ASSESSMENT OF SALINITY TOLERANCE CAPACITY OF PROMISING TOMATO GENOTYPES

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ABSTRACT

An experiment on tomato was conducted at the Net House Premises of Soil Science Division, Bangladesh Agricultural Research Institute; Gazipur during the winter season from Nov.2013 - Feb. 2014. The major objective of the study was to assess the salinity tolerance ability of promising tomato genotypes for the identification of salt tolerant ones. Six levels (1.14, 4, 6, 8, 10 and 12 dS m^{-1}) of irrigation water salinity were imposed to three genotypes of tomato V_1 (BARI Hybrid Tomato 4), V_2 (BARI Hybrid Tomato 5) and V_3 (BARI Hybrid Tomato 8). The pot experiment was set up in a Completely Randomized Design with 3 replications. Salinity was imposed as per treatments at the pre flowering stage two times at 45 and 55 DAS. The variety V_3 gave the highest fruit yield (1.62 kg plant^{-1} equivalent to 55.25 t ha^{-1}) along with better morphological characters. The same variety also gave significantly higher photosynthetic yield (0.64) and total sugar content (146.95 mg/gfw). The photosynthetic rate, transpiration rate, stomatal conductance and intercellular CO_2 concentration was highest for the V_3 as 14.56, 3.09, 0.25 and 199.75 mol m^{-2}s^{-1}, respectively. Potassium: sodium ratio for V_1, V_2 and V_3 was 3.43, 3.55 and 3.72, respectively, which indicates their adaptability under salt stressed situation to a considerable extent, where the performance of V_3 was slightly better over other two varieties. Increasing levels of salinity resulted in lower SPAD values in leaves regardless of genotype. Photosynthetic rate, transpiration rate, intercellular CO_2 concentration showed significant negative linear relationships with electrical conductivity of the irrigation water. Sodium salt stress showed antagonistic effect on the absorption N, P, K, Mg and S while it was synergistic for Ca although root Ca concentration showed declining trend. Considering all studied traits and yield potentiality, BARI hybrid tomato 8 can be regarded as salt tolerant to some extent.

CHAPTER 1

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) botanically referred to the to the family Solanaceae with chromosome number 2n=24 (Jenkins, 1948) and considered as one of the most important, popular and nutritious vegetables crop that has achieved tremendous popularity around the world (FAOSTAT, 2014) because of its taste, high nutritional value, multipurpose uses and commercial importance (Kanyomeka and Shivute, 2005; Demirkaya 2014). Tomato being a rich source of photochemical such as lycopene, -carotene, flavonoids, potassium, vitamins E and C, folic acid, which collectively play beneficial role in human health (Najla *et al*., 2009; Behrooj *et al*, 2012). It contains Calories 97, Iron 2.7 mg, Protein 4.5 g, Riboflavin 0.15 mg, Calcium 50 mg, Niacin 3.2 mg, Phosphorus 123 mg and Ascorbic acid 102 mg per 1 pound edible portion (Lester, 2006). The tomato fruit is consumed in fresh, cooked or after processed forms such as canning, juice, pulp, paste, or as a variety of sauces. It is one of the most important and popular vegetable in Bangladesh which cultivated in an area of 24.7 thousand hectares accounting for production of 94,000 metric tons with productivity of 9.38 tons per hectares (BBS, 2012).

Soil salinity is one of the major environmental stress which adversely affects almost every aspect plant growth and metabolism through water stress, ion toxicity, nutritional disorders, oxidative stress, alteration of metabolic processes, membrane disorganization, resulting in considerable losses in crop productivity worldwide (Munns and Tester, 2008; Martinez-Penalver *et al*., 2008; Maurya and Gothandam, 2014). The detrimental effects of salinity on plant growth may be divided into three broad categories: a) reduction in the soil osmotic potential thus reducing the amount of water available to plants b) specific sodium ion toxicity and c) inhibition of nutrient uptake resulting in nutrient imbalance (Ashraf and Foolad, 2007; Ahl and Omer, 2011). The reduction in crop production observed in various plant species exposed to salt

stress is linked to the decline in every aspect of physiology and biochemistry of plant growth and matabolism (Munns *et al*., 2006; Chaves *et al*., 2009; Bayuelo-Jimenez *et al.* 2012).

Tomato plant is sensitive to moderate levels of salinity depending on cultivar or growth stage and it holds an important position in agriculture. Salinity affects almost all the physiological and biochemical aspects of the plant development and reduces yield and quality of tomato from nutritional value and food safety (Foolad, 2004; Sengupta and Majumder,2009; Koushafaret *et al*. 2011). It was reported that yield decrease of tomato for 2.5, 3.5 and 7.6 dS m^{-1} salinity level was 0, 10 and 50%, respectively. Many other studies showed that the reductions in fruit weights by 10% with 5.0 - 6.0 dS m^{-1}, by 30% with 8.0 dS m^{-1} and by 40% with over 10.0 dS m^{-1} magnitude salinity (Reina-Sànchez *et al.,* 2005, Cuartero *et al.*, 2006). Irrigation with saline water may increase sugar and organic acid content of cherry tomatoes (De Pascale *et al*., 2007) and the flavor of processed tomatoes (Albacete *et al*., 2008). Therefore, salt tolerant cultivars are required to be screened out for the vast coastal regions to overcome the threat posed by salinity.

In Bangladesh, salinization is one of the major natural hazards hampering crop production. Coastal area in Bangladesh constitutes about 20% of the country of which about 53% are affected by different degrees of salinity (Haque, 2006). Currently, More than 45 million hectares (M ha) of irrigated land which account to 20% of total land have been damaged by salt worldwide and 1.5 M ha are taken out of production each year due to high salinity levels in the soil (Munns and Tester. 2008; Khan *et al.* 2014). A study conducted by (Miah *et el.,* 2009) shows that the salt-affected areas in the coastal region of Bangladesh increased sharply, by 26.71 %, to 950,780 hectares in 2009 from 750,350 hectares in 1973. Out of coastal cultivable saline area, about 328 (31%), 274 (26%) and 190 (18%) thousand hectares of land are affected by very slight (2.0-4.0 dS m-1), slight (4.1- 8.0 dS m-1) and moderately salinity (8.1-12.0 dS

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m-1), respectively are scope to successfully crop production (SRDI, 2010). It has become imperative to increase potential production of tomato to saline soils could give novel insight into the planting and modifying of tomato cultivars.

Salt stress affect on photosynthetic non-stomatal components has been pointed out that the assimilation activity may drop as a consequence of salt distribution to the crop, should be caused not only by stomatal closure, but mainly by ion actions at biochemical level (Rahimi *et al*., 2011; Shameem *et al*., 2012; Martinez-Rodriguez, 2008). It was reported that both stomatal conductance and especially the non stomatal ones are reduced by the salts accumulated in plant tissue. The non stomatal limitations of photosynthesis under salinity stress are thought to be an important aspect of photosynthesis research (Chaves *et al*., 2009; Lovelli *et al*., 2012). It was reported that under severe salt stress, photosynthesis of tomato deeply reduced, so in this way stressed plants had a lower amount of fixed carbon to utilize for plant growth (Munns, 2005; Jamil *et al.,* 2007; Lovelli *et al.*, 2012).

Salinity adversely affected the vegetative growth and productivity, which results in decrease in fresh and dry weights of leaves, shoot and roots. Increasing salinity is also accompanied by significant reductions in shoot weight, plant height and root length (Parida and Das, 2005; Perez- Al-Solimani *et al*., 2010). It was observed that lower stomatal conductance and photosynthesis due to salt stressed tomato plants explain the lower leaf growth and consequently the smaller accumulation of dry matter (Paranychianakis and Chartzoulakis, 2005; Lovelli *et al.*, 2012). The increased salinity over 4000 ppm led to reduction in dry weight, leaf area, plant stem, and roots of tomatoes due to osmotic and ionic stress (Albacete *et al*., 2008).

The disturbances regarding nutrient mobilization under saline environment reduce plant growth by affecting the availability, transport, and partitioning of nutrients. Exposure of plants to salt stress usually begins in the roots. The

whole plant is then affected when roots are growing in a salty medium. Increased NaCl concentration showed low fruit yield for a range of crops, including maize (Bar-Tal *et al*., 1991), tomato (Maggio *et al*., 2011 and Pepper (Kaya *et al*., 2009). Salt stress decreased the content of K and P in the leaves and roots of salt-stressed wheat plants (Hajihashemi *et al*., 2007). Therefore, it is hypothesized that increasing NaCl concentrations in nutrient solution may adversely affect K^+ concentration, and K^+/Na^+ ratio in tomato as well. The essential nutrient absorption may also be restricted due to prevalence of Na^+ in the root zone. This phenomenon needs systematic research to improve salt tolerant variety as well as mitigation strategy.

At present, In order to overcome salinity problem, several works have been accomplished that will generate improved economically viable technological means to facilitate crop production under salt stress conditions. Solving salt stress problem in agriculture cannot be overlooked because of increasing demand for food (Koushafar *et al.* 2011; Munns and Tester 2008).Common agronomical practices like irrigation, drainage as well as mulching for reducing soil salinity may be impractical for developing country, due to higher costs and difficulty in use. Poor vegetable growers of coastal belts practically do not have the technological means to grow tomato successfully in their salt affected soils. Nevertheless, development of genotypes with field tolerance to salinity stress is considered as a promising approach. BARI developed many tomato varieties but they are not properly screened against salinity stress. Therefore, identification of salinity tolerance genotype for a moderately sensitive crop like tomato becomes an important aspect of research.

Keeping this view in consideration, the present study has been undertaken with the following objectives:

i)   to assess the salinity tolerance ability of promising tomato genotypes with respect to different morpho-physiological characters, yield and nutrient content

ii)   to identify salt tolerant tomato variety.

CHAPTER 2

REVIEW OF LITERATURE

Tomato is the second-most important vegetable crop and has gained tremendous popularity over the world. Salinity is considered as one of the major environmental stress which adversely affects plant growth, metabolism and ultimately yield. Comprehensive information is not yet available on the morphological, physiological and biochemical attributes of crops like tomato as affected by salt stress. In this chapter, attempts have been made to review some important findings pertinent to variety and salinity level which adversely affects on the morphological, physiological and biochemical traits and yield of tomato genotypes.

2.1 Plant response to salinity

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil (Jacobsen *et al.*, 2012). One of the initial effects of salt stress on plant is the reduction of growth rate. First, the presence of salt in the soil reduces the water uptake capacity of the plant, and this causes quick reduction in the growth rate. This first phase of the growth response is due to the osmotic effect of the soil solution containing salt, and produces a package of effects similar to water stress (Munns 2002; Nahar K. and Hasanuzzaman 2009). The mechanisms by which salinity affects growth of a plant depend on the time scale over which the plant is exposed to salt. Munns (2002) summarized the sequential events in a plant grown in saline environment. He stated that "In the first few seconds or minutes, water is lost from cells and shrinked. Over hours, cells recover their original volume but the elongation rates are still reduced which led to lower growth rates of leaf and root. Over days, cell division rates are also affected, and contribute to lower

rates of leaf and root growth. Over weeks, changes in vegetative development and over months changes in reproductive development can be seen". Later on, Munns R., Tester M. (2008) developed the 'two-phase growth response to salinity' for better understanding the temporal differences in the responses of plants to salinity. The first phase of growth reduction is a quicker process which is due to osmotic effect. The second phase, on the other hand, is much slower process which is due to the salt accumulation in leaves, leading to salt toxicity in the plants. The later one may results in death of leaves and reduce the total photosynthetic leaf area which reduce the supply of photosynthate in plants and ultimately affect the yield. During phase 2, leaves of more sensitive genotype are died and the photosynthetic capacity of the plant is greatly reduced which imposes an additional effect on growth. Upon addition of salt at one step, the growth rate plummets to zero or below and takes 1–24 h to regain the new steady rate, depending on the extent of the osmotic shock (Munns, 2002; Dorais *et al*., 2008; Amoah and J. Onumah 2011).

Tomato as crop is moderately sensitive to salinity (Foolad, 2004; Maggio *et al*., 2007) and undoubtedly, salinity affects almost all the physiological and biochemical aspects of the plant development and reduce yield and quality of tomato from nutritional value and food safety (Favati *et al*., 2009; Kaouther *et al*., 2012). The effect of salinity concentration on plant growth has been studied in different tomato cultivars. From agronomic and physiological point of view as regards salinity response of this crop there are several studies (Maggio *et al*. 2011; Lovelli *et al*., 2012). Extensive research is necessary to develop growing conditions in moderate salinity to produce good vegetative growth.

2.2 Morphological and yield attributes of tomato and other crops as affected by salinity

The plant growth is controlled by a multitude of physiological, biochemical, and molecular processes, photosynthesis is a key phenomenon, which contributes substantially to the plant growth and development. When plant

exposed to high salt at germination it causes physiological drought and reduction in leaf expansion. Plants may eliminate salt from their cells and may tolerate its presence within the cells and high salt, affects of salt on plants morphology and tolerance mechanisms. The osmotic effects of salinity stress can be observed immediately after salt application and are believed to continue for the duration of exposure, resulting in inhibited cell expansion and cell division, as well as stomatal closure (Munns, 2005; Lovelli S, *et al.* 2010). High sodium, chloride concentration has the ability to affect plant enzymes and physiological processes. (Munns, 2002; Koushafar, 2011).

Hasanuzzaman *et al*. (2009) accomplished a field experiment to investigate that in plants, where Na^+ and Cl^- build up in the transpiring leaves over a long period of time, resulting in high salt concentration and leaf death. Leaf injury and death are attributed to the high salt load in the leaf that exceeds the capacity of salt compartmentation in the vacuoles, causing salt to build up in the cytoplasm to toxic levels (Munns *et al*., 2006; Ghanem *et al*., 2011). Result showed that remarkable reduction in plant height and tiller number and leaf area index in *O. sativa* plants grown in saline soil.

Tantawy *et al*. (2009) studied the effect of salinity on plant height. In salt condition, decrease in stem fresh weight may be related to lack of water and lower plant height due to toxicity of Na^+ and Cl^-. Disorder in translocation and distribution of minerals specially K^+ and Ca^{2+} can be another reason for growth reduction (Loukehaich *et al*., 2011). In case of lentil result showed that plant height, number of leaves and leaf area gradually decreased with the increase in salinity levels (4 to 6 dS m^{-1}) also reported by Islam *et al.* (2006).

Rahman *et al*. (2006) reported that increase in plant height of tomato mulched with rice straw while lowest height was observed in control (un-mulched) under saline soil. Furthermore, they have observed lower salinity (approx. 4 dS m^{-1}) in mulched plots than that of non-mulched plots (approx. 6 to 7 dS m^{-1}).

Hajer *et al*. (2006) have also reported reduction in plant height, fresh and dry vegetative biomass in three tomato cultivars grown under sea water salinity. Juan *et al*. (2005) conducted an experiment on morphological response of rape to salinity. High salinity reduced plant height, primary and secondary branches number of leaves and leaf area, yield and yield attributes of the crop.

Agrawal *et al.* (2005) executed an experiment on the effect of water salinity on tomato under drip irrigation. Four treatment s with three replications were applied. Treatments were done by drip irrigation with 1.5, 2.0, and 2.5 and 3.0 dSm^{-1} salinity of irrigation water. The result showed that as salinity increased the performance of drip system decreases. In significant critical differences was observed in various growth parameters for the first three treatments.

Dolatabadian *et al*. (2011) observed that salinity stress significantly decreased shoot and root weight, total biomass, plant height and leaf number of Mustard (*Glycine max)*. However, leaf area was not affected by salinity stress. Kaouther *et al*., (2012) studied the salt stress (NaCl) Tunisian cultivars of chili pepper and showed that the growth, chlorophyll content and fluorescence were severely affected. Similar results were reported in potato (Kerkeni, 2002) for root length, in canola (Byund, 2010) for leaf area and in groundnut (Mensah *et al.* 2006) for number of leaves.

Lauchli and Grattan (2007) reported that under saline condition, some crops are most sensitive during vegetative and early reproductive stages, less sensitive during flowering and least sensitive during the seed filling stage. The seed weight is the yield component of interest but similar conclusions regarding growth stage sensitivity were obtained with both determinate crops (the grain crops) and indeterminate (cowpea) crops. Seed set was reduced by 38% when female plants were grown in as low as 10 mM NaCl. In *Suaeda salsa* , plant height, number of branches, length of branches and diameter of shoot were

significantly affected by salt stress which was due to the increased content of Na^+ and Cl^- (Guan *et al.*, 2011) .

Islam *et al.* (2011) studied on tomato genotypes for salt tolerance and observed that primary branches significantly decreased with increasing salinity levels. Rahman *et al.*, (2006) reported that increase in plant height, number of leaves plant[-1] and total leaf area of tomato mulched with rice straw while lowest height was observed in control (un-mulched) under saline soil. Oztekin and Tuzel (2011) found that average number of leaves was counted as 8.3 during the 1st removal; as 9.2 for the salt-free plants and 8.4 for salt-treated plants with 8.4% decrease during the 2nd removal; as 12.9 for salt-free plants and 9.7 for salt-treated plants with 24.7% decrease during the 3rd removal.

Shimul *et al*. (2014) operated a study on the effects of different salinity level on growth of tomato and observed that plant height of tomato genotypes increased significantly with decreasing level of salinity. The tallest plant height (108.2 cm) was obtained from 0 dS m^{-1} and shortest (74.57 cm) with 16 dS m^{-1} salinity level. Sengupta *et al.* (2009) conducted a study to determine the response of tomatoes with different salinity level (0, 6, 8 and 10 dS m^{-1}) and found that the number of branches decreased with the increase in salinity level.

Biswas *et al.* (2015) carried out an experiment to study growth and yield responses of tomato varieties without salt stress condition and found that the tallest plant height (101.3 cm) and maximum number of branches (10.0/plant) was found from BARI Tomato-7. While maximum number of flowers (6.1/cluster), number of fruits (5.0/cluster), number of clusters (17.9/plant) were found from BARI Tomato-9. However, maximum fruit diameter (20.1 cm), individual fruit weight (115.9 g), yield (34.7 kg/plot and 95.9 t/ha) were also found from BARI Tomato-7 respectively.

Alsadon *et al*. (2013) conducted a study to determine the genotypic responses to salinity tolerance in tomato and observed that all the plant growth traits were significantly reduced with successive increases in water salinity levels. At the highest salinity level (9.6 dS m^{-1}), the number of leaves plant[1] were smaller than those at the control level (0.5 dS m^{-1}) by approximately 13, 11, 17, 16 and 18% for plant height, stem diameter, leaf area, leaf fresh weight and dry weight, respectively.

Rubio *et al*. (2009) reported that the negative effect of salinity on leaf area is more than other growth parameters like height, leaf dry weight and so forth. Measured leaf area was affected strongly by salinity sharply by increasing NaCl. Turan *et al*., (2009) stated that exposure of tomato plants to salt strongly prevented growth and average leaf weight. The reduction of the plant organs dry weight due to increased salinity may be a result of a combination of osmotic and specific ion effects of Cl^{-} and Na^{+}. Decrease in some vegetative growth parameters in salt stressed plant can be related to decrease in leaf area in view of fall in photosynthesis products.

Wahid *et al*. (2011) stated that inhibition effect of salt on chlorophylls could be due to suppression of specific enzymes responsible for the synthesis of green pigments. The decrease in chlorophyll may be attributed to increased chlorophyllase activity. Decrease in chlorophyll content under salt stress could be due to the effect on membrane stability (Bidel *et al*., 2007). Similar results were reported for total leaf concentration of cucurbits species (Taffouo *et al*., 2008), and lentil plant (Tester and Davenport, 2003).

Djerroudi *et al*. (2010) observed that significant correlation between morphological traits and physiological traits. Decreasing morphological traits may decrease physiological traits under salt stress condition except proline content in the leaf. Akram *et al*. (2007) reported that significant decrease in leaf area of tomato leaves with application of elevated salt treatment. Under saline

condition as soon as new cell starts its elongation process, the excess of Na+, Cl- and other ions modifies the metabolic activities of cell wall, which causes deposition of several materials on cell wall and limits the cell wall elasticity.

Shimul *et al*. (2014) attained the response of tomato to salinity and revealed that the significant variation was found with different level of salinity for leaf area. Highest leaf area (946.80 cm$^{2)}$) was observed in salinity control while lowest (410.80 cm^2) was recorded with 16 dS m^{-1}. Hassine *et al.(*2012) stated plant height, number of flower cluster, fruit number and yield were not adversely affected up to 8 dS m^{-1} but ripening was delayed. Increased yield over the control was noted with salt concentrations of 4 and 6 dS m^{-1}.

Islam *et al*. (2011) observed that flower cluster, fruit yield and vegetative growth of tomato were unaffected up to a soil salinity of 2.6 dS m-^{1}but yield reduced 6.32% and vegetative growth by 5.38% where yield were positively associated with K and/or K:Na ratio in leaves and negatively associated with Cl and/or Na concentration in leaves. It was observed that the lowest flower cluster plant^{-1} (11.6) with 10 dS m^{-1} salinity level. Cuartero *et al*., (2006) observed that tomato genotype 0178590 produced maximum number of fruits in two salinities of 10 and 15 dS/m and was less affected by increased salt levels which clearly indicated the salt tolerance

Khan *et al*. (2009) reported that number of fruit cluster, fruit size, fresh and fruit dry weight of tomato decreased with increased salinity. Fruit yield of tomato was reduced by 16% and 60% and the shoot biomass by 30% and >75% under moderate and high salinities, respectively. Rubio *et al*. (2009) reported that the number of fruits was unaffected by moderate salinity, and that reduced yield was entirely due to smaller fruit.

Chookhampaeng *et al*. (2007) conducted an experiment to determine the salinity stress inhibits overall plant growth. The result showed that shoot and

root lengths increased with the application of different sand priming treatments under salinity stress. This increased shoot and root lengths as compared to high salt stress may be due to enhanced cell wall extensibility of the primed seeds. Higher fresh and dry weights are reported to correlate with the earlier start of germination. Resultant increased fresh and dry weights in sand primed seeds are in conformity with the findings of earlier researchers (Jamil *et al.* 2006).

Nahar and Hasanuzzaman (2009) accomplished a field experiment to investigate the performance of tomato genotypes under saline irrigation and observed that the yield components of *V. radiata* were significantly affected by salinity stress. The reproductive growth of *V. radiata* was also affected by salinity as the number of pods per plant substantially decreased with increasing salinity levels. An application of 250 mM NaCl reduced 77%, 73% and 66% yield in *V. radiata* cv. BARI mung-2, BARI mung-5 and BARI mung-6, respectively over control.

Sardoei and Mohammadi (2014) conducted a field experiment on the effect of water salinity on tomato to evaluate the response of tomato genotypes (Cal -ji, Flat Ch irani, Chef Flat Americ, Primo Earily and Chef) against five salinity levels (distilled water as control, 25, 50, 75 and 100 mM) and observed at germination and early seedling stages. Results indicated interaction effect on growth indices in all the cases ($P < 0.05$). With increase in salinity level, germination percentage was significantly decreased. In the salt level of 25mM cultivar primo early showed 66.27% germination whereas the germination percentage of chef and calji was 62.13 and 77.68 respectively.

Shameem *et al.* (2012) performed an experiment of tomato plants, to evaluate the effects salinity on fruit yield and quality and observed 8 tomato genotypes with different salinity level 10, 15 dS m^{-1} at early development stages. It was observed that the tomato genotype O17859O adapted to salinity, based on number of fruits, number of flowers, K$^+$ concentration and K$^+$/Na$^+$ ratio.

Alam (2013) perfumed a pot experiment to evaluate the growth and yield of onion varieties against different salinity level *viz.* BARI Piaz-1, BARI Piaz-2, BARI Piaz-3, BARI Piaz-4, BARI Piaz-5 and four levels of salt (NaCl) *viz.* control (no salt, water only), 50 mM NaCl, 100 mM NaCl and 200 mM NaCl. The result showed that maximum plant height (24.08 cm), number of leaves per plant (4.13), individual weight of bulb (8.14 g), dry matter content of bulb (21.46 %) and yield of bulb ha^{1} (11.08t/ha) were produced by BARI Piaz-4. Most of the parameters showed decreasing trend with the highest level of salinity(200 mM NaCl) producing the lowest bulb yield(4.15 t/ha) respectively.

Shabani, *et al.* (2012) reported that fruit number was determined as the total number of fruit per plant. Fruit length was recorded (in cm) from stem end to blossom end, to two decimal place, at maturity from clusters (4 fruit for each plant). Fruit width was recorded (in cm) as the largest diameter of fruits two decimal place at maturity from clusters (4 fruit for each plant). Al-Busaidi *et al.,* (2010) studied that different genotypes with higher salinity treatment, varieties number 38 and 46 got the highest values for fruits number, diameter and weight (33,17and 555.23g, 344.34g respectively.

Mirabdulbaghi *et al.* (2012) noticed in two barley varieties namely Afzal and EMB82-12 with increasing levels of salinity. The reduction in shoot biomass production by the plant may be due to the chlorosis and necrosis of the leaves that reduce the photosynthetically active area (Lester G.E. 2006). The decrease in fresh reducing number of fruit and diameter causes the lower yield of 20-40%. Potato and cucumber showed no loss in yield and quality due to soil moisture stress developed under saline conditions and the suppression of growth under salinity stress during the early developmental stages.

Basirat *et al.* (2011) stated that an increase of 1 dS m^{-1} electrical conductivity resulted in a yield reduction of about 9-10%. At low EC yield reduction was caused mainly by reduction in the average fruit weight and reduced yield was

found for reduced number of fruits at high EC. Chookhampaeng *et al.,* (2007) concluded that the fruit yield, number of fruits and fruit weight of tomato cultivars significantly decreased with increased in salinity level.

Lauchli and Grattan (2007) excluded that under saline condition, some crops are most sensitive during vegetative and early reproductive stages, less sensitive during flowering and least sensitive during the seed filling stage. Seed set was reduced by 38% when female plants were grown in as low as 10 mM NaCl. Guan *et al.,* (2011) observed that plant height, number of branches, length of branches and diameter of shoot of *Suaeda salsa* were significantly affected by salt stress which was due to the increased content of Na^+ and Cl^-.

