EFFECT OF SALINITY ON MORPHO-PHYSIOLOGICAL AND YIELD CONTRIBUTING CHARACTERS OF POTATO (*Solanum tuberosum* L.)

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF SALINITY ON MORPHO-PHYSIOLOGICAL AND YIELD CONTRIBUTING CHARACTERS OF POTATO (*Solanum tuberosum* L.)''** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bona-fide research work carried out by **MOST. FATEMA JOHORA**, Registration No. **11-04284** any other degree or diploma.

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

Dated: June, 2017
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ABSTRACT

A pot experiment was conducted at the Agricultural Botany experimental field of Sher-e-Bangla Agricultural University during the period from November 2016 to February 2017 to investigate the effects of salinity on morpho-physiological and yield contributing characters of potato (*Solanum tuberosum* L). The experimental treatments were consisted of nine different level of salinity viz. T_0 = without salt (control), T_1 = 2 dS/m, T_2 = 4 dS/m, T_3 = 6 dS/m, T_4 = 8 dS/m, T_5 = 10 dS/m, T_6 = 12 dS/m, T_7 = 14 dS/m and T_8 = 16 dS/m. The variety Diamond (BARI ALU-7) was used as planting material. The experiment was laid out in Completely Randomized Design (CRD) with 3 replications. The highest plant height (38.04cm), highest number of leaves/plant (21.23), maximum no. of branch/plant (9.27), highest chlorophyll content (2.64 mgg^{-1}), highest SPAD value (55.60), highest proline accumulation (16.12 µ mol^{-1} FW), highest leaf area (21.74 cm^2), maximum no. of tuber/plant (8.67) and maximum tuber dry weight (11.62%) were found in T_0 (control) treatment and the lowest value was in T_8 (16 dS/m) treatment. The highest membrane stability (93.51 %) was obtained from T_8 treatment and the lowest (52.29%) was observed in T_0 (control) treatment. The highest tuber yield was 379.13 gm in control plant which was satistically similar with T_1 and the lowest yield was 89.24 gm in T_8 (16 dS/m) which was satistically similar with T_7. The highest to lowest value gradually decreased from T_0 to T_8 treatment. Finally, it may be concluded that, the decreased of yield was observed to cultivate under saline water (≤8 ds/m) treatment from T_0 to T_4. Hence the variety may be used for the cultivation in the southern part of Bangladesh where salinity level is upto 8 dS/m.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ = Agro-Ecological Zone

BARI = Bangladesh Agricultural Research Institute

BBS = Bangladesh Bureau of Statistics

cm = Centimeter

Conc. = Concentration

CRD = Completely Randomized Design

CV = Coefficient of Variance

C = Carbon

C^0 = Degree Celsius

CAT = Catalage

DAP = Days After Planting

DMRT = Duncan`s new Multiple Range Test

DW = Dry Weight

ds/m = Decisiemens per meter

et al. = And others

ECe = Electrical Coductivity of extract

FAO = Food and Agricultural Organization

FW = Fresh Weight

G = gram (s)

ha^{-1} = Per hectare

i.e. = id est (L), that is

H2O2 = Hydrogen peroxide

Kg = Kilogram (g)

Lsd = Least Significant Difference

MOP = Muriate of Potash

mg = Milligram

mm = Millimeter

Max = Maximum

Min = Minimum

MDA = Malondialdihyde

MS = Murashige-Skoog

mM = Millimola

N = Nitrogen

NaCl = Sodium Chloride

NS = Not significant

NPK = Nitrogen, Phosphorus and Potasium

OP = Osmotic Potential

POD= Peroxide

PPO = Polyphenoloxide

ppt = parts per thousand

ROS = Reactive Oxygen Species

SNP = Sodium Nitroprusside

SDI= Shoot Distribution Index

SOD = Superoxide Dismetase

SAU = Sher-e-Bangla Agricultural University

SRDI = Soil Resources and Development Institute

TCRC = Tuber Crops Research Centre

TSP = Triple Super Phosphate

Wt = Weight

% = Percentage

CHAPTER I
INTRODUCTION

Potato (*Solanum tuberosum* L.) is known as *Alu* is edible tuber yielding plant of the family Solanaceae. The potato plant is a herbaceous annual, normally propagated by planting pieces of tubers that bear two or three eyes. Potato is popularly known as "The King of Vegetables". Potato has become one of the major food and cash crops in Bangladesh. It is the fourth most important food crop in the world after rice, wheat and maize. Bangladesh is the 7th potato producing country in the world. In Bangladesh, it ranks second after rice production (FAOSTAT, 2013). Nutritionally, it has a balanced food containing about 75 to 80% water, 16 to 20% carbohydrates, 2.5 to 3.2% crude protein, 1.2 to 2.2% true protein, 0.8 to 1.2% mineral matter; 0.1 to 0.2% crude fat, 0.6% crude fiber and some vitamins (Schoeremann , 1977). In Bangladesh, potato is mainly consumed as vegetable. Potatoes are used for a variety of purposes, such as boiled, baked and fried potatoes, dehydrated mashed potatoes, canned potatoes, and as starch for culinary purposes (Hoque,1994). Otherwise, various other food items (Singara, Samucha, Chop, Chips etc.) are also made from potato.

Potato is widely cultivated in all districts of our country during winter season. November is the best time for planting tuber. Of the total 11,83,000 acres of land used for potato cultivation and the total production of potatoes were 96,74,000 metric tons in Bangladesh in the year of 2016-2017 (BBS, 2017). Thus the average yield of potato is 19.23 tons/ha. Meanwhile, there is a wide gap between average national yield of potato in Bangladesh compared to other potato growing countries of the world like Netherlands, UK, France, USA and Germany. Among the various factors responsible for the low yield in Bangladesh, the yield performance of a variety plays an important role. There are many scope of increasing the yield of potato through the producing of high yielding potato varieties possessing good keeping quality and resistant against pests and diseases. The local varieties exist in Bangladesh that giving

extremely low yield. On the other hand, the yield of high yielding varieties are much better than the local ones under the identical conditions and cultural practices. Recently, the government has been trying to diversify food habits and encourage potato production to reduce pressure on rice. So, potato is becoming an important food for food security in Bangladesh. A number of studies to agronomic, economic and physiological aspects of potato cultivation have so far been conducted in Bangladesh.

The united nation environment program estimates that approximately 20% of agricultural land and 50% of crop land in the world is salt stressed. Six of 14 billion ha of arable land available in the world are located in these areas and out of this about one billion hectares are affected by excess salt. In Bangladesh, out of 2.85 million hectares of the coastal and offshore areas of which about 833,000 hectares of the arable lands, constitute nearly 52.8% net saline area dispersed in 64 upazilla of 13 districts are affected by different degrees of salinity which occur in the southern parts of the ganges tidal floodplain, in the young Meghna estuarine floodplain. Coastal area in Bangladesh constitutes 20% of the country of which 53% are affected by different degrees of salinity (Karim *et al*., 2001).

