RESPONSE OF TOMATO (*Lycopersicon esculentum L.*) TO SALINITY IN HYDROPONIC STUDY

Submitted by

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CERTIFICATE

This is to certify that the thesis entitled **"RESPONSE OF TOMATO (*Lycopersicon esculentum L.)* TO SALINITY IN HYDROPONIC STUDY"** submitted to the Department of **Agricultural Chemistry**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL CHEMISTRY**, embodies the result of a piece of bona fide research work carried out by **Md. Akram Hossain Shimul,** Registration Number: **05-1761** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: June, 2011
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TO

MY BELOVED PARENTS

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ABSTRACT

The research work presented in this thesis was conducted to evaluate the performance of tomato under the different levels of salinity (NaCl) in the hydrophonic culture house of Bangladesh Agricultural Research Institute (BARI), Horticulture Research Centre, Gazipur, during the period of November 2011 to February 2012. The experiment was laid out in Completely Randomized Design (CRD) with four replications. There were five treatment combinations Salinity levels (T_1=0 dSm^{-1}, T_2=4 dSm^{-1}, T_3=8 dSm^{-1}, T_4=12 dSm^{-1} and T_5=16 dSm^{-1}). Results revealed that T_1 (control) showed the best performance in terms of growth, yield and yield contributing attributes, plant physiological parameter, plant nutrient concentration. The maximum number of fruits (19 $plant^{-1}$) and the highest fruit weight $plant^{-1}$ (1.60 kg) were found from the control treatment. This experiment showed different impact of each nutrient and its interactions on tomato plant. The experiment showed that at 16 dSm^{-1} salinity level highest Na and Cl uptake reduced the uptake of K and at 0 dSm^{-1} salinity when Na and Cl ions were low in water, K uptake increased. Salinity had a greater impact on stomata resistance and chlorophyll content of plants. The experiment also showed that at control treatment leaf area $plant^{-1}$, total chlorophyll content and plant dry matter was highest but stomata resistance was minimum and on the other hand, at 16 dSm^{-1} salinity level these factors showed fully reverse. However, the overall impact of salinity had negative impact on growth and yield of tomato plant.

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CHAPTER I

INTRODUCTION

Tomato *(Lycopersicon esculentum* Mill.) is one of the most important horticultural crops in the world. In terms of human health, tomato fruit is a major component of daily meals in many countries and constitutes an important source of minerals, vitamins, and antioxidant compounds (Dorais *et al.* 2005). In recent years, the interest has been focused on the health aspects of tomato fruit. Consumer habits for fresh vegetables have shown that taste and aroma are the most important factors in the selection of a product. Tomato fruit quality for fresh consumption is determined by appearance (colour, size, shape, freedom from physiological disorders and decay), firmness, texture, dry matter, and organoleptic (flavour) and nutraceutic (health benefit) properties. The organoleptic quality of tomato is mainly attributed to its aroma volatiles, sugar and acid content, while its .mineral, vitamin, carotenoid and flavonoid content define the nutriant quality. Sugar content is considered to be one of the most important factors in tomato fruit quality and consumer satisfaction (Malone and Andrews, 2001).

Salinity is a significant problem affecting agriculture worldwide, including Bangladesh, resulting in substantial losses in crop yield. In Bangladesh, coastal areas of about 2.86 million ha is 30 % of the total crop land of the country. Of this, nearly 1.056 million ha are affected by varying degrees of salinity (SRDI, 2010). Plants use three main mechanisms to survive salinity stress: Osmotic tolerance, Shoot Na^+ exclusion and Na^+ tissue tolerance. One way to overcome the problem is to develop crop varieties able to tolerate salinity stress.

The coastal and offshore area of Bangladesh includes tidal, estuaries and river floodplains in the south along the Bay of Bengal. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen & Shireen, 2001).The cultivable areas in coastal districts are affected with varying degrees of soil salinity. Soil salinity is in increasing trends with time. The soil salinity maps (2009) indicate that soils of Jessore, Magura, Narail, Faridpur, Gopalgonj, Barisal, Jhalakhati and Patuakhili have been newly salinized during 36 years.

Salinity stress in the root zone is accompanied by yield loss through a reduction in fruit weight, but not in the number of fruits (Li *et al.*, 2001; Willumsen *et al.*, 1996). Water influx into fruits is reduced by the high osmotic pressure of the irrigation solution and the water stress inhibits fruit size (Chretien *et al.*, 2000; Li *et al.*, 2001; Mavrogianopoulos *et al.*, 2002). The duration of salinity stress is important because it affects fruit yield and quality. There have been a few studies on the starting time and duration of salinity treatment in the tomato (Sakamoto *et al.*, 1999). However a few studies were done on the effect of water stress on the growth, yield and the quality of tomato fruits. At the same time very small number of investigation were done on the effect of salinity stress on tomato. It is necessary to investigate how both the stress factors affect 'the growth, yield and quality of tomato. To produce high quality tomato fruit the effect of stresses on chemical contents and physiological response must be known.

Most of the southern coastal districts of the country are under saline zones, which cover an area of 25-30 percent of the total arable land. The severity of salinity of this area increases with the desiccation of the soil. Salinity affects crops depending on degree of salinity at the critical stages of growth, reduces yield and in severe cases total yield is lost. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increasing production of crops. Out of coastal cultivable saline area, 86% area i.e. low saline (0-4 dS m^{-1}) area of 287 thousand hectares and medium saline (4-8 dS m^{-1}) area of 426 thousand hectares have scope for successful crop production (BRRI, 2004). Suitable vegetables are required to overcome the serious limitation posed by salt affected coastal areas. Tomato *(Lycopersicon esculentum* L.*)* is an important vegetable in Bangladesh. Extensive research is necessary to develop growing conditions in moderate salinity to produce good vegetative growth. The tomato plant is moderately sensitive to salinity. Tomato can tolerate salinity up to 2.5-2.9 dS m^{-1} in the root zone without yield losses (Sonneveld and Burg, 1991). The exact salinity impact may vary depending on cultivar sensitivity and environmental conditions (Karlberg *et al.*, 2006). Therefore, the experiment was undertaken to observe the performance of tomato under different salinity level.

Salinity problem received very little attention in the past. Nevertheless, symptoms of land degradation with salinization are becoming too pronounced in recent years to be ignored. Increased pressure of growing population demand more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops. Thus combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy.

Considering the above mentioned facts the present study has been planned and designed with the following objectives:

1. To observe the growth and yield of tomato under different salinity condition.

2. To observe the different physiological parameters of tomato plants affected by salt stress.

3. To study the content of plant nutrient Na, Cl and K affected by salt stress.

CHAPTER II

REVIEW OF ITERATURE

Tomato is a popular vegetable adapting in the salinity prone marginal areas in order to increase more production. Salinity problem received very little attention in the past. Nevertheless, symptoms of such land degradation with salinization are becoming too pronounced in recent years to be ignored. Increased pressure of growing population demand more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops. Thus combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy. Information concerning the effect of different salinity level of hydroponic tomato under the climatic condition of Bangladesh is meager. An attempt has been made to review some of the available literatures pertinent to the present study in this chapter.

2.1 Literatures on salinity of hydroponic tomato

Carl *et al.* (1993) Commercial recommendations exist for using short-term salt-shocks on tomato *(Lycopersicon esculentum* Mill.) to improve fruit quality. Six experiments were conducted to 1 assess the influence of nutrient concentration and short-term salt-shocks on fruit quality and yield and 2) identify a vegetative predictor of subsequent fruit quality. Here four treatments were applied: two maintained constant at two baseline concentrations (0.25X and 1X-commercial level) and two provided salt-shock periods of 30 min, twice daily. There were no effects of baseline concentration or salt-shocks on total number and weight of marketable fruit. Fruit quality was better at the 1X baseline concentration as observed by higher titratable acidity, higher percent dry matter, higher soluble solids concentration and lower pH. However, weight per marketable fruit was low. Salt-shocks had little effect on fruit quality, refuting its commercial potential. Salt-shocks decreased fruit pH. However, titratable acidity increased at the 0.25X level and decreased at the 1X level., but not citrate concentration in the fifth leaf from the apex of young vegetative plants was correlated with subsequent fruit quality. Three additional experiments in static hydroponics with vegetative plants showed no significant differences in leaf citrate levels due to a single, short-term salt-shock. Thus, citrate is not a good predictor of fruit quality.

Tari *et al.* (2002) carried out an experiment where they showed that long-term incubation of tomato plants in low concentration of salicylic acid enabled plants to tolerate salt stress caused by 100 mM NaCl. Na^+ ions accumulated in the leaf tissues of treated plants and functioned as osmolytes without the well-known detrimental effects of the excess sodium.

Bishnu *et al.* (2003) conducted an experiment to show the effect of partial replacement of KCl in the fertigation by $KCl.MgCl_2$ on growth, yield and quality of greenhouse tomato (cv. Durinta) which was studied in a soil-less system. 47 days after planting (DAP), three treatment solutions were applied to the plants using different K sources: (1) KNO_2, (2) KCl, and (3) $KCl.MgCl_2$+ KCl (25%:75% in terms of K supplied). In both treatments 2 and 3, NH_4NO_3, $Ca(NO_3)_2$ and HNO_3 were added as source of N. Plant height and total chlorophyll were the highest in the KCl+KCl · $MgCl_2$ treatment. Leaf Mg content was significantly lower in the KCl treatment, whereas highest in the KCl+$KCl.MgCl_2$ treatment. Both KCl and KCl+$KCl.MgCl_2$ led to a significantly higher leaf Cl content as compared with the KNO_3 treatment, but no Cl toxicity was observed in either treatment. Total yield was not different among treatments. Fruit firmness and freshness of the calyx were significantly improved by KCl and KCl+KCl.$MgCl_2$, and the number of rotten and blotchy fruits was significantly reduced by both these treatments. KCl+KCl.$MgCl_2$ also led to significantly higher levels of glucose, Mg and dry matter content in the fruit. Lower NO_3 and higher Fe contents were measured in both treatments 2 and 3. Although KCl as sole K source showed lower foliar Mg level as compared to KNO_3, the use of the KCl in tomato fertigation improved tomato fruit appearance and qualities. However, 25% replacement of KCl by KCl+ KCl.$MgCl_2$ increased the foliar Mg level and improved fruit qualities even further.

Sayed *et al.* (2004) carried out an experiment on the responses of three cultivated genotypes (Castlrock, Oriet and Super Marmande) and three breeding lines (BL-1076, BL-1077 and BL-1079) of tomato (*Lycopersicon esculentum*) to NaCl stress were studied in callus and regenerated plants. The six investigated tomato genotypes differed in their callus growth and regeneration capacities. Based on the responses to NaCl, six tomato genotypes were ranked in the order BL-1079 > BL-1077 > Super Marmande > Oriet > BL-1076 > Castlrock, when callus fresh and dry weights, length and number of roots were considered as indicators for salinity tolerance *in vitro*. Chlorophyll *a* was less susceptable to NaCl than Chlorophyll *b* in all genotypes. It seems that genotypes with high organogenetic potential may be better able to grow in saline environment. It is evident that tissue cultur technique was able to evaluate several genotypes for salt tolerance under controlled environment with relatively little space and less time required comparing with such process studies at the whole plant level.

Maggio *et al.* (2007) showed that crop salt tolerance is generally assessed as the relative yield response to increasing root zone salinity, expressed as soil or irrigation water electrical conductivity. Alternatively, the dynamic process of salt accumulation into the shoot relative to the shoot biomass has also been considered as a tolerance index. They exposed hydroponically grown tomato plants to eight different salinity levels (EC = 2.5 (non-salinized control); 4.2; 6.0; 7.8; 9.6; 11.4; 13.2; 15.0 dS m^{-1}). Based on biomass production, water relations, leaf ions accumulation, leaf and root abscisic acid and stomatal conductance measurements and to identify a specific EC value (approximately 9.6 dS m^{-1}) at which a sharp increase of the shoot and root ABA levels coincided with (1) a decreased sensitivity of stomatal response to ABA; (2) a different partitioning of Na^{+} ions between young and mature leaves; (3) a remarkable increase of the root-to-shoot ratio.

Oztekin and Tuzel (2011) conducted this study in a greenhouse to determine the response of 4 commercial tomato rootstocks, 21 cultivars and 8 candidate varieties to salinity stress. Seeds were germinated in peat and when the plants were at the fifth-true leaf stage, salt treatment was initiated except control treatment. NaCl was added to nutrient solution daily with 25 mM concentration and had been reached to 200 mM final concentration. On harvest day, genotypes were classified based on the severity of leaf symptoms caused by NaCl treatment. This study showed that, on average, NaCl stress decreased all parameters and the rootstocks gave the highest performance than genotypes. Among all rootstocks, three varieties (819, 2211 and 2275) and ten genotypes (Astona, Astona RN, Caracas, Deniz, Durinta, Export, Gökçe, Target, Yeni Talya and 144 HY) were selected as tolerant with slight chlorosis whereas the genotype Malike was selected as sensitive with severe chlorosis. Candidate varieties 2316 and 1482 were the most sensitive ones. Plant growth and dry matter production differed among the tested genotypes. However no correlation was found between plant growth and dry matter production. Rootstock Beaufort gave the highest shoot dry matter although Heman had highest root dry matter. Newton showed more shoot and root dry matter than other genotypes.

Tomato cultivar PKM 1 was subjected to 25, 50, 100, 150 and 200 mM NaCl stress and response of tomato plant to salt stress were determined by Babu *et al.* (2012) by assessing the variability of different biochemical parameters. In this present study endogenous content of growth hormones IAA and ABA in leaves, proline and mineral (Na^+ and K^+) content in leaves and mature fruits were estimated. Leaf area and dry matter content of tomato fruits under salt stress were determined to study the effect of salinity on photosynthetic yield. Results showed that leaf area and dry matter content of tomato fruits decreased with application of elevated salt stress, however endogenous content of IAA, ABA and proline was found to be increasing with increase in salt treatment. Application of NaCl caused increase in Na^+ content, while K^+ content and K^+/Na^+ ratio decreased with increase in salt stress. Another striking point is that increase in proline and Na^+ content was more in leaves than fruits, which suggests that leaves are more sensitive than fruits.

