.

Separate application of L-TRP and Rhizobium showed significant increase in number of nodules/plant compared with respective uninoculated control at all salinity levels (Table 9), except at 6 dS/m where L-TRP application produced similar effects to control. However, their combined application (L-TRP and Rhizobium) showed more pronounced effects than their separate application, and showed maximum increase in number of nodules/plant that ranged from 47% to 72% higher than respective uninoculated control.

Data regarding number of pods/plant revealed that integrated application of L-TRP and Rhizobium performed significantly better than their separate application at all salinity levels, except at original salinity (2 dS/m) where combined application was statistically similar to Rhizobium inoculation alone (Table 10). However, L-TRP application with Rhizobium gave maximum increase (up to 67% over uninoculated, control) in number of pods/plant at all salinity levels, followed by Rhizobium inoculation alone.

Table 7. Effects of inoculation with Rhizobium supplemented with L-TRP on plant height, root length, number of nodules/plant, and number of pods/plant of mungbean at different salinity levels

Treatments	Plant height(cm)			Root length (cm)		
	Electrical conductivity(ds/m)			Electrical conductivity(ds/m)		
	2	4	6	2	4	6
Control	25.47b	21.92d	1.820f	17.23e	14.30g	9.99i
Rhizobium	28.38a	25.63b	20.75e	20.11cd	20.47c	11.85h
Triptophan	28.19a	23.78c	20.65e	16.68f	19.83d	11.52h
Combination	28.70a	25.88b	23.32c	25.14a	24.05b	17.04ef
	Number of nodules/plant			Number of pods/plant		
Control	15.0de	11.0g	7.0i	13.0c	8.0f	6.0g
Rhizobium	21.00a	16.0cd	9.0h	17.0a	10.0e	8.0f
Triptophan	17.0bc	14.0ef	7.0i	15.0b	8.0f	7.0f
Combination	22.00a	18.0b	12.0fg	17.0a	11.0d	10.0d

***values sharing single letters (s) do not differ significantly at $p<0.05$ LSD**

Source: Zahir *et al.*,(2015)

Data in Table 8 clear that, the irrigation of mungbean with saline water (1500 and 3000 ppm) increased significantly plant height and dry weight /plant as compared with control plant. While the higher levels of salinity (4500 and 6000 ppm) decreased significantly these parameters as compared with untreated plant. The results in same table also showed that, spraying mungbean with arginine (1.25, 2.5 and 5 mM) reduced significantly plant height of mung bean plants as compared with control plant. Increasing arginine concentration reduced gradually plant height of mung bean plant. Plant dry weight increased significantly over the control plant.T he plant height at harvest, number and weight pods per plant, pods weight per plant, seeds number /pod, seeds and biological yield per plant affected by salinity irrigation and spraying plants with arginine concentrations. All these criteria decreased under different salinity irrigation. The plant height, pods number/plant and seeds number /pod were significantly decreased under all salinity levels. Increasing salinity levels induced gradual reduction as respect.

Table 8. Effect of different concentration of arginine on mungbean yield and its components grown under salinity stress

Chracter treatment		Plant height at harvest (cm)	Pods /plant	Pods weight (g/plant)	Seeds no/pod	Yields/plant			HI%
Salinity (ppm)	Arginine (mM)					Seed	Straw	Bio.	
Zero	Zero	59.00	6.00	2.08	4.07	1.62	8.38	10.00	16.20
	1.5	43.67	6.58	2.46	4.37	1.88	8.90	10.78	17.44
	2.50	42.00	8.67	2.91	4.89	2.03	9.86	11.89	17.07
	5.00	43.33	5.08	1.81	2.80	1.26	8.74	10.00	12.60
1500	Zero	50.67	5.67	2.59	4.95	2.06	7.16	9.22	22.34
	1.5	41.33	7.33	2.80	5.42	2.36	8.09	10.45	22.58
	2.50	40.00	7.33	3.09	4.68	2.55	8.12	10.67	23.90
	5.00	40.00	3.02	2.20	3.34	2.01	7.10	9.11	22.06
3000	Zero	47.33	4.83	2.36	3.90	1.88	7.23	9.11	20.64
	1.5	41.33	6.50	2.58	4.63	2.22	8.11	10.33	21.49
	2.50	34.33	6.75	2.75	3.49	2.52	7.03	9.55	26.39
	5.00	24.00	3.17	1.84	2.95	1.20	8.13	9.33	12.86
4500	Zero	39.67	3.58	1.59	2.80	1.07	8.04	9.11	11.75
	1.5	40.00	3.92	1.96	3.52	1.34	8.44	9.78	13.70
	2.50	30.67	5.00	2.12	2.86	1.56	7.44	9.00	17.33
	5.00	31.33	2.33	1.33	2.17	0.87	7.02	7.89	11.03
6000	Zero	21.33	3.42	0.86	2.56	0.92	7.86	8.78	10.48
	1.5	34.00	3.08	0.99	3.09	1.06	8.27	9.33	11.36
	2.50	28.67	3.42	1.11	2.62	1.27	7.95	9.22	13.77
	5.00	28.00	1.33	0.64	1.34	0.55	6.89	7.44	5.72