Shibli *et al.* (2007) found that growth and consequent fresh and dry weights are less impaired by salinity; this would indicate greater salt tolerance ability to the variety. At low transpiration treatment, yield loss was only 3.4% per EC unit in accordance with the reduction of fruit weight. It was concluded that transpiration control in a greenhouse has the same importance for tomato production as salinity control in root environment and depressed transpiration may reduce the negative effect of salinity on tomato yield.

Takeshi *et al.* (2006) performed an experiment of tomato plants, using a nutrient film technique in a hydroponic system to evaluate the effects of starting time and duration of salinity treatment and the interaction between salinity and planting density on fruit yield and quality. NaCl was added to the nutrient solution until EC 8 dSm^{-1}, it was applied from anthesis of the first flower truss until 20 days after anthesis and from 20 DAA until fruit harvest. The average fruit weight in the whole, early and late respectively were 46.71 and 58% of' the control weight respectively.

Azarmi *et al.* (2010) conducted an experiment on the effects of salinity on morphological and physiological changes and yield of tomato on growth, yield

and quality of greenhouse tomato grown in hydroponics culture. The results of this experiment showed that growth parameters and yield reduced with increasing salinity, but qualitative properties were improved by salinity.

Hasanuzzaman *et al.* (2009) reported that in *O. sativa* varieties, the loss of grain yield due to 150 mM salinity are 50%, 38%, 44% and 36% over control for the cultivars BR11, BRRI dhan41, BRRI dhan44 and BRRI dhan46, respectively. The severe inhibitory effects of salts on fertility may be due to differential competition in carbohydrate supply between vegetative growth and constrained supply. Reduced viability of pollen under stress condition could result in failure of seed set (Abdelrahman *et al*. 2005).

Maggio *et al.* (2011) reported that salinization of the root environment reduced plant growth and, consequently, plant water usage, obtained similar results. Subsequently, salinization gradually reduced both total and osmotic water potentials in tomato plant. Separately, it is hypothesized that protection of salinity in triazole compound-treated plants was associated with longer roots and smaller leaves for absorbing more water and losing less water, which improve salt tolerance in salt-stressed plants (Hajihashemi et al., 2007).

2.3 Biochemical attributes of tomato and other crops as governed by salinity

The detrimental effects of salt on plants are the consequence of both water deficit that results from the relatively high solute concentrations in the soil as well as stress specific to Cl^- and Na^+, resulting in a wide variety of physiological and biochemical changes that inhibit plant growth, development (Hasegawa *et al*., 2000; Taffouo *et al*., 2010). Some studies have shown that the chlorophyll content and photosynthetic pigments decrease in salt susceptible plants such as tomato (Zadeh *et al*., 2007; Loukehaich *et al.,* 2011; Oztekin and Tuzel, 2011).

Xinwen *et al.* (2008) found that the Chlorophyll level is an index of the photosynthesis and decrease in Chlorophyll level lead to reduction in growth parameters. Salinity can lead to oxidative stress and causing significant decrease to photosynthetic systems. Carotenoids can protect photosynthetic system against reactive oxygen species generate under salt stress (Parida and Das, 2005; Perveen, 2010). Decrease in chlorophylls level under salt stress may be due to reduction in pigment biosynthesis or enzymatic chlorophyll degradation (Xu *et al.*, 2008; Yang *et al.*, 2009).

Juan *et al.* (2005) studied that the control of Na+ accumulations and high K^+/Na^+ ratios may enhance salt tolerance and the K^+/Na^+ ratio has been used as a indicator by a number of authors to select salt tolerant in tomato crops. The result showed that a weak relationship between leaf Na^+ and photosynthetic pigments in tomato cultivars differing in salinity tolerance. They concluded that Chl *a* and *b* are not good indicators for salt tolerance in tomato. Therefore, using Chl accumulation as an indicator of salt tolerance depends on the nature of the plant species or cultivar. Salt stress can break down chlorophyll (Chl), the effect ascribed to increase level of the toxic cation, Na+ (Pinheiro *et al.* 2008 and Yang *et al.* 2011).

Ahmad *et al.* (2012) conducted A series of experiments with sunflower callus and plants and have shown that the important precursors of Chl, *i.e.*, glutamate and 5-aminolaevulinic acid (ALA), decreased in salt-stressed calli and leaves, which indicates that salt stress affects more markedly Chl biosynthesis than Chl breakdown (Khan *et al.*, 2009). Khan *et al.*, (2011) stated that reduction in photosynthetic pigments, such as Chl *a* and *b* has been reported in some earlier studies on different crops, *e.g.*, sunflower (Ashraf and Foolad, 2007), wheat (Arfan *et al.* 2007, Perveen *et al.*, 2010) and castor bean (Pinheiro *et al.*, 2008). The salt-induced alterations in a leaf Chl content could be due to impaired biosynthesis or accelerated pigment degradation.

Shimul *et al*. (2014) stated that the lowest chlorophyll content (15.9 mg/gfw) in tomato leaves at 16 dS m^{-1} salinity under hydrophonic culture. Islam *et al*., (2011) found that highest chlorophyll in leaves (51.3 mg/gfw) for BARI tomato-7 under non saline condition. The lowest chlorophyll content in leaves (29.2 mg/gfw) observed in BINA tomato-5 when salinity was 10 dS m^{-1}.

Maggio *et al*. (2007) reported that photosynthetic rate is also affected by salt stress. Decrease in photosynthetic rate may be attributed to decrease in chlorophyll contents. Hajer *et al*. (2006) observed that tomato plant photosynthesis decreased when subjected to salt stress. Others, reported that stomatal closure and high NaCl concentration may be responsible for the decrease in chlorophyll content in cotton plants when were treated with NaCl.

Chaves *et al*. (2009) reported that photosynthesis and the rhythm of cell growth are the first processes to be compromised by salinity. The maximum photochemical efficiency (Fv/Fm) indicates the capacity of absorption of excitation energy by leaves and it is usually decreasing thereafter as a consequence of leaf senescence and decrease of photosynthetic assimilation (Munns *et al*., 2006). The ratio (Fv/Fm) showed parallel trend with chlorophyll a and chlorophyll b content. Increasing salinity level is accompanied by a significant reduce in Fv/Fm ratio below 0.8 and showing the health and vigor of the plant while value below 0.8 indicates that plants are experiencing stress conditions (Schwarz *et al*., 2003).

Demiral and Koseoglu (2005) confirmed reported that the ratio for a normally functioning leaf varies between 0.75 and 0.85 and a decline in this ratio is indicative of photoinhibitory damage. Salt stress has significant effect on PSII photochemical activity, in strawberry (Rahimi and Biglarifard, 2011) and maize (Suriyan and Chalermpol, 2009). However, there are some reports that suggest that salt stress may not causes changes in Fv/Fm ratio in wheat (Akram *et al.,* 2007) and pepper (Ibn Maaouia Houimli *et al.,* 2008).

Piao *et al*. (2008) executed a study on the effects of different salinity level on plant growth and reveal that carbon dioxide exchange characteristics have been regarded an important indicator of the growth of plants, because of their direct link to net productivity. However, the effect of any stress on photosynthesis could be caused by stomatal, nonstomatal or both factors (Saibo *et al*., 2009; Al-Busaidi et al. 2010). It is known that salinity stress, similarly to other abiotic stresses, can significantly affect both stomatal and nonstomatal regulation of photosynthesis (Shabani *et al*., 2012).

Perveen *et al*. (2010) reported that salt-induced osmotic effect may induce a gradual decline in photosynthesis due to stomata closure under saline regimes. Salt stress imposed at the reproductive stage was reported to decrease the net CO_2 assimilation rate and stomatal conductance of intact leaves in various wheat genotypes (Shahbaz and Ashraf, 2007). Down-regulation of various gas-exchange characteristics to a varying extent has been observed in different plant species exposed to saline stress in a number of studies (Raza *et al*., 2007, Ali *et al*., 2008, and Noreen *et al*., 2012).

Zhang *et al*. (2009) reported that salinity-induced osmotic effect on plants consequently leads to a partial stomata closure thereby lowering the stomatal conductance as well as substomatal CO_2 concentration. It is evident that photosynthetic capacity has a positive association with a biomass production or a seed yield in plants under saline stress, including the crops, *Triticum aestivum* (James *et al*. 2002), *Oryza sativa* (Moradi and Ismail 2007), *Phaseolus vulgaris* (Seemann and Critchley 1985), *Zea mays* (Crosbie and Pearce, 1982), *Vigna mungo* (Chandra Babu *et al*. 1985), *Gossypium hirsutum* (Pettigrew and Meredith 1994), *Spinacia oleracea* (Robinson *et al*. 1983). Levent Tuna (2007) reported that water stress reduced transpiration water losses by reducing stomatal conductance.

Amirjani *et al.* (2011) illustrated that sugars are source of energy and carbons needed for adaptive and /or defensive responses to stresses. The high salinities stimulated sugar accumulation in leaves, whereas proline accumulation was primarily induced by increased NO_3^- in leaves (Bayoud, 2010) and In addition, sugars such as raffinose and sucrose are indicated to have important roles in protecting cells from water stress (Ashraf *et al*., 2007).

Silambarasan and Natarajan (2014) reported that the sodium chloride salinity levels in *C. inerme* increased the starch content up to 200 mM, but decreased the total sugar content of the leaf, stem and root. The increase in starch may be due to increase in the nitrogen content which plays an important role in photosynthesis (Chook hampaeng 2011). The highest reducing sugar in tomato leaves (21.1 mg/gfw) was found at 10 dS/m salinity level whereas lowest (15.7 mg/gfw) was observed in control (Islam, 2011) respectively.

2.4 Dry matter production and distribution of tomato and other crops as affected by salinity

Salinity adversely affected the vegetative growth of tomato and other crops, and it reduced plant length and dry weight. Salinity also significantly reduced the fresh and dry shoot and root weight of tomato as compared with the control (Abdelrahman *et al.,* 2005; Shibli *et al.,* 2007). The reduction in shoot and root dry matter could be a result of salinity induced water stress which inhibits photosynthesis and subsequent failure in the translocation of assimilates.

Lovelli, *et al.* (2012) reported that the leaf and stem dry weights of tomato were also reduced significantly in plants irrigated with saline nutrient solution in contrast with control plants. The increased salinity over 4000 ppm led to reduction in dry weight, leaf area, plant stem, and roots of tomatoes. All the desirable quality aspects for the processed tomato industry such as dry matter, soluble solids and titratable acidity seem to increase with salinity.

Juan *et al.* (2005) execute an experiment on ten cultivars of tomato and observed that that Jaguar and Brilliant cultivars were the most tolerant to salt stress and characterized by a reduction of the uptake and accumulation of toxic ions in leaves. In developing salt tolerant tomato cultivars, heritability of the selected trait has to be considered along with its physiological and metabolic importance. Leaf area showed the highest heritability as compared to shoot dry weight, measures of ion contents and water relations (Cuartero *et al.*, 2006).

Lovelli *et al.* (2012) observed a detailed, quantitative study of the responses of leaf growth and development in sorghum to salt stress showed that the length of the growth zone was shortened by 20% under salt stress, and that salt stress also reduced the maximal relative elemental growth rate, particularly in the youngest region of the leaf. Salt stress induced a dramatic decrease in Ca in the growing sorghum leaf which could be at least partly responsible for leaf growth inhibition (Nahar *et al.,* (2009). This appears to be the consequence of inhibition by salt of symplastic xylem loading of Ca in the root, leading to reduced Ca status in growing region of leaves (Nazar, *et al.* 2011).

Hasanuzzaman *et al.* (2009) reported that sodium was preferentially accumulated in the basal part of the growing zone where growth was least affected by salt stress. Salinity stress results in a clear stunting of plant growth, which results in a considerable decrease in dry weights (root, stem and leaf). Al-Busaidi *et al.*, (2010) studied that increasing salinity is companied also by significant reductions in root, stem and leaf Ca/Na and K/Na ratios.

Albacete *et al.* (2008) reported that dry matter weigh was maximum at 4 dS m^{-1}, after which a constant decrease in dry matter weight of shoot was observed as salinity levels increased. Besides plant height and siliqua plant^{-1} were decreased with increasing salinity.

Munns and Tester (2008) operated a study a greenhouse on the growth, mineral nutrition and quality of tomato grown under different levels of salinity (3, 6, 12 and 18 dS m^{-1}) in quartz sand. The dry matter of shoot and root yield decreased with an increase in the salt concentration of medium. The variety, Tusa Ruby could tolerate salts up to an EC value of 18 dS m^{-1}.

Manikandan and Desingh (2009) studied an experiment on the effects of different sodium chloride concentrations on the growth and photosynthesis parameters of tomato and found that the shoots fresh weights were significantly reduced with the 50 mM sodium chloride treatment showing the least fresh weight.The photosynthetic rate was 53% lower than that of the control treatment and the efficiency of photosynthetic water consumption was 29% less than treatment.

Feleafel and Mirdad (2014) evaluated rapid early growth of tomato to avoid the deleterious effect of water salinity by using four NPK starter solutions (SS); SS$_1$: without SS, SS$_2$: 200 -200-200 (1:1:1), SS3: 150-300-150 (1:2:1) and SS4: 100-400-100 (1:4:1) mg L-1 of N- P$_2$O$_5$-K$_2$O and three rates of humic acid (HA); 0, 750 and 1500 mg L -1, as well as their interactions. Tomato plants receiving SS$_4$ recorded maximum plant height; at 6, 8 and 10 weeks after transplanting (WAT), and leaves number; at 6 and 8 WAT, as well leaf P content. While, tomato plants receiving SS$_3$ achieved maximum root and shoot fresh weight and highest mean values of the number of flowers per cluster, leaf NK contents and fruit yield per plant.

Hossain and Nonami (2012) mentioned that dry weight of roots and shoots, shoot/root ratios and yields of tomato increased with increasing moisture content and decreased with increasing salinity. The adverse effect of salinity on growth and yield could be reduced by increasing the moisture regimes up to field capacity. In case of higher salinity also promoted to uptake Cl in tomato

plants which was exhibited in shoot and root dry matter and induced mineral nutrition disturbance.

Abdelhamid *et al.* (2010) conducted a study to determine the effect of NaCl stress on the growth of tomato plants is reflected in lower dry weights. The reduction of the dry weights due to increased salinity may be a result of a combination of osmotic and specific ion effects of Cl and Na. The results indicated that the stems, leaves and roots dry weights decreased in saline condition, due to the exposure to salinity stress. The same trend was observed on the leaves and roots as also documented by other workers (Shibli *et al.,* 2007; Salama, 2009).

Nasser *et al. (*2011) reported that plant roots and their function in mediating shoot responses to abiotic stresses such as salinity was recently emphasized. Ghanem *et al.* (2011) stated that absorbing water and nutrients, the root system is the main part of the plant to meet soil salinity, and likely plays an important role to cope with salts. Salts affect root growth and architecture is of great importance to elucidate mechanisms for plant adaptation process to salinity.

Albacete *et al.* (2008) observed that no modification of Root Length Density in hydroponically-grown tomato plants under salinity. Both a root fresh weight reduction (30 %) was observed on tomato after 3 weeks under saline conditions and a root dry matter reduction under salinity together with a root/shoot increase (Snapp and Shennan 1992; Lovelli *et al.*, 2012). Root growth traits reduction associated to salinity agree with the results of several authors (Schwarz Grosch 2003).

Lovelli *et al*. (2012) conducted an experiment on hydroponically-growth plants analyzing root length density along the depth and found a significant interaction between salinity and root depth on specific root length (SRL).The increase of SRL under salinity reflects differences in diameter distribution and

may be used as an indicator of plant response to management (Basirat *et al*., 2011) or environmental change (Ostonen *et al*., 2007).

Abu Khadejeh *et al.* (2012) showed that in saline conditions increased radicle to primary shoot (R/S) ratio more than NaCl 1%. Reduction in potassium absorption, coupled with a sharp increase in sodium accumulation had a negative impact on photosynthesis, therefore reducing growth and the accumulation of dry matter (Saibo, *et al.* 2009; Maggio *et al., 2007*).

Shibli *et al.* (2007) reported that salinity reduced the fresh and dry shoot and root weight of tomato. Increased salinity over 4000 ppm led to reduction in dry weight, leaf area, plant stem, and roots of tomatoes. Majkowska *et al.* (2008) observed that the rise in root/shoot dry weight in tomato under salt stress must be accompanied by the allocation of assimilates between root and shoot.

2.5 Nutrient concentration in tomato shoots and roots as affected by salinity application

Nutrition is a complex process involving 16 essential nutrients, as well as many other chemical elements that are either beneficial or harmful to plant metabolism. Ion uptake and compartmentalization are crucial not only for normal growth but also for growth under saline conditions (Shibli *et al.,* 2007). Increased salt concentration in the vicinity of the root system can interfere with mineral nutrition of plants and limit yield due to salinity or osmotic value of the soil solution. Al-Busaidi, *et al* (2010) found that tomato cultivars varied greatly in their response to different salinity levels. Increasing NaCl concentration in nutrient solution adversely affected on crop shoot and roots, plant height, K concentration, and K/Na ratio (Al-Karaki *et al.* 2000).Kumar *et al*, (2008) excluded that high concentrations of NaCl act antagonistically to the uptake of the other nutrients, such as K^+, Ca^{2+}, N, P.

Increased concentrations of NaCl increase concentrations of Na^+ and Cl^- and reduce concentrations of Ca^{2+}, K^+ and Mg^{2+} in many plant species (Grattan and Grieve, 1999; Yildirim *et al*., 2009). In presence of NaCl, the concentration of K+, Ca_2+ and P in vegetative parts decreased and in pods and grains increased. Ratios between concentrations of essential cations are changed as well. It was reported that deleterious effects of salinity on tomato biomass production can be ameliorated by an enhanced supply of calcium (Grattan and Grieve, 1999 and Afshari *et al*., 2011).

Nasser *et al*. (2012) conducted an experiment to find out the plant growth and seed germination severely affected by salinity and observed that, the effect of four levels of salinity (0, 50, 100 and 150 mM NaCl) on seed germination, plants growth (relative fresh and relative dry weight), K^+ and Na^+ content and photosynthetic rate of the four local cultivars (Heb, Ram and J1) and one commercial cultivar (Mar) was studied. Significant difference in G_{50} of Heb cultivar was seen at 50 and 100 mM NaCl when compared with the other four cultivars (p<0.05) and the only one achieved 50% germination at 150 NaCl. No significant difference was seen in K^+/Na^+ ratio among four cultivars tested, but Ram showed the maximum value of 5.72 and 35.09 at 50 and 100 mM NaCl, respectively. Ram also showed better photosynthesis rate (5.1, 3.71) at 50 and 100 mM NaCl, respectively, than the other four cultivars.

Moniruzzaman *et al*. (2010) screened out tomato genotypes *viz*., C-71, C11 x C51, C-51, WP7, WP8, WP2 and BARI Hybrid Tomato-4 under different concentration of salinity levels *viz*., (control, 4, 6, 10 dS/m) hydroponic system and salinity were imposed at pre-flowering stage in nutrient solutions. The result showed that photosynthetic data reflected Genotype C-71 was fairly tolerant to salinity levels up to 10 dS/m^{-1} while Genotype WP-7 was found sensitive to salinity. Chlorophyll fluorescence intensity of dark adopted leaves of genotypes might be due to high potential in Ribulose carboxylase (RuBP) of Photo System II.

Abdelgadir *et al.* (2010) studied that nitrogen usually improves plant growth and yield regardless of whether the crop is salt-stressed or not. In many field studies, horticulturists and agronomists set out to test the hypothesis that N-fertilizer additions alleviate, at least to some extent, the deleterious effect of salinity on plants. Nitrogen fertilization on saline soils is often necessary because in such soils there is a lack of accessible nitrogen and also because losses of nitrogen due to leaching typical for nitrate form (Yin *et al.*, 2007).

Levent Tuna *et al.* (2007) reported that the increase in soil salinity, total removal of nitrogen through the yield often decreases. Reduction in nitrogen fertilizer use efficiency is primarily a result of reduction of plant growth rate rather than the reduction of nitrogen uptake rate. Due to the toxic effects of salts on rhizobium the metabolism of nodulating bacteria can drastically alter.

Nightingale and Farhoud (2011) found that with increase in osmotic pressure the amount of soluble organic nitrogen and proteins in sweet peas decreased, while the nitrate form of nitrogen accumulated. Yildirim *et al.*, (2009) found that the lack of water through a salt stress may result in slowing down the metabolism of plants grown on saline soils. Nitrogen concentration in control plants was higher than salt stressed plants. Different studies showed nitrogen concentration decrease in salinity conditions (Kumar *et al.*, 2008).

Monireh *et al.* (2013) found that antagonist effect of Cl^- on nitrate can be responsible for nitrogen concentration fall. Tabatabaei (2006) illustrated that rising in NaCl concentration in the nutrient solution reduced nitrogen and nitrate concentration of the olive leaves. In salinity conditions, nitrogen concentration increased as Ca^{2+} and K^+ level were elevated. Levent Tuna *et al.* (2007) stated that the increase in nitrogen concentration resulting from high level of Ca^{2+} in salinity conditions.

In saline soil phosphorus availability is to a greater extent dependent on the length and area of the root system and antagonistic effects of excess chloride on the uptake of phosphorus by the root system. Elahi *et al.* (2010) reported that phosphate availability is reduced in saline soils not only because of ionic strength effects that reduce the activity of phosphate but also because phosphate concentrations in soil solution are tightly controlled by sorption processes and by the low-solubility of calcium phosphate minerals. Most of the studies that show salinity-reduced P concentrations in plant tissues were conducted in soils. In many cases, tissue P concentration was reduced between 20% to 50%, yet there was no evidence of P deficiency in the crops.

The interaction between salinity and phosphorus (P) nutrition of plants is equally as complex as that between salinity and N. In most cases, salinity decreases the concentration of P in plant tissue (Sharpley *et al.*, 1992), but the results of some studies indicated salinity either increased or had no effect on P uptake. Plant-growing conditions, plant type and even cultivar play a large role in P accumulation (Grattan and Grieve, 1999). Therefore, it is understandable that phosphate concentrations in field-grown agronomic crops decreased as salinity increased.

Rubio *et al.* (2009) suggested that reduction of the availability of phosphorus in saline soils is the result of the activity of ions antagonists, which can reduce the activity of phosphate and phosphate transporters of both high and low affinity, which are necessary for the uptake of phosphorus (Tabatabaei, 2006). Reduced uptake of phosphorus can also be a consequence of the strong influence of sorption processes that control the concentration of phosphorus in the soil and low solubility of Ca-P minerals (Mirabdulbaghi, 2012).

Singh *et al.* (2009) illustrated that plant response to phosphorus fertilizers depends on the degree of soil salinity. In general, the use of phosphorus fertilizers in saline soils helps to increase vegetable yields directly by adding

phosphorus and by reducing absorption of toxic elements such as chlorine Cl^- (Carillo *et al.*, 2005) and fluorine F^-. Rising in calcium level in the saline conditions contributed to increasing phosphorus concentration in leaf significantly.

Potassium is essential for many physiological processes, such as photosynthesis, translocation of photosynthates into sink organs, maintenance of turgor, activation of enzymes, and reducing excess uptake of ions such as sodium and iron in saline soils (Mengel and Kirkby, 2001). Sohrabi *et al.*, (2008) reported that among the mineral nutrients, potassium plays an important role in contributing to the survival of crop plants under environmental stress conditions. It can be stated that the ability of plants to retain K^+ at high Na+ concentration of the external solution may be involved in reducing the damage associated with excessive Na+ concentration in plant tissue.

Horchani *et al.* (2010) observed that potassium is the most prominent inorganic plant solute, and as such makes a major contribution to the low osmotic potential in the stele of the roots that is a prerequisite for turgor-pressure-driven solute transport in the xylem and the water balance of plants. Under saline-sodic or sodic conditions, high levels of external Na not only interfere with K acquisition by the roots, but also may disrupt the integrity of root membranes and alter their selectivity. The selectivity of the root system for K over Na must be sufficient to meet the levels of K required for metabolic processes, for the regulation of ion transport, and for osmotic adjustment.

Ashraf *et al.* (2008) elucidated an experiment where genotypes of tomato were grown at salinity (100 mM NaCl) significantly reduced leaf growth and shoot development. Application of K^+ could be useful to overcome the adverse effect of salinity (NaCl) on the leaf area of tomato. Application of K^+ ameliorated partially the adverse effects of high levels of salinity.

Mohammad *et al*. (2011) operated a study and observed that leaf pheophytin total and carotene content were reduced significantly from 32.84, 22.19 µg/g MF in control to 19.39, 13.37 µg/g MF respectively at 150 m M NaCl while in contrast application of potassium increase this pigments in the leaf of tomato. K^+ had an ameliorative effect under the salinity stress.

Levent Tuna (2007) found that reducing sodium uptake and increasing potassium following from high calcium consecration and causing an increase in plant growth. In conditions of high salinity plants may show signs of potassium deficiency due to antagonistic effects of Na^+ and Ca^2+ on K^+ absorption and/or abnormal Na+/K+ or Ca$_2$+/K+ ratio. In such circumstances, the application of potassium fertilizers can increase the yield of plants. The degree of tolerance of plants to the salinity is higher if they have a more efficient system for the selective uptake of K^+ instead of N^+ (Carden *et al*., 2003; Ashraf and Foolad, 2007; Sengupta *et al*. 2009) showed addition of calcium in nutrient solution resulted in membrane permeability preservation, rising in calcium and potassium and fall in sodium uptake.