In this study the effect of salt stress on physiological response of hydroponically grown tomato fruit was investigated by Hossain and Nonami 2012. Fruit growth rate, water status, cuticle permeability and induction of blossom-end rot (BER) of tomato fruit were considered for this study. Salt stress was applied by using Ca. Fruit growth rate, predawn water potential, osmotic potential and cuticle permeability were significantly lower in treated plants than in control plants. On the other hand, tissue turgor of control and treated fruit showed almost similar values 12 days after flowering (DAF). This result indicated that turgor was osmotically regulated in fruit under stress condition. Fruit growth rate was found to decline from 12 DAF and eventually ceased when BER externally appeared on fruit surface at the age of 19 DAF in this experiment. The reduction of growth rate coincided with the reduction of water potential in fruit tissue due to salt stress. Although BER externally appeared at 19 DAF anatomical investigation showed that intercellular air space becomes discoloured at least one week before external symptoms appeared on fruit tip. Different levels of cuticular permeability indicated that the deposition of cuticular wax on fruit surface was enhanced by the salt stress condition in tomato fruit. Since, BER was found to appear on fruit tip under high calcium concentration in solution it can be concluded that calcium deficiency was not the only the cause of BER in tomato, rather salt stress might alter metabolic activity in developing tomato fruit.

Botrini *et al.* (2000) carried out an experiment where the tomato cultivars Edkawi and UC 82B (*Lycopersicon esculentum* Mill.) were grown hydroponically in a solution [electrical conductivity (EC) 2.4 dS m^{-1}] containing 150 mM Na (EC 11.4 dS m^{-1}), 37 mM of K (EC 14.1 dS m^{-1}), or 75 mM of K (EC 19.7 dS m^{-1}). The leaf Na content of 'Edkawi' and 'UC 82B' reached values of 1717 and 2022 mM kg^{-1} dry weight at EC 19.7 dS m^{-1}, respectively. The high levels of K in the hydroponic solution reduced the Na concentration in the roots, petioles, and stems, but not in the leaves. Potassium concentrations in the petioles of 'Edkawi' and 'UC 82 B' reached values of 2655 and 2966 mM kg^{-1} dry weight, respectively. At these elevated ECs, the Ca concentrations in the leaves of 'Edkawi' and 'UC 82B' were 30% and 40% lower than in the control, respectively. The elevated rates of K improved the fruit : flower ratio of 'UC82B', but the high salinity of the solution reduced yields significantly. Plant fresh weight and root dry weight of 'UC 82B' were most affected by high EC levels. The elevated levels of K used in this study did not increase yield, but K ions can adjust to Na uptake.

Ashraf (2011) showed the performance and suitability of different medium for the soilless culture of tomato plants were studied in a closed soilless culture system employing six different substrates (perlite, pumice, zeolite and their mixtures 1:1 in an glasshouse).The plants grown in medium with salty irrigation water. Tomato leaf analysis showed high concentrations of Ca^{2+}, Mg^{2+} and K^+ due to saline water especially in the medium treated with zeolite. The results suggest that the addition of zeolite in perlite and pumice could improve inorganic medium properties for tomato soilless culture, leading to higher yields. The overall results indicated that medium amendment with zeolite could effectively ameliorate salinity stress and improve nutrient balance in the medium.

Horchani *et al.* (2010) investigated the interactive effects of salinity and hypoxia on the physiological responses of tomato (*Solanum lycopersicum* L.) plants. To this end, growth, photosynthesis, stomatal conductance and organic solute accumulation was determined in hydroponically grown plants exposed for 4 weeks to hypoxia, salinity (100 mM) or to the combination of salinity and hypoxia. Obtained results showed that plants exposed to salinity, either alone or in combination to hypoxia showed decreased root and shoot biomass production. However, root and shoot water contents were decreased only for plants exposed to the combination of the two stresses. Concomitantly, leaf area, leaf mass per area, and K^+ and sugar contents were significantly decreased in comparison with control (0 mM NaCl) plants. Na^+ and proline significantly accumulated in roots and leaves of plants exposed to salinity, either alone or in combination to hypoxia. Taken together, these results suggest that tomato plants are strongly sensitive to the combination of hypoxia and salinity stresses. This is most probably due to a low K^+-uptake selectivity, a strong Na^+ absorption, and the disturbance of K^+ translocation towards shoots and the loss of its use efficiency for biomass production.

In this study the effect of salinity at different levels on growth, yield and quality of greenhouse tomato (*Lycopersicon esculentum* Mill.) grown in hydroponics culture was evaluated by Azarmi *et al.*, 2010. Salinity treatments were applied at EC of 2.5, 3, 4, 5 and 6 dS m^{-1} by adding NaCl to standard nutrient solution. The results indicated that plant height and leaf number were significantly ($P \leq 0.05$) decreased with increasing salinity. Total leaf area at EC of 6 dS m^{-1} decreased by 29% in comparison to 2.5 dS m^{-1}. Chlorophyll content was significantly ($P \leq 0.05$) reduced at EC of above 3 dS m^{-1}. Stomatal conductance in nutrient solution with EC of 6 dS m^{-1}, reduced by 28.2% compared to 2.5 dS m^{-1}. Fruit fresh weight at EC of 6 dS m^{-1} decreased by 29% in comparison to 2.5 dS m^{-1}. Total fruit yield reduced by 8.7, 21.7, 36 and 48.9% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, compared with 2.5 dS m^{-1}. Total soluble solid was significantly ($P \leq 0.05$) increased at EC of above 3 dS m^{-1}. Fruit dry weight at EC of 6 dS m^{-1} increased by 8.7% compared with 2.5 dS m^{-1}. Titratable acidity increased by 2.7, 9.9, 20.3 and 28.9% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, compared with 2.5 dS m^{-1}. The results of this experiment showed that growth parameters and yield reduced with increasing salinity, but qualitative properties were improved by salinity.

This study examined by Dileo *et al.* (2010) on the impact of brief salinity stress on infection of tomato and chrysanthemum roots by *Phytophthora spp*. Roots of plants in hydroponic culture exposed to a brief episode of salt (sodium chloride) stress prior to or after inoculation were severely diseased relative to nonstressed plants. Tomato roots remained in a predisposed state up to 24 h following removal from the stress. An increase in root ABA levels in tomato preceded or temporally paralleled the onset of stress-induced susceptibility, with levels declining in roots prior to recovery from the predisposed state. Exogenous ABA could substitute for salt stress and significantly enhanced pathogen colonization and disease development. ABA deficient tomato mutants lacked the predisposition response, which could be restored by complementation of the mutant with exogenous ABA. In contrast, ethylene, which exacerbates disease symptoms in some host-parasite interactions, did not appear to contribute to the predisposition response. Thus, several lines of evidence support ABA as a critical and dominant factor in the salinity-induced predisposition to *Phytophthora* spp. infection.

Zahedifar *et al.* (2010) conducted this experiment to determine the effect of salinity and nitrogen on growth and yield of tomato and concentration and total uptake of some nutrients in different parts of plant in hydroponics culture. Nitrogen (N) was used at 0, 1.5 and 3% levels as NH_4Cl and $NH_4H_2PO_4$ and salinity consisted of 0, 30 and 60 mM as NaCl and $CaCl_2$. This experiment was carried out under greenhouse conditions. Results showed that fruit fresh weight increased with N application but salinity treatment decreased fruit yield. Maximum fresh weight was observed in treatment with 3% N and without any salinity application, whereas minimum fresh weight was obtained with 30 mM salinity and without any N application. Application of 30 and 60 mM salinity increased fruit phosphorous concentration significantly ($P<0.05$), but it did not affect shoot and fruit concentration. Nitrogen application increased fruit, shoot and root phosphorous concentration significantly. Root, shoot and fruit N uptake increased with N application (without salinity) whereas at high salinity level, increase in N uptake was lower than at low salinity level. Salinity increase without N decreased fruit phosphorous and manganese uptake, root copper, zinc and manganese concentration and shoot manganese uptake. Furthermore, results showed that at low salinity level, N application can alleviate the negative effects of salinity on growth and yield of plant.

An experiment was conducted by Papadopoulos and Rendig (1983) on tomato (*Lycopersicon esculentum* var. VF 145) plants which were grown in a greenhouse to determine the effects of salinity on growth and yield. Nutrient solutions made saline with NaCl and $CaCl_2$ to electrical conductivities (EC) of 1, 2, 3, 4, and 5 dS/m (dS m^{-1} = mmho cm^{-1}, referenced at 25°C) were applied twice a day in the undivided root systems. The nutrient solutions were recycled through the containers, so that responses of plants subjected to increasing salinity up to 35 dS m^{-1} could be evaluated. With increasing salinity fruit fresh weights decreased markedly, with lesser decreases in shoot weights in both systems. Plants with their root systems divided and growing in containers with differentially salinized soil were less severely affected. Yield and growth correlated better with the initial electrical conductivity (EC) of the nutrient solutions applied than with the EC values of the solutions extracted from the soil. Roots were less sensitive to root-zone salinity than were tops. In the split-root system, any reduction in the root growth in the compartments with high salinity levels was compensated for by more growth of those portions of the root system in the less saline environment.

Ali (2010) showed that transgenic technology involving the TMT gene encoding thiol methyltransferase enzyme has been suggested as an effective solution for engineering a chloride detoxification capability into a high value crops to improve tolerance against chloride ion toxicity under saline environments. This study was performed to examine the relationship between salt tolerance and chloride volatilizing capacity of transgenic plants containing TMT gene as well as to explore the possibility of generating transgenic tomato containing TMT gene for salinity tolerance. To achieve these objectives, transgenic tomato plants containing TMT gene were grown in comparison with wild type tomato plants under three levels of sodium chloride (NaCl) salinity (0, 100 and 200 mM), three levels of soil water content (40%, 60% and 80% of the field capacity) and their tolerance to NaCl and water stress was studied. Plant growth parameters recorded included plant height, number of leaves, leaf area, stem dry weight, leaf dry weight, root dry weight, plant dry biomass and root/shoot ratio. Similarly, both types of plants were exposed to five levels of NaCl concentrations (0, 50, 100, 150 and 200 mM) and three levels of soil water content (40%, 60% and 80% of the field capacity), and the quantity of CH_3Cl emitted was recorded. Significant decrease in plants growth parameters of both types of plants were recorded upon exposure to salinity and water stress. Under 100 mM NaCl, however, transgenic plants showed better tolerance to salinity by suffering less reduction in growth parameters compared to wild type plants. Under 200 mM NaCl, growth of both types of plants was completely inhibited. The interactive effects of salinity and water stress were more pronounced in wild type plants than in transgenic plants. Results also showed that all engineered plants acquired an ability to efficiently transform chloride ion to CH_3Cl, and the rate of such transformation was higher under greater NaCl and soil water content compared to lower NaCl concentrations and soil water content.

Agong *et al.* (2003) carried out an experiment on thirteen tomato genotypes were subjected to salt treatment under hydroponics and their responses monitored in a set of two experiments with the objective of advancing them as potential salt tolerant tomato scion and/or rootstocks. Salt applications ranged from 0 to 2% NaCl, with the resultant EC values of 1.4 to 37 dS m^{-1}, respectively. Genotypes were cultured in the experimental solutions for up to four weeks in the greenhouse. Salt treatment effects were registered on plant height, leaf green matter value and area, dry matter yield, Na^+ and Cl^- accumulation in tomato tissues. Salt treatment at 2% NaCl stimulated chlorophyll production, but caused severe depression on dry matter yield and leaf area. Some tomato genotypes consistently showed superior biological activity at higher salinity and others exhibited greater shift in the shoot:root ratio (from 8:1 to 5:1 for 'First'), based on dry matter biomass production thus displaying relatively greater adaptation to salt stress. Two tomato genotypes ('Siozawa' and 'Gambaru Ne-3') displayed superior performance.

Mycorrhizal fungi species *Glomus fasciculatum* was used by Yildiz *et al.* (2008) to determine its effects on tomato growth, yield, fruit properties, nutrient uptake and substrate ion accumulation of plants grown hydroponically under open and re-cycling (closed) perlite substrate. Fungal inoculation in both open and closed soilless systems did not increasingly influence the vegetative plant growing and nutrient uptake of tomato cultivar M19. However, fruit yield absolutely increased with inoculation. Inoculated tomato plants could effectively use photo assimilates for fruit production instead of vegetative growing. In the closed system with fungal inoculation, ion accumulation and EC increases (salinity effects) were well controlled. Results indicated that mycorrhizal inoculation improved yield and fruit size, which can help alleviate deleterious effects of re-cycling soilless systems for tomato crop.

The effect of the electrical conductivity (EC) of nutrient solution on total soluble solids (TSS) and fruit yield was studied by Cornish (1992), using table tomatoes grown outdoors in hydroponic culture, with the aim of seeing if salt stress could be used to increase TSS and thereby improve fruit quality. Two initial experiments compared the responses of 3 different cultivars and compared responses to different salts. The main experiment aimed to quantify the trade-off between yield and TSS as EC was raised with NaCl. The 3 cultivars responded similarly to raised EC, although they ranged in TSS from 4.1 to 5.4 Brix under nonsaline conditions. Raising solution EC with NaCl, KCl, or a mixture of $NaCl/CaCl_2$ all gave significant increases in TSS. Increasing EC also increased titratable acidity and reduced fruit size, but had no effect on fruit firmness. Yield in the main experiment declined with increasing EC, but not linearly. Over all experiments, it was shown that salt stress could be used to achieve an increase in TSS of about 0.5 Brix with little or no effect on yield.

Adams and Ho (2010) carried out an experiment where tomatoes were grown at salinities of 3 to 9 mS cm^{-1} either in deep solution culture and at four combinations of day and night humidities of 0.1 and 0.8 kPa. Increasing salinity had no effect on dry matter accumulation or partitioning in tomato. In tomato, salinity only increased the proportion in the top but not in the fruit and leaves. High salinity decreased the volume and Ca content of the stem exudate in both crops. High humidity decreased movement of Ca into the leaves of both crops but increased that into the fruit of tomato, particularly during the day. Fruit transpiration plays an important role in determining the Ca status of different plant organs and their susceptibility to Ca related disorders.

In this study Rasool *et al.* (2010) showed that the effect of salinity at different levels on growth, yield and quality of greenhouse tomato (*Lycopersicon esculentum* Mill.) grown in hydroponics culture was evaluated. Salinity treatments were applied at EC of 2.5, 3, 4, 5 and 6 dS m^{-1} by adding NaCl to standard nutrient solution. The results indicated that plant height and leaf number were significantly ($P \leq 0.05$) decreased with increasing salinity. Total leaf area at EC of 6 dS m' decreased by 29% in comparison to 2.5 dS m^{-1}. Chlorophyll content was significantly ($P<0.05$) reduced at EC of above 3 dS m^{-1}. Stomatal conductance in nutrient solution with EC of 6 dS m^{-1}, reduced by 28.2% compared to 2.5 dS m^{-1}. Fruit fresh weight at EC of 6 dS m^{-1} decreased by 29% in comparison to 2.5 dS m^{-1}. Total fruit yield reduced by 8.7, 21.7, 36 and 48.9% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, compared with 2.5 dS m^{-1}. Total soluble solid was significantly ($P \leq 0.05$) increased at EC of above 3 dS m^{-1}. Fruit dry weight at EC of 6 dS m^{-1} increased by 8.7% compared with 2.5 dS m^{-1}. Titratable acidity increased by 2.7, 9.9, 20.3 and 28.9% at EC of 3, 4, 5 and 6 dS m^{-1}, respectively, compared with 2.5 dS m^{-1}. The results of this experiment showed that growth parameters and yield reduced with increasing salinity, but qualitative properties were improved by salinity.