Source: Amira and Qados,(2014)

It is worthy to mention that, arginine treatments induced the appearance of new protein bands at molecular weight 131.00 KDa. This band disappeared when plants irrigated with different salinity levels. Moreover, there are proteins bands appeared at molecular weights 92, 90, 71.5, 60, 32.5, 16.5 and 8 KDa are appeared in plants sprayed with all arginine concentrations and irrigated with all salinity levels.

Several methods like prolonged cultivation in increasingly saline soils, presowing soaking treatment in salt, growth substance, micronutrients and other chemicals, spraying with various regulator solutions, dipping the intact flowering or fruiting branches in salt solution and grafting on salt tolerant root stocks have been used to induce salt tolerance in different crops. Very little efforts have been made on different crops including vegetables in this connection in Bangladesh. Some successful efforts have been made in case of onion, tomato, okra, cauliflower and potato crops in different countries and the results are summarized in Table 11

Table 9. Salt tolerance induction in some vegetable crops

Name of the crop	Name of the chemical/growth substance	Concentration	Method of treatment	Time for treatment (Hours)
Cauliflower	Cycocel	250ppm	Root dipping for transplants	2.0
Okra	Cycocel	5OOppm	Seed soaking	6.0
Onion	Cycocel	1.0%	Root dipping for transplants	8.0
Potato	Sodium salt solution or Cycocel	6.0 dS/m EC or 250ppm	Tuber soaking	2.0
Tomato	Sodium salt solution	8.0 dS/m EC	Root dipping for transplants	2.0

Source: Technical Bulletin-1, Hisar Agricultural University. (SRDI, 2013)

Effect of irrigation and planting methods

For management of saline soil in different areas of Bangladesh, Bangladesh Agricultural Research Institute conducted some experiment on tomato, watermelon and chilli to find out the effective measures as well as to have better yield and their findings showed that drip irrigation in raised bed with mulch for tomato and watermelon and manual pump irrigation at an interval of seven days in raised beds with mulch for chilli was found more effective for the production of the crops.

Table 10. Effect of different irrigation and planting methods ill on the yield of tomato, watermelon and chilli in saline area of Charmajid, Noakhali

Treatment	Yield (t ha1)		
	Tomato	Watermelon	Chilli
Ti	18.60	16.39	1.02
T2	27.18	23.38	1.28
T3	51.77	30.94	2.40
T4	71.57	36.13	3.02
T5	70.45	34.01	-

Ti= Farmers Practice, T2= No irrigation in raised bed with mulch, Ts=Manual pump irrigation in raised bed with mulch, can irrigation at an interval of seven days in raised beds with mulch for chilli, T4= Drip irrigation in raised bed with mulch, manual pump irrigation at an interval of seven days in raised beds with mulch for chilli and Ts= Drip irrigation in raised bed without mulch.

Source: BARI,(2013)

Management practices for coastal saline soils

It is important to adopt various land and soil management practices including agronomical techniques for reducing the adverse effect of salts.

Protective embankment: Land may be protected from inundation by saline water through establishment of earthen embankment of suitable size. The recommended size is of free breadth with 1 meter high above the high tide level. The side slope of the embankment should be of 2:1 ratio. The top width of the embankment may range from 1 to 3 m.

Provision of sluice gate on the protective embankment: There should be provision of one way manually operated sluice gate in the embankment system to remove excess rain water and also to prevent ingression of saline water inward during high tide in dry season.