Levent Tuna *et al*. (2007) pointed out that decrease in Na+ influx through non selective cation channels may be a mechanism for sodium uptake reduction. Supplemental K+ could not reduce Na+ uptake, due to the fact that Na+ is a powerful competitor for K+ especially in absorption through the "high-affinity K+ transporters". The less accumulation of Na^+ and more of K^+, seed germination and plant total weight were used as indicator for salt stress tolerance. All these parameters are considered as a good index to evaluate the photosynthetic performance of plants under salt stress reported by (Bidel, 2007, Najla *et al.,* 2009).

Tabatabaei, (2006) found that mechanisms of salinity resistance depend on plant ability to preserve K+/Na+ ratio. Fall in K+/Na+ ratio can be related to K+ efflux due to changing in membrane integrity and permeability or Na+

accumulation. In cherry tomatoes, this ratio decreased markedly in salinity conditions, but rise in calcium and potassium levels in nutrient solution elevated K+/Na+ ratio significantly (Levent Tuna, 2007).

Calcium is strongly competitive with Mg^{2+}. and the binding sites on the root plasma membrane appear to have less affinity for the highly hydrated Mg^{2+} than for Ca^{2+} (Marschner, 1995). Mirabdulbaghi, (2012) reported that calcium concentration decreased in both leave and fruit in salt stressed plants. High hydraulic resistance in salinity conditions results in low speed of water and calcium translocation; consequently, calcium concentration in fruits significantly falls. Decrease in calcium concentration by rising potassium level is related to its slow translocation (Levent Tuna, 2007) or antagonistic effects.

Rubio *et al.* (2009) stated that elevation in calcium level increased calcium uptake but elevation in potassium reduced calcium uptake in bell pepper. Torre *et al.*, (2007) investigated that calcium concentration of cherry tomato fruits was lower than leaves resulting from difference transpiration between fruits and leaves leading to high xylem flow to leaves compared with fruits. This finding provides another example of the negative effect of salinity on root pressure-driven calcium transport to meristematic tissue.

Ferrante *et. al*. (2011) studied that salinity that have analyzed plant tissue for magnesium, most of the salinity nutrition studies have directed little attention to magnesium nutrition as affected by salinity. Thus, high concentrations of substrate Ca^{2+} often result in increased leaf-Ca along with a marked reduction in leaf-Mg (Cachorro *et al.,* 1993). Reina-Sànchez *et al.,* (2005) where they found that NaCl salinity reduced leaf Mg^{2+} concentrations in citrus. However increases in salinity are not always associated with decreases in leaf Mg^{2+}.

Ferguson *et al.,* (2005) observed that solutions with a Mg^{2+}. /Ca^{2+}.ratio greater than one, such as those that result by diluting sea-water, reduce the growth of

maize. In eucalyptus, Mg-salts were found to reduce root growth more than Na-salts (Chen *et al.* 2010) and this effect was associated with low concentrations of calcium in the root. Calcium-induced Mg^{2+} deficiency has been observed in sesame but little work has focused on horticultural crops.

Sulphur as sulphate cannot be underestimated regarding its pivotal role in improving K/Na selectivity and increasing the capability of calcium ions to decrease the induced injurious effects of sodium ions in sunflower growth. To a marginal saline-sodic system, with S application, the cultivation of this important oil seed crop can be more productive. Nazar *et. al.* (2011) reported that sulfur has a very effective and positive role in reducing the effects of salinity and alkalinity stresses via improvement of physicochemical properties of saline and alkaline soil, increasing of permeability, decreasing of pH, loss and removal of irrigation water bicarbonate. Increases, decreases or remain unaffected sulfur assimilation enzymes by salinity stress.

Loukehaich *et al.* (2011) studied the response of plants to high salinity and observed the differences in crop response to chloride and sulphate salinity have measured in terms of identical electrical conductivities (Awada *et al.* 1995) molar or equivalent basis or iso osmotic potentials. Chloride-salinity reduced the sulphur content in the straw. Sulphur accumulation in the roots, however, that was enhanced by Cl-salinity. For most vegetable crops the salt-tolerance would be 2 dS/m greater in a sulphate system as opposed to chloride system reported by (Mori et al. 2007).

Davenport *et al.* (2005) observed that sulphate or sulphate-salinity reduces selenate uptake and accumulation in crops. The inhibition of selenate uptake and accumulation in edible tissue by sulphate reduces the health risk to the consumer when horticultural crops are irrigated with sulphate-dominated saline drainage water that contains high levels of this potentially toxic trace element

(Carillo *et al*. 2005). Similarly, sulphate has been found to reduce another potentially toxic oxyanion, molybdate (Al-Solimnai *et al*. 2010).

Khalid *et al*. (2012) carried out the experiment with three different treatments of Na_2SO_4 to check the effect of salinity on brinjal plant growth. Results showed that replicates with maximum salt concentration i.e. 60 ppm Na_2SO_4 gave best growth and stress showed positive response on the plants. The investigators found that Na_2SO_4 salinity substantially reduced Mo accumulation.

Kaya *et al*. (2009) reported that phosphorus uptake showed a strong positive correlation with S uptake under both types of soils. The higher rate of S^0 concentrated in a small volume of calcareous soil creates an acidic zone and increases the availability of P and micronutrients to roots growing zone. Sulfur uptake was enhanced with application of S^0 and its interaction with N and had a strong positive effect on total dry matter (TDM) accumulation. The higher levels of S^0 with N played significant role in respect of Mn uptake of maize plants. Manganese uptake was higher along with higher application of N which was most evident at higher S application rates.

CHAPTER 3

MATERIALS AND METHODS

A pot experiment on tomato genotypes was carried out to identify salt tolerant variety imposing different levels of irrigation water salinity at pre-flowering stage. In this chapter the description of different materials used and the methodology followed during the experimental period are narrated below:

3.1. Experimental site

The research was conducted at the Net House Premises of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the winter season November 2013 to February 2014. The experimental field is located at $24^{°}09$ N latitude and $90^{°}26$ E longitudes at a height of 8.4 m above the mean sea level (Rahman, 2002).

3.2. Soil

The soil was collected from 0-15 cm depth from HRC farm, BARI. The soil was clay loam in texture having P^{H} 6.2 and electrical conductivity (EC) 2.0 dS m^{-1}. The initial soil (0-15 cm depth) test revealed that the soil contained 0.05 % total N, 0.91% organic matter, 13 µ g g^{-1} available P, 17 µ g g^{-1} available S and 0.19 meq 100 g^{-1} exchangeable K, 0.74 µ g g^{-1} available Zn and 0.26 µ g g^{-1} available B (Appendix-I).

3.3. Weather and Climate

The experimental site is suited in the sub-tropical climate zone and characterized by heavy rainfall during the months of May to August and medium to low during the rest of the year. The crop was grown in winter season when the day length (sunshine period) was reduced to 10.5-11.0 hours per day only. Temperature during the cropping period ranged between $13.32^{°}$C and $34.58^{°}$ C with generally 57.10 - 96.70 % humidity in the air (BARI, Gazipur

2012-2013). The monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental site during the cropping season are presented in (Appendix-II).

3.4. Experimental material

Three promising tomato genotypes viz, BARI Hybrid Tomato 4, BARI Hybrid Tomato 5 and BARI Hybrid Tomato 8 were used as the test crop. The seeds of the tested varieties were collected collected from Olericulture Division, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.5. Preparation of soil and filling of pots

A total of 54 plastic pots were prepared with 10 kg air dried soil. The size of the pot was 30 cm top diameter with a height of 25 cm. Thus the surface area of an individual pot was 706.5 sq cm. Plant parts, inert materials, visible insects and pests were removed from soil by sieving. Collected soil was dried under the sun. The dry soil was thoroughly mixed with well rotten cow dung and fertilizers before filling the pots. The pots were placed in the green house.

3.6. Determination of initial salinity of soil

Three random samples of growth medium each with 50g were taken, sun dried. Pulverized and sieved with a fine sieve. Twenty ml distilled water was added to 10 g of this sieved media and was stirred for 30 minutes at 250 rpm. In following day, it was stirred again and intense of salinity was measured by electrical conductivity meter.

3.7. Experimental treatments and design

Six levels (1.14.4, 6, 8, 10 and 12 dS m^{-1}) of saline water irrigation were imposed to three varieties of tomato (BARI Hybrid Tomato 4, BARI Hybrid Tomato 5 and BARI Hybrid Tomato 8), which composed 18 treatments

altogether. The experiment was set up in a two factor completely randomized design with three replications. Thus 54 experimental pots were placed in ambient air at the greenhouse premises of Soil Science Division, BARI.

The salinity in irrigation water was developed by adding required amounts of NaC1 salt in irrigation water as per the procedure of Michael (1978) and Ponnamperuma (1984). The treatments were as follows:

Factor A: Tomato genotypes
    1.   BARI Hybrid Tomato 4 (V_1)
    2.   BARI Hybrid Tomato 5 (V_2)
    3.   BARI Hybrid Tomato 8 (V_3)

Factor B: Salinity levels (dS/m)
    1.   1.14 (S_0)
    2.   4 dS/m (S_1)
    3.   6dS/m (S_2)
    4.   8 dS/m (S_3)
    5. 10 dS/m (S_4)
    6. 12 dS/m (S_5)

3.8. Application of Fertilizer in the pot

The required amount of fertilizers ($N_{155}P_{34}K_{47}S_9Zn_{1.4}B_{0.6}$ kg ha^{-1}) and manure (cowdung @ 10 t ha^{-1}) was estimated on the basis of initial soil test result following Fertilizer Recommendation Guide (BARC, 2012). As per such recommendation urea 28g, triple super phosphate (TSP) 12g, muriate of potash (MP) 6.64 g, gypsum 4.0 g, zinc sulphate 0.28 g, boric acid 0.25g and 1.18 g cowdung pot^{-1} was applied. One third of urea and entire amount of cowdung, TSP MoP, gypsum, boric acid and zinc sulphate were mixed with the soil in each pot before sowing. Rest of the urea was applied as side dressing at 25 and 45 days after transplanting.

3.9. Imposition of salinity treatments

Salinity was imposed as per treatments at the pre flowering stage two times at 45 and 55 DAS. The developed irrigation water salinity and pot soil were measured by using an electrical conductivity meter (HANNA HI 993310 (Direct Salinity Meter) which was expressed in mS/cm.

3.10. Preparation of stock solution

Saline water was synthesized by using a mixture of different salts (50% NaCl, 5% Na_2SO_4, 10% each of $NaHCO_3$, $CaCl_2$ and $MgCl_2$ together with 5% $MgSO_4$) so that their composition was almost alike with the average composition of the ground water (SRDI; 2003). Eight hundred g of salt was dissolved in 16 liter tap water to prepare the stock solution. The salinity of the stock solution was 80 dS/m.

3.11. Development of salinity in the irrigation water

Irrigation water salinity as per treatment was developed by diluting the stock solution following the formula as stated below:

$$V_1 S_1 = V_2 S_2$$

Where,

V_I = Volume of stock solution needed to prepare the desired salinity

S_1 = Salinity of the stock solution

V_2 = Volume of saline water intending to prepare

S_2 = Desired salinity (dS/m)

3.12. Sowing of seeds

The seeds of three tomato genotypes were sown on the last week of October 2013 by hand in separate tray to raise the seedling. Proper care was taken following recommended measures for the development of healthy seedlings.

3.13. Transplanting of seedling

Healthy 30 days old tomato seedlings were uprooted separately from the seed beds. The seedlings were watered before uprooting so as to minimize damage

of roots. Two seedlings were transplanted to the each experimental pot in the afternoon during the last week of November 2013. Light irrigation was given immediately after transplanting by using water can. One seedling was uprooted leaving one seedling in each pot after seedling establishment.

3.14. Intercultural operations

Proper intercultural operations were done for better growth and development of tomato plants in pots. Weeding and mulching were accomplished as and when necessary to keep the crop free from weeds, better soil aeration and to break the soil crust.

3.14.1. Staking

At pre flowering stage, the juvenile plants were staked with bamboo sticks to keep them erect and to protect from damage caused by storm and strong wind. The plants were tied by plastic ropes to the stems with bamboo slices which are hung above them.

3.14.2. Irrigation

Immediately after transplanting, light irrigation to the individual pot was provided to overcome water deficit. After establishment of seedlings, each pot was watered in alternate days to keep the soil moist for normal growth and development of the plants. During pre flowering stage, irrigation was done with saline water as per treatments twice at 45 and 55 DAS. Thereafter, no irrigation was given. However, water was sprayed over the foliage at regular intervals up to 75 DAS.

3.14.3. Plant protection measures

Plant protection measures were done whenever it was necessary.

Insect pests

As a preventive measure against as the insect pest Malathion 57 EC was applied @ 2 ml L[1]. To prevent plants from fungal infection, Diathane M 45 was applied @ 2g1L[1] at the early stage of tomato (Mohanta, 2005).

Diseases

Dithane M-45 was applied @ 2 g/L at the early stage against late blight of tomato (Mohanta, 2005).

3.15. Harvesting of fruits

Fruits were harvested during early ripening stage when they attained red color. Harvesting was started on 6 January 2014 and completed by 25 February, 2014. At harvest one plant in each pot were uprooted, washed with running tap water. Thereafter, leaves, stems, roots were separated and dried in the sun. Finally, the leaves, stems and roots were oven dried at $70^{o}C$ for 72 hours in an electric oven.

3.16. Parameter Studied:

Data on the following parameters were recorded:

3.16.1. Measurement of morphological characters

1) Plant height (cm)
2) Number of primary branch $Plant^{-I}$
3) Number of leaves $Plant^{-I}$
4) Total Leaf area (cm^2)

3.16.2. Measurement of yield and yield contributing characters

1) Number of Flower Cluster $Plant^{-I}$
2) Number of Fruits Cluster $Plant^{-I}$
3) Number of Fruits $Plant^{-I}$
4) Individual Fruit Weight (gm)
5) Fruit length (cm)
6) Fruit diameter (cm)
7) Average fruit weight (gm)
8) Total fruit yield $Plant^{-I}$ (gm)

3.16.3. Measurements of Biochemical parameters

1) Chlorophyll contents in leaves (SPAD value) (mgm^{-2})
2) Photosynthetic yield (Fv/Fm)
3) Total sugar content in leaves(mg/gfw)
4) Reducing sugar contents in leaves (mg/gfw)
5) Photosynthesis rate (A) (μ mol $m^{-2}s^{-1}$)
6) Transpiration rate (E) (mmol $m^{-2}s^{-1}$)
7) Stomatal Conductance (gs) (mmol $m^{-2} s^{-1}$)
8) Sub-stomatal CO_2 (ci) (mmol $m^{-2}s^{-1}$)

3.16.4. Dry matter production and distribution

1) Shoot dry matter weight $Plant^{-I}$(g)
2) Root dry matter weight $Plant^{-I}$(g)
3) Root and Shoot dry matter Ratio (g/g)
4) Total dry Fruit weight $Plant^{-I}$ (gm)
5) Total Dry matter (TDM) $Plant^{-I}$(g)

3.16.5. Mineral ions uptake in root and shoot of tomato plant

1. Mineral ions (Na, N, P, K, Ca, Mg and S) uptake in shoot of tomato
2. Mineral ions (Na, N, P, K, Ca, Mg and S) uptake in root of tomato

3.17. Measurement of morphological characters

3.17.1. Plant height (cm)

Plant heights were measured in centimeter (cm) from the ground level to the tip of the longest stem at final harvest.

3.17.2 Number of branch $plant^{-I}$

The branch number of individual plant was counted and the average number of branch $plant^{-1}$ was calculated.

3.17. 3 Number of leaves $plant^{-I}$

The leaf number of individual plant was counted and the average number of leaves $plant^{-1}$ was calculated.

3.17.4 Leaf area (cm^2) plant^{-1}

Leaf area was measured with Licor leaf area meter (Model–LT 3000LT, COR.NC, Nebrashka, USA) and expressed in cm^2. Sample leaves were detached with a sharp blade from the lower middle and upper portion of plant and introduced in the device.

3.18. Measurement of yield and yield contributing characters

3.18. 1 Number of flower cluster plant^{-1}

The number of flower cluster of individual plant was recorded and the average number of clusters was recorded.

3.18. 2 Number of fruits cluster plant^{-1}

The number of fruit cluster of individual plant was recorded and the average number of cluster was recorded.

3.18. 3 Number of fruits plant^{-1}

The number of fruits of individual plant was recorded and the average number of fruit was recorded.

3.18.4. Individual fruits weight (g)

The fresh weight of individual fruits of from individual plant was recorded by an electric balance and the mean value was calculated.

3.18.5. Fruit length (cm)

Fruit length was measured in centimeter (cm) after harvest of matured tomato fruit.

3.18.6. Fruit diameter (cm)

Fruit diameter was measured in centimeter (cm) after harvest of matured tomato fruit.

3.18. 7. Fruit yield plant[-I]

The average fruits weight of in individual plant was recorded by an electric balance and then the fruit yield was calculated.

3.19. Measurement of biochemical parameters

3.19.1. Chlorophy'll contents (SPAD value)

Leaf chlorophyll content as SPAD values were measured from the youngest fully-expanded leaf in the third position from the tip by a portable chlorophyll meter (SPAD-502, Konica Minolta Sensing, Inc., Japan). The SPAD-502 chlorophyll meter can estimate total chlorophyll amounts in the leaves of a variety of species with a high degree of accuracy and is a nondestructive method (Neufeld *et al*., 2006).

3.19. 2. Chlorophyll fluorescence

The polyphasic rise of fluorescence transients was measured by an ADC Infrared Gas Analysis plant Efficiency Analyzer (PEA, Handsatech Instruments Ltd., King's Lynn, UK). The initial fluorescence (F_0), maximum fluorescence (F_m) were analyzed and quantum efficiency of open photosystem II centers (quantum yield) (Fv/Fm) was calculated. The leaf discs were previously adapted to the dark for 30 minutes. Chlorophyll fluorescence measurements and calculations were made according to Jamil *et al.* (2007)

3.19. 3. Gas exchange parameters

Gas exchange attributes calculations such as A (assimilation rate), E (transpiration rate), gs (stomatal conductance) and Ci (intercellular concentration of CO_2) from gas exchange measurements according to Von Caemmer and Farquhar (1981) were measured from the youngest fully-expanded leaf in the third position from the tip at flowering stage using an Portable photosynthesis system (ADC 2250 Gas Analyser ADC, England). All the measurements were recorded under ambient air composition (350 μmol mol-1 CO_2 and 210 mmol mol^{-1}CO_2)

3.19. 4. Total and reducing sugar content in leaves

Extraction and measurement of total sugar

Sugar was extracted by boiling the 10 ml 80% Ethanol for 5 minutes. Leaf sample of 0.25 gm and 0.1 gm powder of leaf was taken in separate vial and then 3 ml methanol was added preserved the sample. After 7 days vial wear kept in an oven at 80 ^{o} C temperature for drying the sample. After drying the vials wear made to volume with 1 L distilled water.

After 2 days, 0.5 ml extracted sample was shaken. The samples wear cooled fro 10 minutes. The optical density was measured at 490 nm with a spectrophotometer (SPECTRONIC 401,USA). Total wear determined following the method of Debois *et al* (1956) and Nelson (1944), respectively.

Calculation:

Total sugar measurement was estimated as follows:

Total sugar (mg $^{-1}$ dry wt): CF (Correction factor) X Dilution factor X OD (Optical density) mg/gfw

3.19. 5. Reducing sugar content in leaves

Extraction and measurement of reducing sugar

Reducing sugar was determined following the method of Karmoker (1981). 0.1 g of leaf sample was extracted by boiling in 10 ml 80% ethanol for 5 minutes. The procedure was repeated. The combined extract was mate volume to 10 ml by distilled water. For reaction, 2.0 ml extracted sample was taken in a test tube and added 2.0 ml solution (mixture of potassium sodium tartared + Na_2CO_3 + $NaHCO_3$ + $NaSO_4$ + $CuSO_4$). The aliquot was then heated for 15 minutes at 80°C and thereafter sample was cooled immediately in ice-cool water. Then 2 ml arsenic molibdate was added for colour development. The optical density was measured at 520 times using a spectrophotometer (SPECTRONIC 401, USA). Reducing sugar determined following the method of Debois *et al* (1956) and Nelson (1944), respectively.

Calculation:

Reducing sugar measurement was estimated as follows:

Reducing sugar (mg/gfw) = CF (Correction factor) ^{x} DE (Dilution factor) x OD (Optical density).

3.20. Measurement of dry matter production and distribution

3.20. 1. Root weight of plant^{-I}

Fresh and dry weight of roots was taken after harvest and then the samples were dried in an electric oven at 80^0 C at 72 hours and the average result was calculated.

3.20. 2. Shoot weight plant^{-I}

Fresh and dry weight of stem was taken after harvest and recorded in gram (g) and dried in an electric oven at 80^0 C at 72 hours and the average was calculated.

3.20.3. Root and shoot ratio (g/g)

The root: shoot ratio was calculated by using the following formula

$$\text{Root: shoot} = \frac{\text{Root dry weight Plant}^{-I}}{\text{Shoot dry weight Plant}^{-I}} \quad \text{g/g}$$

3.20. 4. Total dry Fruit weight Plant^{-I} (gm)

The fresh and dry weight of fruit was recorded in gram after harvesting and dried in an oven at 80^0 C at 72 hours and the average was calculated.

3.20.5. Total Dry matter (TDM) plant^{-I}

Total dry matter was calculated from summation of root, shoot and leaf dry matter and then the mean value was recorded.

3.21. Chemical analysis of plant samples

After dying in oven 70 ^{o}C for 72 hours to have the constant weight root and shoot samples of tomato plants were grinded and passed through 20 mesh sieve

separately. Total nitrogen content was determined by Micro Kjeldahl Method (Black, 1965) digesting with conc. H_2SO_4. Rest of the elements such as Na, K, Ca, Mg, P and S were determined by nitric:perchloric acid (3:1) digestion method (Yamakawa, 1992). Phosphorus and S were determined calorimetrically following Vanadomolybdate yellow colour method (Jackson, 1973) and turbidity method (Page *et al.,* 1982), respectively. Basic cations (Na, K, Ca and Mg) in the digest were measured using atomic absorption spectrophotometer (Varian Spectra AA 200).

3.22. Analysis of data

The data in respect of growth, yield contributing characters and yield were statistically analyzed to find out the statistical significance of the experimental results. The means for all the treatments were calculated and the analyses of variance for all the characters were performed by F test. The analyses were done following the software STATISTICA, Version 5 (Statsoft France, 1997). The significance of the difference among the means was evaluated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The study was undertaken to assess the effect of irrigation water induced salinity on some morphological, biochemical and yield contributing characters of tomato genotypes. The results are presented in tables with subsequent discussion under following sub-headings. The analyses of variances for different characters are given in Appendices (III-X), Tables (1a-9b) and Figures (1-20), respectively.

4.1. Morphological attributes of tomato genotypes as influenced by different salinity level

4.1.1. Plant height

Irrespective of salinity levels, the plant height tomato genotypes at harvest varied significantly ($p < 0.05$). The highest plant height (97.8 cm) was obtained from V_3 (BARI Hybrid Tomato 8), which was significantly higher over rest of the tested varieties. The second tallest plant (83.1 cm) was obtained from V_2 (BARI Hybrid Tomato 5), which was significantly higher over V_1 (BARI Hybrid Tomato 4). The shortest plant height (79.2 cm) was observed in V_1 (BARI Hybrid Tomato 4). It is therefore reveled that among the tested varieties BARI Hybrid Tomato 8 appeared as the tallest genotype as compared to BARI Hybrid Tomato 5 and BARI Hybrid Tomato 4 even if under salinity stressed situation. Such varietal character was also observed by Islam *et al.*, 2011, Moniruzzaman *et al.*2013, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

Different salinity levels significantly ($p < 0.05$) affected the plant height of tomato genotypes at harvest (Table 1a and Appendix Ill). Plant height decreased with the increasing level of salinity irrespective of variety. The lowest plant height (78.6 cm) was obtained with S_5 (12 dS m^{-1}), which was

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statistically identical to S_4 (10 dS m^{-1}) but significantly lower than the rest of the levels. The highest plant height (93.9 cm) was recorded in S_0 (1.14), which was statistically similar with S_1 (4 dS m^{-1}) but beyond that level the plant height decreased significantly. These results are in agreement with Tantawy *et al.,* 2009, Islam *et al.,* 2011 and Juan *et al.,* 2005.

The combined effect of tomato genotypes and salinity level in respect of plant height was statistically non-significant (Table 1b and Appendix III). Nonetheless, the plant height varied from 69.5 cm to 103.5 cm where the tallest plant was observed with V_3xS_0 and the shortest with $V_1 \times S_5$ but such variation might have been mostly governed either by variety or salinity level and very little for their interaction and thus the interaction effect appeared to be statistically non-significant.

4.1.2. Number of primary branch plant^{-I}

The number of primary branch plant^{-1} varied significantly among the tested genotypes irrespective of salinity level (Table 1a and Appendix Ill). The highest number (8.55) of primary branch per plant was obtained from V_1 (BARI Hybrid Tomato 4), which was significantly higher over other two varieties. The second highest number of primary branch (6.49) was recorded in V2 (BARI Hybrid Tomato 5) which was significantly higher over V. The lowest number of primary branch plant^{-1} (5.53) was recorded in V_3 (BARI Hybrid Tomato 8), which was significantly lower than other two varieties. Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al.*2013, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

Imposition of irrigation water salinity at pre flowering stage reduced the primary branch plant^{-1} significantly (Table 1a and Appendix III).The highest number of primary branch plant^{-I} (7.72) was obtained from the lowest salinity level S_0 (1.14), which was statistically identical to S_1 (4 dSm^{-1}). Beyond that, the number of primary branches per plant decreased significantly with

increasing level of salinity. The lowest number of primary branch plant^{-1} (5.77) was observed from S_5 (12 dSm^{-1}) which was which was significantly lower than rest of the salinity levels. Almost similar result was obtained by (Kaouther, *et al*., 2012, Islam *et al.,* 2011 and Sengupta *et al*., 2009).