Stamatakis (2010) conducted an experiment on the effects of silicon (Si) added to the nutrient solution either at a standard electrical conductivity (EC) of 2.2 dS m^{-1} or at an increased EC of 4.8 dS m^{-1} on yield, nutritional status and fruit quality were investigated in a tomato crop grown in a closed hydroponic system. Si was added in form of a water-soluble potassium silicate compound at a reference concentration of 2.25 mM. The average EC values in the drainage water were 3.7 and 3.4 dS m^{-1} in the low EC treatments without and with Si supply, respectively, and 5.8, 5.7 and 5.8 dS m^{-1} in the salinity treatments involving NaCl addition, NaCl and Si addition, and extra nutrients combined with Si addition, respectively. The increase of the EC up to 4.8 dS m^{-1} by adding NaCl had no significant influence on the fruit yield of tomato, when Si was added to the saline nutrient solution. In contrast, the fruit yield per plant was significantly restricted at this level of salinity, when no Si was added to the NaCl enriched nutrient solution, or when Si was included but salinity was induced by extra addition of major nutrients. In both cases, the yield depressions were exclusively due to a lower mean fruit weight. Both Si and EC enhanced the fruit firmness and the contents of total solid solutes and vitamin C in the tomato fruit. Moreover, the addition of Si significantly restricted the occurrence of blossom-end rot in tomato fruit when the plants were not exposed to salinity.

The effects of salinity on the yield and chemical composition of tomato fruits produced in soilless culture under protected environment were investigated by Raqeeb *et al.* (2004). Increasing salinity (EC) from 2 dS m-^{1} to 6 dS m-^{1} early reduced total yield, size, firmness and water content of tomato fruits, and dry weights of roots and shoots of plants. On the contrary, high salinity conditions resulted in increasing total soluble solids, carbohydrates (fructose, glucose, sucrose), titratable acidity and ascorbic acid (Vitamin C) concentrations and dry matter content of tomato fruits. These observations indicated that it is possible to obtain a good quality tomato fruits with acceptable yield reduction at EC 4.5 dS m^{-1}. Salinity affected both shelf life of tomato fruits stored at ambient temperature (2 1°C) or in cool condition (15°C) with relative humidity (RH) between 48-66% and 91-92%, respectively. There was a negative relationship between salinity and fruit shelf life, probably due to an increase in polyglacturonase activity, which enhances softening and hence causes shorter shelf life.

Tomato plants (*Solanum lycopersicum* L. cv. Durinta) grown by Giuffrida *et al.* (2004) in an open soilless system to evaluate the effects of sodium chloride (NaCl) concentration in the nutrient solution on the ion compositions in plant tissues. The treatments were of five NaCl concentrations and three leaves position/age and two fruits position. Five salinity treatments were imposed by adding 7, 21, 37, 49, or 64 mm of NaCl to the nutrient solutions; the final electrical conductivities were: 2.7, 4.5, 6.0, 7.5, and 8.6 dS m^{-1}, respectively. Increased salinity in the nutrient solution resulted in a reduction in tomato dry matter (from 534 to 375 g $plant^{-1}$) and in a linear increase in sodium (from 0.37% to 1.39%) and chloride (from 1.75% to 5.73%) in the leaves as well as in the fruit tissues (from 0.08% to 0.26% for sodium and from 0.63% to 1.34% for chloride). Leaf under the first cluster showed higher levels of sodium (+54%) and chloride (+32%) than leaf under the fifth cluster and old leaf accumulated more sodium (+15%) and chloride (+25%) than younger ones. The exposure of the tomato plants to increasing salinity resulted in a linear decline in nitrate (from 1.21% to 0.50%), total nitrogen (from 3.31% to 3.03%), sulphate (from 3.71% to 3.12%), and potassium leaves (from 2.76% to 1.51%); the potassium reduction was more evident in younger leaves than in older ones. All macronutrients, except calcium, decreased in the fruit tissues with increasing NaCl concentration in the nutrient solution. However, for phosphate, the reduction of the ion concentration was evident only in the fruit from the fifth cluster (–35%). The position of the fruit on the plant significantly affected the concentration of ion, which was higher for all determined ions in the fruit of the first truss. The levels of Na^+ and Cl^- found in the plant tissue seem to confirm the hypothesis that the plant dry biomass reduction may also be traced to the toxicity of these ions as a consequence of this high concentration. On the other hand, although generally influenced by antagonism with sodium and chloride, the amount of main macronutrients did not reach deficiency levels that influenced the growth processes, except in the case of potassium.

Zhou *et al.* (2011) was reported on this article, salt-induced changes in leaf and root after wild tomato (*Solanum chilense*) plants were treated with 200 mm NaCl. In leaf tissues, a total of 176 protein spots showed significant changes ($P < 0.05$), of which 104 spots were induced and 72 spots suppressed. Salt-induced proteins are associated with the following pathways: photosynthesis, carbohydrate metabolism, glyoxylate shunt, glycine cleavage system, branched-chain amino acid biosynthesis, protein folding, defense and cellular protection, signal transduction, ion transport, and antioxidant activities. Suppressed proteins belong to the following categories: oxidative phosphorylation pathway, photorespiration and protein translational machinery, oxidative stress, and ATPases. In root tissues, 106 protein spots changed significantly ($P < 0.05$) after the salt treatment, 63 spots were induced, and 43 suppressed by salt treatment. Salt-induced proteins are associated with the following functional pathways: regeneration of *S*-adenosyl methionine, protein folding, selective ion transport, antioxidants and defense mechanism, signal transduction and gene expression regulation, and branched-chain amino acid synthesis. Salt-suppressed proteins are receptor kinase proteins, peroxidases and germin-like proteins, malate dehydrogenase, and glycine dehydrogenase. In this study, different members of proteins were identified from leaf and root tissues after plants were subjected to salt treatment. These proteins represent tissue-specific changes in salt-induced roots.

In this paper, a number of strategies to overcome the deleterious effects of salinity on plants will be reviewed by Cuartero *et al.* (2006). These strategies include using molecular markers and genetic transformation as tools to develop salinity-tolerant genotypes, and some cultural techniques. For more than 12 years, analysis has been attempted in order to understand the genetics of salt tolerance and to deal with component traits in breeding programmes. It has been shown that the expression of several transgenes promotes a higher level of salt tolerance in some species. Three cultural techniques have proved useful in tomato to overcome, in part, the effects of salinity: treatment of seedlings with drought or NaCl ameliorates the adaptation of adult plants to salinity; mist applied to tomato plants grown in Mediterranean conditions improves vegetative growth and yield in saline conditions; and grafting tomato cultivars onto appropriate rootstocks could reduce the effects of salinity.

Min *et al.* (2004) conducted an experiment on Four cultivars (Blitz, Mariachi, Quest and Rapsodie) of tomato which were grown hydroponically on rockwool in two microclimates(east and west) inside the green house under two nutrient solution electrical conductivity (EC) levels (2.6 or 4.5 dS m^{-1}), adjusted by adding NaCl and $CaCl_2$ after the setting of first fruit truss. In all cultivars, total soluble solid (TSS, %Brix at 20oC) and lycopene concentration of fruits increased by 12-23% and 34-85%, respectively, with increasing EC level. Fruits harvested from the east side of the greenhouse had higher TSS than those from the west side However, lycopene concentration in fruits was not significantly affected by plant microclimate regardless of cultivars or EC. The cultivar of Mariachi showed the strongest effect in response to nutrient solution EC levels regarding both TSS and lycopene concentration among the cultivarsexamined. The cumulative yield at 7 weeks showed no significant differences between nutrient solution EC and locations, regardless of cultivars. The results indicated that value added tomato fruits couldbe produced by manipulating EC and plant microclimate in the green house without causing yield reduction.

Snappi and Shennan (1992) conducted numerous hydroponic studies that have shown that root growth of tomato is little affected by salinity. In contrast, data from soil-grown plants show salinity may induce reductions of up to 50% in root length density. In this study, root growth of two tomato cultivars exposed to salinity (NaCl and $CaCl_2$, 4:1) was examined in the field, in large soil-filled containers, and in hydroponics. The two cultivars, UC82B and CX83O3 were hypothesized to differ in root growth response to environmental stress. In agreement with the literature, root weight of young, hydroponically-grown plants was unaffected by salinity in both cultivars. In contrast, root length density of cv. UC82B was reduced 40 % by salinity in the field, whereas root length density of root rot-tolerant cv. CX83O3 was unaffected. Similar responses to salinity were observed in the containers, with root counts from horizontal minirhizotron tubes reduced in cv. UC82B, but not in cv. CX83O3. Observations from windows in the sides of the containers showed that reduction in net root growth in cv. UC82B was primarily due to an increased rate of root death at high salinity. Root turnover remained low in cv. CX83O3 under both low and high salinity. Differential effects of salinity on root growth of the two cultivars in containers were not evident until about 60 day after transplanting. Enhanced rates of root death during the reproductive growth stage may represent an important, previously undocumented carbon cost to some genotypes exposed to salinity.

This research was conducted by Boamah *et al.* (2011) to determine the salinity level of irrigation water from a dug well, pond and tap water as well as its effect on the yield of a tomato crop. Water samples were taken at fortnight intervals to determine the electrical conductivity (dS m^{-1}). Flowering and yield of crop were the parameters used to assess the effect of salinity level on the tomato crop. Electrical conductivity as a measure of salinity was higher in the pond (0.25 dS m^{-1}) than the well and tap water (0.07 dS m^{-1} and 0.02 dS m^{-1}, respectively). Flowering and yield of tomato was high with crops treated with well water (45.22%; 99.08 kg ha^{-1}) followed by the pond (27.70%; 43.76 kg ha^{-1}) and tap water (27.08%; 27.25 kg ha^{-1}) in that order. There was no significant difference in flowering and in yield of crops between the tap and pond treatments at both 0.05 and 0.01 levels but there was a significant difference in yield between the well treated crops and other sources.

Krauss *et al.* (2006) showed in their experiment that, irrigation with saline water affects tomato fruit quality. While total fruit yield decreases with salinity, inner quality characterized by taste and health-promoting compounds can be improved. In this experiment the influence of three different salt levels (EC 3, 6.5, and 10 dS m^{-1}) in hydroponically grown tomatoes was investigated. The higher EC values caused an increase of total soluble solids and organic acids, parameters determining the taste of tomatoes. Total fruit yield, single fruit weight, and firmness significantly decreased with rising EC levels. As all desirable characteristics in the freshly produced tomato increased when exposed to salinity, salinity itself constitutes an alternative method of quality improvement. Moreover, it can compensate for the loss of yield by the higher inner quality due to changing demands by the market and the consumer. This investigation is to our knowledge the first comprehensive overview regarding parameters of outer quality (yield and firmness), taste (total soluble solids and acids), nutritional value (vitamin C, carotenoids, and phenolics), as well as antioxidative capacity in tomatoes grown under saline conditions.

Busaidi *et al.* (2010) carried out pot experiments to evaluate the effects of saline irrigations on five varieties of tomato (4, 22, 38, 46 and 54). Plants were irrigated with diluted seawater adjusted to three levels of electrical conductivity; freshwater (control), 3, and 6 dS m^{-1}. The results of the experiment showed that saline waters remarkably affected the evapotranspiration rate, soil moisture, salts accumulation and plant biomass production. Saline irrigation had the ability to keep much water in the soil with higher level of salt content. Low salinity treatment exhibited highest plant growth and lowest soil moisture and salts deposition. Varieties number 38 and 46 gave the highest values for fruits number and weight. Whereas, variety number 22 got the lowest values. However, variety number 4 was the tallest and had the highest value for green matter even under high salinity treatment. However fruit weight for variety number 38 was enhanced by saline irrigation which could be a good sign for salt tolerance in saline conditions.

Noureen *et al.* (2010) conducted an experiment for the hydroponic culturing of three tomato hybrid genotypes under the green house conditions at in vitro preservation. Three tomato hybrids were assigned as Factor A, whereas, two nutrient solutions were assigned as Factor B. The difference between nutrient solutions in channel-1 and channel-2 was the additional supplementation of $MgSO_4 .7H_2O$ at the initial stage and K_2HPO_4 at the final phase in channel-2. Parameters included in this study were: plant height (cm), number of nodes per plant, number of fruits per plant, fruit yield per plant (g), fresh and dried shoot weight (g) and fresh and dried root weight (g). Amongst the hybrids, Gala and Roma produced statistically alike results for plant height (72.8 and 69.6 cm), number of nodes per plant (17.60 and 17.00), number of fruits per plant (28.8 and 34.4), fresh shoot weight (216.0 and 219.6 g) and dried shoot mass (61.52 and 63.13 g) respectively. However, hybrid Roma excelled all the hybrid genotypes for fruit yield per plant (451.3 g), fresh root mass (142.7 g) and dried root mass (16.65 g). For the nutrient solutions, the result indicated that nutrient solution in channel-2 excelled the channel-1 in almost all the parameter studied.

Busaidi *et al.* (2009) carried out pot experiments to evaluate the effects of saline irrigations on five varieties of tomato (4, 22, 38, 46 and 54). Plants were irrigated with diluted seawater adjusted to three levels of EC; freshwater (control), 3 and 6 dS m^{-1}. The results of the experiment showed that saline water remarkably affected the evapo-transpiration rate, soil moisture, salts accumulation and plant biomass production. Saline irrigation had the ability to keep much water in the soil with higher value of salt content. Low salinity treatment exhibited highest plant growth and lowest soil moisture and salts deposition. Varieties number 38 and 46 gave the highest values for fruits number and weight. Whereas, variety number 22 got the lowest values. However, variety no. 4 was the tallest and had the highest value for green matter even under high salinity treatment. Overall, under saline condition it was observed that all plant parameters of different varieties were reduced compared to the control except for the number of fruits of some varieties such as 38, 46 and 54. However, fruit fresh weight for variety number 38 was enhanced by saline irrigation which could be a good sign for salt tolerance in saline conditions.

