SALINITY TOLERANCE OF FOUR WINTER VEGETABLES

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CERTIFICATE

This is to certify that the thesis entitled ***"SALINITY TOLERANCE OF FOUR WINTER VEGETABLES"*** *submitted to the* ***DEPARTMENT OF AGRICULTURAL CHEMISTRY,*** *Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTERS OF SCIENCE (M.S.)*** *in* ***AGRICULTURAL CHEMISTRY,*** *embodies the result of a piece of bonafide research work carried out by* ***MD. ROMJAN ALI****, Registration No.* ***13-05487*** *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.

June, 2020

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Dedicated to
My
Beloved Parents

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The Author

SALINITY TOLERANCE OF FOUR WINTER VEGETABLES

ABSTRACT

A pot experiment was conducted with four winter vegetables to assess the salinity tolerance ability of four selected crops *viz.* tomato, brinjal, radish and turnip. Four salinity levels *viz.* T_0 (no salinity; control), T_1 (3 dSm^{-1} NaCl), T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) were used. The experiment was conducted in Completely Randomized Design (CRD) with three replications during the period from November 2018 to February 2019. Different data on growth, yield contributing parameters and yield were collected and analyzed statistically. For all test crops (tomato, brinjal, radish and turnip), control treatment T_0 (no salinity) showed best performance on all the studied parameters. But considering salinity treatments significant influence was found on all growth and yield parameters and also on nutrient content in plant shoot. Results revealed that T_3 (9 dSm^{-1} NaCl) treatment showed lowest growth characters and yield of tomato (1.87 kg $plant^{-1}$) and brinjal (0.65 kg $plant^{-1}$) followed by T_2 (6 dSm^{-1} NaCl) compared to T_0 (no salinity) and T_1 (3 dSm^{-1} NaCl) (3.78 and 3.17 kg $plant^{-1}$, respectively in tomato and 1.34 and 1.10 kg $plant^{-1}$, respectively in brinjal). Radish and turnip had low salt tolerance capacity and with the salinity levels of T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl), death occurred at 40 and 30 DAT, respectively. Results also revealed that among the selected crops, radish and turnip was more sensitive to salinity stress and death occurred with higher salinity. So, it can be concluded that among four winter vegetables *viz.* tomato, brinjal radish and turnip; tomato and brinjal showed more tolerance to salinity compared to radish and turnip.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
dSm^{-1}	=	Decisiemen per meter
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
mL	=	Mili Liter
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percent
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

The human population relies on a relatively small number of staple crops for the bulk of its food intake. The major cereal crops rice, wheat and maize provide over 60 percent of energy intake, with potato, millet, sorghum, and yam also being regionally important as staple food. The staple foods alone do not provide a complete profile of all nutrients required for normal human growth and development. For example, rice generally is deficient in vitamin A. Thus, complementary foods play a vital role in reinforcing the nutritional value of the staple foods. Complementary foods such as meat, poultry, fish, legumes, and milk products are good sources of protein; oils, fats and sugars while vegetables, fruits, and animal products provide a variety of vitamins and minerals (Shannon and Grieve, 1998).

Vegetables provide a variety of health benefits being generally low in fat content and calories but rich in vitamins, protein, and fiber. They are also an important source of mineral nutrients such as phosphorus, potassium calcium, magnesium, iron, copper, manganese, selenium, and zinc (Savage and Deo, 1989; Demir and Mavi, 2008). They provide essential amino acids and antioxidants that the human body needs to function normally. Almost all vegetables used world-over are free of cholesterol. Vegetables, if eaten fresh or partially cooked, can help counter of many of the common diseases such as cancer, diabetes, blood pressure, vision loss, heart diseases, and a number of intestinal disorders (Khan, 1979; Shukla and Naik, 1993).

The worldwide demand for vegetables is increasing and this has boosted global vegetable production. According to the FAO (Food and Agriculture Organization) world vegetable production increased almost three-fold during the 30-year period from 1972 to 2002, from 158.73 to 429.40 million metric tonnes (Koike *et al.*, 2007). They further reported that the substantial increase in production has been particularly important in key vegetable crops such as

tomato, onion, cucumber, eggplant, cauliflower, pepper, lettuce, carrot, and spinach.

Vegetable crops are especially important for farmers with small holdings because an appreciably higher income per hectare can be generated by growing vegetables than from conventional staple crops (Genova *et al.*, 2006). However, vegetables are generally considered more vulnerable than staple crops to stressful environmental conditions including extreme of temperature, drought, salinity, waterlogging, mineral nutrient excess and deficiency, and changes in soil pH (Chinnusamy *et al.*, 2005). These environmental stresses are likely to be exacerbated by the prevalent climatic change in many parts of the world.

Excessive amounts of soluble salts in soil in many regions of the world, particularly in arid and semi-arid areas, limit production of most crops including vegetables (FAO, 2002). Like other crops, considerable variation in salinity tolerance of some vegetable crops has been reported. For example, broccoli, cabbage, cauliflower, tomato, eggplant, potato, turnip, radish, lettuce, pumpkin, cucumber, and pepper have been reported to be moderately sensitive, red beet *(Beta vulgaris)* is moderately tolerant, whereas okra, pea, onion, and carrot are highly sensitive to salt (Maas, 1990).

Of all the common vegetable crops, tomato has received most research attention regarding the effects of abiotic stresses including salt stress. Salinity negatively affects tomato root growth under soilless cultivation. According to the studies of Snapp *et al*. (1991), salinity reduces tomato root length density in the late growing season (after 67 days after transplant). Albacete *et al*. (2008) reported that tomato root fresh weight reduced (30%) after three weeks under saline conditions (100 mM NaCl). Root dry matter also showed reduction under salinity (10 dSm^{-1}) together with an increase in root-shoot ratio (Lovelli *et al*., 2011).

Eggplant (*Solanum melongena* L.) is an important vegetable crop for human nutrition worldwide and is a traditional vegetable crop in many tropical, subtropical, and Mediterranean countries. Eggplant growth has been shown to be sensitive (Bresler *et al*., 1982 and Jung *et al*., 2011) or moderately sensitive (Maas 1984 and Paul and Nair, 2008) to salinity depending on varieties or cultivars and environmental conditions.

Considering the area and production radish stands as one of the major vegetables crop of Bangladesh (Anonymous, 2010). The yield of radish is much lower in saline soil compared to salt free soil. The production technology of any vegetable as well as radish is a complex process and in saline condition it becomes more complex (Sivritepe *et al*., 2003).

Turnip (*Brassica rapa* L.) is also an important vegetable crop which is rich in vitamins, minerals (such as calcium, potassium, iron, copper, magnesium and zinc) and anti-oxidants. Like some other vegetable crops, turnip is also sensitive to salinity which depends on varieties or cultivars and environmental conditions (Noreen and Ashraf, 2008).

Accumulation of excess salt in the root zone resulting in the partial/complete loss of soil productivity is a worldwide phenomenon. Soil salinity is also a serious problem in areas where groundwater of high salt content is used for irrigation. It is a major challenge to crop plants and which limits agriculture all over the world, particularly on irrigated farmlands (Rausch and Wachter, 2005). Salinization of soils leads to soil degradation and reduced crop productivity on a global scale. (Acosta *et al*., 2011). Salt stress is one of the most brutal environmental factors limiting the productivity of vegetable crops because most of the vegetable crops are glycophyte in nature. Salt tolerance is important in vegetables because of their cash value.

Salt stress affects plant metabolism, which results in decreased growth and yields. Excess salt in the soil solution adversely affects plant growth either through osmotic inhibition of water uptake by roots or specific ion effects.

Specific ion effects may cause direct toxicity, while the insolubility and competitive absorption of ions may affect the nutritional imbalance of plants (Greenway and Munns 1980; Yoon *et al*. 2004; Yang *et al*. 2009). Additionally, salinity has been shown to increase the uptake of sodium (Na^+) or decrease the uptake of potassium (K^+) and calcium (Ca^{2+}) (Neel *et al*. 2002).

Terefore, the present study was conducted to study the salinity (NaCl) tolerance of some winter vegetables with the following objectives:

1. To evaluate the growth and yield contributing characters of four vegetables species (tomato, brinjal, radish and turnip) under salinity stress condition
2. To find out the best vegetables on the basis of yielding among four vegetables under different level of salinity

CHAPTER II

REVIEW OF LITERATURE

Comprehensive information is not yet available on the morphological, physiological and biochemical attributes of crops like tomato, brinjal, radish and rurnip as affected by salt stress. In this chapter, attempts have been made to review some important findings pertinent to salinity level which adversely affects on the morphological, physiological and biochemical traits and yield of different vegetables.