Potatoes are relatively sensitive to salinity, particularly in the early growth stage. It is morphologically and physiologically harmful to crop plants. High salt contents reduce the growth and production of potato by affecting physiological processes. Salt stress has various effect on plant such as increased respiration rate and ion toxicity, membrane instability resulting from calcium and sodium displacement and decreased efficiency of photosynthesis. Higher level of salinity disrupts plants roots making water deficiency, nutrients imbalance by altering uptake and transport, ionic stress by higher Na^+ and Cl^- accumulation, cell membrane ineffectiveness, interfering cell division and genotoxicity resulting in reduced plant growth, development and yield. The most important process that is affected by salinity is photosynthesis. But it appears that is scope for increasing the yield of potato by narrowing the yield gap.

The southern belt of Bangladesh is severely affected by salinity. Most of the saline areas remain fallow during Rabi season. By the expansion of potato cultivation in these areas, part of the food crisis may be mitigated. So, suitable varieties of potato are essential for these regions.

Considering the importance and constrains to cultivate potato in saline areas of Bangladesh an investigation was carried out with the following objectives:

- To find out the salinity tolerant level of potato at which potato can be grown
- To find out the effect of salinity on morpho-physiological characters in potato
- To know the effect of salinity on yield and yield contributing characters of potato

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh, potato is a very important vegetable crop and it is specially valued for its tuber. Many research works have been conducted on potato but information regarding salinity tolerance in potato varieties and their effects on growth, yield and quality parameters are still inadequate (Van Hoorn *et al.*,1993). However, some of the important and informative works conducted at home and abroad in this aspect have been reviewed under the following headings:

2.1 Salinity

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants including potato are sensitive to salinity that is caused by high concentrations of salts in the soil, and the area of land affected by it is increasing day by day.

It is one of the important constraints to potato production in coastal region of Bangladesh. Salinity is caused by the presence of excess amount of soluble salts in soil and water. The concentration of dissolved salt in a given volume of water is known as salinity. Salts are compounds like sodium chloride, magnesium sulfate, potassium nitrate and sodium bicarbonate which dissolve into ions. The chemical properties of salinity depend on temperature and pressure.

Soil salinity is determined by measuring the electrical conductivity of solution extracted from a water-saturated soil paste. Salinity is abbreviated as ECe (Electrical Conductivity of the extract) with units of decisiemens per meter (dS/m) or millimhos per centimeter (mmhos/cm). Both are equivalent units of measurement and give the same numerical value. Salinity is either expressed in grams of salt per kilogram of water, or in parts per thousand (ppt or %).

There are presented classification of soil based on EC in dS/m:

EC 0- 2 non saline soil

EC 2- 4 slightly saline, yield of sensitive crops reduced

EC 4- 8 moderately saline, yield reduction of many crops

EC 8-16 saline, normal yield for salt tolerant crops only

EC > 16 reasonable crop yields only for very tolerant crops

Potato is classified as one of moderately sensitive crops of salinity tolerant group (Katerji *et al*., 2003)

The USDA Salinity Laboratory defines a saline soil as having EC of 4 dSm^{-1} or more (US Salinity Lab. Staff., 1954). The Soil Science Society of America (1979) prescribed salinity to soil that has an electrical conductivity greater than 2 dSm^{-1}at 25°C, an exchangeable sodium percentage (ESP) less than 15 and pH less than 8.5 (U.S. Salinity Laboratory Staff, 1954).

Salt stress can be described to two salts calcium salts and sodium salts, although most of the salt stresses in nature are due to Na salts, particularly NaCl. Salinity effects can be classified as osmotic, toxic or nutritional. Salt stress causing toxicity could be termed primary salt injury and that causing osmotic stress and nutritional stress (including deficiency of other nutrients) is secondary salt-induced stress (Manneh, 2004).

Agricultural crops exhibit a spectrum of responses under salt stress. Salinity not only decreases the agricultural production of most crops, but also, effects soil physicochemical properties, and ecological balance of the area. The impacts of salinity include low agricultural productivity, low economic returns and soil erosions (Hu and Schmidhalter, 2002).

2.2 Effect of salinity on growth and development

Salinity effects are the results of complex interactions among morphological, physiological, and biochemical processes including seed germination, plant growth and water and nutrient uptake (Akbarimoghaddam *et al*., 2011). Salinity affects almost all aspects of plant development including: germination, vegetative growth and reproductive development. Soil salinity imposes ion toxicity, osmotic stress, nutrient (N, Ca, K, P, Fe, Zn) deficiency and oxidative stress on plants, and thus limits water uptake from soil. Soil salinity significantly reduces plant phosphorus (P) uptake because phosphate ions precipitate with Ca ions (Bano and Fatima, 2009).

Excessive accumulation of sodium in cell walls can rapidly lead to osmotic stress and cell death (Munns, 2002). Plants sensitive to these elements may be affected at relatively low salt concentrations if the soil contains enough of the toxic element. Because many salts are also plant nutrients, high salt levels in the soil can upset the nutrient balance in the plant or interfere with the uptake of some nutrients (Blaylock *et al*., 1994).

Salinity also affects photosynthesis mainly through a reduction in leaf area, chlorophyll content and stomatal conductance, and to a lesser extent through a decrease in photosystem II efficiency (Netondo *et al*., 2004). Salinity adversely affects reproductive development by inhabiting microsporogenesis and filament elongation, enhancing programmed cell death in some tissue types, ovule abortion and senescence of fertilized embryos. The saline growth medium causes many adverse effects on plant growth, due to a low osmotic potential of soil solution (osmotic stress), specific ion effects (salt stress), nutritional imbalances or a combination of these factors (Ashraf, 2004). All these factors cause adverse effects on plant growth and development at physiological and biochemical levels (Munns and James, 2003) and at the molecular level (Tester and Davenport, 2003).

In order to assess the tolerance of plants to salinity stress, growth or survival of the plant is measured because it integrates the up or down-regulation of many physiological mechanisms occurring within the plant. Osmotic balance is essential for plants growing in saline medium. Failure of this balance results in loss of turgidity, cell dehydration and ultimately, death of cells.

On the other hand, adverse effects of salinity on plant growth may also result from impariment of the supply of photosynthetic assimilates or hormones to the growing tissues (Ashraf, 2004). The resulting of ion toxicity the replacement of K^+ by Na^+ in biochemical reactions, and Na^+ and Cl^- induced conformational changes in proteins is occurred.

For several enzymes, K^+ acts as cofactor and cannot be substituted by Na^+. High K^+ concentration is also required for binding tRNA to ribosomes and thus protein synthesis (Zhu, 2002). Ion toxicity and osmotic stress cause metabolic imbalance, which in turn leads to oxidative stress (Chinnusamy *et al*., 2006).