The combined effect of genotype and salinity on number of primary branches plant-1 found to be statistically non-significant (Table 1b and Appendix III). However, the number of primary branch plant-1 for interaction (VxS) varied from 4.44 to 9.41 where the highest number of branch was recorded in $V_3 \times S_0$ followed by $V_3 \times S_1$ and the lowest from $V_1 \times S_5$ .This result revealed that the branch number governed either by genotype where V_1 gave the better performance or by the salinity level where S_5 showed the worst result irrespective of genotype and thus the interaction effect appeared to be statistically non-significant. These results are in agreement with the findings of (Kaouther, *et al*., 2012, Islam *et al.,* 2011 and Sengupta *et al*., 2009).

4.1.3 Number of leaves plant^{-I}

A significant ($p<0.05$) difference in number of leaves plant^{-1} was observed among the tomato genotypes under study (Table 1a and Appendix III). The highest number of leaves plant^{-1} (57.03) was obtained from V_3 (BARI Hybrid Tomato 8) that was significantly higher over V_1 and $V_2.$ The lowest number of leaves per plants (49.23) was observed in V_1, which was significantly lower than V_2 as well. As such the tested genotypes differed significantly irrespective of salinity levels in terms of number of leaves plant^{-1}.Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al.*2013, Kibria *et al.*2015, Biswas *et al.*2015 under non-stressed situation.

Table 1a. **Morphological characters of tomato genotypes as affected by different levels of salinity**

Treatment	Plant height (cm) at last harvest	Number of primary branch plant^{-I}	Number of leaves plant^{-I}	Total leaf area (cm^2) plant^{-I}
Genotypes				
V_1	76.9c	8.55a	49.23c	2677.0c
V_2	83.1b	6.49 b	51.79b	2786.5b
V_3	97.8a	5.53 c	57.03a	3117.0a
LSD (0.05)	1.7	0.13	0.74	26.088
Level of Significance	**	**	**	**
Salinity(dS/m)				
S_0	93.9a	7.72a	60.17a	2922.7a
S_1	90.0ab	7.41ab	56.80b	2901.8ab
S_2	87.4bc	7.19b	54.09c	2875.7ab
S_3	84.1cd	6.80 c	51.02d	2851.5abc
S_4	81.5de	6.26 d	48.47e	2830.2bc
S_5	78.6e	5.77e	45.55f	2779.2 c
LSD (0.05)	2.9	0.19	1.05	36.89
Level of Significance	**	**	**	**
CV%	6.13	5.94	4.25	2.74

Means within a column having similar letter (s) are not significant at 5% level of probability. NS= Not Significant

Genotypes:

V_1 = BARI Hybrid Tomato 4
V_2 =BARI Hybrid Tomato 5
V_3 =BARI Hybrid Tomato 8

Salinity levels:

S_0 = Control
S_1= 4 dS/m
S_2= 6 dS/m
S_3= 8 dS/m
S_4= 10 dS/m

Table 1b. Combined effects of tomato genotypes and salinity levels on morphological characters

Treatment		Plant height (cm) at last harvest	Number of branch plant^{-I}	Number of leaves plant^{-I}	Total leaf area plant^{-I} (cm^2)
V_1	S_0	84.2	6.68	55.42	2709.9
	S_1	79.3	6.07	52.41	2689.2
	S_2	80.1	5.55	50.99	2686.9
	S_3	75.7	5.32	48.29	2668.5
	S_4	72.8	5.14	45.44	2662.7
	S_5	69.5	4.44	42.86	2644.8
V_2	S_0	93.9	7.07	59.36	2885.7
	S_1	89.3	7.20	56.32	2865.5
	S_2	83.1	6.90	52.64	2775.6
	S_3	80.2	6.56	50.28	2752.2
	S_4	77.8	5.72	47.64	2729.6
	S_5	74.5	5.51	44.52	2710.5
V_3	S_0	103.5	9.41	65.75	3193.2
	S_1	101.6	9.13	61.68	3171.3
	S_2	99.2	8.96	58.65	3141.5
	S_3	96.6	8.70	54.48	3115.4
	S_4	94.2	7.74	52.34	3098.4
	S_5	91.8	7.37	49.28	2982.2
LSD (0.05)		4.3	0.33	1.82	63.90
Level of Significance		NS	NS	NS	NS
CV%		6.13	5.94	4.25	2.74

Means within a column are not significant at 5% level of probability. NS= Not significantly different at p<0.05

The number of leaves per plant was significantly affected by different levels of salinity (Table 1a and Appendix III).The highest number of leaves per plant (60.17) was obtained from lowest salinity level S_0 (0 dSm^{-1}), which was significantly higher than rest of the salinity levels. The number of leaves per plant decreased significantly with the increasing level of salinity. The second highest number of leaves plant^{-1} (56.80) was obtained from S_1 (4 dSm^{-1}), which was significantly higher over the increasing salinity levels. The lowest number of leaves plant^{-1} (45.55) was observed from S_5 (12 dSm^{-1}) that was significantly lower than rest of the salinity levels. The results are in conformity with the

findings of Rahman *et al*., 2006, Alsadon *et al*., 2013, Mousa *et al*., 2013 and Kaouther *et al*., 2012.

No significant combined effect for number of leaves plant^{-1} was observed between tomato varieties and salinity levels (Table 1b and Appendix III). This result suggests that genotypes and salinity levels acted independently on the variation in leaf number. In spite of this, the number of leaves plant^{-1} for interaction varied from 42.86 to 65.75 where the highest result was found from the combination $V_3 \times S_0$ and the lowest from $V_1 \times S_5$.

4.1.4 Total leaf area (cm^2) plant^{-I}

The tested tomato genotypes varied significantly in respect of total leaf area plant^{-1} (Table 1a and Appendix III). The variety BARI Hybrid Tomato 8 gave the highest total leaf area plant^{-1} (3117 cm^2), which was highly significant over rest of the two varieties. The second highest total leaf area plant^{-1} (3117 cm^2) was recorded from BARI Hybrid Tomato 5, which was significantly higher over V_1. Thus the lowest total leaf area plant^{-1} was observed in BARI Hybrid Tomato 4 (V_1). Such varietal character was also observed by Kibria *et al.*2015; Asmy *et al.*2014; Biswas *et al.*2015 under non-stressed situation.

The total leaf area plant^{-1} reduced significantly due to application of salinity induced irrigation water (Table 1a and Appendix III). The total leaf area plant^{-1} for S_0 (salinity control) was the highest (2923 cm2), which reduced gradually with the increase of salinity levels and fell down significantly to the lowest value (2779 cm^2) for S_5 (EC = 12 dS m^{-1}). Of course, up to S3 (EC = 8 dS m^{-1}) the leaf area did not reduce significantly irrespective of the genotypes. Almost similar results were reported by Turan *et al*., 2007, Kaouther, *et al*., 2012 and Shimul *et al*., 2014.

The combined (V x S) effect for total leaf area plant^{-1} was appeared to be statistically non significant (Table 1b and Appendix III). Nonetheless, the highest total leaf area (3193 cm^2) was recorded in $V_3 \times S_0$, which was closely followed $V_3 \times S_1$, $V_3 \times S_2$, $V_3 \times S_3$ and $V_3 \times S_4$ and the lowest total leaf area (2645 cm^2) was found with $V_1 \times S_5$. These results revealed that the leaf area mostly varied for genotypes, less for the salinity level and thus trivial for their interaction.

4.2. Yield attributes and fruit yield of tomato genotypes as affected by different salinity levels

4.2.1. Number of flower cluster plant^{-I}

The tested tomato genotypes varied significantly in respect of number of flower cluster plant^{-1} (Table 2a). The highest number of flower cluster plant^{-1}(13.05) was recorded in V_3 (BARI Hybrid Tomato 8), which was significantly higher over V_1 and V_2. The second highest flower cluster plant^{-1}(10.61) was observed in V_2 (BARI Hybrid Tomato 5), which was significantly higher over V_1 (BARI Hybrid Tomato 4). The lowest flower cluster plant^{-1} (7.82) was recorded in V_1. Thus irrespective of salinity level, the tomato genotypes might be due to their inherent genetic character showed wide range of variation in producing flower cluster. Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al.*2013, Kibria *et al.*2015, Biswas *et al.*2015 under non-stressed situation.

Imposition of irrigation water salinity at pre flowering stage decreased the number of flower cluster plant^{-1} significantly (Table 2a). The flower cluster decreased with the increasing level of salinity. For salinity control treatment (S_0), the number of flower cluster plant^{-1} was 7.77, which did not decreased significantly up to S_1 (EC = 4 dS m^{-1}) but beyond that level the flower cluster decreased significantly. The lowest number of flower cluster (5.92) was found with S_5 (EC = 12 dS m^{-1}), which was significantly lower than S_0, S_1 and S_2.

Almost similar result was reported by Sabir *et al*., 2009, Islam *et al.,* 2011 and Hossain and Nonami, 2012.

No significant combined (V x S) effect was seen for the number of flower cluster plant[-1] (Table 2b). However, the number of flower cluster plant[-1] varied from 6.74 to 14.06 where the highest result was observed in V_3 x S_0 and the lowest in V_1 x S_5. But such wide variation was governed by genotypes and salinity individually and very little for their interaction and thus it was found to be statistically non- significant.

4.2.2 Number of fruits cluster plant[-I]

The number of fruit cluster plant[-1] varied significantly due to genotypic effect (Table 2a). The highest number of fruit cluster plant[-1] (8.82) was recorded in V_3, which was significantly higher over other two varieties. The number of fruit cluster plant[-1] for V_2 and V_1 was 6.53 and 5.02, respectively and they also differed significantly. Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al.*2013, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

Different levels of salinity significantly reduced the number of fruits cluster plant[-1] of the tomato genotypes under study (Table 2a). The highest number of fruits cluster plant[-1] (7.77) was obtained from S_0 (control), which was statistically identical to S_1 (EC = 4 dS m^{-1}) but significantly higher over the higher salinity levels. The number of fruits cluster per plant reduced gradually and significantly with the increasing level of salinity. The lowest number of fruit cluster plant[-1] (5.92) was observed from S_5 (12 dS m^{-1}), which was significantly lower up to $_{S2}$ (6 dS m^{-1}) but statistically similar to rest of the salinity treatments. Almost similar kind of result was noticed by Rubio *et al*., 2009, Islam *et al.,* 2011 and Khan *et al*., 2009).

The combined effect between genotype and salinity on the number of fruit cluster plant[-1] was statistically non significant (Table 2b). Nonetheless, the number of fruit cluster plant[-1] varied from 3.91 to 9.83 where the highest result was observed from V_3 x S_0 and the lowest from V_1 x S_5 but this variation was mostly governed either by genotypic character or by salinity gradient and very little for their interaction and thus it (V x S) was appeared to be statistically non-significant.

4.2.3. Number of fruits plant[-1]

The yield attribute like number of fruits plant[-1] also varied significantly due to mean effect of genotypes (Table 2a). The highest number of fruits plant[-1] (52.43) was obtained from V_3 (BARI Hybrid Tomato 8), which was significantly higher over rest two varieties. The number of fruits plant[-1] for V_2 (BARI Hybrid Tomato 5) found to be 44.2, which was significantly higher over V_1 (BARI Hybrid Tomato 4) that produced 36.42 number of fruits plant[-1]. Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al.*2013, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

In case of salinity treatment however, the number of fruits plant[-1] decreased gradually and significantly irrespective of genotype (Table 2a). The magnitude of such reduction increased with the increasing level of salinity. For salinity control treatment (S_0) the highest number of fruits plant[-1] was recorded, which was statistically identical to S_1 (4 dSm[-1]) but significantly higher over rest of the higher salinity levels. For the application of saline irrigation water (EC > 6 dS m^{-1}) the number of fruits plant[-1] decreased sharply and fell down to 37.42 for S_5 (12 dS m^{-1}). Such kind of result was also reported by Rubio *et al*., 2009, Shabani *et al*., 2012, Islam *et al.,* 2011 and Nahar and Hasanuzzaman, 2009.

The number of fruits plant[-1] of course did not significantly influenced due to combined (V x S) effect (Table 2b). However, the number of fruits plant[-1]

varied from 31.09 to 65.80 where the highest result was obtained with $V_3 \times S_0$ and the lowest with $V_1 \times S_5$ but such variation was either for the mean effect of genotypes or salinity not appreciably for their combined and thus the said individual factors acted independently.

Table 2a. Yield and yield contributing character of tomato genotypes as affected by different levels of salinity

Treatment	Number of flower cluster plant^{-I}	Number of fruit cluster plant^{-I}	Number of fruits plant^{-I}	Individual fruit weight (g)
Genotypes				
V_1	7.82 c	5.02c	36.42c	33.27c
V_2	10.61b	6.53b	44.92b	38.01b
V_3	13.05a	8.82a	52.43a	44.52a
LSD (0.05)	0.25	0.22	2.07	0.59
Level of Significance	**	**	**	**
Salinity(dS/m)				
S_0	11.407a	7.77a	54.26a	43.33a
S_1	10.980a	7.34ab	49.40ab	42.16a
S_2	10.707ab	6.93 bc	46.48bc	39.54b
S_3	10.180bc	6.55cd	42.33cd	37.42c
S_4	10.017bc	6.25d	37.64d	36.01c
S_5	9.690c	5.92d	37.42d	33.13d
LSD (0.05)	0.36	0.32	2.93	0.83
Level of Significance	**	**	**	**
CV%	7.34	10.10	8.73	4.60

Means within a column having similar letter (s) are not significant at 5% level of probability. NS= Not Significant

Genotypes: Salinity levels:

V_1 = BARI Hybrid Tomato 4 S_0 = Control
V_2 =BARI Hybrid Tomato 5 S_1= 4 dS/m
V_3 =BARI Hybrid Tomato 8 S_2= 6 dS/m
                                        S_3= 8 dS/m
                                        S_4= 10 dS/m

Table 2b.Combined effects of tomato genotypes and salinity levels on yield and yield contributing characters

Treatment		Number of flower cluster plant^{-1}	Number of Fruit cluster plant^{-1}	Number of fruits plant^{-1}	Individual fruit weight (g)
V_1	S_0	8.68	5.85	41.65	42.30
	S_1	8.51	5.45	39.88	40.70
	S_2	8.28	5.54	37.28	37.93
	S_3	7.66	5.20	35.54	36.33
	S_4	7.04	4.21	33.09	35.96
	S_5	6.74	3.91	31.09	34.80
V_2	S_0	11.47	7.64	55.30	38.46
	S_1	11.07	7.24	51.90	37.40
	S_2	10.79	6.26	44.93	35.20
	S_3	10.49	5.88	41.55	32.50
	S_4	10.18	6.26f	39.93	30.40
	S_5	9.66	5.95	35.91	24.70
V_3	S_0	14.06	9.83	65.8	49.23
	S_1	13.58	9.35	59.01	47.40
	S_2	13.21	8.98	54.64	45.50
	S_3	12.81	8.58	49.91	43.80
	S_4	12.51	8.28	43.94	41.30
	S_5	12.14	7.91	41.24	39.90
LSD (0.05)		0.62	0.56	5.09	1.45
Level of Significance		NS	NS	NS	NS
CV%		7.34	10.10	8.73	4.60

Means within a column are not significant at 5% level of probability. NS= Not significantly different at p<0.05

The mean effect of salinity showed significant variation for the individual fruit weight plant^{-1} as well (Table 2a). The highest individual fruit weight (56.26 g) was recorded where no saline water was applied and it remained statistically similar up to S_1 (4 dSm^{-1}) and thereafter declined significantly. The weight of individual fruit decreased gradually with the increasing level of salinity and reached at the lowest (33.13 g) for this case for S_5 (12 dSm^{-1}), which was significantly lower than the rest of the lower levels of salinity. Basirat, *et al*., 2011, Islam *et al.,* 2011 and Amjad *et al*., 2014 also observed similar kind of result.

Like other yield attributes the combined (V x S) effect for the individual fruit weight was statistically non significant (Table 2b). Nevertheless, it varied from 24.70 to 49.23 g where the highest result was recorded in $V_3 \times S_0$ followed by $V_3 \times S_1$, $V_3 \times S_2$, $V_3 \times S_3$ and V_1 x S_0 and the lowest in $V_2 \times S_5$. Such result revealed that the individual fruit weight was also governed by the mean effect of the two said factors not exactly for their interaction. The performance of genotype V_3 was better and the higher salinity brought poor output irrespective of salinity levels and genotypes.

4.2.5. Fruit length (cm)

Tomato genotypes under this trial varied significantly with respect to fruit length for the mean effect (Table 3a). The highest fruit length (5.68 cm) was obtained from V_3, which was significantly higher over V_2 and V_1. Intermediate fruit length (4.46 cm) was found in V_2, which was significantly higher over V_1 with shortest (3.89 cm in length) fruit. Such varietal character was also observed by Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

Fruit length of tomato genotypes decreased significantly with the increasing level of salinity (Table 3a). For salinity control (S_0), the highest fruit length (5.70 cm) was recorded, which was significantly higher over salinity treatments. The second highest fruit length was obtained for S_1 having an EC value 4 dS m^{-1}(practically non-saline), which was statistically identical to S_2 (EC 6 dS m^{-1}) but significantly higher over rest of the salinity treatments. Fruit length further decreased for higher level of salinity with shortest fruit (3.57 cm) for S_5 (EC 12 dS m^{-1}), which was significantly lower than all other salinity treatments. This result can be justified by the findings of Hossain *et al.*, 2012, Mozafariyan *et al.*, 2013 and Horchani *et al.*, 2010 who reported that the fruit length of tomato plant decreased with elevated level of salinity .

Table 3a. Yield and yield contributing character of tomato genotypes as affected by different levels of salinity

Treatment	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight(g)	Fruit yield (kg plant^{-1})	Fruit yield (t ha^{-1})
Genotypes					
V_1	3.89c	3.79c	45.74c	1.34b	45.69b
V_2	4.46b	4.62b	49.49b	1.42b	48.37b
V_3	5.68a	5.68a	55.68a	1.62a	55.25a
LSD (0.05)	0.16	0.06	0.77	0.04	1.48
Level of Significance	**	**	**	**	**
Salinity(dS/m)					
S_0	5.70a	5.77a	51.44a	2.41a	82.05a
S_1	5.12b	5.34b	50.60a	2.20b	75.02b
S_2	4.92bc	4.93c	50.30a	1.71c	58.25c
S_3	4.64c	4.55d	50.12a	1.19d	40.57d
S_4	4.10d	4.02e	49.95a	0.65e	22.32e
S_5	3.57e	3.56f	49.42a	0.60e	20.40e
LSD (0.05)	0.23	0.08	1.08	0.06	2.10
Level of Significance	**	**	**	**	**
CV%	10.47	3.97	4.59	8.97	8.97

Means within a column having similar letter (s) are not significant at 5% level of probability. NS= Not Significant

Genotypes:

V_1 = BARI Hybrid Tomato 4
V_2 =BARI Hybrid Tomato 5
V_3 =BARI Hybrid Tomato 8

Salinity levels:

S_0 = Control
S_1= 4 dS/m
S_2= 6 dS/m
S_3= 8 dS/m
S_4= 10 dS/m
S_5= 12 dS/m

Table 3b. Combined effects of tomato genotypes and salinity levels on yield and yield attributing characters

Treatments		Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (gm)	Fruit yield	
					(kg plant^{-1})	(t ha^{-1})
V_1	S_0	4.45	4.85	46.96	2.31	78.54
	S_1	4.25	4.45	46.64	2.12	72.08
	S_2	4.30	3.83	45.85	1.54	52.58
	S_3	4.01	3.53	45.45	1.08	36.83
	S_4	3.46	3.24	44.62	0.57	19.49
	S_5	2.87	2.84	43.91	0.43	14.62
V_2	S_0	5.84	5.64	51.64	2.42	82.28
	S_1	4.77	5.24	49.10	2.25	76.50
	S_2	4.49	4.98	48.86	1.71	58.25
	S_3	4.34	4.56	48.14	1.21	41.36
	S_4	3.86	3.86	49.26	0.51	17.56
	S_5	3.45	3.45	49.95	0.32	14.28
V_3	S_0	6.83	6.83	56.83	2.51	85.34
	S_1	6.35	6.35	56.35	2.25	76.50
	S_2	5.98	5.98	55.98	1.88	63.92
	S_3	5.58	5.58	55.58	1.28	43.52
	S_4	4.98	4.98	54.98	0.95	29.92
	S_5	4.41	4.41	54.41	0.78	32.30
LSD (0.05)		0.40	0.15	1.88	0.10	3.64
Level of Significance		NS	NS	NS	NS	NS
CV%		10.47	3.97	4.59	8.97	8.97

Means within a column are not significant at 5% level of probability. NS= Not significantly different at p<0.05

4.2.6. Fruit diameter

The tomato genotypes under this study varied significantly in respect of fruit diameter for the mean effect of genotype (Table 2a). The highest fruit diameter (5.68 cm) was obtained from V_3 (BARI Hybrid Tomato 8), which was significantly higher over other two varieties. Intermediate fruit diameter (4.62 cm) was found with V_2, which was significantly higher over V1 as well. The smallest fruit diameter (3.79 cm) was of course recorded in V_1. Such varietal character was also observed by Kibria *et al.*2015, Biswas *et al.*2015 under non-stressed situation.

Application of saline water at pre flowering stage reduced the fruit diameter of tomato significantly irrespective of genotypes (Table 3a). The highest fruit diameter (5.77 cm) was obtained in salinity control treatment (S_0), which was significantly higher over salinity treated ones. The fruit diameter gradually reduced with increasing level of salinity. The lowest fruit diameter (3.56 cm) was recorded from S_5 (12 dS m^{-1}), which was significantly lower than all other reduced strength salinity treatment. Almost similar trend of result was reported by Hossain et al., 2012, Mozafariyan *et al*., 2013 and Horchani *et al*., 2010.

No significant combination (V x S) effect was seen for the fruit diameter of tomato genotypes (Table 3b). Besides, it varied from 2.84 to 6.83 cm but such wider variation was governed mostly by genotypic effect followed by salinity level and only a little for their interaction and thus interaction effect appeared to be statistically non significant.

4.2.7. Fruit yield

Highly significant variation was observed among the tomato varieties for fruit yield plant^{-1} due to mean effect of genotype (Table 3a). The highest fruit yield (1.62 kg plant^{-1} equivalent to 55.25 t ha^{-1}) was obtained from V_3 (BARI Hybrid Tomato 8), which was significantly higher over other two varieties. The next promising variety, V_2 produced the second highest yield (1.42 kg plant^{-1} equivalent to 48.37 t ha^{-1}), which was statistically similar to the third variety, V_3 (1.34 kg plant^{-1} equivalent to 45.39 t ha^{-1}). Thus the tested tomato genotypes showed significant yield potential irrespective of salinity level. Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al*.2013, Kibria *et al*.2015, Biswas *et al*.2015 under non- stressed situation.

Fruit yield plant^{-1} decreased significantly with the increasing levels of irrigation water salinity imposed at pre flowering stage (Table 3a). The highest yield was (2.41 kg plant^{-1} equivalent to 82.05 t ha^{-1}) obtained with salinity control treatment (S_0), which was significantly higher over rest of the treatments.

The second highest yield (2.20 kg plant^{-1} equivalent to 75.02 t ha^{-1}) was obtained from S_2 (4 dS m^{-1}), which was significantly higher over rest of the levels as well. The lowest fruit yield (0.60 kg plant^{-1} equivalent to 20.40 t ha^{-1}) was recorded from S_5 (12 dS m^{-1}), which was statistically identical to S_4 (10 dS m^{-1}) but both of them were significantly lower than aforementioned diluted salinity levels. These results revealed that irrigation water salinity (>6 dS m^{-1}) may impair the growth and yield of tomato plant to a great extent. These results are in agreement with the findings of Azarmi *et al*., 2010, Islam *et al.,* 2011 and Hasanuzzaman *et al*., 2009.

Like yield parameters, the fruit yield plant^{-1} did not influence significantly due to combined (V x S) effect (Table 3b). Nonetheless, the fruit yield plant^{-1} varied from 0.32 to 2.51 kg plant^{-1} equivalent to 14.28 to 85.43 t ha^{-1}, where the highest result was observed from $V_3 \times S_0$ followed by $V_2 \times S_0$, $V_1 \times S_0$ and $V_3 \times S_1$. The lowest fruit yield was obtained from $V_2 \times S_5$. Thus the fruit yield of tomato was mostly affected by the intensity of salinity as in the order of $S_5 > S_4 > S_3 > S_2 > S_1 > S_0$ where V_3 performed relatively better followed by V_2 and least by the V_1.

4.3. Dry matter production and distribution of tomato genotypes as affect from different salinity levels

4.3.1. Shoot dry weight plant^{-1}

The shoot dry weight of tomato varieties varies significantly due to genotypic effect irrespective of salinity level (Table 4a). The highest shoot dry matter (2.27 g plant^{-1}) was recorded in V_3, which was significantly higher over V_1 and V_2. An intermediate shoot dry weight (2.10 g plant^{-1}) was found from V_2, which was significantly higher over V_3. The lowest shoot dry weight (2.06 g plant^{-1}) was observed in V_3. Such varietal character was also observed by Elahi *et al.*2010, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

The mean effect of salinity showed significant variation in the shoot dry weight of tomato (Table 4a). The shoot dry matter weight decreased gradually and significantly with the increase of salinity level. For salinity control treatment (S_0), the shoot dry matter was the highest (2.41 g plant^{-1}), which was significantly higher over rest of the treatments. The second highest shoot dry weight (2.24 g plant^{-1}) was observed in S1 (4 dS m^{-1}), which was statistically identical to S_2 but significantly better over the higher salinity levels. The lowest shoot dry matter weight (1.89 g plant^{-1}) was found in S_5 (12 dS m^{-1}), which was statistically identical to immediate lower dose, S_4 (10 dS m-1) but significantly lighter than the rest of the salinity levels. Shibli *et al.,* 2007, Salama, 2009, Shameem *et al.*, 2012 and Shimul *et al.*, 2014 also reported similar kind of observation.