2.1 Plant response to salinity

The effect of salinity concentration on plant growth has been studied in different vegetable cultivars. From agronomic and physiological point of view as regards salinity response of this crop there are several studies (Maggio *et al*. 2011; Lovelli *et al.*, 2012). Extensive research is necessary to develop growing conditions in moderate salinity to produce good vegetative growth.

One of the initial effects of salt stress on plant is the reduction of growth rate. First, the presence of salt in the soil reduces the water uptake capacity of the plant, and this causes quick reduction in the growth rate. This first phase of the growth response is due to the osmotic effect of the soil solution containing salt, and produces a package of effects similar to water stress (Munns 2002; Nahar and Hasanuzzaman, 2009).

The mechanisms by which salinity affects growth of a plant depend on the time scale over which the plant is exposed to salt. Munns (2002) summarized the sequential events in a plant grown in saline environment. He stated that “In the first few seconds or minutes, water is lost from cells and shrinked. Over hours, cells recover their original volume but the elongation rates are still reduced which led to lower growth rates of leaf and root. Over days, cell division rates are also affected, and contribute to lower rates of leaf and root growth. Over

weeks, changes in vegetative development and over months changes in reproductive development can be seen".

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

Tomato as crop is moderately sensitive to salinity (Maggio *et al.*, 2007) and undoubtedly, salinity affects almost all the physiological and biochemical aspects of the plant development and reduce yield and quality of tomato from nutritional value and food safety (Kaouther *et al.*, 2012).

Although salinity stress has been reported to adversely affect the growth and productivity of okra, it is considered a semitolerant or moderately tolerant crop compared with many other vegetable crops. Salinity (NaCl) had a considerable inhibitory effect on seed germination of okra with Na^+, sugar, and phenols increased, and K^+, starch, and amylase activity decreased significantly in the cotyledons of germinating seeds (Dkhil and Denden, 2010). Fifty percent reduction in fresh fruit yield of okra has been reported at 6.7 dS m^{-1}. High levels of salinity have multiple adverse effects at the later growth stages of the crop life cycle. The morphology, physiology and metabolism of okra including the activities of various enzymes are adversely affected due to high levels of

salinity and crop yield is reduced (Abid *et al*., 2002). Ashraf *et al*. (2003) observed that rooting medium salinity significantly reduced shoot and root fresh and dry weights, total leaf area per plant, shoot length, and fresh pod yield of different cultivars of okra.

Despite the reduction in growth attributes, gas exchange characteristics like transpiration rate, stomatal conductance, leaf water potential, and turgor pressure were not severely inhibited under saline conditions (Abid *et al*., 2002; Ashraf *et al*., 2003). However, the photosynthetic pigment chlorophyll a and the chlorophyll a/b ratio increased in okra leaves in saline medium while no significant effect of salt stress was reported on chlorophyll b and carotenoid contents (Ashraf *et al*., 2003).

The mechanism of ion homeostasis has also been reported to be perturbed in okra. For example, concentrations and uptake of Na+ and Cl− increased, while those of K^+ and Ca^{2+} decreased in okra in response to NaCl-induced salt stress (Ashraf *et al*., 2003). Furthermore, shoot and root K^+/Na^+ and Ca^{2+}/Na^+ ratios were reported to be markedly decreased in okra under saline conditions (Ashraf *et al*., 2003).

Tomato is considered by some authors to be sensitive to moderately sensitive to salt stress (Ciobanu and Sumalan, 2009) and 50% yield loss occurs at moderate salinity level (5 dS m^{-1}) (Ciobanu and Sumalan, 2009). Other authors report tomato to be moderately tolerant with 50% yield losses at 7.5-8 dS m^{-1} (Parra *et al*., 2007). Salinity stress has been reported to cause alteration in a variety of morphological attributes and to decrease almost all growth parameters, including shoot and root fresh and dry weights, plant height, total leaf area and yield, and some yield quality attributes (Eraslan *et al*., 2008), although some salinity is commonly used to improve fruit quality. It has also been reported that both vegetative and fruit growth of tomato decrease markedly under saline conditions (Campos *et al*., 2006). However, this growth reduction is more apparent in salt sensitive than that in salt-tolerant genotypes

(Eraslan *et al*., 2008).

Salt stress also causes changes in a range of metabolic processes. For example, protein contents and activities of ascorbate peroxidase and catalase decreased, proline contents increased, and superoxide dismutase activity remained unchanged under saline conditions (Chookhampaeng *et al*., 2008). In mature tomato fruit, the amount of sucrose and the activity of sucrose phosphate synthase increased while fruit yield decreased under saline conditions (Chookhampaeng *et al*., 2008). Carbon partitioning and sucrose metabolism in both sink and source organs have been studied in salt-tolerant and salt-sensitive tomato genotypes (Balibrea *et al*., 2000).

Physiological efficiency of tomato is also adversely affected by saline conditions. For example, leaf water and osmotic potentials decreased in tomato plants while endogenous ABA concentrations increased under saline conditions (Maggio *et al*., 2007). Furthermore, considerable decrease in stomatal conductance and evapotranspiration was observed in tomato plants subjected to saline medium (Katerji *et al*., 1998). The activity of the nitrate reductase decreased under saline conditions and this reduction was ascribed mainly to lower uptake of NO3 and higher uptake of Cl^- (Flores *et al*., 2002). Increase in proline content, MDA, ascorbic acid, and hydrogen peroxide was reported in tomato under saline regimes by Eraslan *et al*. (2008).

Eggplant is considered to be moderately sensitive to salt stress (Savvas and Lenz, 1996), whereas Bresler *et al*. (1982) considered it a salt-sensitive vegetable. However, tolerance varies amongst eggplant varieties. Yield loss up to 50% was observed in eggplant at 8.5 dS m^{-1} of soil salinity. As well as appraising overall response of various varieties of eggplant to soil stress, their response to salinity stress at various growth stages has also been examined (Chartzoulakis and Loupassiki, 1997). However, they concluded that initial growth stages, i.e. germination and seedling stages, are the most sensitive to salinity stress. For example, salt (NaCl) stress caused considerable reduction in

germination percentage and rate, radicle and hypocotyl fresh and dry weights and their length, seedling length, seedling root and shoot fresh and dry biomass, and leaf area. Under saline conditions seedling leaf Na^+ concentration increased while that of K^+, and K^+/Na^+ ratios decreased. It has been noted that salinity tolerance in eggplant increases with growth period (Akinci *et al*., 2004).

Salt stress also adversely affects the plants at later stages including shoot and root fresh and dry weights, shoot and root lengths (Hamdy *et al*., 2009; Akinci *et al*., 2004; Abbas *et al*., 2010), and the gas exchange characteristics, net CO_2 assimilation rate, transpiration rate, stomatal conductance, and internal CO_2 concentration. In contrast, water use efficiency of eggplant is not affected by salt stress (Abbas *et al*., 2010). It has been observed that water consumption of eggplant decreases under saline conditions (Unlukara *et al*., 2010). Potassium (K^+) and Ca^{2+} concentrations and the K^+/Na^+ ratio also decrease while concentrations of Na^+ and Cl^- in plant tissues increase in saline medium. Similarly, leaf glycinebetaine and proline concentrations were reported to increase under saline conditions. Salinity also markedly reduces both fruit weight and number of fruits per plant (Abbas *et al*., 2010).

Research on the effect of salt on carrot response to salinity stress is scarce. For example, shoot and root fresh and dry weights of carrot have been reported to be reduced markedly under saline conditions (Inal *et al*., 2009). In storage roots, Na^+, K^+, Ca^{2+}, and Cl^- concentrations were considerably lower than those in the shoots under saline conditions (Gibberd *et al*., 2002; Inal *et al*., 2009). As in most glycophytes shoot and root Na^+ and Cl^- concentrations increase significantly while those of K^+ and Ca^{2+} decrease in the carrot plant under saline conditions. Salinity of the root growing medium reduces Br, S, and Si and increases Mg, Cu, Fe, Al, Cs, and Ni concentrations in carrot (Inal *et al*., 2009). According to one estimate, salinity stress reduces root yield by 14% per unit increase in salinity beyond the threshold of 1.0 dS m^{-1} (Maas,

1984).

All growth stages of the potato plant are affected by salt stress. Root medium salt stress was reported to reduce shoot and root lengths with more reduction in salt-sensitive cultivars than in tolerant ones. The tolerant cultivars showed enhanced accumulation of free proline and total soluble sugars compared with the sensitive cultivars (Aghaei *et al*., 2008; Zhang *et al*., 2009). Although total soluble proteins have been reported to reduce in potato plants under saline conditions (Zhang *et al*., 2009), defense-associated proteins were found to be upregulated under saline conditions, and these have been suggested to be involved in the mechanism of salt tolerance (Aghaei *et al*., 2008). Activities of antioxidants also undergo considerable changes in the potato plant under saline conditions. For example, superoxide dismutase activity increased, while that of catalase decreased, and ascorbic acid showed no significant change under salt stress conditions. Also cellular H_2O_2 was reported to increase in the potato plant under saline conditions. Other physiological parameters such as water content, transpiration rate, and stomatal conductance also reduce under saline conditions (Fidalgo *et al*., 2004).