This study was conducted by Magan *et al.* (2009) to obtain criteria for determining when to flush out recirculating solution in closed systems used for tomato production. During a spring growing season, seven levels of nutrient solution salinity (control, 2.5, 3, 4, 5, 6, 7 and 8 dS m^{-1}) were compared on long life tomato (cv. Daniela). The different salinity levels beyond the control were obtained by the addition of sodium chloride. The experiment was conducted in Almeria, Spain. Total and marketable fresh yield, size distribution, visual imperfections, dry matter content, soluble sugar content, and acidity were measured. After a threshold value of 3.85 dS m^{-1}, fresh weight decreased 9.1% per dS m^{-1}. Salinity negatively influenced fresh weight and marketable fruit number. The values of several quality parameters tended to increase with salinity. The percentage of class 'extra' fruits (highest visual quality) increased progressively with salinity until 5 dS m^{-1}, after which there was no consistent increase. The increase of blossom-end rot with salinity was compensated by a large decrease in blotchy ripening. Fruit dry matter percentage increased linearly, but both the marketable dry matter yield and dry weight per marketable fruit tended to decrease above 5 dS m^{-1}.

Shafshak *et al.* (2008) was conducted this study aimed to investigate some possible approaches to alleviate the negative effects of salinity on tomato plant. Plants were irrigated with saline water with 5500- 500 ppm and the standard recommended fertilization dose. Plants were also receiving four experimental fertilization treatments namely control (no additional fertilization), mono potassium phosphate, potassium humate and amino acids. Recorded data showed that all vegetative and reproductive parameters responded positively to the individual effect of hardening and fertilization treatments and their interactions. The hardening level of 3000 ppm showed the best effect followed by the 4500 level and the least for 1500 ppm. Meanwhile the fertilization of mon potassium phosphate gave the best results followed by potassium humate then the amino acids. The interactive effect of the treatments appeared to be cumulative on plant response.

Manaa *et al.* (2011) conducted an experiment to evaluate the genotypic variation of salt stress response in tomato, physiological analyses and a proteomic approach have been conducted in parallel on four contrasting tomato genotypes. After a 14 day period of salt stress in hydroponic conditions, the genotypes exhibited different responses in terms of plant growth, particularly root growth, foliar accumulation of Na^{+}, and foliar K/Na ratio. As a whole, Levovil appeared to be the most tolerant genotype while Cervil was the most sensitive one. Roma and Supermarmande exhibited intermediary behaviours.

Gol (2003) showed that the most effective way to eliminate salinity effects is to produce salt tolerant crops. Both transgenic applications and molecular marker technology are of importance in producing salt tolerant plants. In this study, responses to salt stress of tomato were studied during the germination and vegetative stages of the life cycle. Inbred Backross Lines (IBLs) from a cross between salt-sensitive *L. esculentum* and a salt-tolerant *L. pimpinellifolium* were used for evaluation of salt tolerance during seed germination and QTL mapping. At the end of the germination study, it was observed that the IBLs have some degree of salt tolerance. *L. esculentum* alleles provided improved total percent germination on salt, however, *L. pimpinellifolium* alleles provided an improved rate of germination on salt. Thus, different parameters of salt tolerance are controlled by different mechanisms during seed germination. *L. pennellii* introgression lines (ILs) generated by crossing *L. pennellii* (LA716) to *L. esculentum* cv. M82 were used to map antioxidant traits related to salt tolerance at the vegetative stage of tomato. Plants of cultivated tomato (M82) and 32 IL lines were grown in aerated Hoagland solution in the greenhouse. At the seventrue leaf stage salt treatment was started and was achieved with the gradual addition of NaCl to the nutrient solution until 150 mM NaCl was reached. Superoxide dismutase (SOD) and catalase (CAT) activities were measured in the leaf tissues of these plants. Enzyme activities of the ILs were compared with M82 and QTLs associated with SOD and CAT activity under control and salt conditions were mapped.

Mohammad *et al.* (1998) conducted this study to evaluate the root and shoot responses of tomato to salt stress conditions under different levels of phosphorus (P) nutrition. Tomato seedlings (cv Riogrande) were grown which were salinized by four levels of NaCl salt (0, 50, 100 and 150 mM NaCl) and/or enriched with three P levels (0.5, 1 and 2 mM P) making nine combination treatments. The results indicate that increasing salinity stress was accompanied by significant reductions in shoot weight, plant height, number of leaves per plant, and a significant increase in leaf osmotic potential and peroxidase activity regardless of the level of P supplied. Both root length and root surface area per plant were decreased significantly under higher salinity conditions at all levels of phosphorus. On the other hand, increasing the phosphorus levels enhanced root growth through increasing both root length and root surface area. This phenomenon was observed at all levels of salinity. It can be concluded that root morphology parameters and peroxidase activity are additional sensitive parameters which are affected by salt stress and, therefore, can be employed as a criteria for monitoring plant response mechanisms to salt stress conditions.

CHAPTER III

MATERIALS AND METHODS

The research work presented in this manuscript was conducted to evaluate the performance of tomato under the different levels of salinity (NaCl) in the Hydrophonic Culture House of Bangladesh Agricultural Research Institute (BARI), Horticulture Research Centre, Gazipur. This study was carried out in solution culture conditions to find out the performance of tomato in the said environment. The details of experimentation are given as under.

3. Growth conditions and experimental techniques

3.1 Experimental site

Solution culture study was conducted in the Hydroponic Culture House of Bangladesh Agricultural Research Institute (BARI), Horticulture Research Centre, Gazipur during the period 2011-2012. The glass house has a glass roof with no control over temperature, humidity and light as the sides are open having only a wire net to control birds.

3.2 Seed source

Tomato seed was collected from Olericulture Division, Horticulture Research Centre (HRC), BARI, Gazipur, Bangladesh.

3.3 Solution culture study

3.3.1 Tomato seedling established

Tomato seeds (var. BARI Tomato 14) were germinated in open polythene-coated iron trays containing foam on the November 2011. Size of each foam was 3 m x 2 m size and thickness was 2.5 cm. One centimeter depth furrows were made following the length and breadth of foam. Furrow to furrow distances in each direction was 2 cm and as such 2 cm x 2 cm blocks were made. A ½ cm depth cut was made at the centre of each block in which seed were put. The foams were placed on water in 3 m x 4 m water tanks made in steel plate. Germination of seedlings was monitored and recorded everyday.

3.3.2 Seedling transplanting

At two-leaf stage, seedlings of uniform size were transplanted in foam-plugged holes of polystyrene sheets floating over 1/2 strength Hoagland's nutrient solution (Hoagland and Arnon, 1950).

Cork sheet was used on the water tank to hold the seedlings in the nutrient solutions. Ten seedlings were planted in each tank supported with cork sheet. The experiment was laid out in a Completely Randomized Design (CRD) with four replications. Each two seedlings were considered a replication. Salinity was developed in respective treatments (salinity of 4, 8, 12 and 16 dS m^{-1}) by adding NaCl in three/four applications, starting two days after transplanting. No NaCl was added in the control solution. Electrical Conductivity Meter (EC meter) was used to measure the salinity of the nutrient solution. Proper aeration of the culture solution was provided for 10 minutes daily by a bamboo stick. The pH of the solution was monitored daily and adjusted at 6.0±0.5, when needed. The substrate solutions were changed fortnightly.

Table 3.1: Stock solution (Hoagland's nutrient) prepared

Nutrient	Chemical	Amount for 1 litre
N, K	KNO_3	0.81 g
N, P	$NH_4H_2PO_4$	0.15 g
S, Mg	$MgSO_4.7H_2O$	0.49 g
N, Ca	$Ca(NO_3)_2.4H_2O$	0.94 g
Fe	Fe-EDTA	0.5 mg
Zn	$ZnSO_4.7H_2O$	0.02 mg
B	H_3BO_3	0.02 mg
Mn	$MnCl_2.4H_2O$	0.05 mg
Cu	$CuSO_4.5H_2O$	0.02 mg
Mo	$NaMoO_4.2H_2O$	0.01 mg

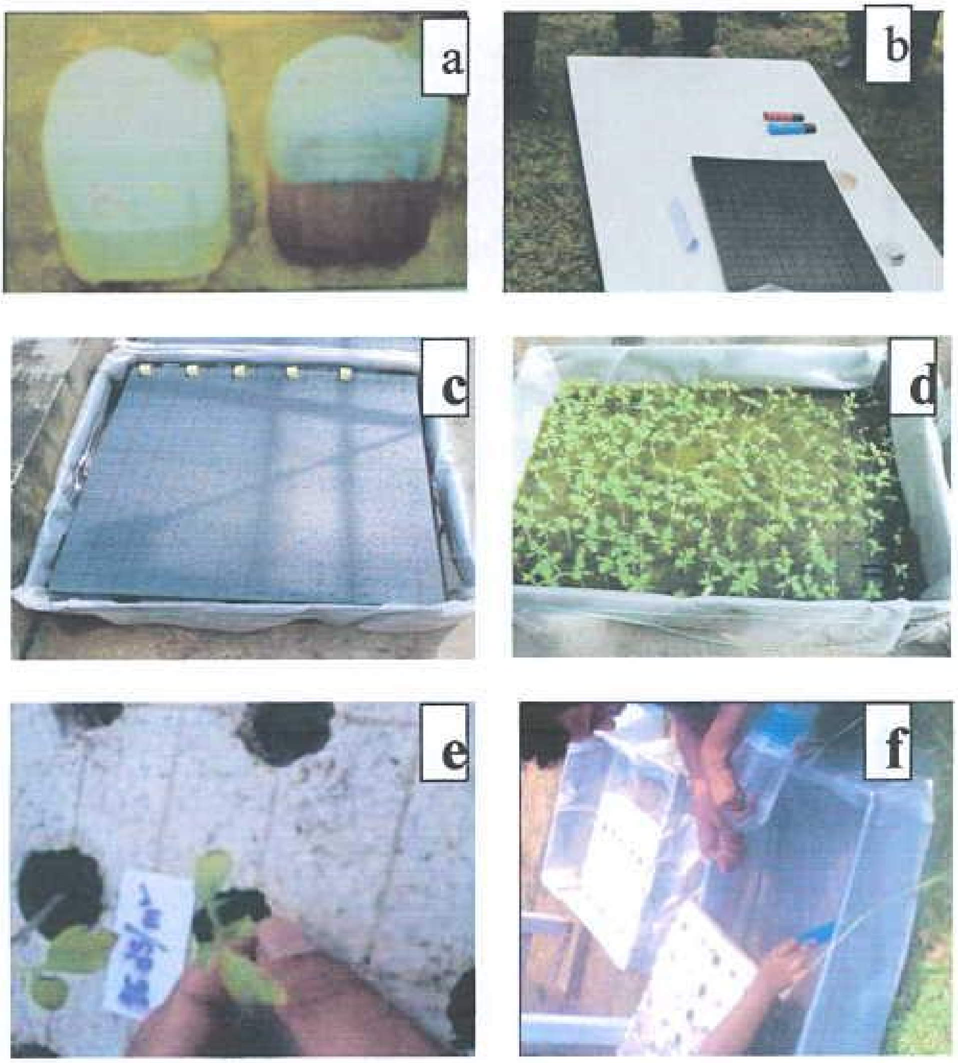

Plate 1. Photographs showing different stage of hydroponic study in tomato (a) Hogland's nutrient stock solution (b) Foam prepared for seed sowing (c) Tomato seeds were sown in foam plugged holes of polysterin coated iron trays (d) Distilled water were used for maintaing optimum moisture for seedling germination (e) Seedling transplanting (f) Salinity developed in respective treatments

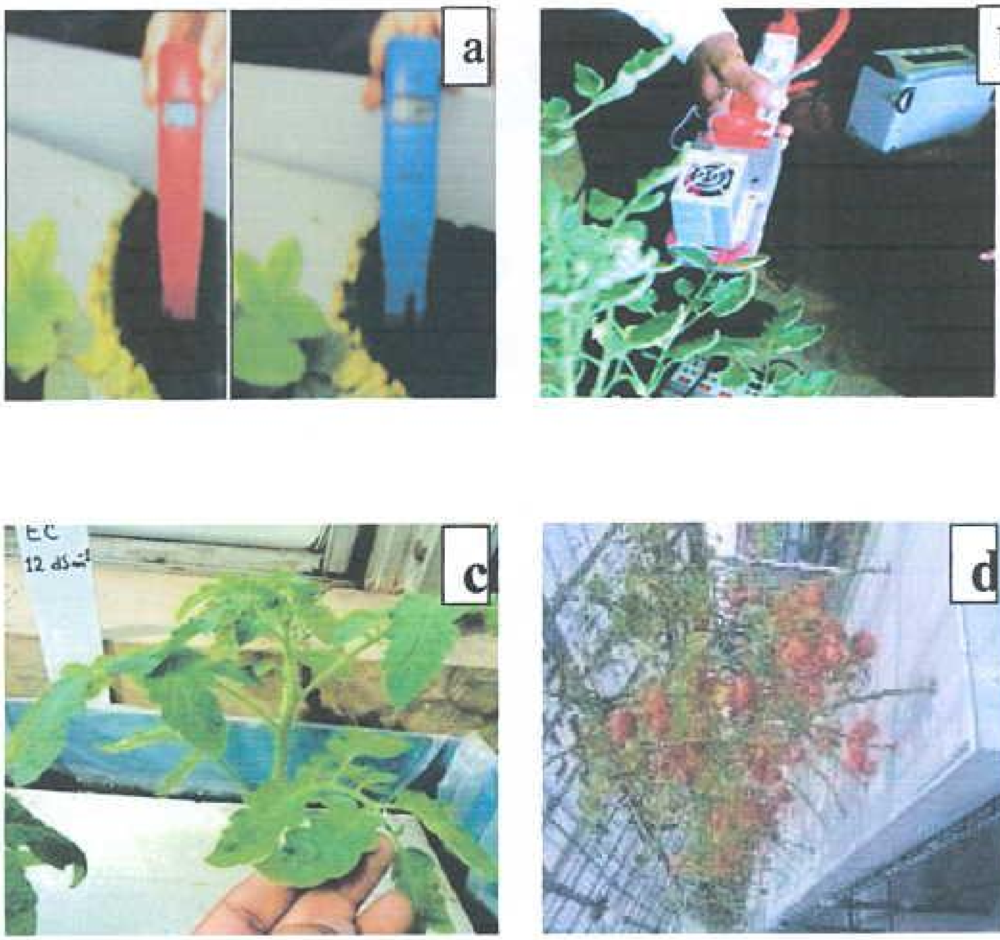

Plate 2. Photographs showing different stage of hydroponic study in tomato (a) pH and Ec monitored daily (b) SPAD reading (c) After 4 weeks plants were harvested manually (d) At maturity plants were harvested manually

3.3.3 Visual quality

Leaf greenness (total chlorophyll content) was measured using a hand-held chlorophyll meter (measured as the optical density, SPAD reading, Minolta Camera Co., Osaka, Japan) at the four weeks plants in each treatment. SPAD readings of three leaves per plant selected from the middle sections of the shoots were measured for all five treatments in each tank. Leaf area was measured by leaf area meter. In stomatal resistance determination we applied a diffusion porometer (Delta T Manufacturers, AP_4 type transient porometer.), that provides all the leaf resistance to water vapour, including any cuticular part and boundary layer resistance in the porometer chamber. The instrument measures the humidity increase in a closed chamber arising from the water loss of the leaf section.