The genotype and salinity combination (V x S) on the shoot dry matter weight was of course statistically non-significant (Table 4b). However, shoot dry matter weight varied from 1.77 to 2.52 g plant^{-1} where the highest result was recorded in $V_3 \times S_5$ followed by $V_2 \times S_0$ and the lowest in $V_3 \times S_5$. It is revealed that shoot dry matter weight was greater for V_3, intermediate for V_2 and lower for V_1, where combination with S_0 gave the better result and it was declined with increasing level of salinity and thus the variation was mostly governed by the mean effect and very little for their combination.

4.3.2 Root dry matter weight plant^{-I}

Root dry matter weight also varied significantly due to mean effect of genotype (Table 4a). The highest root dry matter weight (1.02 g plant^{-1}) was recorded in V_3, which was exactly similar for the variety V_1 and both of them were significantly higher over V_2 (0.89). Such varietal character was also observed by Elahi *et al.*2010, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

The dry matter weight of root decreased significantly with the increasing level of salinity (Table 4a). For control (S_0), the root dry matter weight was 1.11 g plant^{-1}, which decreased to 1.03 g plant^{-1} when plant was irrigated with S_1 (4 dS m^{-1}) thereafter it decreased significantly with the increasing level of salinity and fell down to 0.74 g plant^{-1} for S_5 (12 dS m^{-1}). These results can be justified with the findings of Shibli, *et al.* 2007, Salama, 2009, Shameem, *et al.*, 2012 and Shimul *et al.*, 2014.

However, the combined effect (V x C) was appeared to be non-significant for root dry matter weight as well. Nonetheless, it still varied from 0.68 to 1.21 g plant^{-1} where the highest result was observed in V_3 x S_0 and the lowest in V_1 x S_5 but such wide variation as revealed was mainly for the mean effects and only a little for the combination and so it was statistically non-significant.

4.3.3. Shoot root ratio

The shoot: root ratio also varied significantly due to mean effect of genotype (Table 4a). Such ratio was higher (2.39) but similar for the variety V_1 and V_2, which was significantly greater than the variety V_3 (2.26). Higher shoot: root ratio irrespective of salinity levels, signifies more potentiality to produce above ground biomass yield. In this respect V_3 appeared as better variety as well. Such varietal character was also observed by Elahi, *et al.*2010, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

Increasing level of salinity gradually increased the shoot: root ratio to a great extent (Table 4a). Up to S_1 (4 dS m^{-1}), the shoot: root ratio was almost similar (2.17~2.19) thereafter it declined appreciably to 2.30 for S_2 and ultimately fell down to 2.57 for S_5 (12 dS m^{-1}), which was statistically similar to S_4 but significantly higher over rest of the lower salinity levels. The significantly higher shoot: root ratio than salinity control may be attributed to the impairment of root biomass due to abundance of Na$^+$ ions

in the root zone. The rise in root/shoot dry weight in tomato under salt stress must be accompanied by changes in the allocation of assimilates between root and shoot i.e. greater proportion of assimilates for root compared with shoot (Maggio *et al.* 2007; Amirjani *et al.* 2011; Hamed *et al.* 2011; Chookhampaeng *et al.* 2007 and Shimul *et al.*, 2014).

Table 4a. Dry matter production and distribution of tomato genotypes as affected by different levels of salinity

Treatments	Shoot dry weight plant^{-I} (g)	Root dry weight plant^{-I} (g)	Shoot: root ratio (g/g)	Fruit dry matter weight plant^{-I}(g)	Total dry matter (TDM) plant^{-I}(g)
Genotypes					
V_1	2.06c	1.02a	2.39a	173.13c	175.98c
V_2	2.10b	0.89b	2.39a	181.31b	184.31b
V_3	2.27a	1.02a	2.26b	189.54a	192.84a
LSD (0.05)	0.04	0.01	0.05	1.93	1.96
Level of Significance	**	**	**	**	**
Salinity(dS/m)					
S_0	2.41a	1.11a	2.17d	193.83a	197.36a
S_1	2.24b	1.03b	2.19d	187.60 b	190.88b
S_2	2.14bc	0.94c	2.30cd	183.08 bc	186.17bc
S_3	2.07cd	0.87d	2.38bc	179.13 cd	182.09cd
S_4	2.04de	0.81e	2.49ab	175.06d	177.88d
S_5	1.89e	0.74f	2.57a	169.26 e	171.89e
LSD (0.05)	0.06	0.01	0.07	2.72	2.77
Level of Significance	**	**	**	**	**
CV%	6.07	11.46	6.76	3.19	3.19

Means within a column are not significant at 5% level of probability. NS= Not Significant

Genotypes: Salinity levels:

V_1 = BARI Hybrid Tomato 4 S_0 = Control
V_2 =BARI Hybrid Tomato 5 S_1= 4 dS/m
V_3 =BARI Hybrid Tomato 8 S_2= 6 dS/m
                                              S_3= 8 dS/m
                                              S_4= 10 dS/m
                                              S_5= 12 dS/m

Table 4b.   Combined effect between tomato genotypes and salinity levels on the dry matter production and distribution

Treatment		Shoot dry weight plant^{-I} (g)	Root dry weight plant^{-I} (g)	Shoot: root ratio (g/g)	Fruit dry weight plant^{-I} (gm)	Total dry matter (TDM) plant^{-I} (g)
V_1	S_0	2.31	1.02	2.26	181.23	184.56
	S_1	2.07	0.92	2.27	177.14	178.41
	S_2	2.07	0.87	2.38	175.42	180.09
	S_3	1.93	0.82	2.36	173.24	175.99
	S_4	1.88	0.75	2.52	169.05	171.69
	S_5	1.77	0.68	2.59	162.68	165.14
V_2	S_0	2.41	1.11	2.17	195.14	198.66
	S_1	2.35	1.02	2.31	191.23	194.60
	S_2	2.16	0.89	2.41	182.85	185.90
	S_3	1.99	0.83	2.40	177.84	180.66
	S_4	1.92	0.78	2.50	173.69	176.39
	S_5	1.81	0.72	2.56	167.12	169.66
V_3	S_0	2.52	1.21	2.08	205.12	208.85
	S_1	2.32	1.15	2.01	196.14	199.62
	S_2	2.21	1.05	2.10	189.24	192.51
	S_3	2.31	0.98	2.36	186.32	189.61
	S_4	2.20	0.91	2.44	182.44	185.55
	S_5	2.08	0.82	2.57	177.98	180.88
LSD (0.05)		0.10	0.02	0.13	4.72	4.80
Level of Significance		NS	NS	NS	NS	NS
CV%		6.07	11.46	6.76	3.19	3.19

Means within a column are not significant at 5% level of probability. NS= Not significantly different at $p<0.05$

The combined effect (V x S) in respect of shoot: root ratio for the tomato genotypes was statistically non-significant (Table 4b). However, shoot: root ratio for the interaction varied from 2.01 to 2.59 where the wider ratio was recorded from V_1 x S_5 and the narrowest ratio from V_3 x S_1 but such variation was statistically non-significant.

4.3.3 Fruit dry matter weight plant^{-1}

Fruit dry matter weight also varied significantly due to mean effect of genotype (Table 4a). The highest root dry matter weight (189.54g plant^{-1}) was recorded in V_3, which was exactly similar for the variety V_1 and both of them were significantly higher over V_2 (181.31g). Such varietal character was also observed by Elahi, *et al.*2010, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

The dry matter weight of fruit decreased significantly with the increasing level of salinity (Table 4a). For control (S_0), the fruit dry matter weight was 193.83 g plant^{-1}, which decreased to 187.60 g plant^{-1} when plant was irrigated with S_1 (4 dS m^{-1}) thereafter it decreased significantly with the increasing level of salinity and fell down to 169.26 g plant^{-1} for S_5 (12 dS m^{-1}). These results can be justified with the findings of Shibli, *et al.* 2007, Shameem, *et al.*, 2012 and Shimul *et al.*, 2014.

However, the combined effect (V x C) was appeared to be non-significant for fruit dry matter weight as well. Nonetheless, it still varied from 162.68 to 205.12g plant^{-1} where the highest result was observed in V_3 x S_0 and the lowest in V_1 x S_5 but such wide variation as revealed was mainly for the mean effects and only a little for the combination and so it was statistically non-significant.

4.3.5. Total dry matter (TDM) plant^{-1}

The total dry matter (TDM) plant^{-1} also varied significantly due to mean effect of genotype (Table 4a). The highest TDM (192.84 g plant^{-1}) was recorded from V_3, which was significantly higher over V_2 and V_1. As per varieties potential, V_2 was intermediate with 184.31 g TDM plant^{-1} and V_1 at the least (175 g plant^{-1}) where they varied significantly. Such varietal character was also observed by Elahi *et al.*2010, Kibria *et al.*2015, Biswas *et al.*2015 under non- stressed situation.

Increasing salinity level resulted in lower total dry matter (TDM) production in tomato plants irrespective of genotypes (Table 4a). In case of salinity control, the TDM was 197.36 g plant^{-1}, which gradually and significantly decreased with the increase of salinity level. For the minimum salinity level S_1 (4 dS m^{-1}), the TDM was 190.88 g plant^{-1}, which reduced significantly to 171.89 g plant^{-1} for S_5 (12 dS m^{-1}). Similar kind of results were also reported by Shibli, *et al.,* 2007, Shameem, *et al.,* 2012 and Shimul *et al.,* 2014.

However, the total dry matter (TDM) did not vary significantly due to interaction (V x C) effect (Table 4b). Nonetheless, the TDM varied from 165.14 to 208.85 g plant^{-1} where the highest result was found with $V_3 \times S_0$ followed by $V_3 \times S_1$ and $V_2 \times S_0$ and the lowest was found in $V_1 \times S_5$. But this variation was mostly governed by salinity and variety as revealed from the result presented in Table 4b and so the combination appeared to be statistically non-significant.

4.4. Biochemical attributes of tomato genotype under different salinity levels

4.4.1 SPAD values of leaves

Soil Plant Analysis Development (SPAD) is the device for indicating the leaf chlorophyll and leaf N status of the plant without destructive sampling (Fallet *et al.,* 1992; Markwell., 1995). It is the measure of relative greenness of leaves which depends on chlorophyll and N contents in them. However, leaf SPAD values of tomato genotypes varied significantly regardless of salinity level (Table 5a). The highest SPAD value 47.26 mg g^{-1} was found in V_3, which was significantly higher over rest of the two varieties. The second highest SPAD was recorded from V_2, which was significantly higher over V_1. The lowest (36.37 mg g^{-1}) SPAD was thus found with V_1. The results are in conformity with the results. Such varietal character was also observed by Islam *et al.,* 2011, Ahmad *et al.,* 2012; Moniruzzaman *et al.*2013. under non- stressed situation.

Increasing levels of salinity resulted in low SPAD values in leaves regardless of variety (Table 5a). For salinity control treatment, leaf SPAD was 43.8, which was statistically similar to the low salinity level (S_1) but both of them were significantly higher over rest of the elevated levels of irrigation water salinity. The lowest SPAD (38.5 mg g^{-1}) in leaf was recorded in S_5 (12 dS m^{-1}). Low SPAD indicates low chlorophyll and N content in leaves. It was thus revealed that the total chlorophyll content in leaf decreased with increasing levels of salinity. Almost similar trend of results were reported by Anjum *et al*., 2011, Islam *et al.,* 2011 and Oztekin *et al*., 2011.

However, leaf SPAD value did not vary significantly due to genotype salinity interaction (Table 5b). Nonetheless, the highest SPAD (50.5) was found with V_3 x S_0, which was followed by V_3 x S_1 and the lowest (34.66) in V_1 x S_5. It is revealed from the Table 5b that the SPAD was mostly governed by the variety followed by salinity. Thus the combined effect appeared to be statistically non-significant.

4.4.2 Photosynthetic yield (Fv/Fm)

The ratio Fv/Fm means photosynthetic yield, the maximal photochemical efficiency of photo system II (PSII) photochemistry in the dark- adapted state where Fv indicates variable fluorescence and Fm is the maximal fluorescence intensity when all reaction centers (RCs) are closed (Anastasia *et al*., 2013). However, the highest photosynthetic yield 0.64 was observed in V_3, which was significantly higher over other two varieties. A bit lower Fv/Fm ratio (0.61) was found with V_2, which was of course significantly higher over V_1. The lowest photosynthetic yield was recorded in V_1, which was significantly lower than rest of the varieties. Such varietal character was also observed by Islam *et al*., 2011, Ahmad *et al*., 2012; Moniruzzaman *et al*.2013 under non- stressed situation.

Photosystem II is believed to be the most stress sensitive. The in *vivo* chlorophyll fluorescence technique is a powerful non-destructive and fast method to detect changes in the photosynthetic activity in leaves influenced by changes in the environment. Thus the ratio Fv/Fm has been shown to be reliable stress indicator. Salinity stress is one of the most detrimental abiotic stress factors that may affect the biochemical process in plant body. In these contexts, it was observed that Fv/Fm ratio decreased significantly with the increasing level of salinity (Table 5a). The highest fv/fm ratio was recorded in salinity control treatment (S_0), which was significantly higher over rest of the salinity levels. The lowest photosynthetic yield (0.49) was found with S_5 when the plant was forced to the highest level of salt stress. It was thus revealed that in each successive increase in salinity level, the photosynthetic yield decreased significantly. Almost similar trend of result was reported by Zhang *et al*., 2009, Rahimi and Biglarifard, 2011 and Azarmi, 2010.

A significant ($R^2 = 0.994**$) but negative linear relationship was observed between salinity levels of irrigation water with photosynthetic yield (Fig. 1). The regression equation implied that for each unit of electrical conductivity increase there is a possibility of loosing 0.024 unit photosynthetic yield and this phenomenon might be influenced by 99% cases for this study.
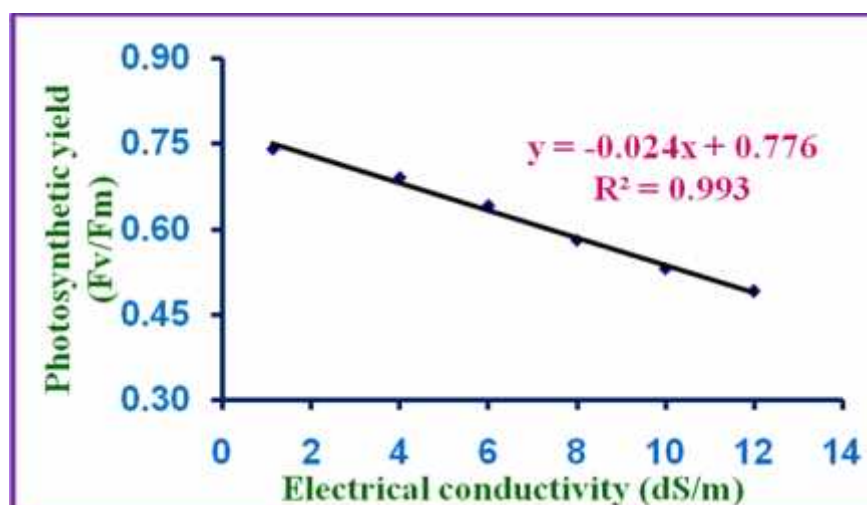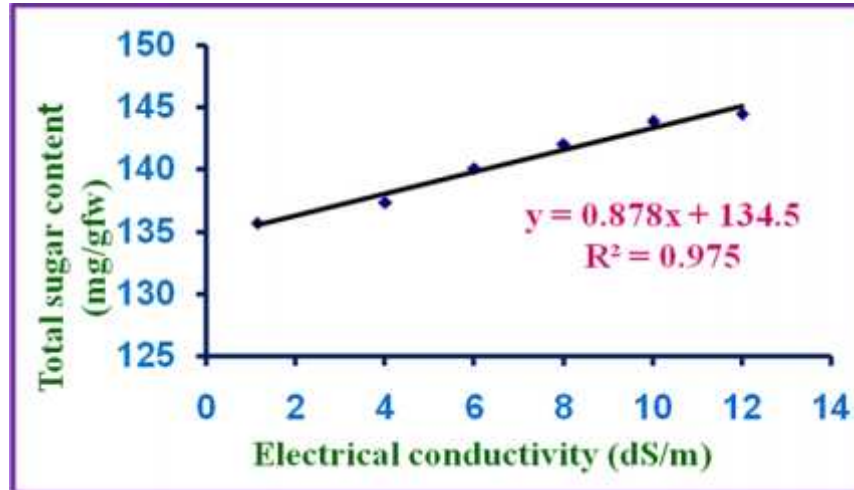

Fig. 1. Relationship between salinity levels in irrigation water with photosynthetic yield

However, photosynthetic yield (Fv/Fm) did not influence significantly due to combined effect (Table 5b). Even though Fv/Fm varied from 0.47 – 0.79 where the highest result was observed in $V_3 \times S_0$ followed by V_2 x S_0 and $V_3 \times S_1$ and the lowest in $V_1 \times S_5$. The variation was mostly due salinity followed by genotype and trivial for their combination. Therefore, salt stress appeared to be the major reason in controlling the photosynthetic yield.

4.4.3. Total sugar contents in leaves

Total sugar contents in leaves of tomato varied significantly due to mean effect of genotype (Table 5a). The highest total sugar content (146.95 mg/gfw) was recorded in V_3, which was significantly higher over other two varieties. The second highest total sugar content (139.62 mg/gfw) was found in V_2 followed by V_1 (135.12 mg/gfw) and they also differed significantly. Such varietal character was also observed by Islam *et al.*, 2011, Ahmad *et al.*, 2012; Moniruzzaman *et al.*2013 under non- stressed situation.

Fig.2. Relationship between salinity levels in irrigation water with total sugar contents in tomato leaves

Total sugar contents in leaves varied significantly due to mean effect of salinity regardless of genotype (Table 5a). The highest total sugar content (144.45 mg/gfw) was recorded in S_5 (12 dS/m), which was statistically similar with S4 and S3 but significantly higher over rest of the lower salinity levels. The lowest

total sugar content (135.69 mg/gfw) was found in salinity control treatment, which was at par with immediate higher level S_1 (4 dS/m) but significantly lower than rest of the levels. The total sugar contents in leaves increased significantly with increasing level of salinity. Thus a positive linear relationship (R^2 = 0.9759**) was found between electrical conductivity of irrigation water with total sugar content (Fig. 2). The above results are in conformity with the findings of Noreen *et al*., 2012, Islam *et al.,* 2011; Amoah *et al.,* 2011 and Silambarasan *et al*., 2014.

The combined (V x S) effect for total sugar contents in tomato leaves was however, statistically non-significant (Table 5b). In spite of this total sugar content varied from 128.82-151.12 mg/gfw, where the highest result was observed in $V_3 \times S_5$ followed by $V_3 \times S_4$ and $V_3 \times S_3$ and the lowest in $V_1 \times S_{0.}$ It is revealed that the reducing sugar content varied independently either for salinity level or for genotype and thus there was no significant interaction between them on the total sugar content.

4.4.4. Reducing sugar contents in leaves

Reducing sugar contents in leaves also varied significantly due to mean effect of genotype (Table 5a). In this case too, BARI Hybrid Tomato 8 (V_3) showed the highest (22.84 mg/gfw) reducing sugar, which was followed by V_2 (19.08 mg/gfw) and V_3 (16.93 mg/gfw) and they varied significantly from one another. Such varietal character was also observed by Islam *et al*., 2011, Ahmad *et al*., 2012; Moniruzzaman, *et al.* 2013 under non- stressed situation.

Irrigation water salinity resulted in higher reducing sugar content in tomato leaves (Table 5a). For the mean effect of salinity the reducing sugar content varied from 16.95 – 22.24 mg/gfw where the highest result was recorded in S5 (12 dS/m), which was followed by S_4 and gradually reduced with the decreasing level of salinity showing the lowest result for control (S_0). It is revealed from Fig.3 that reducing sugar content increased with

increasing level of salinity showing a positive linear relationship ($R^2 =$ 0.9968**). Islam *et al.,* 2011, Ahmad *et al.*, 2012 and Silambarasan *et al.*, 2014 also reported similar trend of result.

Table 5a. Biochemical attributes of tomato genotypes as influenced by different levels of salinity

Treatments	SPAD value	Photosynthetic yield (Fv/Fm)	Total sugar contents in leaves (mg/gfw)	Reducing sugar contents in leaves (mg/gfw)
Genotypes				
V_1	36.37c	0.57c	135.12c	16.93c
V_2	39.72b	0.61b	139.62b	19.08b
V_3	47.26a	0.64a	146.95a	22.84a
LSD (0.05)	0.762	0.01	1.11	0.51
Level of Significance	**	**	**	**
Salinity(dS/m)				
S_0	43.80a	0.74a	135.69 d	16.95e
S_1	42.80a	0.69b	137.32 cd	18.12de
S_2	41.60ab	0.64c	140.05 bc	19.25cd
S_3	40.30bc	0.58d	142.03 ab	20.05bc
S_4	39.73bc	0.53e	143.85 a	21.09ab
S_5	38.50c	0.49f	144.45 a	22.24a
LSD (0.05)	1.08	0.01	1.57	0.73
Level of Significance	**	**	**	**
CV%	5.60	4.70	2.37	7.94

Means within a column are not significant at 5% level of probability. NS= Not Significant

Genotypes:

V_1 = BARI Hybrid Tomato 4
V_2 =BARI Hybrid Tomato 5
V_3 =BARI Hybrid Tomato 8

Salinity levels:

S_0 = Control
S_1= 4 dS/m
S_2= 6 dS/m
S_3= 8 dS/m
S_4= 10 dS/m
S_5= 12 dS/m

Table 5b. Combined effects of tomato genotypes and salinity levels on biochemical attributes

Treatments		SPAD value	Photosynthetic yield (Fv/Fm)	Total sugar contents in leaves (mg/gfw)	Reducing Sugar contents in leaves (mg/gfw)
V_1	S_0	37.70	0.69	128.82	13.29
	S_1	37.40	0.60	129.52	14.59
	S_2	36.60	0.64	135.38	16.92
	S_3	36.16	0.55	137.36	17.82
	S_4	35.70	0.51	139.52	18.89
	S_5	34.66	0.47	140.12	20.07
V_2	S_0	43.50	0.75	136.12	17.29
	S_1	42.90	0.71	138.22	18.29
	S_2	39.60	0.63	138.38	18.85
	S_3	38.13	0.58	140.36	19.15
	S_4	37.80	0.53	142.52	20.29
	S_5	36.43	0.49	143.12	21.24
V_3	S_0	50.50	0.79	142.12	20.29
	S_1	48.90	0.73	144.22	21.49
	S_2	47.50	0.68	146.38	22.59
	S_3	46.60	0.61	148.36	23.19
	S_4	45.70	0.56	149.52	24.09
	S_5	44.40	0.51	151.12	25.41
LSD (0.05)		1.87	0.02	2.72	1.27
Level of Significance		NS	NS	NS	NS
CV%		5.60	4.70	2.37	7.94

Means within a column are not significant at 5% level of probability. NS= Not significantly different at p<0.05

Reducing sugar content (RCG) in tomato leaves did not differ significantly due to interaction (V x S) effect (Table 5b). Nevertheless, the highest RCG (25.41 mg/gfw) was recorded from the combination $V_3 \times S_5$, which was followed by $V_3 \times S_4$ and $V_3 \times S_3$ and the lowest from $V_1 \times S_0$. Results presented in Table 5b suggested that the RCG was mostly governed either by genotype or salinity where they acted independently and thus combined effect appeared to be statistically non-significant.
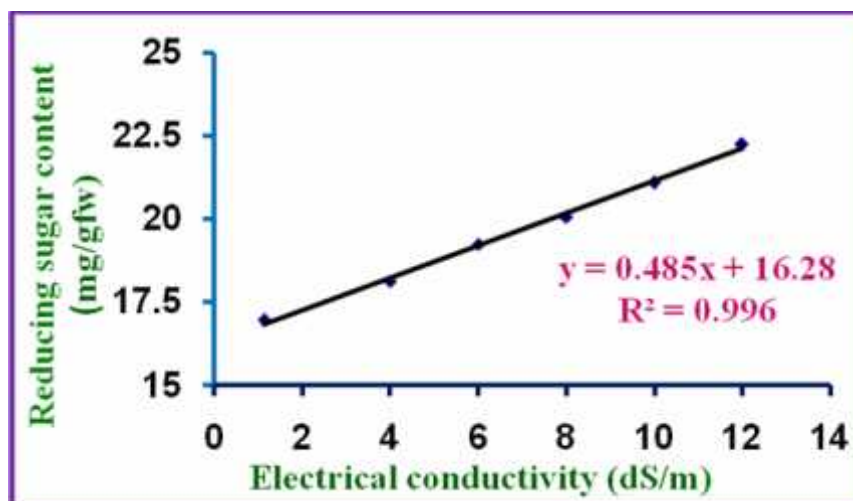
Fig.3. Relationship between salinity levels in irrigation water
with reducing sugar contents in tomato leaves

4.4.5. Photosynthetic rate (A)

Photosynthetic rate (A) of tomato leaves at flowering stage differed significantly due to mean effect of genotype (Table 6a). The highest photosynthetic rate (14.56 μ mol m^{-2}s^{-1}) was observed in V_3, which was significantly higher over other two varieties. The second highest photosynthetic rate (11.08 μ mol m^{-2}s^{-1}) was recorded in V_2, which was significantly higher over V_1 (10.02 μ mol m^{-2}s^{-1}). Such varietal character was also observed by Islam *et al*., 2011, Ahmad *et al*., 2012; Moniruzzaman *et al.*2013 under non-stressed situation.