Ghosh *et al*. (2001) reported that root medium salt increases total water soluble starch and total non-structural starch contents in potato plants. Both these starch contents increase at early growth stages but decrease at later growth stages. They observed considerable changes in endogenous levels of inorganic nutrients have been reported in the potato plant under salt stress, for example, under saline conditions, Na^+ and Cl^- contents increased in all parts of the potato plant including leaves, stem, and tuber, but K+ decreased in leaves and increased in stem and tuber. Calcium contents also decreased in leaves and stem, but increased in the tuber under saline conditions.

Salt stress significantly alters the molecular responses of the potato plant. For example, Legay *et al*. (2009) reported that salinity suppresses several transcripts coding for a variety of proteins related to photosystem-I and -II, and

chlorophyll synthesis. In addition to suppression, various pathways are upregulated by salinity including those of ABA-dependent or ABAindependent pathways and others involved in plant defense mechanisms. These author continued that salt stress also activated other proteins involved in abiotic or biotic stress tolerance, e.g., heat shock proteins, late embryogenesis abundant protein, dehydrins and pathogenesisrelated proteins. Carbohydrate and amino acid metabolisms related to gene expressions have also been reported to undergo significant changes in potato plants exposed to root medium salinity.

2.2 Morphological and yield attributes of crops as affected by salinity

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

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

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

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

Dolatabadian *et al.* (2011) observed that salinity stress significantly decreased shoot and root weight, total biomass, plant height and leaf number of Mustard *(Glycine max).* However, leaf area was not affected by salinity stress. Kaouther *et al.*, (2012) studied the salt stress (NaCl) Tunisian cultivars of chili pepper and showed that the growth, chlorophyll content and fluorescence were severely affected. Similar results were reported in potato (Kerkeni, 2008) for root length, in canola (Byund, 2010) for leaf area and in groundnut (Mensah *et al.* 2006) for number of leaves.

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

Na + and Cl - (Guan *et al.,* 2011) .

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

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

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

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

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

Shimul *et al.* (2014) attained the response of tomato to salinity and revealed that the significant variation was found with different level of salinity for leaf area. Highest leaf area (946.80 $cm^{2)}$ was observed in salinity control while lowest (410.80 cm^{2}) was recorded with 16 dSm^{-1}. Hassine *et al.* (2010) stated plant height, number of flower cluster, fruit number and yield were not adversely affected up to 8 dS m^{-1} but ripening was delayed. Increased yield over the control was noted with salt concentrations of 4 and 6 dSm^{-1}.

Chookhampaeng *et al.* (2007) conducted an experiment to determine the salinity stress inhibits overall plant growth. The result showed that shoot and root lengths increased with the application of different sand priming treatments under salinity stress. This increased shoot and root lengths as compared to high salt stress may be due to enhanced cell wall extensibility of the primed seeds. Higher fresh and dry weights are reported to correlate with the earlier start of germination. Resultant increased fresh and dry weights in sand primed seeds are in conformity with the findings of earlier researchers (Jamil *et al.* 2012).

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

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

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

Mirabdulbaghi and Pishbeen (2012) noticed in two barley varieties namely Afzal and EMB82-12 with increasing levels of salinity. The reduction in shoot

biomass production by the plant may be due to the chlorosis and necrosis of the leaves that reduce the photosynthetically active area (Lester, 2006). The decrease in fresh reducing number of fruit and diameter causes the lower yield of 2040%. Potato and cucumber showed no loss in yield and quality due to soil moisture stress developed under saline conditions and the suppression of growth under salinity stress during the early developmental stages.

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

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

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

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

2.3 Biochemical attributes of crops as governed by salinity

The detrimental effects of salt on plants are the consequence of both water deficit that results from the relatively high solute concentrations in the soil as well as stress specific to Cl^- and Na+, resulting in a wide variety of physiological and biochemical changes that inhibit plant growth, development (Taffouo *et al.,* 2008).

Xinwen *et al.* (2008) found that the Chlorophyll level is an index of the photosynthesis and decrease in Chlorophyll level lead to reduction in growth parameters. Salinity can lead to oxidative stress and causing significant decrease to photosynthetic systems. Carotenoids can protect photosynthetic system against reactive oxygen species generate under salt stress (Perveen, 2010). Decrease in chlorophylls level under salt stress may be due to reduction in pigment biosynthesis or enzymatic chlorophyll degradation (Xu *et al.,* 2008; Yang *et al.,* 2011).

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

the effect ascribed to increase level of the toxic cation, Na+ (Pinheiro *et al.* 2008).

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

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

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

Demir *et al*. (2010) confirmed reported that the ratio for a normally functioning leaf varies between 0.75 and 0.85 and a decline in this ratio is indicative of photoinhibitory damage. Salt stress has significant effect on PSII photochemical activity, in strawberry (Rahimi and Biglarifard, 2011). However, there are some reports that suggest that salt stress may not causes changes in Fv/Fm ratio in wheat (Akram *et al.,* 2007) and pepper (Ibn Maaouia Houimli *etal.*, 2008).

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

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

Zhang *et al*. (2009) reported that salinity-induced osmotic effect on plants consequently leads to a partial stomata closure thereby lowering the stomatal conductance as well as substomatal CO2 concentration. It is evident that photosynthetic capacity has a positive association with a biomass production or a seed yield in plants under saline stress, including the crops, *Oryza sativa* (Moradi and Ismail 2007), *Phaseolus vulgaris* (Seemann and Critchley 1985),

Gossypium hirsutum (Pettigrew and Meredith 1994), *Spinacia oleracea* (Robinson *et al.* 1983). Levent-Tuna *et al.* (2007) reported that water stress reduced transpiration water losses by reducing stomatal conductance.

Amirjani (2011) illustrated that sugars are source of energy and carbons needed for adaptive and /or defensive responses to stresses. The high salinities stimulated sugar accumulation in leaves, whereas proline accumulation was primarily induced by increased NO^-_3 in leaves (Bayoud, 2010) and In addition, sugars such as raffinose and sucrose are indicated to have important roles in protecting cells from water stress (Ashraf *et al.,* 2003).

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

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

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

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

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

Reduction in potassium absorption, coupled with a sharp increase in sodium accumulation had a negative impact on photosynthesis, therefore reducing growth and the accumulation of dry matter (Saibo, *et al.* 2009; Maggio *et al.*, 2007).

2.4 Nutrient concentration in vegetables shoots and roots as affected by salinity

Nutrition is a complex process involving 16 essential nutrients, as well as many other chemical elements that are either beneficial or harmful to plant metabolism. Ion uptake and compartmentalization are crucial not only for normal growth but also for growth under saline conditions (Shibli *et al.,* 2007). Increased salt concentration in the vicinity of the root system can interfere with mineral nutrition of plants and limit yield due to salinity or osmotic value of the soil solution.

Al-Busaidi, *et al.* (2010) found that tomato cultivars varied greatly in their response to different salinity levels. Increasing NaCl concentration in nutrient solution adversely affected on crop shoot and roots, plant height, K concentration, and K/Na ratio. Kumar *et al*, (2008) excluded that high concentrations of NaCl act antagonistically to the uptake of the other nutrients, such as K^+, Ca^{2+}, N, P.

Nasser and Sholi (2012) conducted an experiment to find out the plant growth and seed germination severely affected by salinity and observed that, the effect of four levels of salinity (0, 50, 100 and 150 mM NaCl) on seed germination, plants growth (relative fresh and relative dry weight), K^+ and Na^+ content and photosynthetic rate of the four local cultivars (Heb, Ram and J1) and one commercial cultivar (Mar) was studied. Significant difference in G50 of Heb cultivar was seen at 50 and 100 mM NaCl when compared with the other four cultivars ($p<0.05$) and the only one achieved 50% germination at 150 NaCl. No significant difference was seen in K^+/Na^+ ratio among four cultivars tested, but Ram showed the maximum value of 5.72 and 35.09 at 50 and 100 mM NaCl, respectively. Ram also showed better photosynthesis rate (5.1, 3.71) at 50 and 100 mM NaCl, respectively, than the other four cultivars.

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

Nightingale and Farnham (2011) found that with increase in osmotic pressure the amount of soluble organic nitrogen and proteins in sweet peas decreased, while the nitrate form of nitrogen accumulated. Yildirim *et al.,* (2009) found that the lack of water through a salt stress may result in slowing down the

metabolism of plants grown on saline soils. Nitrogen concentration in control plants was higher than salt stressed plants. Different studies showed nitrogen concentration decrease in salinity conditions (Kumar *et al.*, 2008).