The adverse effects of salinity on plant development are more profound during the reproductive phase. The adverse effects of salinity may be attributed to the salt-stress effect on the cell cycle and differentiation. Salinity arrests the cell cycle transiently by reducing the expression and activity of cyclins and cyclin-dependent kinases that results in fewer cells in the meristem, thus limiting growth. The activity of cyclin-dependent kinase is diminished also by post-translational inhibition during salt stress. Recent reports also show that salinity adversely affects plant growth and development, hindering seed germination, seedling growth, enzyme activity (Seckin *et al*., 2009), DNA, RNA, protein synthesis and mitosis (Tabur and Demir, 2010)

Salinity tolerance by plants depends primarily on the genotype that determined alterations on processes such as uptake and transport of salt by roots, together with metabolic and physiological events (Winicov, 1993). Screening of different cultivars of potato for abiotic stress tolerance was necessary not only

for breeding to abiotic stress, but also for providing better material for studying the abiotic stress tolerance mechanism (Sergeeva *et al*., 2000).

Potatoes are classified as moderately salt-sensitive (Ahmad and Abdullah, 1979). A salinity level as determined by the electrical conductivity of a saturated soil solution extract, in the range of 4 dS/m or above, usually lowers tuber yields by more than 25% (Maianu, 1985).

The extent of tolerance depends on salinity intensity, the cultivar involved and the developmental stage of the crop (Levy 1986; Miller and Martin 1987; Haverkort *et al*. 1990). Responses of potatoes to salinity is generally assessed in terms of survival, vegetative growth, tuber size or total tuber production (Lool Van, 1981; Mac Kerron and Jefferies, 1988; Flowers and Yeo, 1989).

Wild potatoes growing under harsh conditions in the Andes are relatively stress tolerant, but extensive breeding and selection for traits other than abiotic stress tolerance have resulted in cultivars that are considered moderately salt tolerant (Arvin *et al.*, 2008).

A majority of cultivated plant species, especially widely grown horticultural and cereal crops (Chinnusamy *et al*., 2005), are glycophytes i.e. susceptible to excessive concentration of dissolved ions (e.g. >30 mM or >3.0 dS/m) in the rhizosphere solution. Depending on salt concentration and the length of exposure, the stage of growth/development and the environmental conditions (humidity, temperature, insolation, soil moisture etc), in glycophytes increased salinity may induce different physiological malfunctions, such as osmotic, ionic and different secondary (oxidative) disorders (Zhu, 2001), generally known as salt stress.

Osmotic stress, as primary reaction triggered by relatively low or moderate salinity levels, decreases soil water potential i.e. reduces water uptake and causes possible cell dehydration (Ondrasek *et al.*, 2009). For instance, increased concentration of dissolved salts may reduce soil water potential from -1 to -2.5 (-5 in extreme cases) MPa (Flowers and Flowers, 2005).

In saline conditions, osmotic pressure in the rhizosphere solution exceeds that in root cells, influencing water and nutrient uptake. Further plant responses to osmotic stress are stomata closure (partially or fully) i.e. transpiration or C assimilation reduction, decrease in cell growth and development, reduced leaf area and chlorophyll content, accelerated defoliation and senescence i.e. mortality of plant organism (Shannon and Grieve, 1999).

An increase in concentration of certain dissolved ions, will enhance their uptake i.e. ionic stress, and ultimately cause phytotoxic effects (e.g. Cl, B, Al toxicity). Specific ionic stresses disrupt selectivity of root plasma membrane, homeostasis of essential ions and numerous metabolic activities (Zhu, 2001).

For instance, in rice, as one of the most widely grown cereals, salinity is the main limiting variable of mineral nutrition (Marschner, 1995). Moreover, approximately half of global saline (i.e. alkaline) soils used for cereal production are overlain on soils with low levels of plant-available Zn i.e. Zn-deficient soils, due to Zn complexation/competition with dissolved salts (CO_3s, SO_4s, Na^+) at alkaline pHs (Ondrasek *et al.*,2009). Therefore, given that the food crop consumption is the principal route of most essential minerals into the human organism. Salinity may indirectly contribute to mineral deficiency in billions of people.

The primary salinity effects give rise to numerous secondary ones such as oxidative stress, characterised by accumulation of reactive oxygen species (ROS: H_2O_2, O_2 ,$^-$OH), potentially harmful to bio-membranes, proteins, nucleic acids and enzymes (Gomez *et al.*, 2004). Antioxidative enzymes such as superoxide dismutase (SOD), catalases, peroxidises, etc enhance detoxication of ROS. The relatively salt-tolerant species (e.g. pea genotypes) have increased activities of certain antioxidative enzymes. Whereas in salt-sensitive species (e.g. cowpea) Na^+ causes a stronger inhibition effect on particular SOD forms than Cl ions (Hernandez *et al*., 1994)

Two most important ions that induce salt stress in plants are Na^+ and Cl^-. Sodium is nonessential but beneficial element, whereas Cl is essential phyto-micronutrient (Marschner, 1995). However, both are potentially toxic in excessive concentrations, triggering specific disorders and causing substantial damages to crops. Under excessive Na^+ and Cl^- rhizosphere concentration, there are competitive interactions with other nutrient ions (K^+, NO^{3-}, H_2PO_{-4}) for binding sites and transport proteins in root cells and thereafter for (re)translocation, deposition and partitioning within the plant (Grattan and Grieve, 1999; Tester and Davenport, 2003; White and Broadley, 2001).

Significantly enhanced uptake and accumulation of Na and accompanied with a decrease in K concentration in the same tissues (from ~30% in strawberry and ~40% in radish to 4-folds in muskmelon) was obtained under moderate (60 mM) NaCl salinity (Ondrasek *et al.*, 2009).

In the same studies, salinity stress reduced all vegetative parameters (e.g. number of strawberry runners by up to 7-folds and length of the longest runner by 3-folds), decreased total fruit yield (in radish by 35%, muskmelon by 50% and strawberry by 60%), accelerated leaf senescence and reduced the strawberry growing period by up to 22 days i.e. induced plant mortality after 65-day treatment with salinised (60 mMNaCl) nutrient solution.

Salinity tolerance is thus an important character in plant breeding to increase yields in marginal zones (Turkan and Demiral, 2009). Using conventional selection and breeding techniques, significant improvements in the salinity tolerance of agriculturally important plants has been achieved (Ashraf and Harris, 2004), although these techniques are long and expensive. This applies especially to the selection of fruit plant material, due to the long periods of growth required; therefore, strategies to shorten this process are needed.

In vitro culture has emerged as a useful technique for the study of salt stress (Naik and Widholm, 1993; Woodward and Bennett, 2005), and it is being used

for the selection of tomato and Vignaradiata plants tolerant of salinity (Hassan *et al.,* 2008).

Moreover, the accumulation of solutes such as glycine and proline has been linked to water stress, salinity and other abiotic plant stresses (Ashraf and Harris, 2004 and Lu *et al.,* 2009), indicating an essential role for these solutes in tolerance to these stresses.

Proline accumulates under salt stress in both leaf and root tissues (Aziz *et al*., 1999) and putatively protects against the osmotic potential generated by salt (Watanabe *et al*., 2000; Chen *et al*., 2007)

Studies over the last years have revealed a number of important strategies to improve salt tolerance. One strategy is the controlled influx of Na^+ into the root cells. A comparison of Na^+-influx in root cells of the glycophyte *Arabidopsis thaliana* and those of the halophyte *Thellungiella halophila* shows that ion channels in the halophyte species are much more selective for Na^+ than those of *Arabidopsis* (Volkov *et al.*, 2006).