Salt stress due to imposition of salinity at pre flowering stage brought significant variation in photosynthetic rate (A) of tomato leaves regardless of genotype (Table 6a). The highest photosynthetic rate (13.04 μ mol m^{-2}s^{-1}) was recoded in salinity control treatment (S_0), which was statistically identical with the lower salinity level up to (S_2: 6 dS/m) but significantly higher than upper level of salinity levels. Thus photosynthesis rate decreased with the increase of salinity level. Almost similar trend of result was obtained by Saibo *et al*. 2009, Islam *et al.,* 2011 and Chaves *et al*., 2009). A linear negative relationship (R^2 = 0.99**) was observed between electrical conductivity of irrigation water with photosynthetic rate (Fig.4). Regression equation implied that photosynthetic

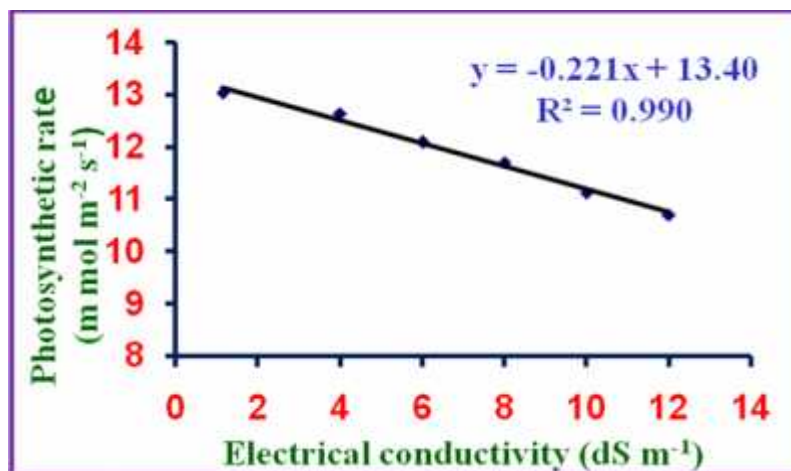rate may be reduced by 0.222 mol $m^{-2}s^{-1}$ for each unit increase in electrical conductivity.

Fig. 4. Relationship between salinity levels in irrigation water
with photosynthetic rate (A) in tomato leaves

4.4.6. Transpiration rate (E)

Transpiration rate (E) also varied significantly among the tested genotypes irrespective of salinity level (Table 6a). The highest transpiration rate (3.09 m mol $m^{-2}s^{-1}$) was recorded from V_3, which was followed by V_2 (2.92 m mol $m^{-2}s^{-1}$) and V_1 (2.88 m mol $m^{-2}s^{-1}$) all these varieties differed significantly from each other. Such varietal character was also observed by Islam *et al*., 2011, Ahmad *et al*., 2012; Moniruzzaman *et al*.2013 under non- stressed situation.

Result presented in Table 6a showed that transpiration rate of tomato leaves decreased significantly with the increase of salinity levels. The highest transpiration rate (3.57 m mol $m^{-2}s^{-1}$) was found in control (S_0), which was significantly higher over rest of the elevated salinity levels. There was gradual decrease in transpiration rate, which went down to 2.21 m mol $m^{-2}s^{-1}$ when the crop was irrigated with highly saline (EC = 12 dS m^{-1}) water. A significant (R^2 = 0.966) liner negative relationship was observed between electrical conductivity of irrigation water and transpiration rate (Fig.5).
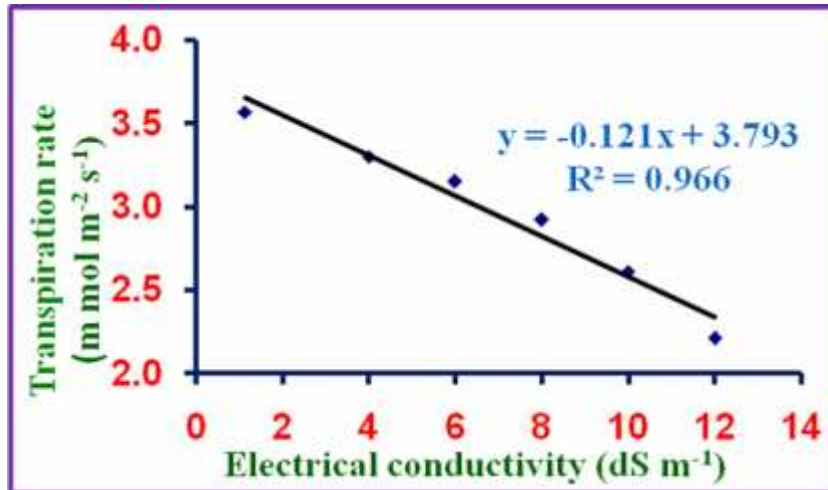
Fig.5. Relationship between salinity levels in irrigation water
with transpiration rate (E)

No significant interaction (V x S) effect was seen regarding transpiration rate of tomato leaves (Table 6 b). However, transpiration rate in this aspect varied from 2.19 - 3.70 m mol $m^{-2}s^{-1}$ where the highest rate was recorded in V_3 x S_0 followed by V_3 x S_1 and V_2 x S_0 and the lowest in V_1 x S_5 but such variation was mostly governed by the mean effect of salinity not actually for the interaction effect. Thus transpiration rate of tomato leaves regulated by salinity level and variety independently.

4.4.7. Stomatal conductance (gs)

Stomatal conductance (gs) of tomato leaves varied significantly due to the mean effect of genotype (Table 6a). The highest stomatal conductance (0.25 m mol m^{-2} s^{-1}) was found with V_3, which was significantly higher over V_2 and V_1. The later two genotypes gave statistically identical amount of (gs) for instance 0.21 and 0.25 m mol m^{-2} for V_2 and V_1, respectively. Such varietal character was also observed by Islam *et al*., 2011, Ahmad *et al*., 2012; Moniruzzaman *et al.*2013 under non- stressed situation.

Irrigation water salinity resulted in significantly lower stomatal conductance in tomato leaves regardless of variety (Table 6a). The highest stomatal conductance 0.31 m mol m^{-2} was recorded in control (S_0), which was

significantly higher over rest of the salinity. The gs reduced significantly to 0.25 for S_1 and then further reduced with subsequent higher doses and finally drop to 0.15 m mol m^{-2}s^{-1} for S_5, which was significantly lower than rest of the diluted salinity levels. Almost similar result was obtained by Zhang *et al*., 2009, Perveen *et al*., 2010, Moud and Maghsoudi, 2008. A linear negative relationship (R^2 = 0.977**) was observed between electrical conductivity of irrigation water with stomatal conductance. (Fig. 6).
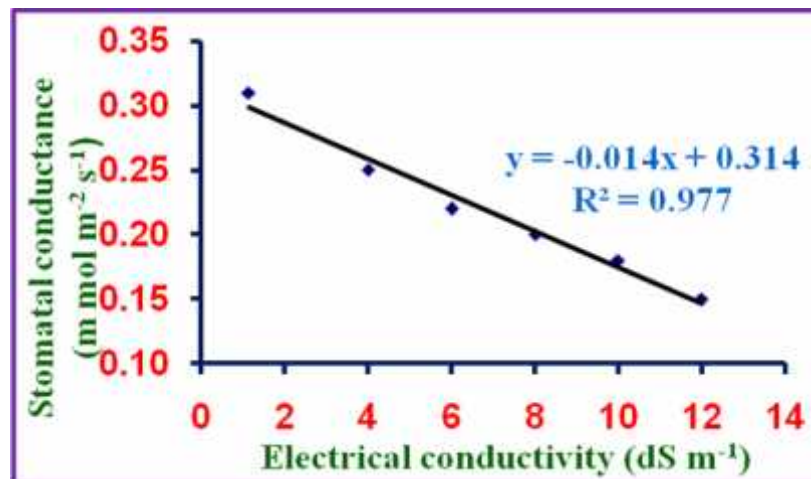
Fig. 6. Relationship between salinity level in irrigation water
with stomatal conductance (gs)

However, stomatal conductance of tomato leaves did not differ significantly due to interaction between genotype and salinity (V x S). Nonetheless, the highest gs (0.35 m mol m^{-2}s^{-1}) was recorded from V_3 x S_0 followed by V_2 x S_0 and V_3 x S_1 (Table 6b). The lowest gs (0.12 m mol m^{-2}s^{-1}) was obtained with V_1 x S_5, the immediate higher gs was derived from V_2 x S_5 and V_2 x S_5. It was thus revealed that stomatal conductance in tomato leaves was mostly regulated by salt concentration in irrigation water followed by the genotype and both the factors acted independently

Table 6a. Gas exchange parameters of tomato genotypes as influenced by different levels of salinity

Treatments	Gaseous exchange of tomato leaves			
	Photosynthesis rate (A) (μ mol m^{-2}s^{-1})	Transpiration rate (E) (m mol m^{-2}s^{-1})	Stomatal Conductance (gs) (m mol m^{-2} s^{-1})	Intercellular concentration of CO_2 (ci) (m mol m^{-2}s^{-1})
Genotypes				
V_1	10.02c	2.884b	0.19b	178.06c
V_2	11.08b	2.923b	0.21b	183.60b
V_3	14.56a	3.086a	0.25a	199.75a
LSD (0.05)	0.34	0.07	0.01	1.35
Level of Significance	**	*	**	**
Salinity(dS/m)				
S_0	13.04a	3.57a	0.31a	241.97a
S_1	12.64ab	3.30b	0.25b	221.56b
S_2	12.09abc	3.15b	0.22c	206.98c
S_3	11.71bc	2.92c	0.20d	183.73d
S_4	11.13cd	2.61d	0.18d	149.06e
S_5	10.71d	2.21e	0.15e	119.54f
LSD (0.05)	0.48	0.10	0.02	1.91
Level of Significance	**	**	**	**
CV%	8.70	7.43	9.83	7.94

Means within a column having similar letters are not significant at 5% (*) level of probability (p<0.05) by DMRT, NS= Not Significant

Genotypes:

V_1 = BARI Hybrid Tomato 4
V_2 =BARI Hybrid Tomato 5
V_3 =BARI Hybrid Tomato 8

Salinity levels:

S_0 = Control
S_1= 4 dS/m
S_2= 6 dS/m
S_3= 8 dS/m
S_4= 10 dS/m
S_5= 12 dS/m

Table 6b. Tomato genotype and salinity combined effect on the gas exchange parameters of leaves

Treatments		Gaseous exchange of tomato leaves			
		Photosynthesis rate (A) (μ mol m^{-2}s^{-1})	Transpiration rate (E) (m mol m^{-2}s^{-1})	Stomatal Conductance (gs) (m mol m^{-2}s^{-1})	Intercellular concentration of CO_2 (ci) (m mol m^{-2}s^{-1})
V_1	S_0	10.54	3.62	0.27	232.13
	S_1	10.35	3.32	0.23	208.21
	S_2	10.14	3.05	0.21	200.41
	S_3	9.94	2.83	0.19	175.79
	S_4	9.62	2.52	0.17	142.45
	S_5	9.29	2.19	0.12	109.39
V_2	S_0	12.85	3.40	0.31	242.45
	S_1	12.54	3.17	0.23	224.32
	S_2	10.86	3.15	0.21	204.42
	S_3	10.57	2.84	0.19	180.16
	S_4	9.95	2.53	0.18	139.38
	S_5	9.70	2.20	0.15	110.87
V_3	S_0	15.75	3.70	0.35	251.34
	S_1	15.44	3.42	0.29	232.14
	S_2	14.88	3.25	0.26	216.12
	S_3	14.34	3.11	0.23	195.23
	S_4	13.82	2.79	0.21	165.34
	S_5	13.14	2.24	0.18	138.35
LSD (0.05)		0.84	0.17	0.02	3.31
Level of Significance		NS	NS	NS	NS
CV%		8.70	7.43	9.83	2.17

Means within a column are not significant at 5% level of probability. NS= Not significantly different at $p < 0.05$

Under severe salt stress, photosynthesis of tomato was deeply reduced, so in this way stressed plants had a lower amount of fixed carbon to utilize for plant growth (Lovelli et al. 2012). Lower stomatal conductance and photosynthesis observed in salt stressed tomato plants explain the lower leaf growth and consequently the smaller accumulation of dry matter (Lovelli *et al.* 2012. One consequence of reduced photosynthesis is the overall plant growth reduction, but different parts of the tomato plant grow in different way.

4.4.8. Intercellular CO_2 concentration (ci)

There was a significant variation in intercellular CO_2 concentration (ci) in tomato leaves among the tested genotypes (Table 6a). The highest ci was recorded from BARI Hybrid Tomato 8 (V_3), which was followed by V_2 (183.60 m mol m^{-2}s^{-1}) and V_1(178.06 m mol m^{-2}s^{-1}) and they differed from one another significantly. More intercellular CO_2 concentration implies more possibility for the formation of carbohydrate if other determinants remain alike. Such varietal character was also observed by Islam *et al*., 2011, Moniruzzaman *et al.*2013 under non- stressed situation.

Intercellular CO_2 concentration in tomato leaves decreased significantly due to interference of irrigation water salinity irrespective of variety (Table 6a). In case of salinity control treatment (S_0), the Ci was the highest (241.97 m mol m^{-2}s^{-1}), which reduced gradually with the increase of salinity level and dropped down to 119.54 m mol m^{-2}s^{-1} for S_5 (12 dS m^{-1}). In such declining trend each treatment differed significantly from one another. The results are in conformity with the findings of Zhang *et al*., 2009b, Perveen *et al*., 2010 and Moud and Maghsoudi, 2008). They pointed out that sub-stomatal CO_2 concentration decreased with increasing level of salinity. Intercellular CO_2 concentration showed significant negative linear relationship (R^2 = 0.963**) with electrical conductivity of the irrigation water (Fig. 7). For each unit increase in electrical conductivity there might be decrease in intercellular CO_2 concentration by 11.36 m mol m^{-2}s^{-1}.

No significant combination effect (V x S) was observed regarding intercellular CO_2 concentration in tomato leaves, which means that genotype and salinity acted independently on this issue as well (Table 6b). Nevertheless, the highest ci (251.34 m mol m^{-2}s^{-1}) was recorded from V_3 x S_0, which was followed by V_2 x S_0, V_3 x S_1 and V_1 x S_0 and the lowest (109.39 m mol m^{-2}s^{-1}) in V_1 x S_5 but such variations as revealed was mostly due to salinity and variety not remarkably for their interaction. The adverse effect of saline water irrigation on

total chlorophyll content in tomato leaves due to the stomatal closure resulting in reduction of stomatal conductance, transpiration rate, intercellular CO_2 oncentration and net photosynthesis (Loukehaich. *et al*., 2009).
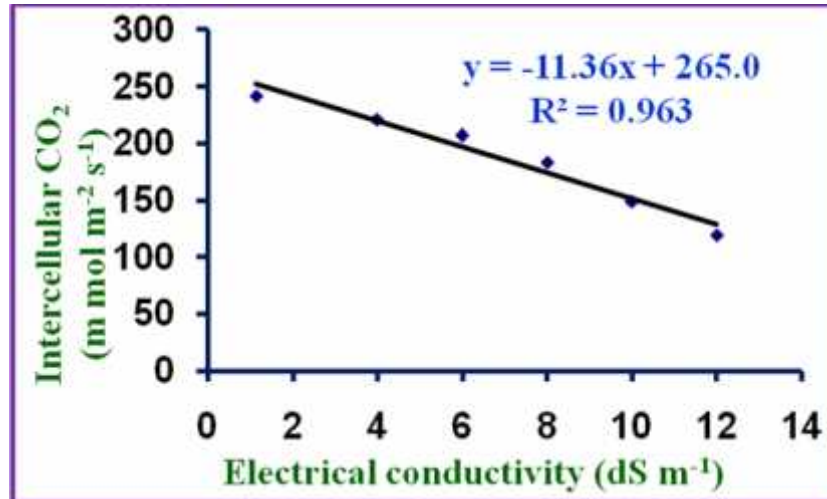

Fig. 7. Relationship between salinity level in irrigation water
with intercellular CO_2 concentration (ci)

Furthermore, increased salt content also interferes with protein synthesis and influences the structural component of chlorophyll (Jaleel *et al.*, 2008). From another point of view, the lowest photosynthetic ability under salt stress conditions was due to inhibition of chlorophyll synthesis (Cuartero *et al.*, 2006) and magnesium (Ahmed, 2010).

4.5. Nutrient concentration in tomato shoots as affected by salinity application

4.5.1. Basic cations (Na, K, Ca and Mg)

Basic cation (Na, K, Ca and Mg) concentration in tomato shoot varied significantly due to the mean effect of genotype (Table 7a). Regardless of salinity level, the highest concentration of Na (0.90%) was found in V_3, which was significantly higher over V_2 and V_1. The later two varieties showed almost similar concentration (0.84-0.86%) of Na in their shoot. Potassium concentration varied from 2.88-3.35%, where the highest result was observed in V_3, which was followed by V_2 (3.05%) and the lowest in V_1 while they

varied significantly. Calcium concentration was the highest for V_2 (4.16%), which was statistically similar with V_3 (4.00%) and they were significantly higher over V_1 (3.72%). However, V1 showed the highest Mg content (0.35%) followed by V_3 (0.30%) and the least in V2 (0.27%) having significant variation for the mean effect. Essential basic cations like K and Ca were in adequate amount while Mg was in little deficient state as per Bennett, 1996. Potassium: sodium ratio for V_1, V_2 and V_3 was 3.43, 3.55 and 3.72, respectively, which indicates their adaptability under salt stressed situation to a considerable extent, where the performance of V_3 was slightly better over other two varieties. Such varietal character was also observed by Elahi, *et al.*2010, Siddiky, *et al.*2012, Kibria *et al.*2015 under non- stressed situation.

Sodium and calcium concentration increased while potassium and magnesium concentration decreased significantly with the increase in salinity level in irrigation water (Table 7a). For salinity control (S_0), Na content in tomato shoot was only 0.28%, which increased significantly to 0.48% for the minimum salinity level, S1 (4 dS m^{-1}). Thereafter Na concentration raised gradually and got the maximum value (1.48%) for S5 (12 dS m-1), which was significantly higher over rest of the salinity levels. For Ca, the highest concentration (6.13%) was also observed with S_5, which was followed by S_4 and then gradually and significantly decreased with decreasing level of salinity. The lowest Ca content was recorded in S_0, which was significantly lower than rest of the levels. In contrary, K and Mg content was significantly higher (3.75 and 0.40%, respectively) for S_0, which gradually decreased with the increasing level of salinity. The lowest concentration (2.60 and 0.22% for K and Mg, respectively) was observed in S_5 regardless of genotypes. Similar trend of results were reported by Shabani *et al*., 2012, Maggio *et al*., 2007 and Chookhampaeng *et al*., 2007.

Table 7a.   Nutrient concentrations in tomato shoot under different salinity levels

Treatment	Nutrient concentration in tomato shoot							
	Na	N	P	K	Ca	Mg	S	K: Na ratio
Genotypes	(%)							
V_1	0.84b	3.15b	0.35c	2.88c	3.72b	0.35a	0.26c	3.43
V_2	0.86b	3.14b	0.37b	3.05b	4.16a	0.30b	0.27b	3.55
V_3	0.90a	3.39a	0.41a	3.35a	4.00a	0.27c	0.32a	3.72
LSD (0.05)	0.01	0.04	4.35	0.06	0.12	9.48	4.83	0.53
Level of Significance	**	**	**	**	**	**	**	NS
Salinity(dS/m)								
S_0	0.28f	3.81a	0.44b	3.75a	1.60f	0.40a	0.37a	13.39a
S_1	0.48e	3.73ab	0.47a	3.48b	2.73e	0.36b	0.33b	7.25b
S_2	0.78d	3.62b	0.39c	3.21c	3.53d	0.33c	0.30c	4.12c
S_3	1.00c	2.87c	0.36d	2.88d	4.62c	0.29d	0.27d	2.88d
S_4	1.16b	2.72d	0.32e	2.67e	5.15b	0.25e	0.23e	2.30de
S_5	1.48a	2.62d	0.29f	2.60e	6.13a	0.22f	0.21f	1.76e
LSD (0.05)	0.02	0.06	6.15	0.09	0.18	0.01	6.84	0.76
Level of Significance	**	**	**	**	**	**	**	**
CV%	4.75	4.45	3.44	6.31	9.66	4.48	2.48	20.64

Means within a column having similar letter (s) are not significant at 5% level of probability.

Genotypes:

V_1 = BARI Hybrid Tomato 4
V_2 = BARI Hybrid Tomato 5
V_3 = BARI Hybrid Tomato 8

Salinity levels:

S_0 = Control
S_1 = 4 dS/m
S_2 = 6 dS/m
S_3 = 8 dS/m
S_4 = 10 dS/m
S_5 = 12 dS/m

Table7b. Nutrient concentrations in tomato shoot as influenced by combination of genotype and salinity

Treatments		Nutrient concentrations in tomato shoot (%)							K: Na ratio
		Na	**N**	**P**	**K**	**Ca**	**Mg**	**S**	
V_1	S_0	0.25	3.71	0.26	3.55	1.41	0.36	0.35	14.20
	S_1	0.45	3.62	0.29	3.28	2.33	0.32	0.32	7.29
	S_2	0.76	3.52	0.34	3.03	3.21	0.30	0.28	3.99
	S_3	0.96	2.80	0.37	2.69	4.26	0.26	0.24	2.80
	S_4	1.16	2.68	0.42	2.45	5.01	0.23	0.21	2.11
	S_5	1.46	2.59	0.45	2.33	6.11	0.20	0.19	1.60
V_2	S_0	0.28	3.81	0.29	3.76	1.89	0.410	0.36	13.43
	S_1	0.48	3.76	0.32	3.45	3.01	0.36	0.32	7.19
	S_2	0.77	3.59	0.35	3.12	3.86	0.31	0.28	4.05
	S_3	0.97	2.65	0.38	2.82	4.86	0.27	0.25	2.91
	S_4	1.17	2.55	0.43	2.65	5.21	0.24	0.22	2.26
	S_5	1.47	2.47	0.46	2.54	6.15	0.21	0.20	1.73
V_3	S_0	0.31	3.91	0.32	3.95	1.51	0.45	0.41	12.74
	S_1	0.51	3.81	0.35	3.71	2.85	0.42	0.36	7.27
	S_2	0.81	3.75	0.39	3.48	3.52	0.38	0.33	4.30
	S_3	1.08	3.15	0.42	3.15	4.75	0.34	0.31	2.92
	S_4	1.15	2.95	0.47	2.92	5.25	0.29	0.27	2.54
	S_5	1.51	2.81	0.51	2.94	6.15	0.26	0.24	1.95
LSD (0.05)		0.03	0.11	3.44	0.15	0.01	0.02	0.02	1.42
Level of Significance		NS	NS	NS	NS	NS	NS	NS	NS
CV%		6.65	4.75	5.45	3.44	5.76	4.48	2.48	20.64

Means within a column are not significant at 5% level of probability. NS= Not significantly different at p<0.05

Again, potassium: sodium ratio (K: N) also varied significantly due to the mean effect of salinity (Table 7a). The highest K: N ratio (13.4) was found with S_0, which was highly significantly greater over rest of the treatments. The said ratio gradually narrowed down with the increasing level of salinity and reached at the bottom (1.76) for S_5, which was significantly lower than all other salinity treatments. Orman *et al.*, 2012, Abu-Khadejeh *et al.*, 2012, Monireh *et al.*, 2013, Amjad *et al.*, 2014 also reported almost similar K:N ratio in tomato shoot.

4.5.2 Major nutrients

Concentration of major nutrients like N, P and S in tomato shoot varies significantly due to mean effect of genotypes (Table 7a), where V_3 showed the higher concentration (3.39, 0.41 and 0.32% N, P and S respectively) followed by V_1 and V_2. Nitrogen concentration in V_1 and V_2 was similar (3.14~3.15%), whereas P and S concentration was significantly higher in V_2 (0.37 and 0.27%) than V_1 (0.35 and 0.26%, respectively). As per Bennett, 1996 such concentration was within the sufficiency level. Such varietal character was also observed by Elahi *et al.*2010; Bybordi *et al.*2010; Siddiky M.A *et al.*2012; Kibria *et al.*2015 under non- stressed situation.

The concentration of N, P and S did not alter significantly due to interaction (V x S) effect (Table 7a). Nonetheless, N content varied from 2.47 to 3.91% where the highest result was observed in $V_3 \times S_0$ and the lowest in V_2 x S_5. Phosphorous concentration was highest (0.51%) for $V_3 \times S_1$ and the lowest (0.26%) in V_1 x S_5. Similarly, $V_3 \times S_0$ combination showed the highest (0.41%) S concentration while it was lowest for V_2 x S_5. But all these variations might have been governed either due to the mean effect of genotype or salinity level individually and very little for their interaction.

4.6.   Nutrient concentration in tomato roots as affected by salinity application

4.6.1. Basic cations (Na, K, Ca and Mg)

Basic cations like Na, K, Ca and Mg concentration in tomato root also varied significantly due to mean effect of genotype (Table 8a). Such concentrations in root showed almost similar trend with shoot although former yielded lower concentrations than the later regardless of nutrients. Sodium, potassium and calcium concentrations were found significantly higher for V_3, while Mg content was higher in V_2. Among the tested varieties Na, K, Ca and Mg concentrations varied from 0.59-0.65, 3.03-3.19, 1.69-2.10 and 0.31-0.38% where except Mg, the highest concentration was found in V_3 followed by V_2

and the lowest in V_1. The variation between V_1 and V_2 was non significant for Na and K but significant for Ca and Mg. However, K: N ratio varied from 4.91-5.14 but such variation was statistically non-significant. Such varietal character was also observed by Elahi *et al.*2010, Siddiky M.A E *et al.*2012, Kibria *et al.*2015 under non- stressed situation.

Sodium concentration in root for salinity control treatment (S_0) was only 0.14%, which increased significantly with the increasing level of salinity and reached at the peak (1.09%) for S_5 (12 ds m^{-1}). The higher concentration of Na in plant root might have affected K uptake which could be clearly understood when K concentration of root is considered. For instance, in absence of salt water application, K concentration in tomato root was 3.41% which decreased significantly with the increase of salinity and fell down to 2.87% for S_5. Similarly, Ca concentration was also lowered down due to salt water application. Magnesium concentration was also decreased appreciably. Regarding K:N ratio, the highest result (24.35) was obviously obtained from control (S_0), which was significantly higher over rest of the salinity treatments. Such ratio drastically reduced due to application of saline water for irrigation. For S_1, the K:N ratio was found to be 10.61, which further reduced with increasing level of salinity and fell down to 2.63 for S5 keeping significant difference with all other treatments except S_4. Application of sodium salt might have reduced K: N ratio irrespective of genotype. Quintero *et al.*, 2007; Abu-Khadejeh *et al.*, 2012, Monireh *et al.*, 2013, Amjad *et al.*, 2014 also reported almost similar K:N ratio in tomato root.