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

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

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

Singh and Pishbeen (2009) illustrated that plant response to phosphorus fertilizers depends on the degree of soil salinity. In general, the use of phosphorus fertilizers in saline soils helps to increase vegetable yields directly by adding phosphorus and by reducing absorption of toxic elements such as chlorine Cl^- (Carillo *et al.*, 2005) and fluorine F^-. Rising in calcium level in the saline conditions contributed to increasing phosphorus concentration in leaf significantly.

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

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

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

Nazar *et. al.* (2011) reported that sulfur has a very effective and positive role in reducing the effects of salinity and alkalinity stresses via improvement of physicochemical properties of saline and alkaline soil, increasing of

permeability, decreasing of pH, loss and removal of irrigation water bicarbonate. Increases, decreases or remain unaffected sulfur assimilation enzymes by salinity stress.

Davenport *et al.* (2005) observed that sulphate or sulphate-salinity reduces selenate uptake and accumulation in crops. The inhibition of selenate uptake and accumulation in edible tissue by sulphate reduces the health risk to the consumer when horticultural crops are irrigated with sulphate-dominated saline drainage water that contains high levels of this potentially toxic trace element (Carillo *et al.* 2005). Similarly, sulphate has been found to reduce another potentially toxic oxyanion, molybdate (Al-Solimnai *et al.* 2010).

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

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental site

The research was conducted at the Net House of Agro-Environmental Chemistry Laboratory of the Department of Agricultural Chemistry, SAU during the winter season November 2018 to February 2019. The experimental field is located at 24°9´ N latitude and 90°26' E longitudes at a height of 8.4 m above the mean sea level.

3.2 Soil

The soil was collected from 0-15 cm depth from Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka. The soil was clay loam in texture having pH 5.6 and electrical conductivity (EC) 2.0 dS m^{-1}. The initial soil (0-15 cm depth) test revealed that the soil contained 0.03% total N, 0.45% organic matter, 20 µg g^{-1} available P, 45 µg g^{-1} available S and 0.01 meq 100 g^{-1} exchangeable K (Source: SRDI).

3.3 Weather and Climate

The climate of the study area was subtropical in nature. It was characterized by high temperature (28° - 32°C) accompanied by moderately high rainfall during Kharif (April-September) season and low temperature (15° -20°C) in the Rabi (October-March) season. The weather data of experimental site was collected during the period of experiment from the Bangladesh Meteorological Department (Climate Division), Agargoan, Dhaka.

3.4 Experimental material

Tomato (BARI tomato-17), Brinjal (BARI BT begun-1), Radish (BARI mula-4) and Turnip (Tokyo cross) were used as the test crops. The seeds of the selected varieties were collected from Olericulture Division, Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. The seeds were healthy, vigorous, well matured and free from other crop seeds and inert materials.

3.5 Preparation of soil and filling of pots

A total of 48 plastic pots were prepared with 10 kg air dried soil. The size of the pot was 30 cm top diameter with a height of 25 cm. Thus the surface area of an individual pot was 706.5 sq cm. Plant parts, inert materials, visible insects and pests were removed from soil by sieving. Collected soil was dried under the sun. The dry soil was thoroughly mixed with well rotten cow dung and fertilizers before filling the pots. The pots were placed in the net house.

3.6 Determination of initial salinity of soil

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

3.7 Experimental treatments and design

The experiment was set up in single factor completely randomized design with three replications. Thus 48 experimental pots were placed in ambient air at the Net house of SAU. The salinity in irrigation water was developed by adding required amounts of SAU.

3.8 Treatments

The treatments were as follows:

1. T_0 = Control
2. T_1 = 3 dSm^{-1} NaCl
3. T_2 = 6 dSm^{-1} NaCl
4. T_3 = 9 dSm^{-1} NaCl

3.9 Application of Fertilizer in the pot

Tomato: The required amount of fertilizers; 300, 200 and 220 kg ha^{-1} urea, TSP and MOP, respectively and cowdung @ 10 t ha^{-1} was estimated for pot preparation.

Brinjal: The required amount of fertilizers; 375, 150 and 250 kg ha^{-1} urea, TSP and MOP, respectively and cowdung @ 10 t ha^{-1} was estimated for pot preparation.

Radish: The required amount of fertilizers; 300, 250 and 215 kg ha^{-1} urea, TSP and MOP, respectively and cowdung @ 10 t ha^{-1} was estimated for pot preparation.

Turnip: The required amount of fertilizers; 300, 220 and 200 kg ha^{-1} urea, TSP and MOP, respectively and cowdung @ 10 t ha^{-1} was estimated for pot preparation.

One third of urea and entire amount of cowdung, TSP, MoP were mixed with the soil in each pot before transplanting. Rest of the urea was applied as side dressing.

3.10 Imposition of salinity treatments

Salinity was imposed as per treatments. The developed irrigation water salinity and pot soil were measured by using an electrical conductivity meter (HANNA HI 993310 (Direct Salinity Meter) which was expressed in mS/cm.

3.11 Preparation of stock solution

Saline water was synthesized by using NaCl. Eight hundred g of NaCl was dissolved in 16 liter tap water to prepare the stock solution. The salinity of the stock solution was 80 dSm^{-1}.

3.12 Sowing of seeds

The seeds of tomato and genotypes were sown on 5 October 2018 by hand in separate tray to raise the seedling. Seeds of radish and turnip were sown on 20 October 2018 by hand in separate tray to raise the seedling. Proper care was taken following recommended measures for the development of healthy seedlings.

3.13 Transplanting of seedling

Healthy 30 days old seedlings for tomato and brinjal and 15 days old seedling for okra and turnip were uprooted separately from the seed beds. The seedlings were watered before uprooting so as to minimize damage of roots. Two seedlings were transplanted to the each experimental pot in the afternoon. Light irrigation was given immediately after transplanting by using water can. One seedling was uprooted leaving one seedling in each pot after seedling establishment.

3.14 Intercultural operations

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

3.14.1 Staking

At the flowering stage, the juvenile plants were staked with bamboo sticks to keep them erect and to protect from damage caused by storm and strong wind.

The plants were tied by plastic ropes to the stems with bamboo slices which are hung above them. Staking was done for tomato and brinjal.

3.14.2 Irrigation

Immediately after transplanting, light irrigation to the individual pot was provided to overcome water deficit. After establishment of seedlings, each pot was watered in alternate days to keep the soil moist for normal growth and development of the plants.

3.14.3 Plant protection measures

Plant protection measures were done whenever it was necessary.

3.15 Harvesting of fruits

Fruits were harvested several times (for tomato and brinjal) when it was mature. Radish and turnip were harvested when these attained maturity.

3.16 Parameter Studied

The parameters recorded crop wise and were as follows:

Tomato

1. Plant height (cm) at 30, 60 and 90 DAT
2. Number of branches plant^{-1} at 30, 60 and 90 DAT
3. Number of flowers plant^{-1}
4. Number of fruits plant^{-1}
5. Single fruit weight (g)
6. Fruit weight plant^{-1}

Brinjal

1. Plant height (cm) at 30, 60 and 90 DAT
2. Number of branches plant^{-1} at 30, 60 and 90 DAT
3. Number of flowers plant^{-1}
4. Number of fruits plant^{-1}
5. Single fruit weight (g)
6. Fruit weight plant^{-1} (g)

Radish

1. Plant height (cm) at 30, 45 and 60 DAS
2. Number of leaves plant^{-1} at 30, 45 and 60 DAS
3. Length of modified root (cm)
4. Diameter of modified root (cm)
5. Fresh weight of modified root (yield plant^{-1}) (g)

Turnip

1. Plant height (cm) at 30, 45 and 60 DAS
2. Number of leaves at 30, 45 and 60 DAS
3. Length of modified root (cm)
4. Diameter of modified root (cm)
5. Fresh weight of modified root (yield plant^{-1}) (g)

3.17 Analysis of data

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

CHAPTER IV

RESULTS AND DISCUSSION

The study was undertaken to assess salinity tolerance on some morphological, biochemical and yield contributing characters of winter vegetables. The results are presented in tables with subsequent discussion under following sub-headings. The analyses of variances for different characters are given in Appendices and Tables.

4.1 Tomato

4.1.1 Some growth parameters of tomato

4.1.1.1 Plant height of tomato

Irrespective of salinity levels, the plant height of tomato varied significantly at different growth stages (Table 1 and Appendix III). Results indicated that plant height decreased with the increasing level of salinity. The highest plant height (38.43, 64.76 and 84.26 cm at 30, 60 and 90 DAT, respectively) was recorded in control treatment T_0 (no salinity), which was also significantly different from other treatments. The lowest plant height (22.11, 44.36 and 53.14 cm at 30, 60 and 90 DAT, respectively) was obtained with T_3 (9 dSm^{-1} NaCl) treatment, which was significantly different from other treatments. These results are in agreement with Tantawy *et al.* (2009) who found that plant height gradually decreased with the increase in salinity levels (4 to 6 dS m^{-1}) which was also similar with the findings of Islam *et al.* (2011) and Al-Busaidi, *et al.* (2010).