Excess Na^+ ions that reach the transpiration stream in the root system are destined for the shoot by transport through the xylem. However, plants have the ability to absorb Na^+ from the xylem sap to surrounding tissue by means of Na^+ transporters that belong to the HKT gene (Sunarpi *et al.;* 2005).

Plants well adapted to salt like halophytes, have a high capacity to accumulate Na^+ ions in the large central vacuole. Vacuolar sequestration of Na^+ avoids toxic levels of Na^+ in the cytosol and reduces at the same time the water potential of a large volume of the cell. Sequestering Na^+ ions into vacuoles has a large impact on the cellular osmotic potential (Flowers and Colmer, 2008).

To balance the water potential of the cytosol with the apoplast and vacuolar lumen, plants produce osmotically active solutes like proline in response to salt stress (Szabados and Savoure, 2010). Besides regulation of osmotic pressure, proline has been shown to stabilize proteins and membranes, protect plants

against free radical-induced damage and proline maintains appropriate $NADP^+$/NADPH (Mansour, 1998).

A key mechanism in proline metabolism is the reciprocal regulation of the proline biosynthesis gene *P5CS1* and the proline degradation gene *PDH* (Szabados *et al.;* 2010; Peng *et al.*, 1996). During salt stress, *P5CS1* is induced and *PDH* is repressed (Peng *et al*. 1996; Strizhov *et al*. 1997). Over-expression of the *P5CS* gene from *Arabidopsi*s in potato strongly stimulated proline production particularly in the presence of 100 mM NaCl and improved salinity tolerance with respect to tuber yield and weight (Hamida *et al.,* 2005).

Once Na^+ is inside the cytosol of plant cells and is not sequestered in the vacuole, it may interfere with the function of (K^+) as a co-factor for a range of enzymes, since Na^+ replaces K^+ physically but not functionally (Shabala *et al*., 2008). The ability to maintain K^+ homeostasis during salt stress is considered a characteristic of more salt tolerant plants (Shabala *et al*., 2008; Hauser and Horie, 2010). One important novel determinant for salt tolerance is the ability to retain K^+ in the root upon exposure to NaCl as was shown for a range of barley and wheat cultivars by using the vibrating probe technique (Chen *et al*., 2007; Cuin *et al*., 2008).

Karim *et al* (2011) carried out an experiment with ten exotic potato varieties (var. All Blue, All Red, Cardinal, Diamond, Daisy, Granola, Green Mountain, Japanese Red, Pontiac and Summerset) to determine their yield potentiality. The highest total tuber weight per plant (344.60g) recorded in var. Diamond and total tuber weight $plant^{-1}$ was the lowest (65.05g) recorded in var. All red, all blue varieties showed the most potential yield in this experiment.

An experiment with twenty five varieties were evaluated at six locations. They found that, plant height (cm) in case of Diamond (47.87), Sagitta (56.20), Quincy (95.40); No. of stem $hill^{-1}$ in Diamond (3.66), Sagitta (2.53), Quincy (2.26); Foliage coverage at 60 DAP (%) in Diamond (73.33), Sagitta (93.67), Quincy (92.00); No of tuber $hill^{-1}$ in Diamond (6.72), Sagitta (3.94), Quincy

(9.95); Weight of tuber hill^{-1} (kg) in Diamond (0.30), Sagitta (0.34), Quincy (0.35); Dry matter (%) in case of Diamond (19.54), Sagitta (20.10), Quincy (18.70) (BARI, 2009 a).

A field trial with twenty eight varieties was evaluated at five locations. They found that, plant height at 60 DAP (cm) in case of Diamond (54.13), Sagitta (47.27), Quincy (80.93); No. of stem hill^{-1} in Diamond (4.66), Sagitta (5.40), Quincy (5.80); Foliage coverage at 60 DAP (%) in Diamond (93.67), Sagitta (90.67), Quincy (97.00); No. of tubers hill^{-1} in Diamond (8.11), Sagitta (5.41), Quincy (6.95); Weight of tubers hill^{-1} (kg) in Diamond (0.28), Sagitta (0.37), Quincy (0.45); Dry matter (%) in case of Diamond (19.91), Sagitta (20.60), Quincy (18.34) (BARI, 2009 b).

An experiment with twelve varieties were evaluated at six locations in their third generation. They found that, plant height (cm) in case of Diamond (50.93), Granola (69.10), Sagitta (41.33), Quincy (65.87); No. of stem hill^{-1} in Diamond (5.66), Granola (3.20), Sagitta (3.46), Quincy (4.86); Foliage coverage at 60 DAP (%) in Diamond (92.00), Granola (91.00), Sagitta (89.33), Quincy (96.00); No. of tuber hill^{-1} in Diamond (7.24), Granola (6.82), Sagitta (5.23), Quincy (5.76); Weight of tuber hill^{-1} (kg) in Diamond (0.38), Granola (0.26), Sagitta (0.33), Quincy (0.35); Dry matter (%) in case of Diamond (20.80), Granola (20.45), Sagitta (19.80), Quincy (18.40) (BARI, 2009 c).

An experiment with seven potato varieties was evaluated at MLT site. It was found that plant height (cm) in case of Diamond (43.00), Lady Rosetta (37.00), and Courage (44.47); No of stem plant^{-1} in Diamond (3.57), Lady Rosetta (2.80), and Courage (3.67); No of tuber plant^{-1} in Diamond (8.07), Lady Rosetta (5.67), and Courage (6.70) (BARI, 2009 d).

Haque (2007) carried out a field experiment with 12 exotic potato germplasm to determine their suitability as a variety in Bangladesh. It was found that all the varieties gave more than 90% emergence at 20-35 DAP. It was also observed that Plant height (cm) of Quincy was (87.8), Sagitta (65.8), Diamond

(62.6); No. of stems hill^{-1} was counted in Diamond (7.2), Quincy (4.5), Sagitta (4.4); Plant diameter (cm) of Sagitta was (4.0), Quincy (3.7), Diamond (2.6) at 60 DAP; Foliage coverage (%) of Sagitta was (100.0), Diamond (98.3), Quincy (96.6); No. of tubers plant^{-1} of Diamond was (13.06), Sagitta (8.34), Quincy (6.71); Wt. of tubers plant^{-1} (kg) of Quincy was (0.64), Sagitta (0.63), Diamond (0.49); Dry matter (%) of Sagitta was (20.8), Diamond (20.1), Quincy (18.5).

Mahmud *et al.* (2009) assessed the yield of seed size tubers in five standard potato cultivars (Cardinal, Multa, Ailsa, Heera, and Dheera) in relation to dates of dehaulming (65, 70, and 80 days after planting) in a Seed Potato Production Farm, Debijong, Panchagarh. The maximum seed tuber yield was recorded from Cardinal at 80 DAP followed by Heera and Cardinal at 70 DAP, Dheera and Ailsa at 75 DAP.