3.3.4 Plant analysis

After four weeks plants were harvested manually and plant samples from each treatment were collected and divided into, different plant parts. Shoots and roots of one plant from each treatment were washed separately in deionized water to remove nutrient solutions and then dried at 70^0C for 48 h, reweighted, ground to pass a 60-mesh screen and digested for mineral nutrient analysis.

Table 3.2: Standard methods of plant analysis

Plant parameter	Digestion	Determination	References
Na, K	Digesting the samples in di-acid mixture (HNO_3-$HClO_4$ = 5 : 1)	Directly measured by AAS	Peterson, 2002
Cl	Digesting the samples in di-acid mixture (HNO_3-$HClO_4$ = 5 : 1)	Measured by Coulometric-amperometric titration.	SAS Institute, 1997

At maturity, plants were harvested manually and different yield parameters (plant height, root length and fruit yield plant^{-1}) were recorded.

3.3.5 Climate condition

Ambient daytime air temperature in the glasshouse during the experiment ranged from 14 to 30 ^{0}C (mean = 28 ^{0}C); night time temperature ranged from 12 to 30 ^{0}C (mean = 21 ^{0}C). Relative humidity ranged from 41.2% to 47.7% with a mean of 44.6% during the day and during the night.

3.3.6 Statistical analysis

Data were analyzed using MSTAT-C (version 2.1, Michigan State University, 1991). Analysis of varience (ANOVA) was conducted for significance of difference (LSD). Differences were declared significant at $P<0.05$ probability levels by the F-test. The F-protected LSD calculated at 0.05 probability levels according to Steel and Torrie (1980).

CHAPTER IV

RESULT AND DISCUSSION

This chapter contains results of the experiment and the follow-up discussion. For convenience, the whole chapter has been divided into three sections:

1. Yield & yield contributing data
2. Plant physiological parameter
3. Plant nutrient concentration

Indeed this was a study of the effects of different levels of salinity on the performance of tomato e.g. yield and yield contributing data (plant height, plant dry matter, fruit weight plant^{-1} and number of fruits plant^{-1}), plant physiological parameter (leaf area, total chlorophyll content, stomata resistance), Plant nutrient concentration (Na, Cl and K concentration in shoot and root dry matter). The results of the whole experiment are shown in Tables 4.1-4.5 and Figures 4.1-4.13 which have been discussed under the following sub sections.

4.1 Effects of different levels of salinity on growth, yield and yield attributing characters of BARI Tomato 14

4.1.1 Plant height

There were significant ($P<0.05$) differences among the tomato plant height by the application of different levels of salinity (Table 4.1). The plant height increased significantly with decreasing level of salinity. The tallest plant height (108.2 cm) was achieved when salinity was applied at the rate of 0 dSm^{-1} and the shortest plant (74.57 cm) grew from T_5 (16 dSm^{-1}) treatment (Table 4.1).Probably salinity create an unfavorable condition on plant growth, that is why plant height decreases with increasing level of salinity on this hydroponic culture. Tal and Shannon (1983) reported that salinity stress reduces elongation rate of the main stem in tomato. So that plant height may reduce at high salinity level. Oztekin and Tuzel (2011) also showed the same effect that plant height reduced with increasing level of salinity.

Tomato plant heights decreased linearly with an increase in the salinity of the irrigation water, in agreement with results reported by Zaiter and Mahfouz (1993). Cruz *et al.* (1990) reported that shoot length is one of the most reliable response indicators for a wide range of tomato genotypes under salinity stress. Significant reductions in fresh and dry weight of tomato shoots were reported in response to salinity stress (Bolarin *et al.*, 1991). Agong *et al.* (2003) showed the plant height, green matter value were significantly variable among the salt level across the tomato genotypes. The severe reduction in plant height demonstrated a consistent effect of salt stress in plant growth rate.

4.1.2 Leaf area plant^{-1}

Statistically significant variation was recorded for different level of salinity at hydroponic tomato culture for leaf area plant^{-1} (cm^2) (Table 4.1). Agong *et al.* (2003) showed the leaf area and other growth parameter were significantly variable among the salt level across the tomato genotypes. Leaf area plant^{-1} increased with decreasing level of salinity and maximum leaf area plant^{-1} (946.80 cm^2) was recorded at T_1 treatment. The minimum leaf area plant^{-1} (410.80 cm^2) was recorded at T_5 treatment as the application of salinity level (16 dSm^{-1}) (Table 4.1). (Munns & Termaat, 1986) showed the same effect of salinity on leaf area of tomato plant that one of the first plant responses to salinity stress is a reduction in plant growth rate with associated reductions in leaf area available for photosynthesis. Subsequently, excessive accumulation of salts can lead to death of tissues, organs, and whole plants. The sharp increase in leaf Cl^- at higher root to shoot ratio indicates that Cl^- accumulation is mainly associated to both an increased root biomass and a reduced leaf area rather than an increased transpiration flux, since the later decreases with salinity (Moya *et al.*, 1999; Estan *et al.*, 2005).

4.1.3 Plant dry matter

Plant dry matter (g) of tomato plant showed a statistically significant variation for different salinity level under present trial (Table 4.1). Plant dry matter (g) increased with decreasing level of salinity and the lowest plant dry matter (8.108 g) obtained from highest salinity level at the treatment T_5 (16 dSm^{-1}). The greatest significant plant dry matter (17.82 g) obtained with lowest salinity level at the treatment T_1 (0 dSm^{-1}). But T_1 and T_2 treatments are statistically similar and there are no significant difference between them (Table 4.1). Mohammad (1998) showed that shoot weight significantly reduced with increasing salinity stress.

4.1.4 Root dry matter

Statistically significant variation was recorded for different level of salinity at hydroponic tomato culture for root dry matter (g) (Table 4.1). Root dry matter increased with decreasing level of salinity and maximum root dry matter (0.75 g) was recorded at T_1 treatment. The minimum root dry matter (0.33 g) was recorded at T_5 treatment as the application of salinity level (16 dSm^{-1}). But T_1 and T_2 treatments are statistically similar and there were no significant difference between them (Table 4.1).

Table 4.1 Effect of different salinity levels on plant height, plant dry matter content and leaf area plant^{-1} of tomato plant

Treatment (dSm^{-1})	Plant height (cm)	Plant dry matter wt. (g)	Leaf area plant^{-1} (cm^2)	Root dry matter wt. (g)
T_1=0	108.2a	17.82a	946.80a	0.75
T_2=4	94.80b	17.74a	865.90b	0.73
T_3=8	85.60c	14.88b	504.80c	0.60
T_4=12	81.57d	13.82b	424.10d	0.48
T_5= 16	74.57e	8.108c	410.80e	0.33
$LSD_{0.05}$	2.472	2.345	1.108	0.17
CV (%)	1.80	1.51	0.11	9.92

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance

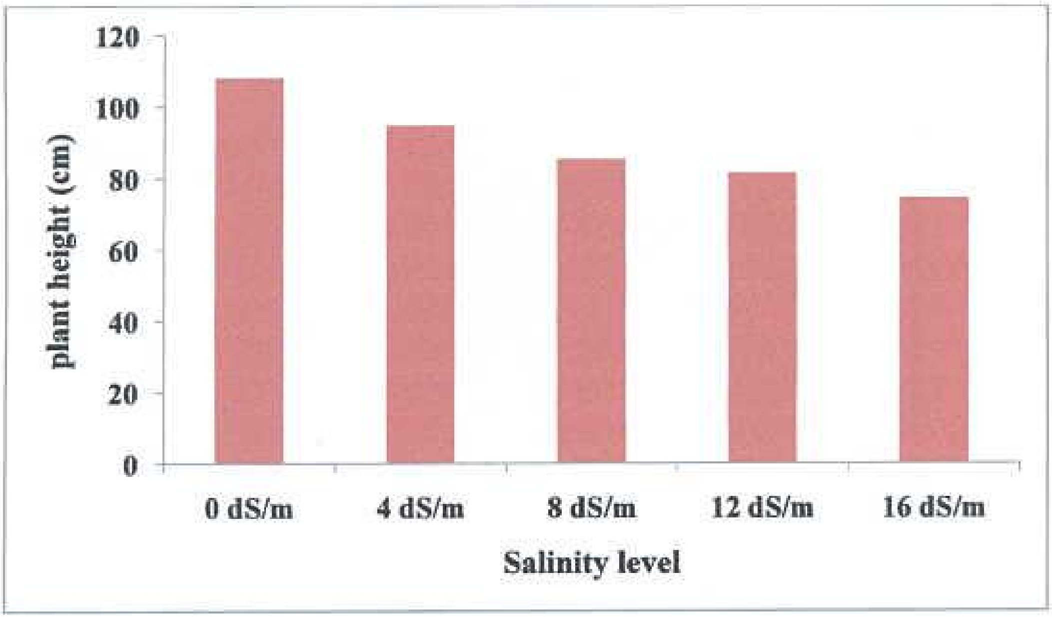

Figure 4.1 Effect of different salinity levels on plant height of tomato plant

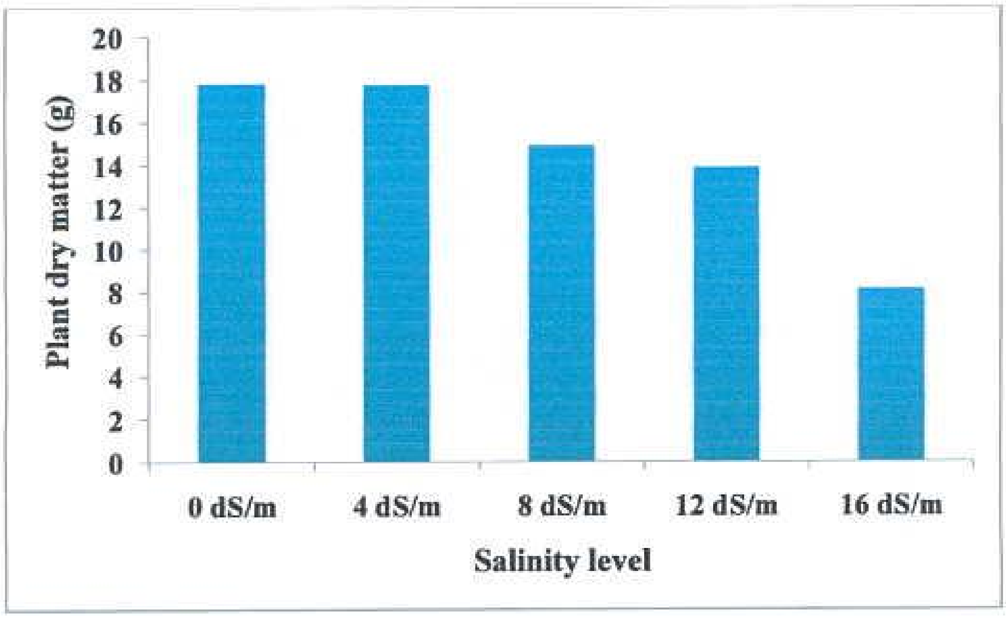

Figure 4.2 Effect of different salinity levels on dry matter content of tomato plant

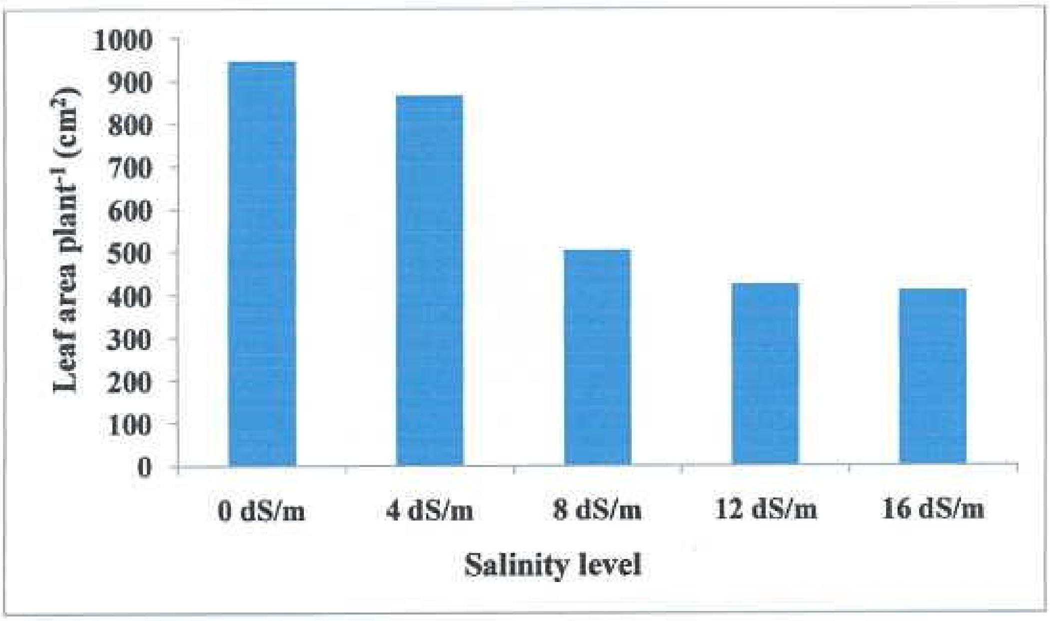

Figure 4.3 Effect of different salinity levels on leaf area plant^{-1} of tomato plant

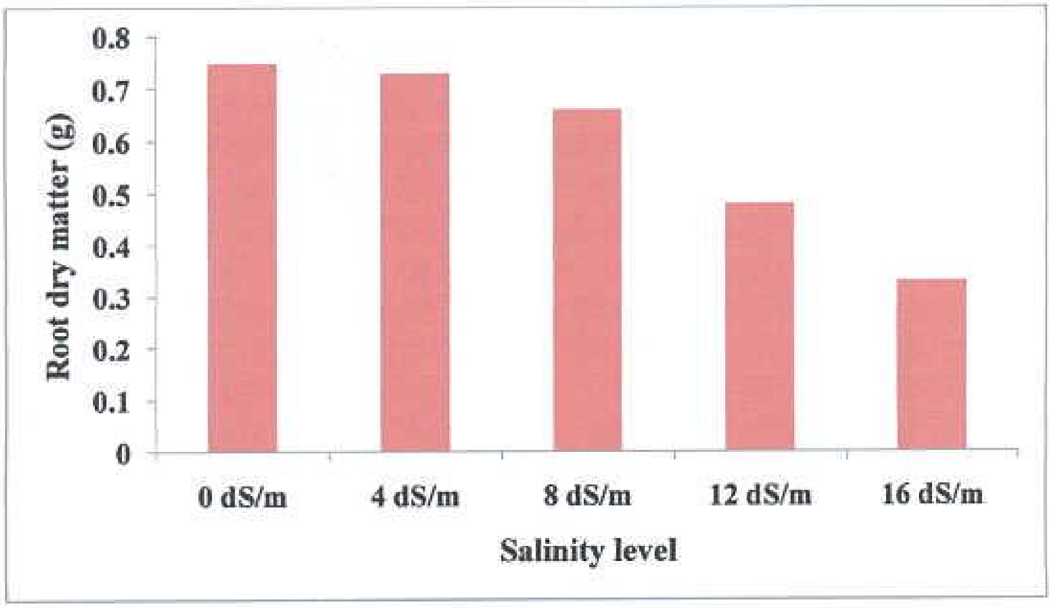

Figure 4.4 Effect of different salinity levels on root dry matter content of tomato plant

4.1.5 Fruit weight plant^{-1}

Fruit weight plant^{-1} was significantly affected by different salinity levels (Table 4.2). In salinity level 0 (control) gave the highest values (1.60 kg) fruit weight plant^{-1}. Whereas, high salinity level i.e. EC 16 dSm^{-1} treatment gave the lowest values (0.40 kg) (Table 4.2). There are inconsistencies in the literature regarding the contribution of fruit number to EC induced reductions in tomato fruit yield. Eltez *et al.* (2002) reported that the number of fruits was unaffected by moderate salinity and that reduced yield was entirely due to smaller fruit.