Leveling of land: Land should be properly leveled to prevent accumulation of water in the low-lying patches and to facilitate uniform drainage of excess water. It will also help to apply irrigation water uniformly in the field during Rabi season.

Control of water through field bunds: About 25 cm high bunds are to be made demarcating the catchments and the field plots, so that the flow of excess water from outside the area and from one plot to another can be regulated. This will also help in retaining about 20 cm standing water to meet the water requirement during the subsequent dry period.

Draining of the catchments: Main and secondary drains are to be provided to directly let the excess rain water to move from different areas towards the sluice gate.

Operation of sluice gate frequently: In coastal area, heaviest showers are received in the month of July and August when most of the land operations are done. During this period, the sluice gate is to be opened more frequently and if necessary for longer periods to maintain desired water levels for optimum crop growth.

Storing of excess rain water for irrigation: After meeting the crop requirement, evaporation and seepage losses in Kharif season, about 500 mm of rain water remain in excess. A part of this excess water may be stored in the dugout pond at the farm level for subsequent utilization as irrigation water during the dry period for Rabi crops. This excess rain water can also be stored in the main drainage channel and re-excavated the derelict natural channels and closed minor tidal rivers/creeks.

Selection of Kharif rice variety: According to the depth of standing water and soil salinity of the field, suitable rice varieties can be selected for maximum production according to the available guidelines. BRRI dhan 23, 30, 40 and 41 are now practiced in the coastal area, particularly in the south-west and southern part in kharif-2 season.

Introduction of a second crop in Rabi season: Cropping intensity may be increased if sufficient irrigation water of good quality is available, introduction to a second rabi crop and even rice crop in winter is possible resulting additional production of grain yield.

Keeping land covered in winter and summer months: As the ground water is saline and is present at a shallow depth (about 1.0 meter), keeping fallow leads to high salinity in the soil due to excessive soil moisture evaporation. Growing cover crop or mulching is expected to mitigate this problem.

Introduction of Sharjan technique: Generally Sharjan technique is practiced in the south and south-west part of coastal saline areas where land type ranges from shallowly flooded medium highland to moderately to deeply flooded medium lowland having late draining condition.

Provision of sub-surface drainage: The sub-surface drainage has to be as such to keep the ground water at least 1 meter below the soil surface. This technology is very effective but in our socio-economic condition it is rather expensive.

Raising of vegetable nursery beds in weakly saline beds of transplanted crops: It has been observed that raising vegetable nursery in weakly saline soils develops a certain amount of adoption to saline soils and when such seedlings are transplanted in more saline fields, they perform better and avoid initial salt injury.

Addition of organic matter and chemical fertilizers: Addition of extra amount of organic matter improves soil physical and biological properties of soil and thus helps in better plant growth. As the problem of nutrient unavailability exists in salt affected soils, either due to fixation or competition in uptake, it is advantageous to supply them through foliage.

Keeping soil always moist: Sprinkler and drip irrigations are better as they keep the surface layer wet near the root zone and also increase humidity near he plant atmosphere, thus lowering the evapotranspirational rate of water.

Biological method: Very few efforts have been made to use biological methods for avoiding salt hazards. Some plants like *Chenopodium* spp. Absorb large amount of salts which can be grown and latter on removed after complete growth to minimize the salt concentrations from the fields. Vesicular-arbusecular mycorrhizal fungi (VAM) are known to increase plant growth and yield in saline soils.

Chapter IV
CONCLUSION

- In Bangladesh, salt affected area has increased 2, 22,810 ha during last 36 years. In 2000, six districts were newly affected by salinity besides 12 districts of 1973.

- High levels of soil salinity can significantly reduce seed germination, seedling growth, plant growth, photosynthesis and increases grain sterility which ultimately reduce yield due to the combined effects of high osmotic potential and specific ion toxicity.

- Different crops and varieties response varies in various degrees of salinity. Rice is more vulnerable than wheat in salinity.

- With the increase of salinity Na^+, Ca^{++}, Cl^- decrease and increase K^+ causing nutritional imbalance in plants resulting ion toxicity.

- Salinity can be mitigated by using Rhizobium inoculums combination with Tryptophan and arginine solutions in mungbean.

- Drip irrigation in raised bed with mulch for tomato and watermelon and manual pump irrigations in raised beds with mulch for chilli was found more effective for the production of the crops.

- Development of saline tolerant varieties is the ultimate solutions for increasing cropping intensity in saline areas.

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