Das (2006) conducted an experiment to study the physio-morphological characteristics and yield potentialities of potato varieties. It was found that Foliage coverage (%) of Diamond was (93.3), Asterix (71.7), Granola (66.7), Quincy (90.0), Courage (63.3), Felsina (83.3), Lady Rosetta (83.3), Laura (78.3); No. of tubers hill^{-1} of Diamond (11.7), Asterix (8.00), Granola (11.3), Quincy (9.33), Courage (7.33), Felsina (8.00), Lady Rosetta (10.3), Laura (8.33); Tuber weight hill^{-1} (g) of Diamond (380), Asterix (285), Granola (275), Quincy (300), Courage (320), Felsina (333), Lady Rosetta (348), Laura (258); Dry matter (%) of Diamond (25), Asterix (17.5), Granola (23), Quincy (31), Courage (34.5), Felsina (22.5), Lady Rosetta (22.0), Laura (27.0); Regarding size grade distribution of tubers the varieties Courage, Espirit, Granola, Lady rosetta, Laura were found superior.

Kumar *et al.* (2005) determined under water weight, specific gravity, dry matter and starch content of potatoes grown at Modipuram, Uttar Pradesh. It was found that there was a positive correlation between under water weight and specific gravity (r=0.99), under water weight and dry matter (r=0.92).

Mondol (2004) conducted an experiment to evaluate the performance of seven exotic (Dutch) varieties of potato. It was found that plant height (cm) of Diamond was (18.07), Granola (13.47); No. of main stem hill^{-1} of Diamond (4.36), Granola (4.90); No. of tubers hill^{-1} of Diamond (12.00), Granola (10.93); Weight of tubers plant^{-1} (kg) of Diamond (0.57), Granola (0.39); Dry matter (%) of Diamond (17), Granola (16.30).

Zhang *et al*. (2005) stated that *in vitro* microtuberization provides an adequate experimental model for the physiological and metabolic studies of tuberization and the preliminary screenings of potential potato genotypes. The effects of saline stress at 0–80 mmol concentration on *in vitro* tuberization of two potato cultivars were investigated in this study. With an increase in the salt concentration, the microtuberization of potato was either delayed by 5–10 days (20 and 40 mmolNaCl) or inhibited completely (80 mmolNaCl) in addition to reduce in microtuber yields. The two potato genotypes studied showed different trends in total soluble sugars, sucrose and starch contents of microtubers under salt stress, while glucose and fructose levels remained unchanged. The vitamin C content in microtubers of two potato genotypes was reduced by salt stress. Salinity applied from 20 to 60 mmol progressively increased proline and malondialdehyde (MDA) levels in microtubers of both the potato cultivars. These results could be used for preliminary selections of salt tolerance in potato breeding programmes.

Rabbani and Rahman (1995) studied the performance of 16 Dutch potato varieties in their third generation. It was reported that the height of the plants significantly varied among the varieties. The highest foliage coverage at maximum vegetative growth stage was found in the variety Cardinal (93.3%) followed by Diamond. The highest yield of tubers per hectare was obtained from Cardinal (35.19 t ha^{-1}) followed by Romano (30.09 t ha^{-1}) and the lowest from stroma (11.11 t ha^{-1}).

Hayat *et al*. (2012) observed when exposed to stressful conditions, plants accumulate an array of metabolites, particularly amino acids. Amino acids have traditionally been considered as precursors to and constituents of proteins, and play an important role in plant metabolism and development.

Proline, an amino acid, has a beneficial role in plants exposed to various stress conditions. Besides acting as an excellent osmolyte, proline plays three major roles during stress, i.e. as a metal chelator, an antioxidative defense molecule and a signaling molecule. Proline indicates that a stressful environment results in its overproduction in plants which in turn imparts stress tolerance by maintaining cell turgor or osmotic balance; stabilizing membranes thereby preventing electrolyte leakage; and bringing concentrations of reactive oxygen species (ROS) within normal ranges, thus preventing oxidative burst in plants. Reports indicate that enhances stress tolerance when proline is supplied exogenously at low concentrations. However, some reports indicate toxic effects of proline when supplied exogenously at higher concentrations.

Huang *et al*. (2013) reported that proline accumulation is an important mechanism for osmotic regulation under salt stress. In this study, It was evaluated proline accumulation profiles in roots, stems and leaves of Jerusalem artichoke (*Helianthus tuberosus* L.) plantlets under NaCl stress. It also examined HtP5CS, HtOAT and HtPDH enzyme activities and gene expression patterns of putative *HtP5CS1*, *HtP5CS2*, *HtOAT*, *HtPDH1*, and *HtPDH2* genes. Jerusalem artichoke, a moderately salt tolerant species which were observed to accumulate proline in roots, stems and leaves during salt stress. HtP5CS enzyme activities were increased under NaCl stress, while HtOAT and HtPDH activities generally decreased.

Houman *et al*. (2011) stated that the culture of potato in saline lands has broadly significance in Iran. Fifteen percent of total lands in Iran include saline and semi saline lands. The reaction of cultivars of potato to salinity is different. Agriacultivar is less sensitive to salinity stress in comparison with Marphona

cultivar. In this research the effect of different salinity concentrations (0, 50, 100 and 150) mg/l NaCl was investigated in green house conditions on Agria and Marphona cultivars to evaluate their reaction to salinity. At first, the grown plantlets in MS medium without hormone were sent out from growth chamber and transfered in tunnel. After a week, the vases were sent out from tunnel, placed in green house conditions; and different salinity concentrations (0, 50, 100 and 150) mg/l NaCl was implemented on them. After two months, plantlets were measured the number, length and diameter of lateral branch; the number, weight, diameter and buds mini tubers. The result showed that salinity stress in Agria variety has a stimulated effect on the number of mini tubers but the diameter and number of buds mini tubers decreased with the increase of salinity stress.

Shaterian *et al.* (2005) cultivated tetraploid potatoes (*Solanum tuberosum* L.) are moderately salt sensitive but greater stress tolerance exists in diploid wild types.

Stem cuttings from salt-tolerant (T) and sensitive (S) clones of early-maturing (EM) and late-maturing (LM) diploid potato clones were stressed for 5 days at the tuber initiation stage with 150 mmolNaCl in a hydroponic sand culture under greenhouse conditions. Under stress, early-maturing clones accumulated Na^+ in the leaf tissues while late-maturing clones generally excluded Na^+ from the leaf tissues. Salt tolerant clones of both maturity types were able to tolerate high levels of Na^+ in the leaf tissues. The lower leaves accumulated more Na^+ than the upper leaves in both maturity types. Proline levels increased upon salt exposure but were not clearly associated with salinity tolerance. Tolerance was manifested in maintenance of vegetative growth, tuber yield, and reduced leaf necrosis. Salt tolerant clones of both maturity types also had less negative tuber OP under salt stress than sensitive types. High yielding EMT and LMT clones either minimized tuber yield loss or even increased yield after exposure to salt stress.