Table 1. Plant height of tomato as influenced by different salinity levels

Treatment	Plant height (cm)		
	30 DAT	60 DAT	90 DAT
T_0	38.43 a	64.76 a	84.26 a
T_1	33.14 b	56.27 b	78.39 b
T_2	26.54 c	52.18 c	67.48 c
T_3	22.11 d	44.36 d	53.14d
$LSD_{0.05}$	1.758	2.417	4.303
CV(%)	6.58	9.24	7.63

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.1.1.2 Number of branches $plant^{-1}$ of tomato

Significant variation was found for number of branches $plant^{-1}$ at different growth stages of tomato affected by different salinity levels (Table 2 and Appendix IV). Results indicated that the highest number of branches $plant^{-1}$ (3.14, 6.14 and 8.87 at 30, 60 and 90 DAT, respectively) was recorded in control treatment T_0 (no salinity) which was significantly different from all other salinity levels followed by T_1 (3 dSm^{-1} NaCl). The lowest number of branches $plant^{-1}$ (1.33, 3.67 and 4.52 at 30, 60 and 90 DAT, respectively) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Almost similar result was obtained by Kaouther, *et al.* (2012), Islam *et al.* (2011), Hajer *et al.* (2006) and Sengupta and Majumder, (2009).

Table 2. Number of branches $plant^{-1}$ of tomato as influenced by different salinity levels

Treatment	Number of branches $plant^{-1}$		
	30 DAT	60 DAT	90 DAT
T_0	3.14 a	6.14 a	8.87 a
T_1	2.20 b	5.88 b	7.12 b
T_2	2.12 b	4.33 c	5.78 c
T_3	1.33 c	3.67 d	4.52 d
$LSD_{0.05}$	0.136	0.284	0.306
CV(%)	5.277	8.342	10.144

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.1.2 Some yield contributing parameters and yield of tomato

4.1.2.1 Number of flowers plant^{-1} of tomato

The number of branches plant^{-1} of tomato was varied significantly due to different salinity levels (Table 3 and Appendix V). Results showed that the highest number of flowers plant^{-1} (32.60) was recorded in control treatment T_0 (no salinity). Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result (28.24) but significantly different from control treatment T_0 (no salinity). It was found that increasing of salinity decreased the of number of flowers plant^{-1} and lowest number of flowers plant^{-1} (20.53) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Al-Busaidi *et al.* (2010) also found similar result with the present study.

4.1.2.2 Number of fruits plant^{-1} of tomato

Different salinity levels showed significant influence on number of fruits plant^{-1} of tomato (Table 3 and Appendix V). The highest number of fruits plant^{-1} (22.45) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result (19.64) but significantly different from control treatment T_0 (no salinity). It was found that with increasing the salinity level, number of fruits plant^{-1} decreased. The lowest number of fruits plant^{-1} (13.73) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Such kind of result was also reported by Rubio *et al.* (2009), Shabani *et al.* (2012), Islam *et al.* (2011), Shimul *et al.* (2014), Nahar and Hasanuzzaman, (2009) and Biswas *et al.* (2015).

4.1.2.3 Single fruit weight of tomato

Single fruit weight of tomato varied significantly due to different salinity levels (Table 3 and Appendix V). It was observed that the highest single fruit weight (168.48 g) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl)

also showed comparatively higher result (161.33 g) but significantly different from control treatment T_0 (no salinity). It was found that increase of salinity level showed decreased single fruit weight and the lowest single fruit weight (136.27 g) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Islam *et al.* (2011) also observed similar kind of result which supported the present study.

Table 3. Some yield contributing parameters and yield of tomato as influenced by different salinity levels

Treatment	Yield contributing parameters and yield			
	Number of flowers $plant^{-1}$	Number of fruits $plant^{-1}$	Single fruit weight (g)	Yield (kg $plant^{-1}$)
T_0	32.60 a	22.45 a	168.48 a	3.78 a
T_1	28.24 b	19.64 b	161.33 b	3.17 b
T_2	23.70 c	15.27 c	144.64 c	2.21 c
T_3	20.53 d	13.73 d	136.27 d	1.87 d
$LSD_{0.05}$	1.173	0.727	3.114	0.136
CV(%)	6.74	8.22	10.24	7.56

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.1.2.4 Fruit weight $plant^{-1}$ of tomato

Different salinity levels showed significant influence on fruit weight $plant^{-1}$ of tomato (Table 3 and Appendix V). Results showed that the highest fruit weight $plant^{-1}$ (3.78 kg) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result (3.17 kg $plant^{-1}$) but significantly different from control treatment T_0 (no salinity). The lowest fruit weight $plant^{-1}$ (1.87 kg) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. These results are in agreement with the findings of Hasanuzzaman *et al.* (2009) and Islam *et al.*, (2011).

4.2 Brinjal

4.2.1 Some growth parameters of brinjal

4.2.1.1 Plant height of brinjal

Different salinity levels showed significant influence on plant height of brinjal at different growth stages (Table 4 and Appendix VI). The highest plant height (36.45, 63.58 and 76.37 cm at 30, 60 and 90 DAT, respectively) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) and T_2 (6 dSm^{-1} NaCl) also showed comparatively higher result but significantly different from control treatment T_0 (no salinity). The lowest plant height (24.18, 46.12 and 52.72 cm at 30, 60 and 90 DAT, respectively) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. It is apparent from the results that plant height decreased with increase in levels of salinity. Tantawy *et al.* (2009) Islam *et al.* (2011) and Al-Busaidi, *et al.* (2010) also found similar result with the present study.

Table 4. Plant height of brinjal as influenced by different salinity levels

Treatment	Plant height (cm)		
	30 DAT	60 DAT	90 DAT
T_0	36.45 a	63.58 a	76.37 a
T_1	33.27 b	57.24 b	71.44 b
T_2	25.62 c	49.37 c	60.18 c
T_3	24.18 c	46.12 d	52.72 d
$LSD_{0.05}$	1.233	1.504	2.052
CV(%)	6.27	10.52	8.36

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.2.1.2 Number of branches $plant^{-1}$ of brinjal

Different salinity levels showed significant influence on number of branches $plant^{-1}$ of brinjal at different growth stages (Table 5 and Appendix VII). The highest number of branches $plant^{-1}$ (3.28, 12.44 and 16.88 at 30, 60 and 90

DAT, respectively) was recorded in control treatment T_0 (no salinity) Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result but significantly different from control treatment T_0 (no salinity). The lowest number of branches $plant^{-1}$ (1.67, 6.48 and 9.12 at 30, 60 and 90 DAT, respectively) was obtained with T_3 (9 dSm^{-1} NaCl) treatment which was statistically identical with T_2 (6 dSm^{-1} NaCl) treatment. The result obtained from the present study was similar with the findings of Kaouther *et al.* (2012), Islam *et al.* (2011) and Hajer *et al.* (2006).

Table 5. Number of branches $plant^{-1}$ of brinjal as influenced by different salinity levels

Treatment	Number of branches $plant^{-1}$		
	30 DAT	60 DAT	90 DAT
T_0	3.28 a	12.44 a	16.88 a
T_1	3.11 b	10.20 b	14.27 b
T_2	1.75 c	6.52 c	9.66 c
T_3	1.67 c	6.48 c	9.12 c
$LSD_{0.05}$	0.113	0.465	0.673
CV(%)	5.29	6.24	8.72

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.2.2 Some yield contributing parameters and yield of brinjal

4.2.2.1 Number of flowers $plant^{-1}$ of brinjal

Different salinity levels showed significant influence on number of fruits $plant^{-1}$of brinjal (Table 6 and Appendix VIII). The highest number of flowers $plant^{-1}$ (102.63) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result (96.48) but significantly different from control treatment T_0 (no salinity). The lowest number of fruits $plant^{-1}$

(71.16) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. The result obtained from Al-Busaidi *et al*. (2010) supported the result of the present study.

4.2.2.2 Number of fruits plant^{-1} of brinjal

Different salinity levels showed significant influence on number of fruits plant^{-1} of brinjal (Table 6 and Appendix VIII). The highest number of fruits plant^{-1} (21.22) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result (18.80) but significantly different from control treatment T_0 (no salinity). The lowest number of fruits plant^{-1} (12.75) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Similar result was also observed by Abbas *et al*., 2010 with the present study. The result on number of fruits plant^{-1} reported by Shabani *et al.* (2012), Islam *et al.* (2011), Shimul *et al.* (2014) and Nahar and Hasanuzzaman, (2009) was also similar with the presentstudy.