The V x S combination on the basic cation concentrations in tomato root was of course statistically non-significant (Table 8a). Although Na, K, Ca and Mg concentrations varied widely among different treatment combinations but such variations as revealed was mostly governed by the salinity levels and a little for the variety and thus the interaction effect was statistically non-significant. Again, K: Na ratio varied from 1.96 to 25.46 where the highest result was

found with V_1 x S_0 followed by V_3 x S_0 and V_2 x S_0 but the lowest in V_3 x S_5 and it was clearly observed that wider variations were for the salinity control and with the increase of salt concentration, the ratio gradually narrowed down; hence, combined effect in this context was non-significant.

Table 8a. Nutrient concentrations in tomato root under different salinity levels

Treatment	Nutrient concentration in tomato root (%)							K: Na ratio
	Na	N	P	K	Ca	Mg	S	
Genotypes								
V_1	0.59b	2.17b	0.23c	3.03b	1.69c	0.31c	0.16c	5.14
V_2	0.61b	2.21b	0.25b	3.08b	1.85b	0.38a	0.18b	5.05
V_3	0.65a	2.41a	0.29a	3.19a	2.10a	0.33b	0.25a	4.91
LSD (0.05)	0.01	0.04	0.09	0.03	0.05	5.36	0.01	0.61
Level of Significance	**	**	**	**	**	**	**	NS
Salinity(dS/m)								
S_0	0.14f	2.81a	0.36a	3.41a	2.22a	0.44a	0.25a	24.35a
S_1	0.31e	2.64b	0.33b	3.29b	2.10ab	0.40ab	0.23b	10.61b
S_2	0.51d	2.45c	0.24d	3.15c	1.98b	0.36c	0.21c	6.18c
S_3	0.75c	2.17d	0.27c	3.01d	1.74c	0.31d	0.19d	4.01d
S_4	0.93b	1.93e	0.20e	2.88e	1.65c	0.28e	0.17e	3.10de
S_5	1.09a	1.60f	0.14f	2.87e	1.59c	0.24f	0.15e	2.63e
LSD (0.05)	0.02	0.06	0.01	0.05	0.07	0.01	0.01	0.94
Level of Significance	**	**	**	**	**	**	**	**
CV%	6.65	5.88	9.34	3.55	8.91	5.65	7.52	23.19

Means within a column having similar letter (s) are not significant at 5% level of probability. NS= Not Significant

Genotypes:

V_1 = BARI Hybrid Tomato 4
V_2 = BARI Hybrid Tomato 5
V_3 = BARI Hybrid Tomato 8

Salinity levels:

S_0 = Control
S_1 = 4 dS/m
S_2 = 6 dS/m
S_3 = 8 dS/m
S_4 = 10 dS/m
S_5 = 12 dS/m

Table 8b. Nutrient concentrations in tomato shoot as influenced by genotype and salinity interaction effect

Treatments		Nutrient concentrations in tomato root (%)							K: Na ratio
		Na	N	P	K	Ca	Mg	S	
V_1	S_0	0.09	2.71	0.11	3.31	2.06	0.42	0.21	25.46
	S_1	0.28	2.52	0.15	3.22	1.91	0.36	0.18	11.50
	S_2	0.49	2.38	0.19	3.09	1.83	0.32	0.17	6.31
	S_3	0.73	2.06	0.26	2.95	1.53	0.28	0.15	4.04
	S_4	0.89	1.85	0.30	2.85	1.42	0.26	0.13	3.20
	S_5	1.10	1.52	0.34	2.79	1.38	0.22	0.12	2.54
V_2	S_0	0.12	2.81	0.15	3.41	2.25	0.47	0.25	21.31
	S_1	0.31	2.66	0.21	3.25	2.16	0.41	0.23	10.48
	S_2	0.50	2.42	0.26	3.07	1.97	0.34	0.19	6.14
	S_3	0.74	2.17	0.24	2.95	1.65	0.29	0.17	3.99
	S_4	0.90	1.90	0.33	2.83	1.57	0.27	0.15	3.14
	S_5	1.11	1.33	0.36	2.97	1.53	0.23	0.13	2.68
V_3	S_0	0.15	2.91	0.18	3.51	2.35	0.52	0.31	25.07
	S_1	0.35	2.74	0.24	3.42	2.25	0.45	0.28	9.77
	S_2	0.55	2.55	0.29	3.28	2.15	0.41	0.26	5.96
	S_3	0.78	2.28	0.32	3.15	2.05	0.36	0.24	4.04
	S_4	1.03	2.05	0.36	2.95	1.96	0.31	0.22	2.86
	S_5	1.15	1.96	0.39	2.84	1.87	0.28	0.21	2.47
LSD (0.05)		0.03	0.10	0.02	0.09	0.09	0.01	0.03	1.92
Level of Significance		NS	NS	NS	NS	NS	NS	NS	NS
CV%		6.65	5.88	9.34	3.55	8.91	5.65	7.52	23.19

Means within a column having similar letter (s) are not significant at 5% level of probability. NS= Not significantly different at $p<0.05$

4.6.2 Major nutrients (N, P and S)

Nitrogen, phosphorus and sulphur concentrations in tomato root were significantly higher in V_3 followed by V_2 and the variation between V_1 and V_2 was statistically non-significant (Table 8a). The said nutrient concentrations in root were remarkably lower than the shoot. Such varietal character was also observed by Elahi *et al.*2010, Siddiky M.A E *et al.*2012, Kibria *et al.*2015 under non- stressed situation.

Different salinity levels also affected N, P and S concentrations in tomato root (Table 8a). For control (S_0), N, P and S concentrations were 2.81, 0.36 and 0.25%, respectively, which reduced significantly due to application of saline water for irrigation at pre flowering stage. The concentrations fell down to 1.60, 0.14 and 0.15% for N, P and K, respectively due to S_5 (12 dS m^{-1}).

The combined (V x S) effect for N, P and S concentrations in root were statistically non-significant like shoot (Table 8b). Even though wider variations among different treatment combinations were noticed but those were might be due to caused by salinity, not actually for the combination between genotype and salinity.

The combined (V x S) effect for basic cation concentrations in tomato shoot appeared to be statistically non-significant (Table 7b). Potassium: sodium ratios for various treatment combinations were also appeared to be statistically non-significant. This result suggest that element content in tomato shoot was mostly governed either by the single effect of salinity or variety and very trivial for their interaction. Thus neither of the variety showed significant attraction to any of the assigned salinity level rather they acted independently even if for the basic cation concentration in shoot is concerned.

4.7 Trend of nutrient content in root and shoot of tomato plant in relation to sodium content

4.7.1 Nitrogen

Nitrogen content decreased with the increase of sodium content in both shoot and root of tomato plant grown under salt stressed condition in pot (Fig. 8). Nitrogen content in shoot was almost similar when sodium content was < 0.8% thereafter it declined sharply up to 1% Na and maintained similar level. Nitrogen content in root reduced gradually with the increase of Na content. In general, nitrogen content in root was far lower than the shoot.
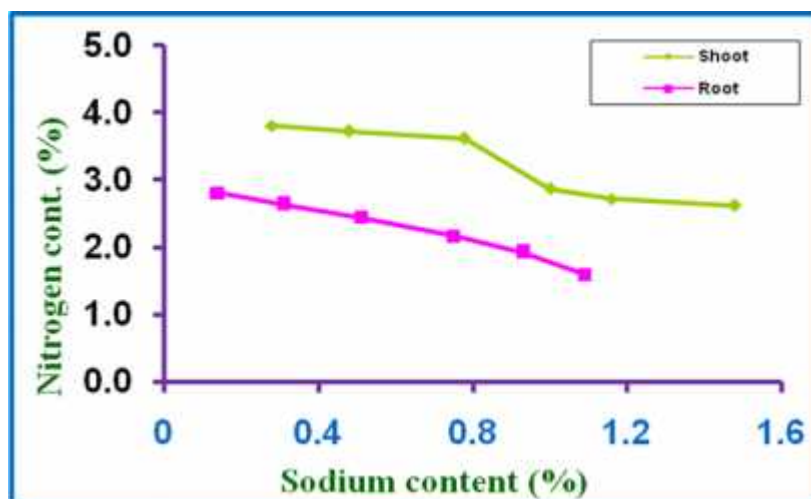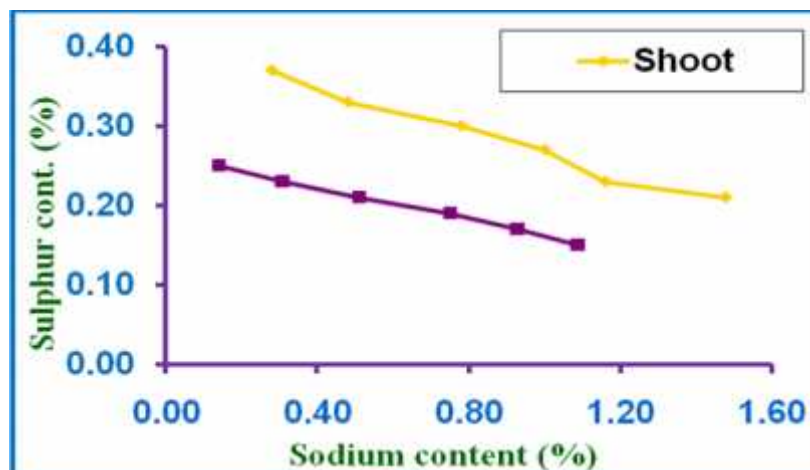
Fig.8. Trend of sodium and nitrogen content in shoot and root of
tomato plant grown under salt stressed condition in pot

4.7.2 Phosphorus

Initially, phosphorus content in shoot increased when sodium content was
about 0.5% and then declined with gradual sloppy trend (Fig.9). In case of
root, P content declined with steeper trend up to about 0.5% Na content then
increased a bit with further declining trend. Phosphorus content in root was
however lower than the shoot.
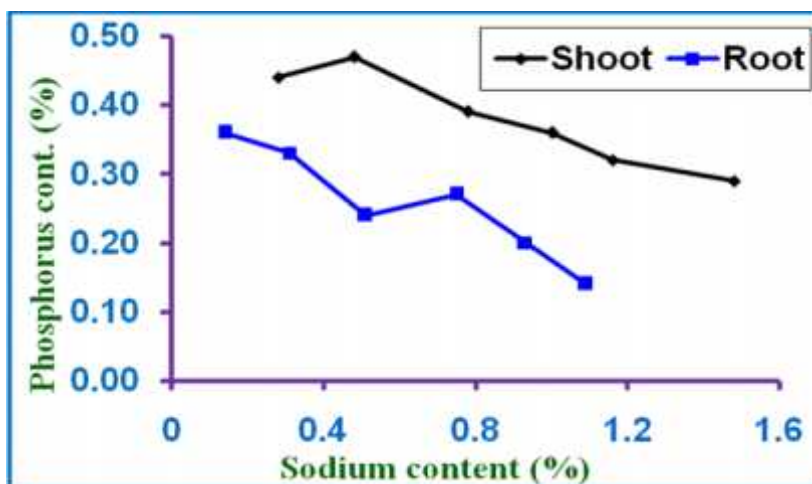
Fig.9. Trend of sodium and phosphorus content in shoot and root
of tomato plant grown under salt stressed condition in pot

4.7.3 Sulphur

Sulphur content in both shoot and root of tomato plant decreased gradually with the increase in Na content (Fig. 10). This result revealed that Na might have played antagonistic role on S uptake.
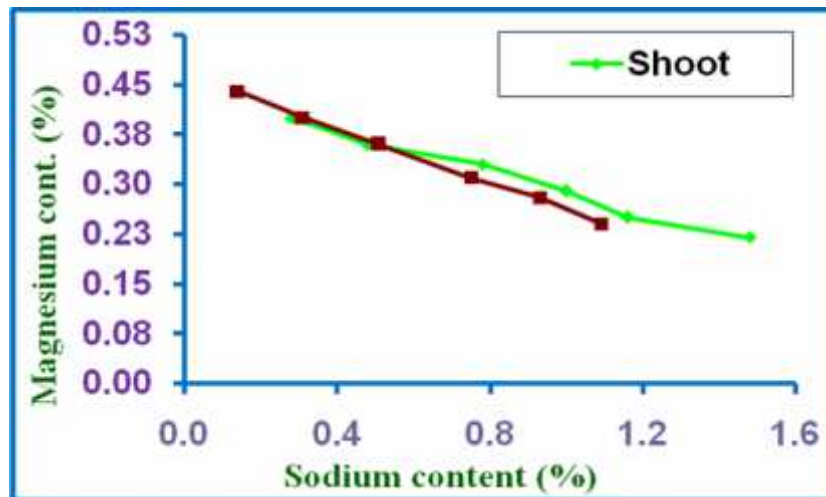

Fig.10. Trend of sodium and sulphur content in shoot and root of
tomato plant grown under salt stressed condition in pot

4.7.4 Potassium

Potassium content in both shoot and root of tomato plant decreased when Na content increased (Fig.11). Initially, the content in shoot was appreciably higher than the root but such difference gradually narrowed down with the increase of Na content. These findings implied that with the prevalence of Na^+ at the rhizospher the absorption of Na^+ in root increased which might have hindered K absorption and ultimately K uptake was restricted.
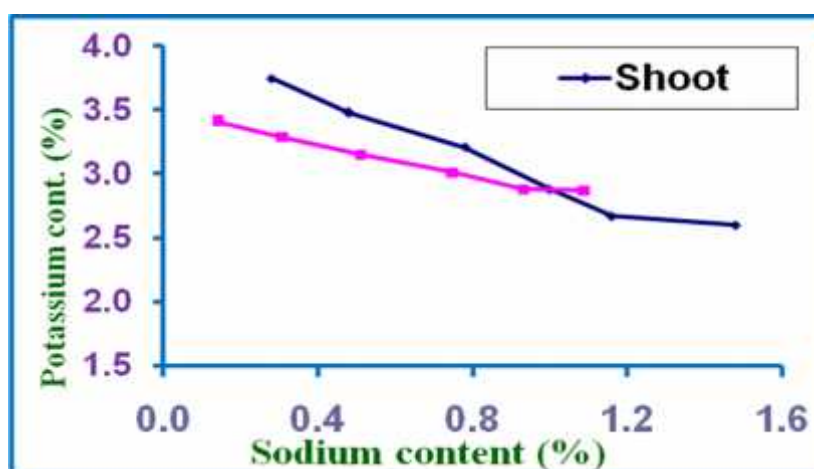
Fig.11. Trend of sodium and potassium content in shoot and root
of tomato plant grown under salt stressed condition in pot

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4.7.5 Calcium

Conversely, Ca absorption showed sharper increasing trend in tomato shoot with the increase of Na content (Fig. 12). Initially, Ca content in root was appreciably higher but it decreased smother decreasing trend with the increase of Na absorption. Prevalence of Na^+ accentuated Ca^{2+} absorption, which rapidly moved to the shoot diluting root Ca concentration. As such, Na showed synergistic effect with Ca absorption.
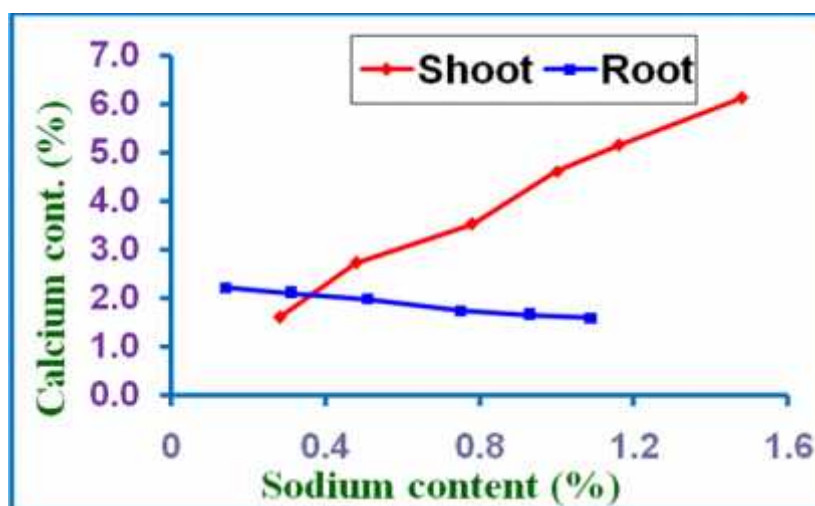
Fig. 12. Trend of sodium and calcium content in shoot and root of
tomato plant grown under salt stressed condition in pot

4.7.6 Magnesium

Absorption of Mg showed decreasing trend with the increase of Na content in both shoot and root of tomato plant (Fig. 13).Incase of shoot, the declining trend was somewhat undulating while for root the trend was almost straight in nature. Sodium and magnesium absorption mode in plant system was however found to be antagonistic.

Fig.13. Trend of sodium and magnesium content in shoot and root
of tomato plant grown under salt stressed condition in pot

4.8. Relationship between irrigation water salinity with nutrient content in tomato shoot and root
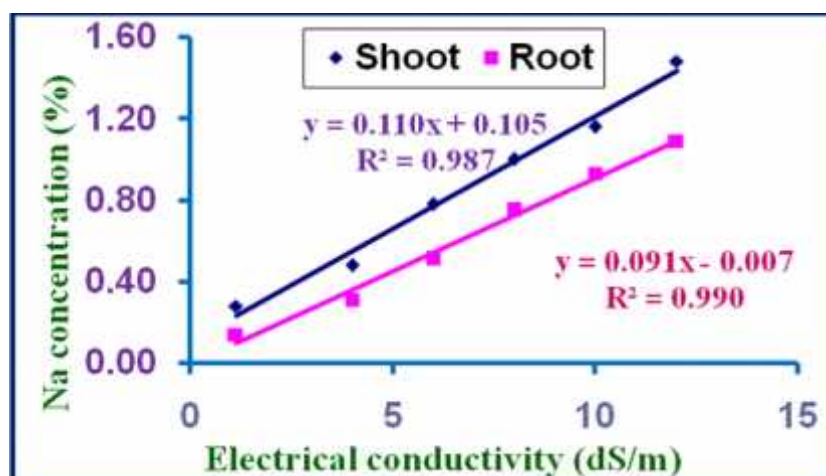
4.8.1 Sodium

Positive linear relationship was observed between electrical conductivity of the irrigation water with sodium concentration in shoot and root of tomato plant (Fig. 14).   This result suggests that sodium concentration in plant tissue increased with the increase of electrical conductivity of the irrigation water. Such association was stronger in root (R^2 = 0. 9877) than the shoot (R^2 = 0.9906) but in both cases the relationship was highly significant.

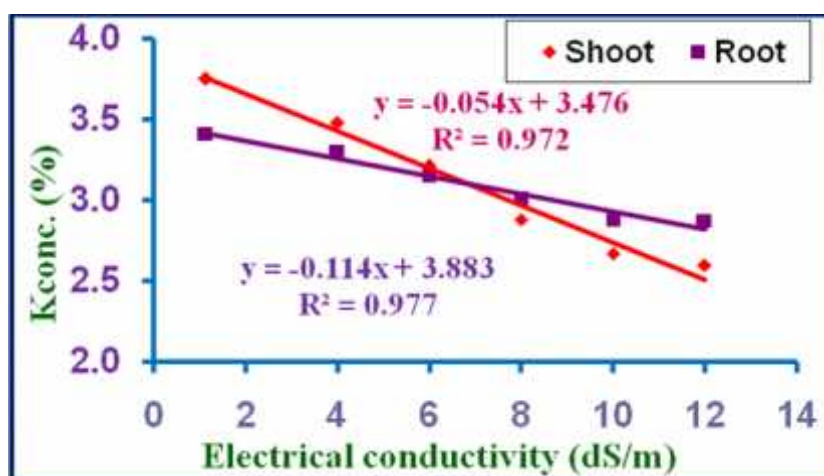Fig.14. Relationship between electrical conductivity of the irrigation water
and sodium concentration in shoot and root of tomato plant

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4.8.2 Potassium

Conversely, potassium showed negative linear relationship with electrical conductivity for both shoot and root of tomato plant (Fig. 15). The relationship was almost equally stronger but highly significant for both shoot and root. Due to application of saline water once at pre flowering stage, which is very likely to happen in the coastal saline soil the potassium absorption may be reduced by 5.5 and 11.5% for shoot and root of tomato plant, respectively. This trend of result may likely to happen for > 97% cases due to such salinity stress.

Fig.15. Relationship between electrical conductivity of the irrigation water and potassium concentrations in shoot and root of tomato plant

4.8.3 Calcium

Calcium concentration in shoot showed linear positive relationship (R^2 = 0.996) with electrical conductivity of irrigation water (Fig.16). Such relationship indicates that Ca concentration in shoot may be increased by 0.42% for each unit increase of irrigation water salinity. In contrary, a linear negative relationship was observed between irrigation water salinity with root Ca content indicating 6.3% decline in Ca absorption.
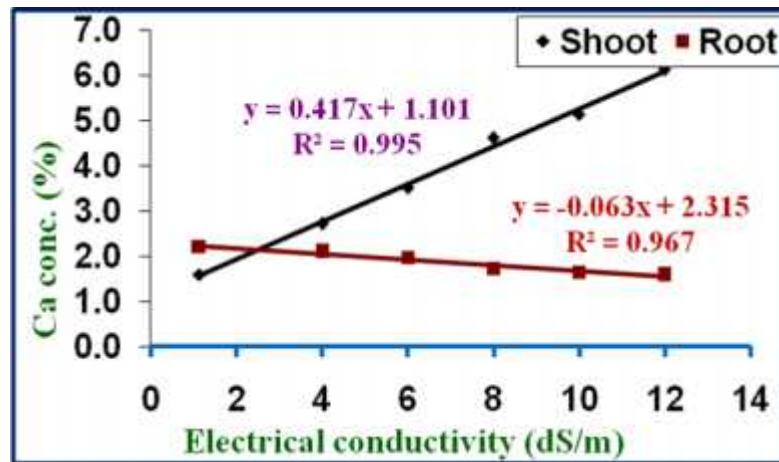
Fig.16. Relationship between electrical conductivity of the irrigation water
and calcium concentration in shoot and root of tomato plant

4.8.4 Magnesium

Saline water also showed significant linear negative relationship with Mg
content in both shoot and root of tomato plant (Fig. 17). Such relationship was
equally stronger for both shoot and root. The rate of reduction in Mg content
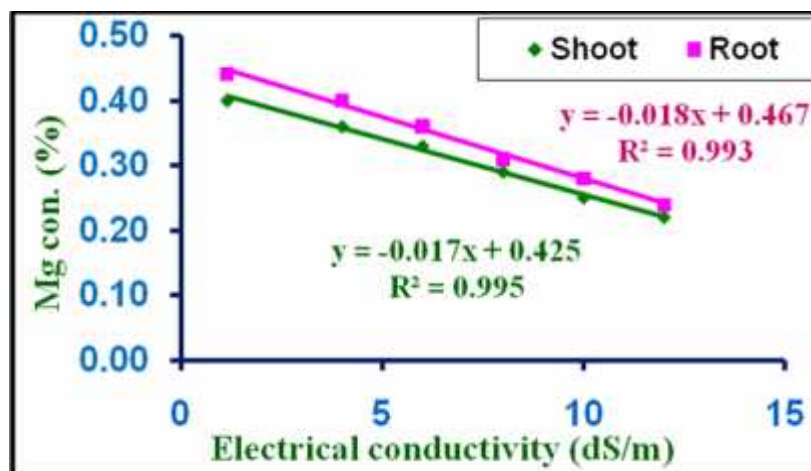was slightly higher in root than the shoot.