Jaarsma *et al*. (2013) compared the response of six potato cultivars to increased root NaCl concentrations. Cuttings were grown hydroponically and treated with 0mM, 60mM and 180mMNaCl for one week. Growth reduction on salt was strongest for the cultivars Mozart and Mona Lisa with a severe senescence response at 180mMNaCl and Mozart barely survived the treatment. The cultivars Desiree and Russett Burbank were more tolerant showing no senescence after salt treatment. A significance difference in Na^+ homeostasis was observed between sensitive and tolerant cultivars. In stem tissue, Mozart accumulated more H_2O_2 and less proline compared to the tolerant cultivars. Analysis of the expression of proline biosynthesis genes in Mozart and Desiree showed a clear reduction in proline dehydrogenase (*PDH*) expression in both cultivars and an increase in pyrroline-5-carboxylate synthetase 1 (*P5CS1*) gene expression in Desiree, but not in Mozart. Taken together, current day commercial cultivars show promising differences in salt tolerance and the results suggest that mechanisms of tolerance reside in the capacity of Na^+ accumulation in stem tissue, resulting in reduced Na^+ transport to the leaves.

Murshed *et al*. (2015) reported that salt stress negatively impacts crops yield throughout the world. Nine varieties of potato (*Solanum tuberosum* L.) were screened for salt stress tolerance by measuring *in-vitro* growth of the aerial plant parts, as well as roots. Salt stress was evaluated by adding 25, 50, 75, 100, 125, 150 and 200mM of NaCl to Murashige-Skoog (MS) medium and compared to MS medium without NaCl. Plant length and stem thickness, leaf area, roots number, length, and thickness, and plant fresh and dry weights were measured. Osmotic pressure (Ψ_{medium}, MPa) and electrical conductivity (EC_{medium}, mS cm^{-1}) of media ranged from −0.2 to −0.91 MPa and 5.8 to 24 mS cm^{-1}, respectively. Salt stress adversely affected the plant growth, and varieties differed in their responses. Progressive reduction in the studied parameters occurred as NaCl levels increased. Grouping all the varieties by cluster analysis, based on the growth parameters response to salt stress, resulted in three distinct groups: (1) salt tolerant group of two varieties, namely, Taurus

and Sultana; (2) moderately salt tolerant group of four varieties, namely, Loane, Diamant, Amarin, and Sylvana; and (3) salt sensitive group of three varieties, namely, Toscana, Soraya, and Kenita. The response variation of these potato varieties under NaCl indicated the possibility of using them for developing salt tolerant varieties for production in Syria.

Sudhersan *et al*. (2012) reported that salinity is a major problem for potato cultivation in Kuwait. In order to select salt tolerant cultivars attempts were made to screen many potato cultivars using tissue culture technology. Potato cultivars Ajiba, Almera, Anabelle, Arnova, Atlas, Bellini, Charlotte, Costanera, Desiree, Diamond, Fontane, Lola, Maria Tropica-1, MF-1, MF-II, Matador, Nicola, Primavera, Rembrandt, Safrane, Santae, Spunta, Tacna, Timate, and Unica were established in tissue culture via meristem culture technique using Murashige and Skoog (MS) shoot proliferation medium. Stem nodal segments were planted on MS culture media containing different concentrations of NaCl (0,750, 1000, 2000, 3000 and 4000 ppm). According to the elongation percentage of shoot against salt stress, the cultivars were grouped as tolerant, sensitive and highly sensitive to salinity. Salt toxicity levels and related morphological symptoms on plant growth were also studied for each cultivar. This study helped to identify the salt tolerant potato cultivars suitable for cultivation in Kuwait and other countries where soil salinity is a major problem in potato production.

Rahnama and Ebrahimzadeh (2004) studied on the accumulation and metabolism of proline and its correlation with Na^+ and K^+ content in shoots and callus tissue of four potato cultivars, viz., Agria, Kennebec (relatively salt tolerant), Diamant and Ajax (relatively salt sensitive). Na^+ and proline contents increased in all cultivars under salt stress. However, K^+ and protein contents reduced in response to NaCl treatments. The activities of enzymes involved in proline metabolism, Δ1-pyrroline-5-carboxylate synthetase (P5CS) and proline dehydrogenase (ProDH) increased and decreased, respectively, in response to salt stress. The changes of P5CS and ProDH activities in more salt sensitive

cultivars (Diamond, Ajax) were more than those in the tolerant ones. In callus tissue, reduced growth and cell size may be partially responsible for high proline accumulation in response to high NaCl levels. However, although the basic proline contents in the seedlings of more salt tolerant cultivars were higher than the sensitive ones, a clear relationship was not generally observed between accumulation of proline and salt tolerance in potato.

Khatun *et at* (2016) conducted an experiment to study the effects of salinity on four potato varieties (Diamant, Asterix, Lady Rosetta and Courage) were investigated with four different salinity levels (T_0=without salt, T_1=4dS/m, T_2=8dS/m, T_3=12dS/m). Here, the SPAD value of potato varieties showed statistically significant variation among the different salinity levels. SPAD value decreased with increasing salinity. The highest SPAD value (53.07) was measured from T_0 treatment and the minimum SPAD value (50.79) was measured from T_3 treatment.

Rahman *et al.* (2008) studied that salinity (NaCI) effects on three potato cultivars (Atlanta, Shepody and Shilbilaty) were investigated with five NaCI levels (0, 25, 50, 75 and 100mM) by using single node explants. Significant differences were noticed among the cultivars followed by different NaCl levels. Salinity stress gradually depressed plant growth and root development with increased NaCl concentration in MS media. All the cultivars survived at high NaCl (100mM) containing MS media with exhibiting different growth status. The results indicate that Shilbilaty performed better in shoot length and shoot fresh mass than Shepody and Atlanta. The Atlanta performed better in root growth than Shepody and Shilbilaty at different NaCl media. Highest salinity level drastically inhibits root growth in all the cultivars tested. The control and 25 mMNaCl containing MS media did not affect the growth traits of in vitro potato plantlets. The control was found superior in growth characterized than rest of the tested NaCl levels.

Biswas *et al.* (2017) conducted and experiment to select salt tolerant cultivars and here to compare the salinity level between indigenous and modern cultivars. In vitro selection of local and modern potato cultivars was investigated with five levels of NaCl (0, 30, 60, 90 and 120 mM). The indigenous potato Challisha and modern cultivars Diamond and Felsina were used as plant materials. Significant differences were noticed among the cultivars in response to different levels of NaCl. Plant growth and root development were gradually reduced with increased concentration of NaCl. All three cultivars were survived well with exhibiting different growth status up to 60 mMNaCl, but they performed poorly at 120 mM of NaCl. Cultivar Challisha performed better regarding shoot length, root length, the number of nodes per plantlet and the fresh weight per plant up to 90 mM of NaCl. Thus, It can be concluded that local indigenous variety Challisha is salt tolerant comparing with the modern cultivated varieties.