4.2.2.3 Single fruit weight of brinjal

Different salinity levels showed significant influence on single fruit weight of brinjal (Table 6 and Appendix VIII). The highest single fruit weight (63.27 g) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) also showed comparatively higher result (58.76 g) but significantly different from control treatment T_0 (no salinity). The lowest single fruit weight (50.71 g) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Islam *et al.* (2011) also observed similar kind of result which supported the present study.

4.2.2.4 Fruit weight plant^{-1} of brinjal

Different salinity levels showed significant influence on fruit weight plant^{-1}of brinjal (Table 6 and Appendix VIII). The highest fruit weight plant^{-1} (1.34 kg) was recorded in control treatment T_0 (no salinity) which was significantly different from other salinity levels. Treatment T_1 (3 dSm^{-1} NaCl) also showed

comparatively higher result (1.10 kg kg plant^{-1}) but significantly different from control treatment T_0 (no salinity). The lowest fruit weight plant^{-1} (0.65 kg) was obtained with T_3 (9 dSm^{-1} NaCl) treatment. Similar result was also observed by Unlukara *et al*., 2010 who found significant yield loss due to higher salt stress. Hasanuzzaman *et al.* (2009) and Islam *et al.* (2011) were also agreed with the result of the present study.

Table 6. Some yield contributing parameters and yield of brinjal as influenced by different salinity levels

Treatment	Yield contributing parameters and yield			
	Number of flowers plant^{-1}	Number of fruits plant^{-1}	Single fruit weight (g)	Yield (kg plant^{-1})
T_0	102.63 a	21.22 a	63.27 a	1.34 a
T_1	96.48 b	18.80 b	58.76 b	1.10 b
T_2	78.47 c	14.55 c	52.48 c	0.76 c
T_3	71.16 d	12.75 d	50.71 c	0.65 d
$LSD_{0.05}$	2.017	0.875	2.053	0.071
CV(%)	8.37	6.52	10.24	7.86

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.3 Radish

4.3.1 Some growth parameters of radish

4.3.1.1 Plant height of radish

Different salinity levels showed significant influence on plant height of radish (Table 7 and Appendix IX). The highest plant height (34.43, 40.50 and 44.27 cm at 30, 45 and 60 DAT, respectively) was recorded in control treatment T_0 (no salinity). The height of radish plant was less than that of control treatment. The lowest plant height at 30 DAT (27.62 cm) was obtained with T_3 (9 dSm^{-1} NaCl) treatment which was statistically identical with T_2 (6 dSm^{-1} NaCl) (28.75). But after 40 DAT, all the plants died in the treatment T_3 (9 dSm^{-1} NaCl) and T_2 (6 dSm^{-1} NaCl) due to higher level of salinity. Hasanuzzaman *et*

al. (2009) found similar result with the present study who observed remarkable reduction of plant height in saline soil which was also supported by Hajer *et al.* (2006).

Table 7. Plant height of radish as influenced by different salinity levels

Treatment	Plant height (cm)		
	30 DAT	45 DAT	60 DAT
T_0	34.43 a	40.50 a	44.27 a
T_1	31.24 b	36.75 b	40.77 b
T_2	28.75 c	--	--
T_3	27.62 c	--	--
$LSD_{0.05}$	0.577	2.363	1.245
CV(%)	8.53	7.64	5.28

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.3.1.2 Number of leaves plant^{-1} of radish

Variation in salinity levels showed significant effect on number of leaves plant^{-1} of radish (Table 8 and Appendix X). The highest number of leaves plant^{-1} (6.22, 9.76 and 15.67 at 30, 45 and 60 DAT, respectively) was recorded in control treatment T_0 (no salinity) followed by Treatment T_1 (3 dSm^{-1} NaCl). The lowest number of leaves plant^{-1} at 30 DAT (4.11) was obtained with T_3 (9 dSm^{-1} NaCl) treatment which was statistically identical with T_2 (6 dSm^{-1} NaCl) (4.24). But at 45 DAT plants did not have any leaf and all plants of T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) levels was died due to salinity. Similar result was also observed by Hasanuzzaman *et al.* (2009) who observed remarkable reduction of leaves plant^{-1} in saline soil which was also supported by Juan *et al.* (2005).

Table 8. Number of branches plant^{-1} of radish as influenced by different salinity levels

Treatment	Number of leaves plant^{-1}		
	30 DAT	45 DAT	60 DAT
T_0	6.22 a	9.76 a	15.67 a
T_1	5.10 b	8.24 b	12.96 b
T_2	4.24 c	--	--
T_3	4.11 c	--	--
$LSD_{0.05}$	0.214	0.542	1.276
CV(%)	7.31	5.20	6.33

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.3.2 Some yield contributing parameters and yield of radish

4.3.2.1 Length of modified root of radish

The length of modified roots of radish was significantly influenced by different levels of salinity (Table 9 and Appendix XI). The highest length of modified root (31.78 cm) was recorded in control treatment T_0 (no salinity) and it was followed by those of T_1 (3 dSm^{-1} NaCl) treatment. There was no modified root of radish in the treatments T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) due to higher doses of salinity. Supported result was also found by Munns (2002) who observed that cell division rates are affected by salinity which contributed to lower rates of root growth. Ashraf *et al*. (2003) also found similar result with the present study.

4.3.2.2 Diameter of modified root of radish

It is evident from 4.3.2.1 above there was no modified root in T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) treatment; only treatment T_0 (control) and T_1 (3 dSm^{-1} NaCl) produced modified roots (Table 9 and Appendix XI). The average length of which were 31.78 cm in T_0 (no salinity) and 28.25 cm in T_1 (3 dSm^{-1} NaCl) treatment respectively which were statistically significant. Similar result

with the present study was also found by Munns (2002) and Ashraf *et al*. (2003).

4.3.2.3 Fresh weight of modified root of radish

Modified root of radish produced only in T_0 (no salinity) and T_1 (3 dSm^{-1} NaCl) treatment which were focused statistically significant (Table 9 and Appendix XI). The fresh weight of produced modified roots was highest (711.37 g) in control treatment T_0 (no salinity) followed by T_1 (3 dSm^{-1} NaCl). Treatment T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) did not produce any modified roots of radish due to the effect of different levels of salinity. The result obtained from the present study was similar with the findings of Ashraf *et al*. (2003) who found that salinity significantly reduces shoot and root fresh weight.

Table 9. Some yield contributing parameters and yield of radish as influenced by different salinity levels

Treatment	Yield contributing parameters and yield		
	Length of modified root (cm)	Diameter of modified root (cm)	Fresh weight of modified root (yield $plant^{-1}$) (g)
T_0	31.78 a	13.52 a	711.37 a
T_1	28.25 b	11.33 b	683.48 b
T_2	--	--	--
T_3	--	--	--
$LSD_{0.05}$	1.144	1.032	8.247
CV(%)	6.31	4.78	7.36

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.4 Turnip

4.4.1 Some growth parameters of turnip

4.4.1.1 Plant height of turnip

Like radish salinity had adverse effect on growth parameters of turnip. Results presented in Table 10 and Appendix XII show that plant height of turnip reduced with increase in levels of salinity and it was statistically significant at 30 DAT only. At 30 DAT, height of plants was highest at T_0 (no salinity) treatment (21.18 cm) and it was lowest in T_3 (9 dSm^{-1} NaCl) (14.33 cm). The plant height decreased with increase in salinity level. Though plant height increased in all DATs of T_0 (no salinity) and T_1 (3 dSm^{-1} NaCl) treatments but at T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) treatment after 45 DAT, all the plants were died due to the effect of higher levels of salinity. Similar result was also observed by Hasanuzzaman *et al.* (2009) and Hajer *et al.* (2006).

Table 10. Plant height of turnip as influenced by different salinity levels

Treatment	Plant height (cm)		
	30 DAT	45 DAT	60 DAT
T_0	21.18 a	47.60 a	58.75 a
T_1	18.76 b	43.28 b	53.77 b
T_2	15.47 c	--	--
T_3	14.33 c	--	--
$LSD_{0.05}$	1.147	2.052	2.115
CV(%)	8.37	6.24	5.78

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.4.1.2 Number of leaves $plant^{-1}$ of turnip

Like plant height the number of leaves $plant^{-1}$ of turnip was also affected by different salinity levels which were statistically significant (Table 11 and Appendix XIII). At 30 DAT leaves were produced in all treatments but it reduced with the increase in levels of salinity. Highest number of leaves $plant^{-1}$

were produced in T_0 (no salinity) treatment (6.72) and it was lowest in T_3 (9 dSm^{-1} NaCl) (4.67). At 45 and 60 DAT, T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) did not produce any leaf. Number of leaves $plant^{-1}$ were less in T_1 (3 dSm^{-1} NaCl) than T_0 (no salinity) at both 45 and 60 DATs. Hasanuzzaman *et al.* (2009) and Juan *et al.* (2005) also found similar result who observed remarkable reduction of leaves $plant^{-1}$ in saline soil.