4.1.6 Number of fruits plant^{-1}

Treatment with lower salinity gave the higher values of most plant parameters as compared to the higher salinity. Tomato fruit number plant^{-1} was significantly affected by different salinity levels (Table 4.2). In salinity level 0 (control), tomato plants gave the highest number of fruits (19) which was statistically similar to the treatment T_2 (4.0 dSm^{-1}) where the fruits number per plant were 17. Whereas high salinity level i.e. EC 16 dSm^{-1} treatment gave the lowest values (Table 4.2). There are inconsistencies in the literature regarding the contribution of fruit number to EC induced reductions in tomato fruit yield. According to Olympios *et al.* (2003) the number of fruits/plant was restricted when the level of salinity in the root zone was 8 dSm^{-1} or higher. Comparing the response of tomato to different salinity levels, it could be clear that the values of fruit number and weight per plant were reduced in 8.0-12.0 dSm^{-1} salinity levels and it is lowest in 16 dSm^{-1}. This evidence could be a good sign for positive response of tomato plants to salinity.

Table 4.2 Effect of different salinity levels on the fruit number and fruit weight plant^{-1} of tomato plant

Salinity levels EC (dS m^{-1})	Fruit weight plant^{-1} (kg)	Fruits plant^{-1} (no.)
T_1=0	1.60 a	19 a
T_2=4	1.48 b	17 a
T_3=8	1.10 c	14 b
T_4=12	1.05 c	12 b
T_5= 16	0.40 d	8 c
LSD (0.05)	0.11	2.79
CV (%)	3.09	3.48

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance

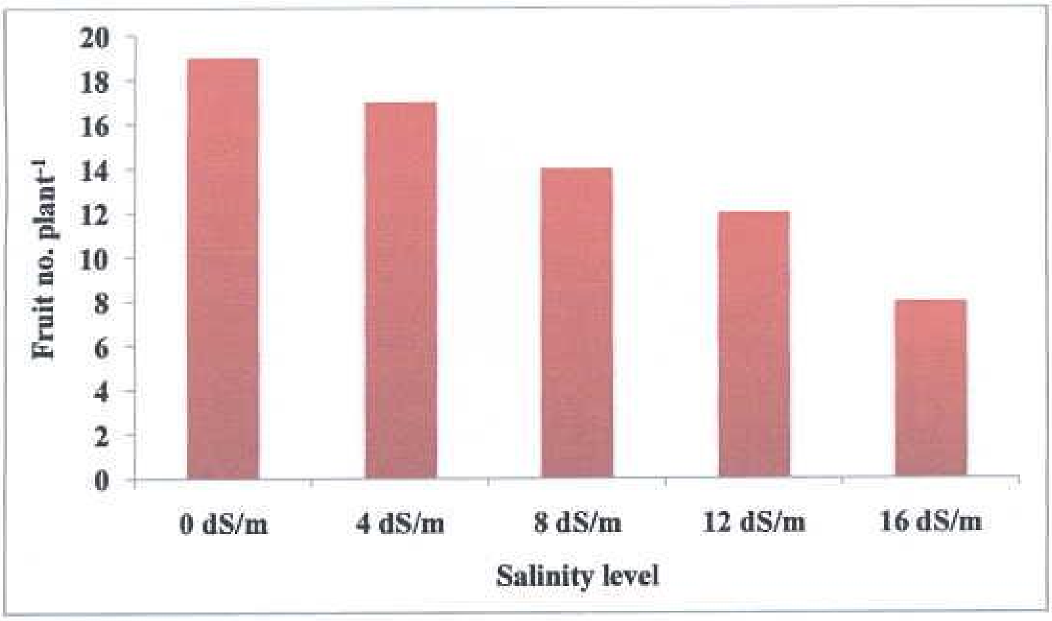

Figure 4.5 Response of tomato to different salinity levels on the fruit number Plant^{-1}

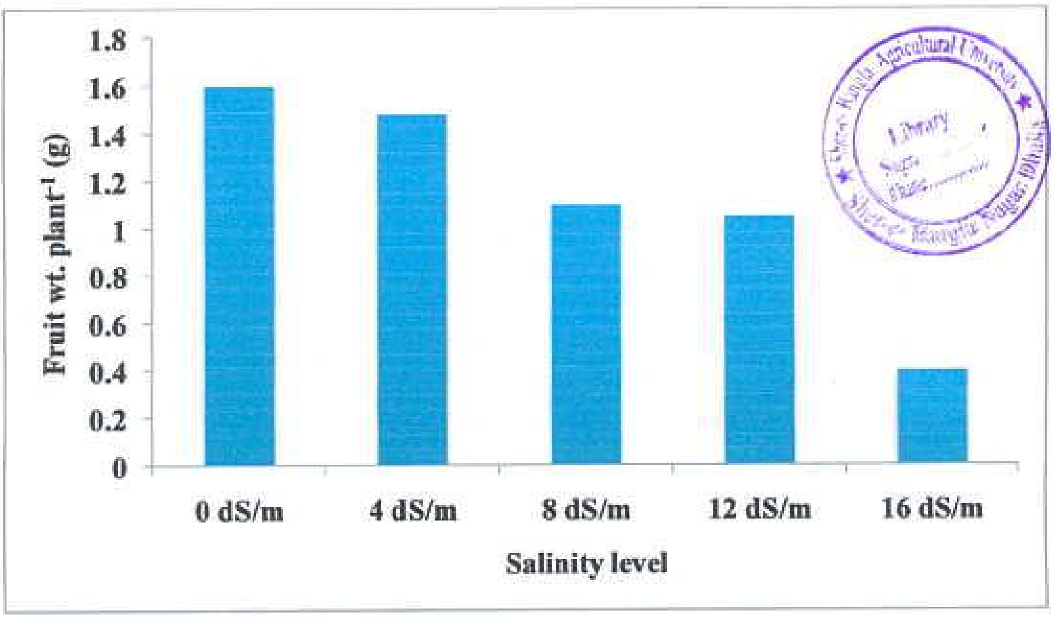

Figure 4.6 Response of tomato to different salinity levels on the fruit weight plant^{-1}

4.2 Effects of different levels of salinity on plant physiological parameters of BARI Tomato 14

4.2.1 Total chlorophyll content (mg g^{-1})

Different levels of salinity exhibited statistically significance variation for total chlorophyll content (mg g^{-1}) of plant (Table 4.3). The chlorophyll content decreased significantly with increasing level of salinity. The highest total chlorophyll content (24.10 mg g^{-1}) was found for the control treatment T_1 (0 dSm^{-1}) which was statistically similar with T_2 treatment comprising of 4 dSm^{-1} salinity level. The lowest total chlorophyll content (1.456 mg g^{-1}) was found at T_5 treatment comprising of 16 dSm^{-1} salinity level (Table 4.3). This result is in agreement with the statement of Munns (2002).

Hossain and Nonami (2012) stated that if excess amount of salt entered into plant, this salt finally rises to toxic level in leaf tissue which can cause early senescence of leaf. Finally, it reduces the photosynthetic capability of plant and retards the growth rate of plant and its other organs. Compared to control plants, total leaf chlorophyll content was decreased and photosynthetic activity were significantly reduced in increasing level of salinity (Horchani *et al.*, 2010).

4.2.2 Stomatal resistance (s cm^{-1})

There were significant (5% level) differences among the stomata resistance (s cm^{-1}) of tomato plant (Table 4.3). Stomata resistance (s cm^{-1}) increased significantly with increasing level of salinity. The highest stomata resistance (7.275 s cm^{-1}) was achieved when salinity was applied at the rate of 16 dSm^{-1} which is statistically similar with T_4 comprising of 12 dSm^{-1} salinity level and the lowest stomata resistance (3.075 s cm^{-1}) obtained from T_1 (0 dSm^{-1}) treatment (Table 4.3). This experiment got same result as Horchani *et al.*

(2010) showed that Compared to control plants stomata conductance and photosynthetic activity were significantly reduced in increasing level of salinity

Table 4.3 Effect of different salinity levels on total chlorophyll content and stomata resistance of tomato plant

Treatment (dSm^{-1})	Total chlorophyll content ($mg\ g^{-1}$)	Stomatal resistance ($s\ cm^{-1}$)
T_1=0	24.10a	3.075d
T_2=4	23.24a	4.565c
T_3=8	20.29b	5.722b
T_4=12	17.74c	6.747a
T_5= 16	15.87d	7.275a
$LSD_{0.05}$	1.456	.664
CV (%)	4.64	7.88

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance

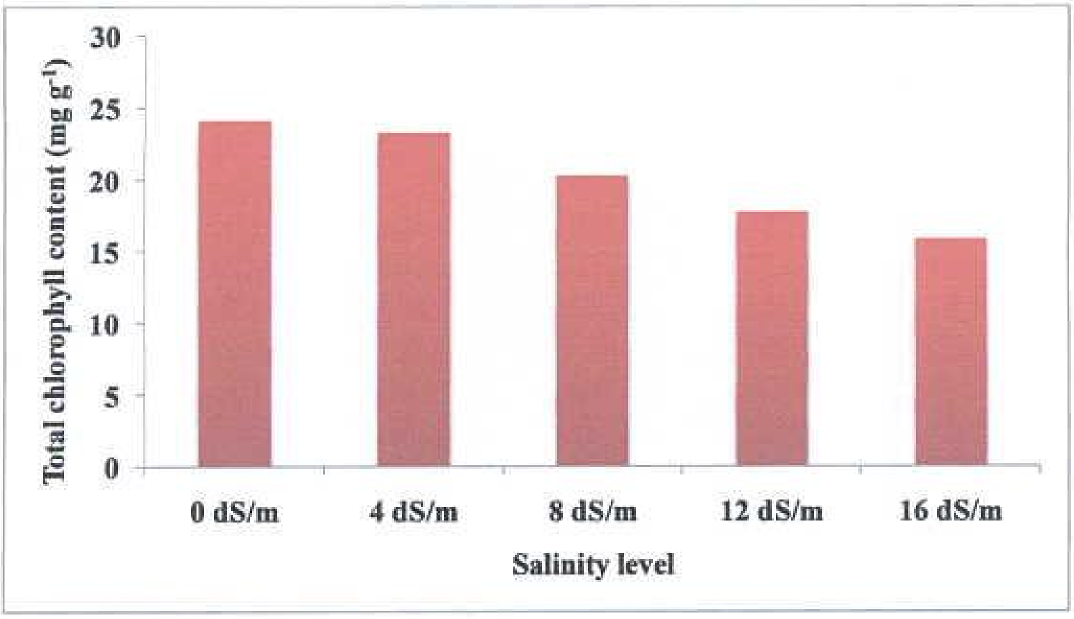

Figure 4.7 Effect of different salinity levels on total chlorophyll content of tomato plant

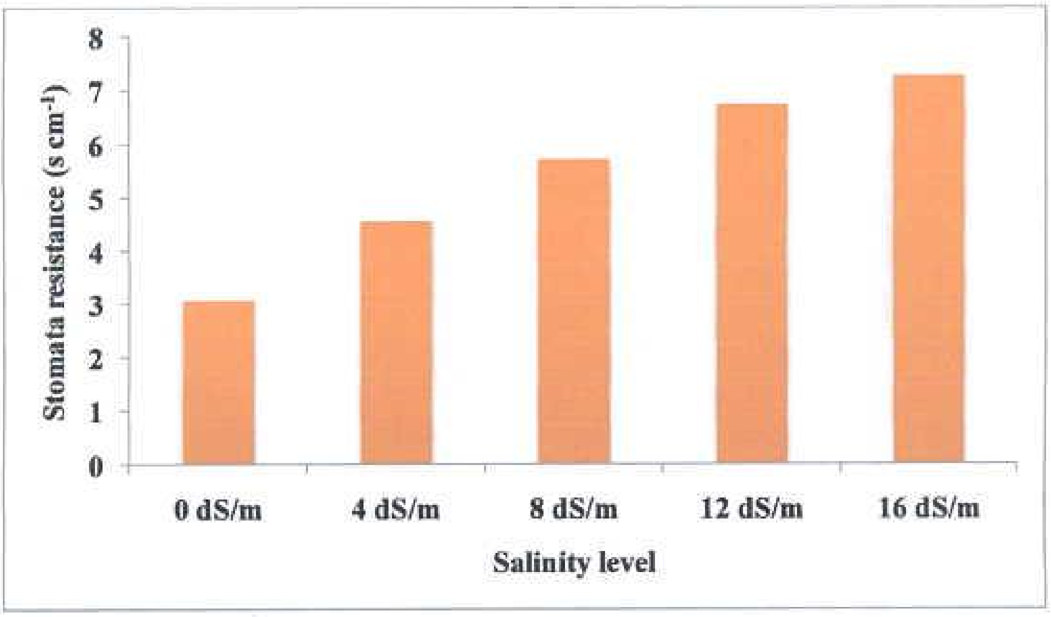

Figure 4.8 Effect of different salinity levels on stomata resistance of tomato plant

4.3. Effects of different levels of salinity on nutrient content of BARI Tomato 14

4.3.1 Nutrient content on shoot

4.3.1.1 Sodium content on shoot dry matter

Statistically significant variation was recorded for different level of salinity at hydroponic tomato culture for Na content on shoot dry matter of tomato plant in hydroponic culture (Table 4.4). Na content on shoot dry matter increased with increasing level of salinity and maximum Na content on shoot dry matter (43.60 mg kg^{-1}) was recorded at T_5 treatment (16 dSm^{-1}). The minimum Na content on shoot dry matter (6.55 mg kg^{-1}) was recorded at T_1 treatment as the application of salinity level (0 dSm^{-1}) which is statistically similar with T_2 comprising of 4 dSm^{-1} salinity level (Table 4.4). Horchani *et al.* (2010) agreed with this result. Data showed that tomato plants had high Na^+ concentrations in roots and leaves under salinity treatment. This may be related to a low K^+/Na^+ selectivity ratios when exposed to NaCl salinity. Nawaz *et al.* (1998) reported increased Na^+ concentration in leaf sap due to enhanced inward movement and inhibited outward active exclusion of this ion under the combined stress of salinity and water logging.