Gao *et al*. (2014) examined the ultrastructural and physiological responses of potato (*Solanum tuberosum* L.) plantlets to gradient saline stress (0, 25, 50, 100, and 200 mMNaCl) with two consequent observations (2 and 6 weeks, respectively). The results showed that, with the increase of external NaCl concentration and the duration of treatments, (1) the number of chloroplasts and cell intercellular spaces markedly decreased, (2) cell walls were thickened and even ruptured, (3) mesophyll cells and chloroplasts were gradually damaged to a complete disorganization containing more starch, (4) leaf Na and Cl contents increased while leaf K content decreased, (5) leaf proline content and the activities of catalase (CAT) and superoxide dismutase (SOD) increased significantly and (6) leaf malondialdehyde (MDA) content increased significantly and stomatal area and chlorophyll content decline were also detected. Severe salt stress (200 mMNaCl) inhibited plantlet growth. These results indicated that potato plantlets adapt to salt stress to some extent through accumulating osmoprotectants, such as proline, increasing the activities of antioxidant enzymes, such as CAT and SOD. The outcomes of this study

provide ultrastructural and physiological insights into characterizing potential damages induced by salt stress for selecting salt-tolerant potato cultivars.

One of the recently experimented strategies is silicon application since its application has been found to be beneficial in increasing tolerance to abiotic stress (Epstein, 2009). Silicon can induce salt tolerance by a variety of methods including reducing Na^+ uptake, decreasing the concentration of malondialdehyde, the endproduct of membrane lipid peroxidation (Liang *et al.,* 2003), increasing plant water content (Romero-Aranda *et al*., 2006), increasing antioxidant enzyme activity (Zhu *et al*., 2004), increasing the plasma membrane H^+ -ATPase activity (Liang *et al.,* 2006), increasing photosynthesis activity (Liang *et al*., 2007) and regulating biosynthesis of compatible solutes (Zhu and Gong, 2014). Silicon can be supplied either as a bulk material (Guntzer *et al*., 2012) or as a nano-particle (Tantawy *et al*., 2015).

Potato breeding can play a role in improving varieties that can be grown under abiotic stress conditions. In plant breeding program the selection of resistant cultivars in the field is considered important, however trial fields are commonly associated with variations in salt spatial distribution, irregular moisture availability and fluctuations of temperature through the growing season. This method also involves considerable space, time, labor, equipment and planting material resources (Arvin and Donnelly, 2008).

The in vitro method of tissue culture is a powerful tool for studying many trends of development and plant growth under controlled conditions. In vitro screening for salinity tolerance has been previously established (Potluri and Prasad, 1993; Zhang and Donnelly, 1997 and Khenifi *et al*., 2011).

Under salt stress, plants are exposed to extensive changes in their metabolism including enzymatic activities (Hasegawa *et al*., 2000; Parida and Das, 2005), changes in protein shape and function (Chen and Tabaeizadeh, 1992) and gene expression (Legay *et al.,* 2009) leading to a rise in the production of reactive oxygen species (ROS), which ultimately leads to a decrease in growth and

increase in damage to the vegetative and productive part of the plants. In response to salt stress and to reduce the effect of oxidation, plants have evolved and developed various strategies of ROS scavenging such as superoxide dismutase (SOD) and glutathione peroxidase (GPX) and accumulation or depletion of certain metabolites resulting in alterations in gene expression and the levels of a small set of cellular proteins (Abu-Hena *et al.,* 2010).

In most cases, antioxidant enzyme activity such as SOD increase in salt tolerant potato genotypes (Daneshmand *et al.,* 2010; Sajid and Faheem, 2014), however, occasionally the activity of SOD decreased with salinity stress.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the Agricultural Botany field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November 2016 to March 2017. Detailed of the experimental materials and methods followed in the study are presented in this chapter.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23º74′ N latitude and 90º35′ E longitude. The altitude location was 8 meter above the sea level.

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where flood plain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain**.**

3.2 Characteristics of soil

Selected land of the experimental field was medium high land in nature and remained utilized for crop production during the previous season. The soil is belonged to the Modhupur Tract under AEZ No. 28. The texture of the experimental soil was sandy loam. The nutrient status of soil was collected from the farm under the experimental plot within a depth of 0-20 cm. The characteristics of the soil under the experiment were analyzed in the Soil Research and Development Institute Dhaka, and results have been presented in Appendix I.

3.3 Climatic condition of the experimental site

The area possesses sub-tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds during the months from April to September (Kharif season) and plenty of sunshine associated with scanty of rainfall prevail during October to March (Rabi season). The average maximum and the minimum temperature were 28°C and 12°C respectively during the experimental period, which was suitable for growing of potato in the area.

3.4 Planting materials

The seed tubers of 'Diamond` potato variety was used in the study. The seeds of potato were collected from Tuber Crops Research Centre (TCRC), Bangladesh Agricultural Research Institute (BARI), Joydepur, Gazipur.

The official name of the "Diamond''variety was BARI ALU-7, a modern potato variety was used as experimental material. BARI ALU-7 was developed by Bangladesh Agricultural Research Institute (BARI). Plant strong and rapid growing, number of stem is lower but tall and hard, leaf slight large and deep green, seed dormancy 50-60 days in general temperature, crop duration 90-95 days. Tuber are white, oval, medium to large size, skin smooth, light yellow, shallow eye, at first sprout initiation round shape, later it will taller, color reddish violet and slight hairy. The yield of tuber (BARI ALU-7) range from 25-30 t ha^{-1}.

3.5 Treatments of the experiment

The one factorial experiment was laid out Completely Randomized Design (CRD) with three replications.

Factor: Different levels of salinity (NaCl)

i. T_0 = 0 without salt (control)
ii. T_1= 2 dS/m
iii. T_2= 4 dS/m
iv. T_3 = 6 dS/m
v. T_4 = 8 dS/m
vi. T_5 = 10 dS/m
vii. T_6 = 12 dS/m
viii. T_7 = 14 dS/m
ix. T_8 = 16 dS/m

3.6 Design and layout of the experiment

The one-factor experiment was laid out in the Completely Randomized Design (CRD) with nine levels of salinity. The total number of pots was 81 (27×3) with three replications. Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height. This experiment was done under the net house which was made by bamboo with net and pots were kept on the individual earthen plate. The distances from net to pot was 0.5 m and replication to replication was 1.0 m.

3.7 Pot preparation and application of the treatment

There were 81 earthen pots, each contained 10 kg of soil (9 kg soil and 1kg cowdung). The recommended chemical fertilizer dose was of 250-150-250-120 kg/ha of Urea, TSP and MOP respectively. All the fertilizers along with half of urea were applied as basal dose during pot preparation and the remaining amount of urea as side dressed 35 days after planting.

Irrigation water applied before emergence of plant. 0 dS/m, 2dS/m 4 dS/m, 6 dS/m, 8 dS/m,10dS/m, 12 dS/m,14 dS/m, and 16 dS/m treatments were prepared from 0, 1.28, 2.56, 3.84, 5.12, 6.40, 7.68, 8.96 and 10.24 gm of NaCl with 1 liter water. Pots were irrigated with NaCl solution according to

treatments after 30 days of planting. Treatments were applied at 4 days interval. Total 6 times treatment were applied.