Fig. 17. Relationship between electrical conductivity of the irrigation water
and magnesium concentration in shoot and root of tomato plant

4.8.5 Nitrogen

Nitrogen concentration in shoot and root of tomato plant showed negative
linear relationship with irrigation water salinity (Fig. 18). Such relationship was
stronger in root ($R^2 = 0.972$) than the shoot ($R^2 = 0.881$). Regression equations
indicate 0.13 and 0.11% decrease in N content in shoot and root, respectively

due to irrigation water salinity (EC up to 12 dS m^{-1}). With low N content due to salinity stress, the plant might have suffered from hidden hunger for N.
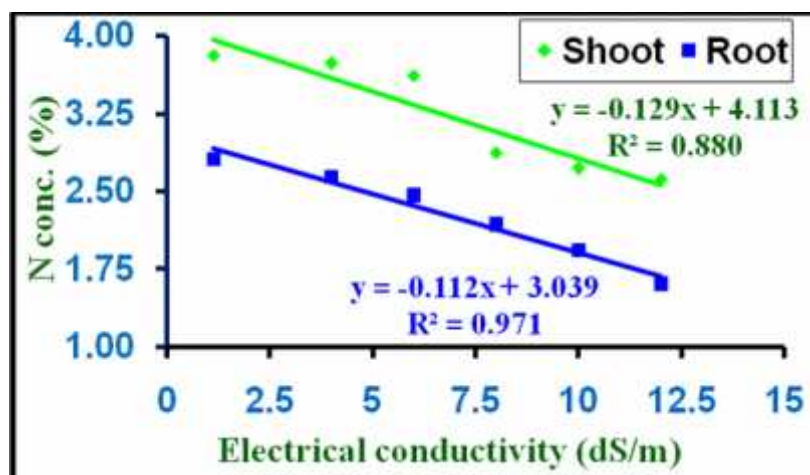

Fig. 18. Relationship between electrical conductivity of the irrigation water and nitrogen concentration in shoot and root of tomato plant

4.8.6 Phosphorus

The relationship between electrical conductivity in irrigation water and P content in both shoot and root of tomato plant was linear but negative (Fig. 19), which indicate that phosphorus absorption might have been restricted significantly due to irrigation water salinity. The effect was thus antagonistic in nature. The possibility of reduction in P concentration may be happened for 87 and 91% cases if the crop was stressed by salinity up to the said levels.
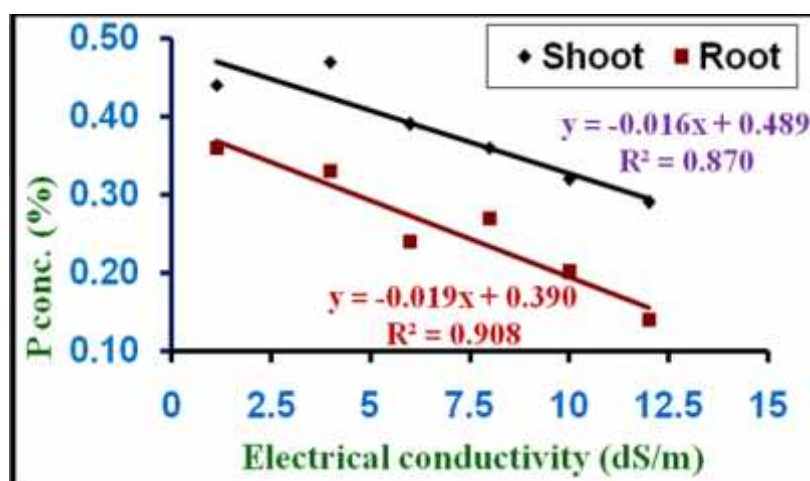

Fig. 19. Relationship between electrical conductivity of the irrigation water and phosphorus concentration in shoot and root of the tomato plant

4.8.7 Sulphur

In this context, sulphur behaved almost like P as revealed from Fig. 20. The association was equally stronger for both shoot and root showing R^2 value 0.9958 and 0.9956, respectively. As such S uptake might have been negatively affected by irrigation water salinity to a great extent. Regression equation suggested that for one unit increase in electrical conductivity, there might be a possibility of reduction in sulphur concentration by 0.015 and 0.009% for shoot and root, respectively and this trend may be attributed for 99% cases.
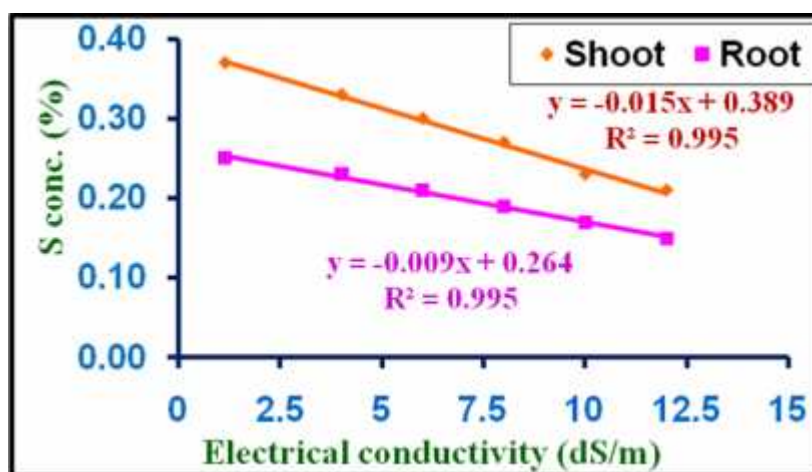

Fig.20. Relationship between electrical conductivity of the irrigation water and sulphur concentration in shoot and root of the tomato plant

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 Summary

A pot experiment on tomato genotypes was conducted imposing different levels of irrigation water salinity at pre-flowering were to assess the salinity tolerance ability of promising tomato genotypes with respect to different morpho-physiological characters, yield and nutrient content and to identify salt tolerant variety. The trial was set up at the Net House Premises of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the winter season November 2013 to February 2014. Six levels (0, 4, 6, 8, 10 and 12 dS m^{-1}) of irrigation water salinity were imposed to three varieties of tomato (BARI Hybrid Tomato 4, BARI Hybrid Tomato 5 and BARI Hybrid Tomato 8), which composed 18 treatments altogether. Salinity was imposed as per treatments at the pre flowering stage two times at 45 and 55 DAS and thereafter no irrigation was given. The experiment was conducted in a two factor completely randomized design with three replications. Fertilizers ($N_{155}P_{34}K_{47}S_9Zn_{1.4}B_{0.6}$ kg ha^{-1}) and manure (cowdung @ 10 t ha^{-1}) was estimated on the basis of initial soil test result following Fertilizer Recommendation Guide (BARC, 2012). One third of urea and entire amount of cow dung, TSP MoP, gypsum, boric acid and zinc sulphate were mixed with the soil in each pot before sowing. Rest of the urea was applied as side dressing at 25 and 45 days after transplanting. Two seedlings of 30 days old were transplanted to the each experimental pot in the afternoon during the last week of November 2013. Light irrigation was given immediately after transplanting by using water can. One seedling was uprooted leaving one seedling in each pot after seedling establishment. After establishment of seedlings, each pot was watered in alternate days to keep the soil moist for normal growth and development of the plants up to the imposition of saline

irrigation water. Harvesting of matured tomato fruits were started on 6 January 2014 and completed by 25 February, 2014. Leaf chlorophyll content as SPAD values were measured from the youngest fully-expanded leaf in the third position from the tip by a portable chlorophyll meter. The initial fluorescence (F_0), maximum fluorescence (F_m) were analyzed and quantum efficiency of open photosystem II centers (quantum yield) (Fv/Fm) was calculated. Gas exchange attributes such as assimilation rate (A), transpiration rate (E), stomatal conductance (gs) and intercellular concentration of CO_2 (ci) were measured from the youngest fully-expanded leaf in the third position from the tip at flowering stage according to Von Caemmer and Farquhar (1981). Total and reducing sugars were determined following the method of Debois *et al* (1956) and Nelson (1944), respectively. Morphological characters like plant height, number of branch plant-1, number of leaves plant-1 and leaf area plant^{-1} at harvest were recorded. Fruit yield and yield attributes data such as number of flower cluster plant-1, number of fruit cluster plant-1, number of fruits-1, fruit length and breadth, individual fruit weight and fruit yield were recorded. Data regarding shoot dry matter weight, root dry matter weight, shoot: root ratio and total dry matter were recorded. Concentration of Na, K, Ca, Mg, N, P and S in root and shoot were determined following standard methods at Soil Science Laboratory, BARI. Relevant data were statistically analyzed following the software STATISTICA, Version 5 (Statsoft France, 1997). The significance of the difference among the treatment means was evaluated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Results of the above study are presented and discussed mainly on morphological characters, yield and yield attributes, dry matter production and distribution, biochemical attributes and nutrient concentration in tomato shoot and root as governed by mean effect of genotype, salinity stress and their interaction (V x S). In almost all cases tomato genotypes varied significantly,

salinity also brought significant variations for the studied characters while the interaction effect appeared to be statistically non-significant.

Incase of morphological characters, BARI Hybrid Tomato 8 (V_3) appeared as the tallest genotype as compared to BARI Hybrid Tomato 5 (V_2) and BARI Hybrid Tomato 4 (V_1) among the tested varieties. The lowest number of primary branch plant^{-1} (5.53) was recorded in V_3, which was significantly lower than other two varieties. The tested genotypes differed significantly in terms of number of leaves plant^{-1} irrespective of salinity levels, where V3 showed the highest number of leaves plant^{-1} followed by V2 and V1. The highest total leaf area plant^{-1} (3117 cm^2) was also recorded from V3, which was highly significant over other two varieties. Regarding yield and yield attributes, the highest number of flower cluster plant-1(13.05), fruit cluster plant^{-1} (8.82), individual fruit weight (44.52 g), fruit length (5.68 cm), fruit diameter (5.68 cm) and fruit yield (1.62 kg plant^{-1} equivalent to 55.25 t ha^{-1}) was obtained from V_3 (BARI Hybrid Tomato 8), which was significantly higher over other two varieties where V_2 performed better than V_1. The genotype, V_3 also gave the highest shoot (2.27 g plant^{-1}), root (1.02 g plant^{-1}) and total (192.84 g plant^{-1}) dry matter yield. For biochemical parameters too, the performance of V3 was the best followed by V2 and V1 in almost all cases. For instance, SPAD (Soil Plant Analysis Development) value the indicator of leaf chlorophyll and leaf N status was found highest (47.26 mg g^{-1}) in V3 keeping V2 and the V3 as the next two positions. Similarly, the highest photosynthetic yield 0.64 was observed in V3, which was significantly higher over other two varieties. A bit lower Fv/Fm ratio (0.61) was found with V_2, which was of course significantly higher over V1. The highest total sugar content (146.95 mg/gfw) was recorded from the same genotype (V_3), which was significantly higher over other two varieties. Reducing sugar contents in leaves also varied significantly due to mean effect of genotype, where the performance was in the order of $V_3 > V_2 > V_1$. The photosynthetic rate, transpiration rate, stomatal conductance and intercellular CO_2 concentration

was highest for the V_3 as 14.56, 3.09, 0.25 and 199.75 mol m^{-2}s^{-1}, respectively. Basic cation (Na, K, Ca and Mg) concentration in tomato shoot varied significantly due to the mean effect of genotype. For instance, Na and K concentrations were higher in V_3 but Ca concentration in V_2 while V_1 gave the highest Mg contents in shoot. Essential basic cations like K and Ca were in adequate amount while Mg was in little deficient state as per Bennett, 1996. Potassium: sodium ratio for V_1, V_2 and V_3 was 3.43, 3.55 and 3.72, respectively, which indicates their adaptability under salt stressed situation to a considerable extent, where the performance of V_3 was slightly better over other two varieties. Again, concentration of major nutrients like N, P and S in tomato shoot varies significantly due to mean effect of genotypes where V_3 showed the higher concentration (3.39, 0.41 and 0.32% N, P and S respectively) followed by V_1 and V_2. Nutrient concentrations in root showed almost similar trend with shoot although former yielded lower concentrations than the later regardless of nutrients.

Salinity stress as imposed with irrigation water twice at pre flowering stage resulted in significant adverse effect on the studied characters. Morphological characters like plant height, number of primary branch plant^{-1}, number of leaves plant^{-1}, and leaf area of the tested tomato varieties decreased significantly with the increasing level of salinity regardless of genotypes. In almost all cases, the highest result was recorded in salinity control (S_0: EC 1.14 dS m^{-1}) and the lowest in S_5 (EC: 12 dS m^{-1}). Similarly, yield components such as flower cluster plant-1, fruit cluster-1, fruits plant-1, individual fruit weight, fruit length and fruit diameter was highest for S0, which was statistically similar to S1 (EC = 4 dS m^{-1}) but significantly higher over rest of the elevated salinity levels. This trend was reflected in the fruit yield as well where the highest yield was (2.41 kg plant^{-1} equivalent to 82.05 t ha^{-1}) obtained with salinity control treatment (S_0), which was significantly higher over rest of the treatments. The lowest fruit yield (0.60 kg plant^{-1} equivalent to 20.40 t ha^{-1}) was recorded from S_5 (12 dS m^{-1}), which was statistically identical to

S_4 (10 dS m^{-1}). The fruit yield of tomato was severely affected by the intensity of salinity as in the order of $S_5 > S_4 > S_3 > S_2 > S_1 > S_0$ where V_3 performed relatively better followed by V_2 and least by the V_1. These results revealed that irrigation water salinity (>8dS m^{-1}) may impair the growth and reduce the yield of tomato plant to a great extent.

Shoot dry matter weight, root dry matter weight as well as total dry matter weight of tomato plant decreased gradually and significantly with the increasing level of salinity. However, shoo: root ratio increased with the increasing level of salinity, which indicate the reduction of root biomass due to the abundance of Na$^+$ in the root zone.

Increasing levels of salinity resulted in low SPAD values in leaves regardless of genotype. Low SPAD indicates low chlorophyll and N content in leaves. It was thus revealed that the total chlorophyll content in leaf decreased with increasing levels of salinity.

The ratio Fv/Fm means photosynthetic yield where Fv indicates variable fluorescence and Fm is the maximal fluorescence intensity when all reaction centers (RCs) are closed. Fv/Fm ratio decreased significantly with the increasing level of salinity. The highest fv/fm ratio (0.74) was recorded in salinity control treatment (S_0), which was significantly higher over rest of the salinity levels. In each successive increase in salinity level, the photosynthetic yield decreased significantly. Regression equation (R^2 = 0.994**) implied that for each unit increase of electrical conductivity there is a possibility of loosing 0.024 unit photosynthetic yield.

The total sugar contents in leaves increased significantly with increasing level of salinity. A positive linear relationship (R^2 = 0.9759**) was found between electrical conductivity of irrigation water with total sugar content. Similar trend of result was observed for reducing sugar content as well. Photosynthesis rate

(A) decreased with the increase of salinity level. A linear negative relationship ($R^2 = 0.99**$) was observed between electrical conductivity of irrigation water with photosynthetic rate. Regression equation implied that photosynthetic rate may be reduced by 0.222 mol m^{-2}s^{-1} for each unit increase in electrical conductivity. Transpiration rate of tomato leaves decreased significantly with the increase of salinity levels. The highest transpiration rate (3.57 m mol m^{-2}s^{-1}) was found in control (S_0), which was significantly higher over rest of the elevated salinity levels. Irrigation water salinity resulted in significantly lower stomatal conductance in tomato leaves regardless of variety. Intercellular CO_2 concentration showed significant negative linear relationship ($R^2 = 0.963**$) with electrical conductivity of the irrigation water. For each unit increase in electrical conductivity there might be decrease in intercellular CO_2 concentration by 11.36 m mol m^{-2}s^{-1}.

Sodium and calcium concentration increased while potassium and magnesium concentration decreased significantly with the increase in salinity level in irrigation water. Potassium: sodium ratio (K: N) also varied significantly due to the mean effect of salinity. The highest K: N ratio (13.4) was found with S_0, which was highly significantly greater over rest of the treatments. The said ratio gradually narrowed down with the increasing level of salinity and dropped to at the least (1.76) for S_5, which was significantly lower than all other salinity treatments. Salt stress in general decreased N, P and S content in tomato shoot regardless of variety. Application of sodium salt with irrigation water reduced K: N ratio irrespective of genotype. Nitrogen content decreased with the increase of sodium content in both shoot and root of tomato plant. Phosphorus and sulphur content in both shoot and root also decreased with the increase of sodium content. Potassium content in both shoot and root of tomato plant decreased when Na content increased. With the prevalence of Na$^+$ at the rhizospher the absorption of Na$^+$ in root increased which might have restricted K absorption. Prevalence of Na$^+$ accentuated Ca^{2+} absorption, which rapidly moved to the shoot diluting root Ca concentration. As such, Na showed

synergistic effect with Ca absorption. Magnesium absorption decreased with the increase of Na content in both shoot and root of tomato plant.

Positive linear relationship was observed between electrical conductivity of the irrigation water with sodium concentration in shoot and root of tomato plant. Potassium showed negative linear relationship with electrical conductivity for both shoot and root of tomato plant. Due to application of saline water twice at pre flowering stage potassium absorption may be reduced by 5.5 and 11.5% for shoot and root of tomato plant, respectively. Calcium concentration in shoot showed linear positive relationship (R^2 = 0.996**) with electrical conductivity of irrigation water. But a linear negative relationship was observed between irrigation water salinity with root Ca content indicating 6.3% decline in Ca absorption. Saline water also showed significant linear negative relationship with Mg content in both shoot and root of tomato plant. Nitrogen concentration in shoot and root of tomato plant showed negative linear relationship with irrigation water salinity. With low N content due to salinity stress, the plant might have suffered from hidden hunger for N. The relationship between electrical conductivity in irrigation water and P content in both shoot and root of tomato plant was linear but negative. The effect was thus antagonistic in nature. Sulphur uptake was negatively affected by irrigation water salinity to a great extent.

No significant interaction effect between genotype and salinity was found for none of the studied characters. The variation was either for genotypes or salinity levels and they acted independently. Genotype BARI hybrid tomato 8 (V_3) performed better irrespective of salinity levels while significantly lower crop response was obtained with the higher salinity level regardless of variety.

5.2 Conclusions

Following conclusions may be drawn from the study entitled **Assessment of Salinity Tolerance Capacity of Promising Tomato Genotypes:**

The genotype, BARI Hybrid tomato 8 (V_3) performed better in terms of morphological characters, yield contributing characters, biochemical attributes dry matter production and showed higher yield potentiality.

The same genotype also gave the highest photosynthetic rate, transpiration rate, stomatal conductance and intercellular CO_2 concentration which ultimately contributed to the higher dry matter production as well as fruit yield.

The photosynthetic yield as well as fruit yield of the genotypes decreased significantly with the increase of salinity but yield reduced greatly at $> 8dS\ m^{-1}$ where V_3 performed better followed V_2 and V_1.

Sodium salt stress showed antagonistic effect on the absorption N, P, K, Mg and S while it was synergistic for Ca although root Ca concentration showed declining trend.

Potassium: sodium ratio in tomato plant narrowed down due to prevalence of sodium for higher salinity indicating low absorption of K, which might have affected biochemical processes of the crop.

5.3 Recommendations

Among the three genotypes under this study, BARI hybrid tomato 8 can be regarded as salt tolerant to some extent. But on farm verification trial is suggested for further evaluation before final recommendation.

5.4 Future Research

In this regard, follow up field study in the affected coastal saline soil is suggested.

CHAPTER 6

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APPENDICES

Appendix I. Physical and chemical characteristics of the initial soil

Table 1. Chemical characters

Soil depth (cm)	Bulk density (g cm^{-3})	Particle density	Porosity (%)	Infiltration (mm hr^{-1})	Field capacity (cm cm^{-3})	Textural class
0-15	1.47	2.69	45.35	8.5	0.392	Clay loam

Source: Soil Science Division, BARI, Gazipur (2013)

Table 2. Physical characters

Soil depth (cm)	P^H	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
			meq 100 ml^{-1}				μ g ml^{-1}						
0-15	6.2	0.91	5.3	1.6	0.29	0.049	33	17	0.17	5.5	55	31	2.0
15-30	6.4	2.81	5.4	1.7	0.13	0.148	over	22	0.61	-	-	-	4.2
Critical level			2.0	0.8	0.2	0.12	14	14	0.2	1	10	5	2

Source: Soil Science Division, BARI, Gazipur (2013)

Appendix 1I. Records of meteorological information (monthly) collected from Agro meteorological Division, BARI, Gazipur during 1st October, 2013 to April, 2014

Month	Air temperature (^{o}C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
October, 2013	35.00	22.24	91	65	74
November, 2013	31.50	13.90	92	62	-
December, 2013	30.00	10.30	57	91	3
January, 2014	28.00	09.60	93	50	-
February, 2014	29.50	12.00	91	31	38
March, 2014	34.20	14.20	91	34	9
April, 2014	40.20	19.00	88	20	28

Source: Agro Meteorological Section, BARI, Gazipur (2013)

Appendix II1: Morphological characters of tomato genotypes as affected by different levels of salinity

Sources of variance	Degrees of freedom	Mean squire (MS)			
		Plant height (cm) at last harvest	Number of branch Plant^{-I}	Number of leaves Plant^{-I}	Total Leaf area Plant^{-I} (cm^2)
Replication	2	183.91	1.18	162.00	450
Genotypes	2	2069.41 **	42.75 **	283.87 **	944517 **
Salinity	5	285.32 **	4.84 **	263.47 **	24135 **
Genotype × Salinity	10	9.88 NS	0.23 NS	2.33 NS	5000 NS
Error	34	28.06	0.16	5.02	6125

* Significant of 5% level of probability;   ** significant of 1% level of probability

NS= Not significant at p<0.05

Appendix IV : Analysis of variance on yield and yield contributing characters of tomato genotypes under different salinity levels

Sources of variance	Degrees of freedom	Mean squire (MS)			
		No. of Flower Cluster Plant^{-I}	No, of Fruits Cluster Plant^{-I}	No. of Fruits Plant^{-I}	ndividual Fruit Weigh (gm)
Replication	2	50.46	150.22	1565.85	134.75
Genotypes	2	123.42 **	65.62 **	1154.91 **	573.76 **
Salinity	5	3.75 **	4.30 **	404.91 **	133.18 **
Genotype ×Salinity	10	0.46 NS	0.31 NS	33.27 NS	7.19 NS
Error	34	0.59	0.47	38.88	3.15

* Significant of 5% level of probability;   ** significant of 1% level of probability

NS= Not significant at p<0.05

Appendix V: Analysis of variance on yield and yield contributing characters tomato genotypes under different salinity levels

Sources of variance	Degrees of freedom	Mean squire (MS)				
		Fruit Length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Total fruit yield Plant^{-I} (kg)	Total fruit yield (t/h)
Replication	2	98.76	90.69	43.55	0.72	317.52
Genotypes	2	15.19 **	16.28 **	454.16 **	0.37 **	1278.89 **
Salinity	5	5.15 **	6.07 **	4.15 **	5.37 **	750.96 **
Genotype ×Salinity	10	0.18 NS	0.05 NS	3.02 NS	0.03 NS	28.36 NS
Error	34	0.24	0.03	5.33	0.01	34.68

* Significant of 5% level of probability;   ** significant of 1% level of probability

NS= Not significant at p<0.05

Appendix VI: Analysis of variance on biochemical attributes of tomato genotypes as affected by different levels of salinity

Sources of variance	Degrees of freedom	Mean squire (MS)			
		Chlorophyll Contents (SPAD value) (mgm^{-2})	Photosynthetic yield (Fv/Fm)	Total sugar contents in leaves (mg/gfw)	Reducing sugar contents in Leaves (mg/gfw)
Replication	2	72.00	0.18	162.00	14.58
Genotypes	2	560.35 **	0.02 **	642.16 **	161.07 **
Salinity	5	35.45 **	0.08 **	112.79 **	33.65 **
Genotype × Salinity	10	3.87 NS	0.01 NS	6.16 NS	1.35 NS
Error	34	5.29	0.00	11.11	2.42

* Significant of 5% level of probability;   ** significant of 1% level of probability

NS= Not significant at p<0.05

Appendix VII: Analysis of variance of biochemical attributes of tomato genotypes under different salinity levels

Sources of variance	Degrees of freedom	Mean squire (MS)			
		Leaves Gaseous Exchange			
		Photosynthesis rate (A) (μ mol $m^{-2}s^{-1}$)	Transpiration rate (E) (mmol $m^{-2}s^{-1}$)	Stomatal Conductance (gs) (mmol $m^{-2}s^{-1}$)	Intercellular concentration of CO_2 (ci) (mmol $m^{-2}s^{-1}$)
Replication	2	16.98	11.52	0.18	11.5
Genotypes	5	101.30 **	0.20 **	0.01 **	2286.1 **
Salinity	10	7.09 **	2.18 **	0.02 **	19110.9 **
Genotype ×Salinity	34	0.92 NS	0.01 NS	0.01 NS	70.3 NS
Error	2	1.07	0.04	0.0	16.5

* Significant of 5% level of probability;   ** significant of 1% level of probability

NS= Not significant at p<0.05

Appendix V1ll: Analysis of variance of dry matter production and distribution of tomato genotypes as affected by different levels of salinity

Sources of variance	Degrees of freedom	Mean squire (MS)				
		Shoot dry weight Plant^{-I} (g)	Root dry weight Plant^{-I} (g)	Root and Shoot dry Ratio (g/g)	Fruit dry weight Plant^{-I} (g)	Total Dry Matter (TDM) Plant^{-I}(g)
Replication	2	0.18	0.18	0.46	288.00	317.52
Genotypes	2	0.33 **	0.14 **	0.10 **	1212.29 **	1278.89 **
Salinity	5	0.30 **	0.16 **	0.22 **	699.11 **	750.96 **
Genotype × Salinity	10	0.01 NS	0.01 NS	0.01 NS	27.57 NS	28.36 NS
Error	34	0.02	0.00	0.02	33.53	

* Significant of 5% level of probability;   ** significant of 1% level of probability

NS= Not significant at p<0.05

Appendix lX: Analysis of variance of nutrient ions (Na, N, P, K, Ca, Mg and S) concentration in shoots of tomato genotypes as affected by different levels of salinity

Sources of variance	Degrees of freedom	Mean squire (MS)						
		Nutrient ion concentration in shoot dry matter (%)						
		Na	N	P	K	Ca	Mg	S
Replication	2	0.73	0.18	0.18	0.18	0.18	0.18	0.18
Genotypes	2	0.50 **	0.37 **	0.12 **	1.01 **	0.16 **	0.02 **	0.01 **
Salinity	5	2.58 **	2.67 **	0.04 **	1.90 **	0.03 **	0.04 **	0.03 **
Genotype × Salinity	10	0.02	0.02 NS	0.00 NS	0.00 NS	0.00 NS	0.00 NS	0.00 NS
Error	34	0.05	0.02	0.00	0.03	0.00	0.00	0.00

* Significant of 5% level of probability;   ** significant of 1% level of probability
NS= Not significant at p<0.05

Appendix X: Analysis of variance of nutrient ions (Na, N, P, K, Ca, Mg and S) concentration in roots of tomato genotypes as affected by different levels of salinity

Sources of variance	Degrees of freedom	Mean squire (MS)						
		Nutrient ion concentration in root dry matter (%)						
		Na	N	P	K	Ca	Mg	S
Replication	2	0.18	0.18	0.08	0.18	0.72	0.70	0.18
Genotypes	2	0.29 **	0.29 **	0.04 **	0.11 **	0.78 **	0.14 **	0.03 **
Salinity	5	1.84 **	1.84 **	0.04 **	0.44 **	0.58 **	0.03 **	0.01 **
Genotype × Salinity	10	0.03	0.03 NS	0.00 NS	0.01 NS	0.01 NS	0.00 NS	0.00 NS
Error	34	0.01	0.01	0.00	0.01	0.02	0.00	0.00

* Significant of 5% level of probability;   ** significant of 1% level of probability
NS= Not significant at p<0.05