Table 11. Number of leaves $plant^{-1}$ of turnip as influenced by different salinity levels

Treatment	Number of leaves $plant^{-1}$		
	30 DAT	45 DAT	60 DAT
T_0	6.72 a	13.88 a	16.15 a
T_1	5.53 b	11.76 b	14.18 b
T_2	4.88 c	--	--
T_3	4.67 c	--	--
$LSD_{0.05}$	0.311	0.614	0.736
CV(%)	5.87	5.22	7.33

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

4.4.2 Some yield contributing parameters and yield of turnip

4.4.2.1 Length of modified root of turnip

It appears from the Table 12 and Appendix XIV that length of modified roots of turnip was significantly affected by different levels of salinity. Only in T_0 (10.12 cm) and T_1 (8.95 cm) treatments produced modified roots of turnip and the length was highest in T_0 (no salinity) than that of T_1 (3 dSm^{-1} NaCl). T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) did not produce any modified root of turnip. Supported result was also found by Munns (2002) who observed that cell division rates are affected by salinity which contributed to lower rates of root growth. Ashraf *et al.* (2003) also found similar result with the present study.

4.4.2.2 Diameter of modified root of turnip

The different levels of salinity had adverse significant effect on diameter of turnip roots. Only T_0 (no salinity) and T_1 (3 dSm^{-1} NaCl) produced modified roots of turnip and T_0 had (6.14 cm) greater modified roots and that of T_1 (8.97 cm). T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) did not produce any modified root of turnip (Table 12 and Appendix XIV). Similar result with the present study was also found by Munns (2002) and Ashraf *et al*. (2003).

4.4.2.3 Fresh weight of modified root of turnip

The different levels of salinity had significantly adverse influence on the fresh weight of modified roots of turnip. In T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) treatments there were no modified roots produced. Only T_0 (no salinity) produced 396.44 g and T_1 (3 dSm^{-1} NaCl) had 372.77 g turnip $plant^{-1}$ fresh weight basis (Table 12 and Appendix XIV). Ashraf *et al*. (2003) also found decreased shoot and root fresh weights with salinity.

Table 12. Some yield contributing parameters and yield of turnip as influenced by different salinity levels

Treatment	Yield contributing parameters and yield		
	Length of modified root $plant^{-1}$ (cm)	Diameter of modified root $plant^{-1}$ (cm)	Fresh weight of modified root (yield $plant^{-1}$) (g)
T_0	10.12 a	6.14 a	396.44 a
T_1	8.95 b	8.97 b	372.77 b
T_2	--	--	--
T_3	--	--	--
$LSD_{0.05}$	2.431	1.014	5.223
CV(%)	6.37	5.29	7.14

In a column means having similar letters) arc statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_0 = Control, T_1 = 3 dSm^{-1} NaCl, T_2 = 6 dSm^{-1} NaCl, T_3 = 9 dSm^{-1} NaCl

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment on four winter vegetables was conducted with 4 different levels of salinity at pre-flowering to assess the salinity tolerance ability of the selected crops. The experiment was set up at the Net House of Agricultural Chemistry Department of Sher-e-Bangla Agricultural University, during the period from November 2018 to February 2019. Four winter vegetables *viz*. tomato, brinjal, radish and turnip were considered as test crops. Four salinity levels *viz*. T_0 (no salinity; control), T_1 (3 dSm^{-1} NaCl), T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) were used to test salinity tolerance ability. The experiment was conducted in Completely Randomized Design (CRD) with three replications. Different data on growth, yield contributing parameters and yield were collected and analyzed statistically. It was observed that most of the parameters varied significantly due to different salinity levels.

Tomato

The highest plant height of tomato(38.43, 64.76 and 84.26 cm at 30, 60 and 90 DAT, respectively) and highest number of branches $plant^{-1}$ (3.14, 6.14 and 8.87 at 30, 60 and 90 DAT, respectively) were recorded in control treatment T_0 (no salinity) whereas the lowest plant height (22.11, 44.36 and 53.14 cm at 30, 60 and 90 DAT, respectively) and lowest number of branches $plant^{-1}$ (1.33, 3.67 and 4.52 at 30, 60 and 90 DAT, respectively) were obtained from T_3 (9 dSm^{-1} NaCl) treatment.

Regarding yield contributing characters and yield of tomato, the highest number of flowers $plant^{-1}$ (32.60), number of fruits $plant^{-1}$ (22.45), single fruit weight (168.48 g) and fruit weight $plant^{-1}$ (3.78 kg) were recorded from control treatment T_0 (no salinity) whereas the lowest number of flowers $plant^{-1}$ (20.53), number of fruits $plant^{-1}$ (13.73), single fruit weight (136.27 g) and fruit weight $plant^{-1}$ (1.87 kg) was obtained with T_3 (9 dSm^{-1} NaCl) treatment.

Brinjal

In terms of growth parameters of brinjal, the highest plant height (36.45, 63.58 and 76.37 cm at 30, 60 and 90 DAT, respectively) and number of branches plant^{-1} (3.28, 12.44 and 16.88 at 30, 60 and 90 DAT, respectively) were recorded in control treatment T_0 (no salinity) whereas the lowest plant height (24.18, 46.12 and 52.72 cm at 30, 60 and 90 DAT, respectively) and number of branches plant^{-1} (1.67, 6.48 and 9.12 at 30, 60 and 90 DAT, respectively) were obtained with T_3 (9 dSm^{-1} NaCl) treatment.

Regarding yield contributing parameters and yield of brinjal, the highest number of flowers plant^{-1} (102.63), number of fruits plant^{-1} (21.22), single fruit weight (63.27 g) and fruit weight plant^{-1} (1.34 kg) were recorded in control treatment T_0 (no salinity) whereas the lowest number of flowers plant^{-1} (71.16), number of fruits plant^{-1} (12.75), single fruit weight (50.71 g) and fruit weight plant^{-1} (0.65 kg) were obtained with T_3 (9 dSm^{-1} NaCl) treatment

Radish

Radish was very sensitive to salinity. At higher concentration the above 6 dSm^{-1} NaCl, radish plant did not survive. However, considering growth parameters of radish, the highest plant height (34.43, 40.50 and 44.27 cm at 30, 60 and 90 DAT, respectively) and number of leaves plant^{-1} (6.22, 9.76 and 15.67 at 30, 60 and 90 DAT, respectively) were recorded in control treatment T_0 (no salinity) and the lowest plant height (27.62 cm) and number of leaves plant^{-1} (4.11) at 30 DAT were observed in T_3 (9 dSm^{-1} NaCl) treatment and after that plants died. At 45 and 60 DAT, no data was recorded on plant height and number of leaves plant^{-1} with T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) due to death of plants.

Similarly, regarding yield contributing parameters and yield of radish, the highest length of modified root (31.78 cm), diameter of modified root (13.52 cm) and fresh weight of modified root (711.37 g) were recorded in control treatment T_0 (no salinity). The lowest length of modified root (28.25), diameter of modified root (11.33) and fresh weight of modified root (683.48 g) were

obtained from T_1 (3 dSm^{-1} NaCl) treatment. Salinity level 6 dSm^{-1} NaCl and avove no plant survived. So, the question of collection of data does not arise at all.

Turnip

Plants of turnip were very sensitive to salinity and at a certain levels plant of turnip cannot live. The results showed that plant of turnip survived upto T_1 (3 dSm^{-1} NaCl) treatment only. However, considering growth parameters of turnip at T_0 (no salinity) treatment, the highest plant height were 21.18, 47.60 and 58.75 cm and number of leaves $plant^{-1}$ were 6.72, 13.88 and 16.15 at 30, 45 and 60 DAT, respectively and in T_1 (3 dSm^{-1} NaCl) treatment plant height were 18.76, 43.28 and 53.77 cm at 30, 45 and 60 DAT, respectively. Though at 30 DAT plant survived at all salinity levels but beyond that at treatments T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) plants did not survive. So, question of collection of data does not arise.

Regarding, yield contributing parameters and yield of turnip, higher length of modified root (10.12 cm), diameter of modified root (6.14 cm) and fresh weight of modified root (396.44 g) were recorded in control treatment T_0 (no salinity) followed by T_1 (3 dSm^{-1} NaCl) treatment where length of modified root was 8.95 cm, diameter of modified root was 8.97 cm and fresh weight of modified root was 372.77 g. No data was recorded from T_2 (6 dSm^{-1} NaCl) and T_3 (9 dSm^{-1} NaCl) treatments due to death of plants with these treatments.