Under salinity stress the shoot dry weight negatively correlated (R^2=0.971) with Na^+ concentration (Figure 4.1). The higher concentrations of Na^+ and Cl^- in leaves become toxic to plants and lead to salt injury (Serrano *et al.*, 1999; Saqib *et al.*, 2005).

4.3.1.2 Chloride content on shoot dry matter

There were significant (5% level) differences among the Cl content on shoot dry matter (mg kg^{-1}) of tomato plant by the application of different levels of salinity (Table 4.4). Cl content on shoot dry matter (mg kg^{-1}) increased significantly with increasing level of salinity. The highest Cl content on shoot dry matter (288.00 mg kg^{-1}) was achieved when salinity was applied at the rate of 16 dSm^{-1} which is statistically similar with T_4 comprising of 12 dSm^{-1} salinity level and the lowest Cl content on shoot dry matter (49.75 mg kg^{-1}) obtained from T_1 (0 dSm^{-1}) treatment (Table 4.4). Increased Cl^- concentration in leaf sap under salinity stress might have resulted from excessive chloride concentration in nutrient medium that resulted in more uptake of Cl^- by plants (Shah and Jones, 1988). Maggio *et al.* (2007) showed that the leaf chloride increased with salinity, also. Similar to Na^+, the accumulation of Cl^- was proportional to the EC of the nutrient solution.

A significant negative correlation was found between shoot dry weight and chloride concentration (Figure 4.2). Under salinity stress the shoot dry weight production by tomato significantly correlated with Cl^- concentration (R^2=0.74). The figure showed that the shoot dry weight of BARI Tomato 14 variety decreased faster with the increase in Cl^- concentration. Amor *et al.* (2004) concluded that due to highest salinity (200 mM NaCl) Na^+ and Cl^- were largely accumulated in shoots and induced mineral nutrition disturbance within the plant shoot, as their Ca^{2+}, Mg^{2+}, and K^+ concentrations significantly declined.

4.3.1.3 Potassium content on shoot dry matter

Plant dry matter of tomato plant showed a statistically significant variation for different salinity level under present trial (Table 4.4). K content on shoot dry matter (mg kg^{-1}) increased with increasing level of salinity. The height K content on shoot dry matter (467 mg kg^{-1}) obtained at salinity level 0 dSm^{-1} at the treatment T_1. The lowest K content on shoot dry matter (314.80 mg kg^{-1}) obtained from highest salinity level at the treatment T_5 (16 dSm^{-1}). Na^+ and Cl^-

may inhibit the uptake of K^+ by root. Gorham and Jones (1993) showed that the effect of high concentrations of Na^+ and Cl^- in the root medium is the suppression of uptake of essential nutrients such as K^+, Ca^{2+}, NO^{3-} etc.

Decreased concentration in leaf sap under salinity could be attributed high external Na^+ concentration, which inhibited K^+ absorption. Also high Na^+ concentration in plants displace Ca^{2+} from the plasmalemma resulting in loss of membrane integrity and efflux of cytosolic K^+ and consequently the K^+ concentration in leaf sap is decreased (Cramer *et al.*, 1985). Maggio *et al.* (2007) showed that leaf calcium and potassium both decreased at increasing salinity indicating a reduced activity of these ions in the presence of NaCl and/or the occurrence of competition effects at the root surface.

Salinity at moderate and higher level of external supply of NaCl reduced the K^+ concentration in the leaves of tomato. An ionic imbalance occurs in the cells due to excessive accumulation of Na^+ and Cl^- and reduced uptake of other mineral nutrients, such as K^+, Ca^{2+}, and Mn^{2+} (Karimi *et al.*, 2005). Under salinity stress the shoot dry weight production by tomato negatively correlated (R^2=0.579) with Na^+ concentration (Figure 4.3). The higher concentrations of Na^+ in leaves also become toxic and lead to salt injury (Serrano *et al.*, 1999). Salt injury in plant leaves and stem is due to higher influx of Na^+ accompanying a reduction in K^+ uptake (Sharma, 1995) that are in accordance with our results where more growth reductions under saline conditions than at 8.0 mM K-level.

Table 4.4 Effect of different salinity levels on Na, Cl and K content of shoot dry matter of tomato plant

Treatment (dSm^{-1})	Dry matter Na (shoot) $mg\ kg^{-1}$	Dry matter Cl (shoot) $mg\ kg^{-1}$	Dry matter K (shoot) $mg\ kg^{-1}$
T_1=0	6.55d	49.75c	467.0 a
T_2=4	7.925d	136.00b	387.8 b
T_3=8	14.55c	145.80b	337.0 c
T_4=12	25.85b	258.50a	333.3 c
T_5= 16	43.60a	288.00a	314.8 d
$LSD_{0.05}$	3.323	31.80	9.296
CV (%)	1.95	1.75	1.56

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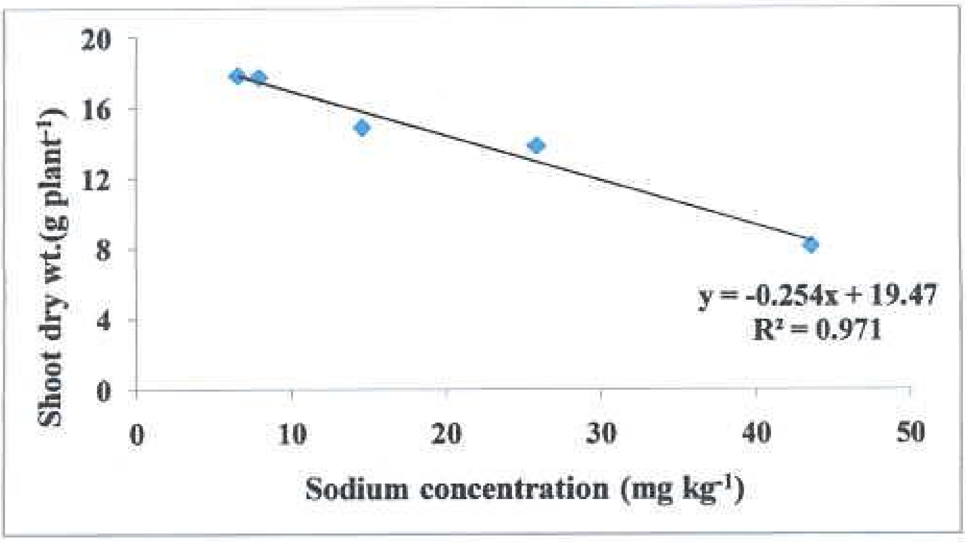

Figure 4.9 Relationship between shoot dry weight and Sodium concentration

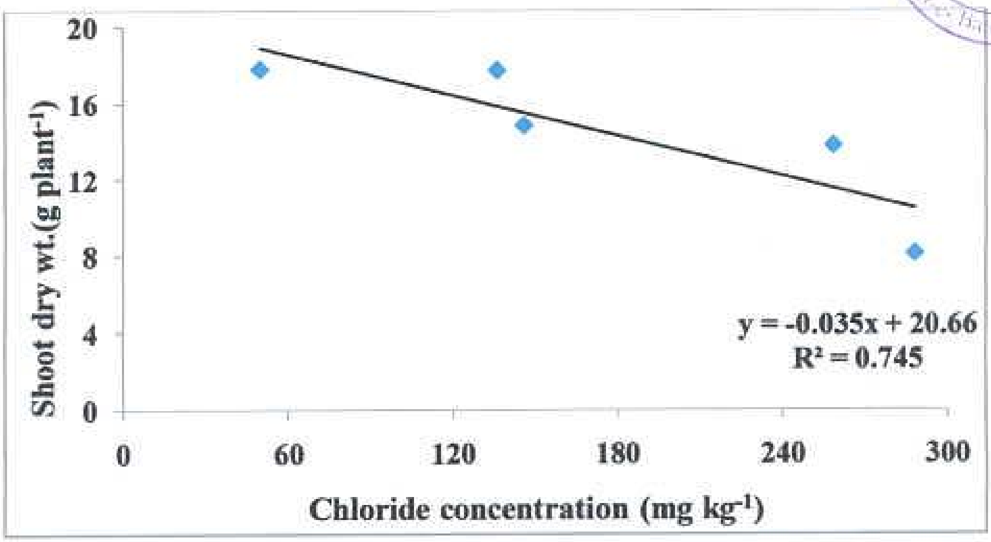

Figure 4.10 Relationship between shoot dry weight and Chloride concentration

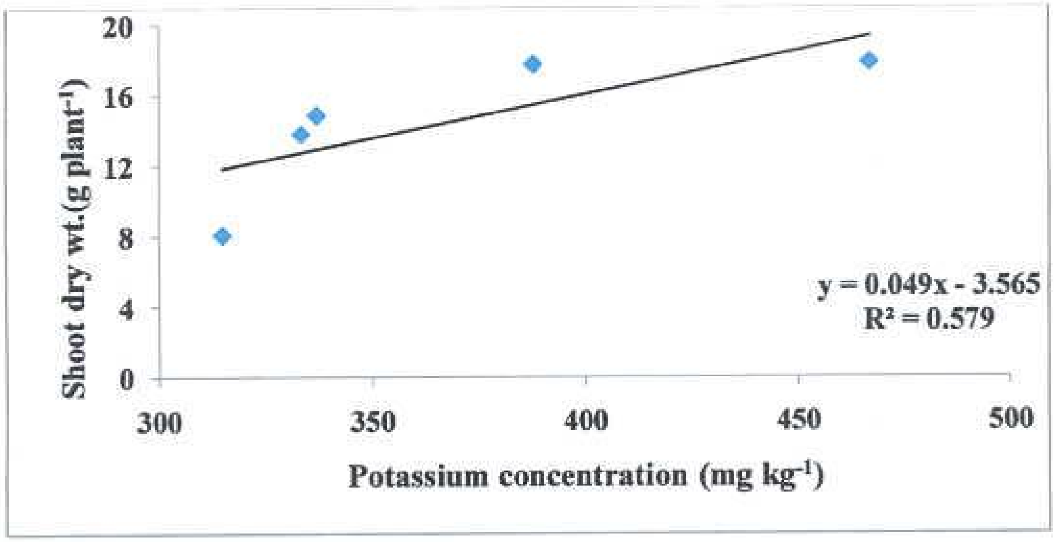

Figure 4.11 Relationship between shoot dry weight and Potassium concentration

4.3.2 Nutrient content on root

4.3.2.1 Sodium content on root dry matter

There were significant (P<0.05) differences among the Sodium (Na) content on root dry matter (mg kg^{-1}) that effects by the application of different levels of salinity on hydroponic tomato culture. (Table 4.5). The Na content on root dry matter (mg kg^{-1}) increased significantly with increasing level of salinity. The highest Na content on root dry matter (169.90 mg kg^{-1}) was achieved when salinity was applied at the rate of 16 dSm^{-1} and the lowest Na content on root dry matter (21.13 mg kg^{-1}) from T_1 (0 dSm^{-1}) treatment (Table 4.5). High concentrations of Na^+ and Cl^- in the root depress nutrient-ion activities and produce extreme relations of Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+} and $Cl^-/NO3^-$ (Grattan and Grieve, 1999). Horchani *et al.* (2010) showed salt treated plants, leaf and root Na^+ content was significantly increased.

4.3.2.2 Chloride content on root dry matter

Statistically significant variation was recorded for different level of salinity at hydroponic tomato culture for Cl content on root dry matter (mg Kg^{-1}) of tomato plant in hydroponic culture (Table 4.5). Cl content on root dry matter increased with increasing level of salinity and maximum Cl content on root dry matter (303.80 mg kg^{-1}) was recorded at T_5 treatment as the application of salinity level (16 dSm^{-1}). The minimum Cl content on root dry matter (45.00 mg kg^{-1}) was recorded at T_1 treatment as the application of (0 dSm^{-1}) salinity level (Table 4.5).

4.3.2.3 Potassium content on root dry matter

Root dry matter of tomato plant showed a statistically significant (5% level) variation for different salinity level under present trial (Table 4.5). K content of root dry matter (mg kg^{-1}) increased with increasing level of salinity application. The lowest K content on root dry matter (204.50 mg kg^{-1}) obtained from highest salinity level at the treatment T_5 (16 dSm^{-1}). The highest K content on root dry matter (440.00 mg kg^{-1}) was obtained at the treatment T_1 (0 dSm^{-1}) (Table 4.5). The decreasing or increasing trend of K content on root dry matter with different levels of salinity depend on the present level of the concentration of Na^+ and Cl^- into water where tomato plant was grown. When higher level of Na^+ and Cl^- present into water then these Na^+ and Cl^- inhibit the uptake of K^+ through root of tomato plant. For that reason K content on root dry matter decreased with increasing level of salinity. Horchani *et al.* (2010) showed leaf and root K^+ contents were significantly decreased by NaCl salinity.