From the above results it can be stated that all the winter vegetables (tomato, brinjal, radish and turnip) under the present study was sensitive to salinity. Among the selected crops, radish and turnip was more sensitive to salinity stress and death was occurred with higher salinity levels. So, from this study, it can be concluded that among four winter vegetables *viz*. tomato, brinjal radish and turnip; tomato and brinjal showed more tolerance to salinity than radish and turnip.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

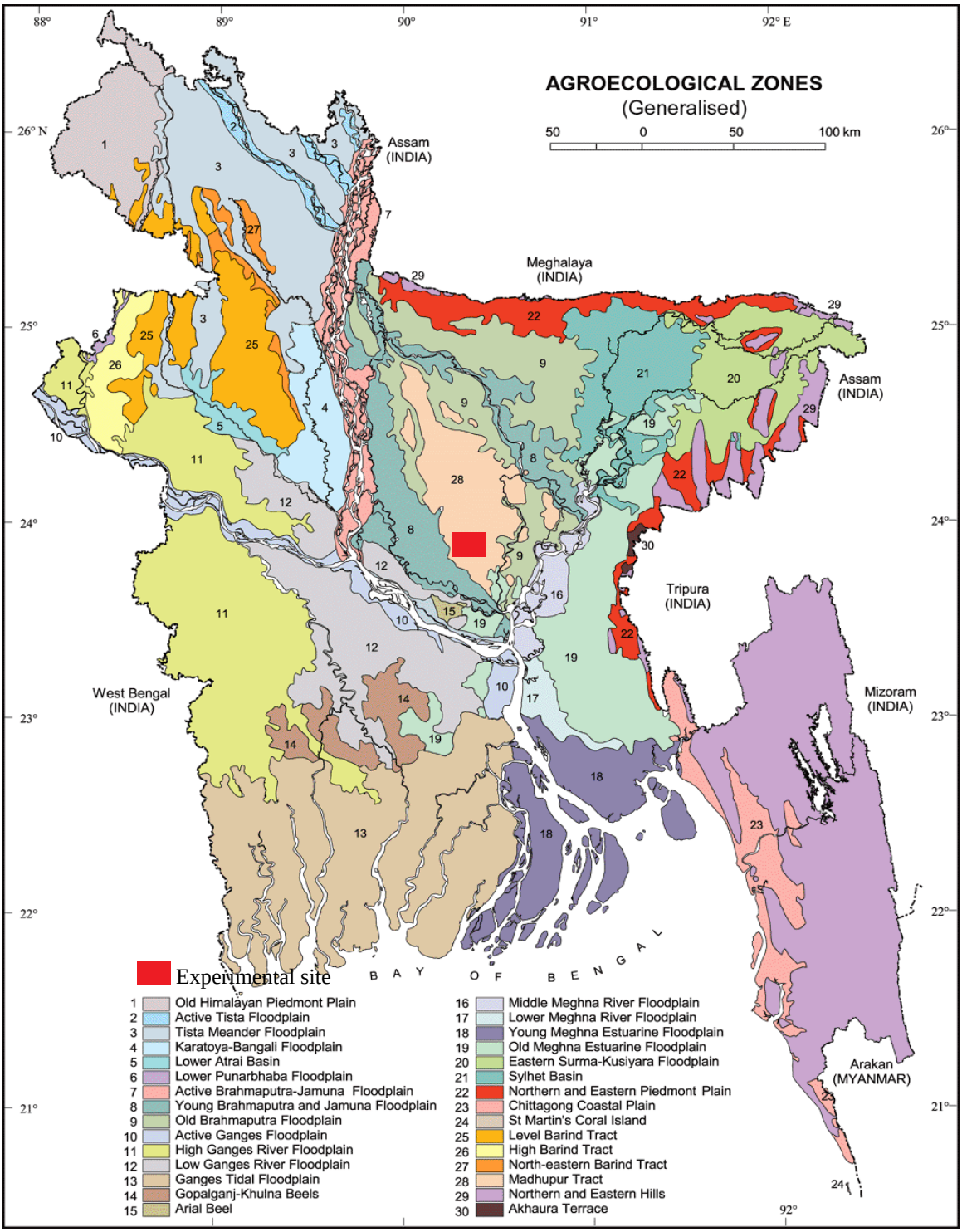

Fig. 1. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from November 2018 to February 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2018	November	28.60	8.52	18.56	56.75	14.40
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	37.90	0.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Plant height of tomato as influenced by different salinity levels

Source of variation	Degrees of freedom	Plant height (cm)		
		30 DAT	60 DAT	90 DAT
Replication	2	2.114	3.052	3.855
Factor A	3	18.35*	42.85*	102.35*
Error	6	3.271	4.144	5.071

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IV. Number of branches plant^{-1} of tomato as influenced by different salinity levels

Source of variation	Degrees of freedom	Number of branches plant^{-1}		
		30 DAT	60 DAT	90 DAT
Replication	2	0.275	0.517	0.771
Factor A	3	6.052**	11.24*	14.21*
Error	6	0.578	0.632	0.589

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Yield contributing parameters and yield of tomato as influenced by different salinity levels

Source of variation	Degrees of freedom	Yield contributing parameters and yield			
		Number of flowers plant^{-1}	Number of fruits plant^{-1}	Single fruit weight (g)	Fruit weight plant^{-1} (kg)
Replication	2	1.785	1.028	4.076	0.314
Factor A	3	49.35*	33.29*	176.32*	8.376**
Error	6	2.075	3.514	6.211	0.711

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Plant height of brinjal as influenced by different salinity levels

Source of variation	Degrees of freedom	Plant height (cm)		
		30 DAT	60 DAT	90 DAT
Replication	2	1.336	3.186	2.971
Factor A	3	22.71*	52.71*	92.56*
Error	6	2.845	3.864	6.317

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Number of branches plant^{-1} of brinjal as influenced by different salinity levels

Source of variation	Degrees of freedom	Number of branches plant^{-1}		
		30 DAT	60 DAT	90 DAT
Replication	2	0.177	1.314	1.611
Factor A	3	11.25**	19.34*	33.63*
Error	6	0.486	2.257	3.214

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Yield contributing parameters and yield of brinjal as influenced by different salinity levels

Source of variation	Degrees of freedom	Yield contributing parameters and yield			
		Number of flowers plant^{-1}	Number of fruits plant^{-1}	Single fruit weight (g)	Fruit weight plant^{-1} (kg)
Replication	2	2.863	1.089	1.614	0.145
Factor A	3	44.37*	27.72*	36.71*	6.036**
Error	6	3.891	1.577	2.369	0.112

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Plant height of radish as influenced by different salinity levels

Source of variation	Degrees of freedom	Plant height (cm)		
		30 DAT	45 DAT	60 DAT
Replication	2	0.716	0.866	1.279
Factor A	3	12.85*	18.371*	42.37*
Error	6	1.355	2.712	3.714

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Number of branches plant^{-1} of radish as influenced by different salinity levels

Source of variation	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAT	45 DAT	60 DAT
Replication	2	0.388	1.014	0.971
Factor A	3	8.712*	16.36*	12.287**
Error	6	1.056	2.152	1.714

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XI. Yield contributing parameters and yield of radish as influenced by different salinity levels

Source of variation	Degrees of freedom	Yield contributing parameters and yield		
		Length of modified root (cm)	Diameter of modified root (cm)	Fresh weight of modified root (yield plant^{-1}) (g)
Replication	2	1.144	0.911	5.614
Factor A	3	28.577*	24.36**	304.56*
Error	6	2.362	1.377	7.293

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XII. Plant height of turnip as influenced by different salinity levels

Source of variation	Degrees of freedom	Plant height (cm)		
		30 DAT	45 DAT	60 DAT
Replication	2	0.857	2.386	1.899
Factor A	3	27.39*	36.21*	43.14*
Error	6	2.114	2.571	1.857

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XIII. Number of branches plant^{-1} of turnip as influenced by different salinity levels

Source of variation	Degrees of freedom	Number of leaves plant^{-1}		
		30 DAT	45 DAT	60 DAT
Replication	2	0.312	0.769	0.633
Factor A	3	9.513**	13.653*	16.21*
Error	6	0.877	1.042	0.986

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix XIV. Yield contributing parameters and yield of turnip as influenced by different salinity levels

Source of variation	Degrees of freedom	Yield contributing parameters and yield		
		Length of modified root (cm)	Diameter of modified root (cm)	Fresh weight of modified root (yield plant^{-1}) (g)
Replication	2	1.371	0.371	5.387
Factor A	3	17.28*	8.853**	271.24*
Error	6	1.045	0.458	8.293

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level