Table 4.5 Effect of different salinity levels on Na, Cl and K content of root dry matter of tomato plant

Treatment (dSm^{-1})	Dry matter Na (root) $mg\ kg^{-1}$	Dry matter Cl (root) $mg\ kg^{-1}$	Dry matter K (root) $mg\ kg^{-1}$
T_1=0	21.13e	45.00e	440.00a
T_2=4	97.82d	89.00d	382.30b
T_3=8	124.40c	150.00c	317.5c
T_4=12	153.90b	253.8b	282.00d
T_5= 16	169.90a	303.8a	204.50e
$LSD_{0.05}$	9.675	41.77	12.95
CV (%)	5.54	16.10	2.58

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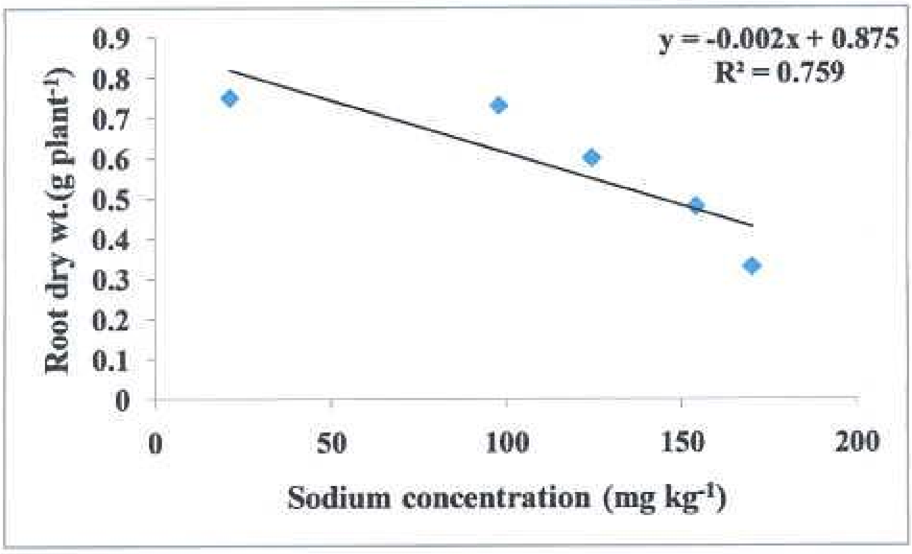

Figure 4.12 Relationship between root dry weight and sodium concentration

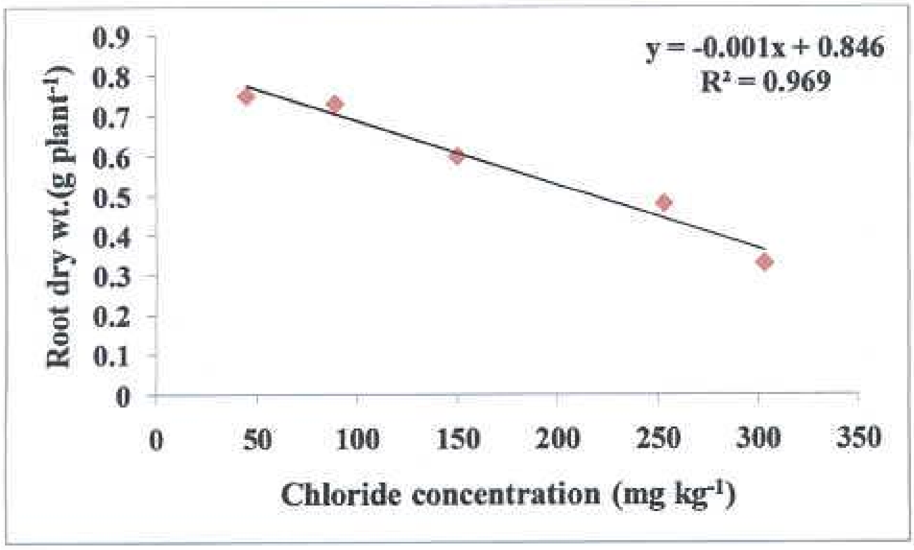

Figure 4.13 Relationship between root dry weight and chloride concentration

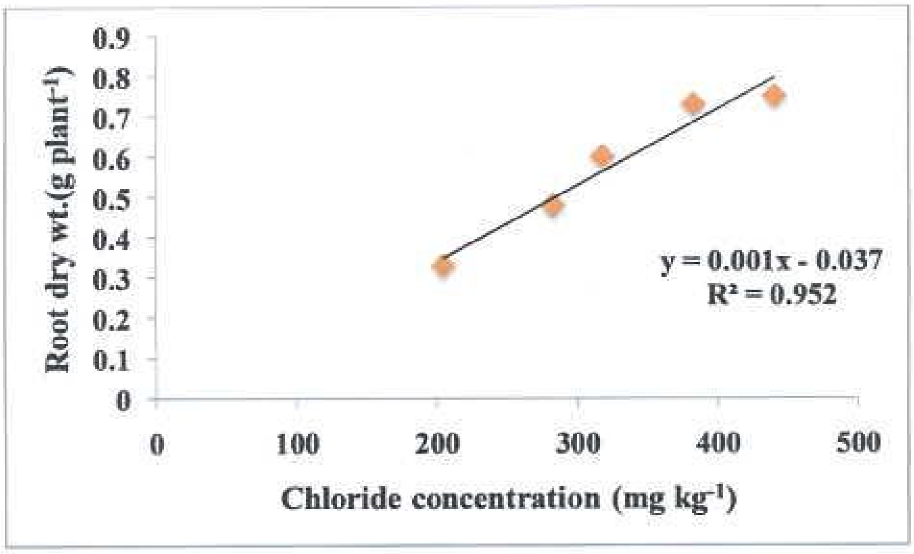

Figure 4.14 Relationship between root dry weight and potassium concentration

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Hydrophonic Culture House of Bangladesh Agricultural Research Institute (BARI), Horticulture Research Centre, Gazipur during the period 2011-2012. The glass house has a glass roof with no control over temperature, humidity and light as the sides are open having only a wire net to control birds.

The objective of the study was to observe the performance of tomato under different salinity level. Cork sheet was used on the water tank to hold the seedlings in the nutrient solutions. Ten seedlings were planted at November 2011 in each tank supported with cork sheet. The experiment consisting of variety BARI Tomato 14 experiments were laid out in Complete Randomized Design (CRD) with four replications. Each two seedlings were considered a replication.

The research was conducted to investigate the performance of different parameters of tomato plant under different salinity levels. Data were taken for different parameters from the entire period of experiment.

The tallest plant height (108.2 cm) was achieved when salinity was applied at the rate of 0 dSm^{-1} and the shortest plant (74.57 cm) grew from T_5 (16 dSm^{-1}) treatment.

Regarding the leaf area, maximum leaf area plant^{-1} (946.80 cm^2) was recorded at T_1 treatment of salinity level (0 dSm^{-1}). The minimum leaf area plant^{-1} (410.80 cm^2) was recorded at T_5 treatment of salinity level (16 dSm^{-1}).

Plant dry matter of tomato plant showed a statistically significant variation for different salinity level under present trial. Plant dry matter (g) increased with decreasing level of salinity and the lowest plant dry matter (8.108 g) was obtained from highest salinity level at the treatment T_5 (16 dSm^{-1}). The greatest significant plant dry matter (17.82 g) was obtained from lowest salinity level at the treatment T_1 (0 dSm^{-1}).

Different levels of salinity exhibited statistically significant variation for total chlorophyll content (mg g^{-1}) of plant. The highest total chlorophyll content (24.10 mg g^{-1}) at T_1 treatment comprising of 0 dSm^{-1} salinity level which was statistically similar with T_2 comprising of 4 dSm^{-1} salinity level. The lowest total chlorophyll content (15.87 mg g^{-1}) at T_5 treatment comprising of 16 dSm^{-1} salinity level.

In case of stomata resistance the highest stomata resistance (7.275 s cm^{-1}) was achieved when salinity was applied at the rate of 16 dSm^{-1} which is statistically similar with T_4 comprising of 12 dSm^{-1} salinity level and the lowest stomata resistance (3.075 s cm^{-1}) obtained from T_1 (0 dSm^{-1}) treatment.

Sodium content on shoot dry matter increased with increasing level of salinity and maximum Na content on shoot dry matter (43.60 mg kg^{-1}) was recorded at T_5 treatment (salinity level 16 dSm^{-1}). The minimum Na content on shoot dry matter (6.55 mg kg^{-1}) was recorded at T_1 treatment (salinity level 0 dSm^{-1}).

The highest Cl content on shoot dry matter (288.00 mg kg^{-1}) was achieved when salinity was applied at the rate of 16 dSm^{-1} which is statistically similar to T_4 comprising of 12 dSm^{-1} salinity level and the lowest Cl content on shoot dry matter (49.75 mg kg^{-1}) obtained from T_1 (0 dSm^{-1}) treatment.

The highest K content on shoot dry matter (487.80 mg kg^{-1}) was obtained at treatment T_1 (salinity level 0 dSm^{-1}) and the lowest K content on shoot dry matter (314.80 mg kg^{-1}) was obtained from highest salinity level at the treatment T_5 (16 dSm^{-1}).

The Na content on root dry matter (mg kg^{-1}) increased significantly with increasing level of salinity. The highest Na content on root dry matter (169.90 mg kg^{-1}) was achieved when salinity was applied at the rate of 16 dSm^{-1} and the lowest Na content on root dry matter (21.13 mg kg^{-1}) from T_1 (0 dSm^{-1}) treatment.

Chloride content on root dry matter increased with increasing level of salinity and maximum Cl content on root dry matter (303.80 mg kg^{-1}) was recorded at T_5 treatment as the application of salinity level was16 dSm^{-1}. The minimum Cl^- content on root dry matter (45.00 mg kg^{-1}) was recorded at T_1 treatment (salinity level 0 dSm^{-1}).

The lowest K content on root dry matter (204.50 mg kg^{-1}) obtained from highest salinity level at the treatment T_5 (16 dSm^{-1}). The highest of K content on root dry matter (440.00 mg kg^{-1}) was obtained at the treatment T_1 (0 dSm^{-1}).

From the result of present investigation it was revealed that-

1. Higher salinity level has hazardous effect on the growth of tomato plant.
2. Salinity inhibited nutrient uptake of tomato plant as well as chlorophyll content that reduces photosynthetic activity of plant which reduces dry matter content of tomato plant.

Considering the situation of the present experiment further studies in the following areas may be suggested :

1. Another level of salinity may be included in the further study.
2. Salinity stress may be used at different stages of life cycle of tomato plant can be also included in the program for future study.

CHAPTER V

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APPENDICES

Appendix.1 Soil salinity classwise area & Development Possibilities

Soil salinity Class	Area (million hactare) (mha)	Agricultural potential area
Very slight (Sl = 2.0-4.0 dS/m)	0.328	0.791 mha
Slight (S2 = 4.1-8.0 dS/m)	0.274	
Moderate (S3 = 8.1-12.0 dS/m)	0.189	
Strong (S4 = 12.1-16.0 dS/m)	0.161	0.262 mha
Very strong (S5 = >16.0)	0.101	

Source: Soil Resource Development Institute, 2010

Appendix II. Monthly records of Air temperature, Relative humidity and Rainfall of the experiment site during the period from November 2011 to April, 2012.

Month	* Air temperature (° C)		*Relative humidity (%)	*Rainfall (mm)
	Maximum	Minimum		
November, 2011	25.82	16.04	78	0
December, 2011	22.4	13.50	74	0
January, 2012	24.5	12.4	68	0
February, 2012	27.1	16.7	67	30
March, 2012	31.4	19.6	54	38
April, 2012	33.2	21.4	51	52

*Monthly Average

Source : Bangladesh Metrological Department (climate and weather division)

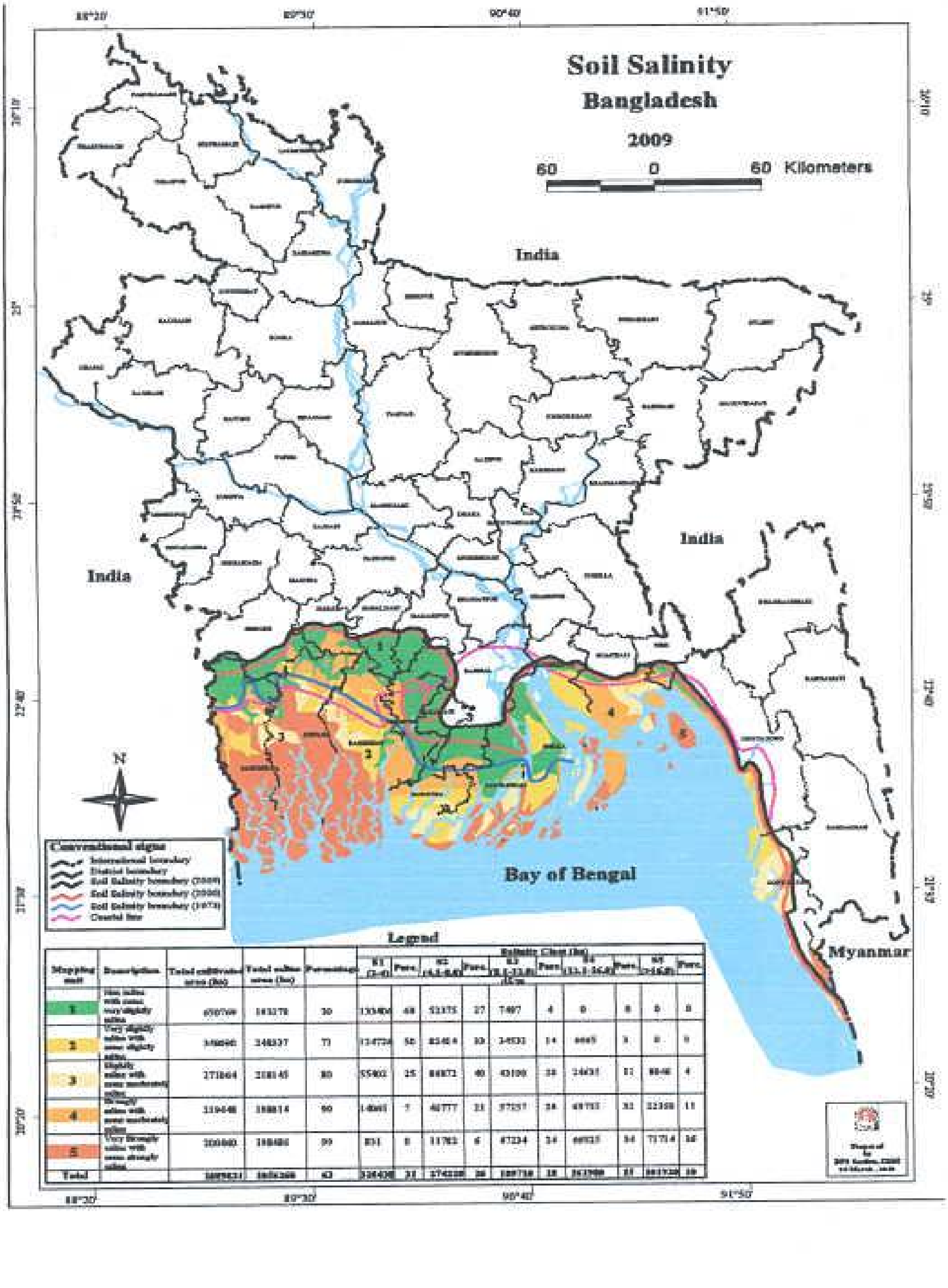

Plate 3. Soil salinity level in different areas of Bangladesh