3.8 Seed sowing

Whole tuber of 30-41 mm size that was planted in each pot. Sowing date of potato was on 25 November 2016. Tuber were placed in 2-3cm depth and then covered with soil properly.

3.9 Intercultural operations

3.9.1 Application of irrigation water

Irrigation water was added to each pot with water cane and first irrigation was done 3 days after sowing of seeds. The amount of irrigation water was limited up to the quantity which does not leached out through the bottom. The water was deposited on the earthen plate which was further poured into pot again for maintain the salinity level as treatment.

3.9.2 Weeding

Lightly weeding was done when required to keep the plant free from weeds. It was mostly done in vegetative stage.

3.9.3 Threshing of soil sureface

Threshing or cracking is done in each pots twice during the growing period, when the upper part of soil become hard.

3.9.4 Plant protection measures

The crop was infested by insects and diseases, those were effectively and timely controlled by applying recommended insecticides and fungicides. Melathion 57 EC and Ridomil Gold was applied @ 1 ml /L and 1 gm/L of water respectively.

3.10 Harvesting

The crop was harvested after 90 days on 23 February 2017 when the 80-90 percent of the plants showed leaf senescence and the tops started drying up. Number of tubers per plant was counted and yield per plant was calculated. Tubers were sun dried for the removing of moisture. Proper care was taken to avoid injury of potatoes during harvesting.

3.11 Recording of data

Experimental data were recorded from 30 days of growth duration and continued until harvest. The following data were recorded during the experiment.

A. Morphological Parameters

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branch plant^{-1}

B. Physiological Parameters

4. Leaf area (cm)
5. SPAD value
6. Membrane leakage
7. Chlorophyll content
8. Proline accumulation
9. Na^+ and K^+ content of tuber

C. Yield and yield contributing Parameters

10. Number of tuber per plant
11. Yield of tuber per plant (gm)
12. Dry weight of tuber (g)

3.12 Detailed procedures of recording data

A brief outline of the data recording procedure followed during the study given below:

1. Plant height

It was measured in centimeter from the base of the plant to the tip of the stem and plant height was recorded at 30, 50, 70 days after planting (DAP) and at harvest respectively.

2. Number of branch per plant

Number of branch per plant was counted from each selected plant sample and then averaged at 30, 50, 70 days after planting (DAP) and at harvest respectively.

3. Number of leaves per plant

Number of leaves per plant was counted from each selected plant sample and recorded at the time of 30, 50 and 70 days after planing.

4. SPAD value

Potato leaves were selected from the experimental field. Upper, middle and lower leaves were used for SPAD readings. For each leaf average of three readings were taken. Finally the SPAD value was taken from the average of three readings per leaf basis.

5. Chlorophyll content in leaves

The determination of the chlorophyll content of leaves is a key technique in studies of photosynthesis and for estimation of bio-productivity (Medina and Lieth, 1964). The absolute amount of chlorophyll and the changes in concentration over a period of time led to conclusions about the mineral nutrient supply as well as about the mode of action of herbicides.

The selected leaf samples was collected and kept in separate polythene bag along with marked with SPAD value and numbering. After collection the leaf samples were immediately taken to the crop physiological laboratory for

subsequent analysis. Around 20 mg leaf samples was weighted and pored into glass vial containing 20 ml of 80% acetone solution. The glass vials were kept into dark condition for 48 hours. After 48 hours chlorophyll content was determined by using double beam spectrophotometer at 663 nm and 645 nm wave length and chlorophyll was determined by using the following formula:

$$\text{Total chlorophyll (mg/g)} = \frac{\{20.2\ (D645)+8.02\ (D663)\}\times V}{1000\times W}$$

Where,

V= final volume (ml) of the 80% acetone with chlorophyll extract.

D= optical density regarding of the chlorophyll extract at wave length of 663 and 645nm

W= weight of fresh sample in gm.

6. Proline accumulation in leaf

Free proline content in the leaves will be determined according to the method of Bates (Bates, *et al.,* 1973). The protocol is based on the formation of red colored by proline with ninhydrin in acidic medium, which is soluble in organic solvents like toluene.

The 0.5 g plant tissue and homogenized in 5 ml of 3% sulphosalycylic acid was taken which used pre washed mortar and pestle. Filter the homogenate through Whatman no.1 filter paper and collect filtrate was used for the estimation of proline content. 2 ml of extract was taken in test tube and added 2 ml of gacial acetic acid and 2 ml of ninhydrin reagent. Heat reaction mixture was in a boiling water bath at 100^{o} C for 1 hour. Brick red color was developed. After cooling the reaction mixtures, 4 ml of toluene was added and then transferred to a separating funnel. After thorough missing, the chromospheres containing toluene was separated and its absorbance read at 520 nm in spectrophotometer against toluene blank. Prepared standard curve of proline by taking 5 to 100 µg ml^{-1} concentration. Free proline content in sample was estimated by referring to a standard curve made from known concentrations of proline by taking following formula.

Where,

FW = fresh weight of leaf tissue

D = Initial dilution

S = absorbance at 520 nm

115.5 = Molecular weight of proline

µ moles proline/g of fresh plant material = {(mg proline/ml×ml toluene)/115.5µg/µmoles}/g sample/5

7. Leaf area per plant

Leaves were collected from the plants and leaf area was measured by non-destructive method using CL-202 Leaf Area Meter (USA) in the central laboratory of Sher-e-Bangla Agricultural University. Leaf area plant^{-1} was measured from 40 DAP till 90 DAP at 15 days interval and the average value was worked out for recording the leaf area.

8. Membrane Leakage (%)

The plasma membrane intactness was estimated through the leakage of electrolytes (Blum *et al*, 1981). Weighted approximately 30 mg fresh leaf materials were placed into tubes, containing 30 ml distilled water and kept for 2 hours in water bath at 30º C and the initial conductivity (EC_1) was measured using a EC meter. After boiling the plant samples for 15 min, the final value of electrolyte conductivity (EC_2) was measured. The leakage percentage or cell membrane leakage was calculated as (EC_l/EC_2)×100.

9. Number of tubers per plant at harvest

The number of tubers was counted from plants and average number of tubers was calculated.

10. Weight of tubers per plant at harvest

The weight of tubers was recorded from plant and average weight of tubers per plant was calculated.

11. Dry weight of tubers

Two hundred grams of potatoes from sample plants were sliced, sun dried for 2 days and then dried at 70°C in an oven for 3 days. Just after oven drying the dried pieces were weighed and were expressed in percentage.

Weight of tuber (%) = $\frac{Dryweight}{Freashweight} \times 100$

12. Na^+ and K^+ content in Tuber

Oven-dried tuber samples of potato were ground in a Wiley Hammer Mill, and 1 gm of powder from each sample was taken to analyze Na^+ and K^+ content by flame photometric method.

3.14 Statistical analysis

The collected data were analyzed statistically following CRD design by MSTAT-C computer package programme to find out the significance of the difference among the treatments. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomes (1984).

CHAPTER IV
RESULTS AND DISCUSSION

This chapter comprises the presentation of data and discussion of the result obtained from the experiment. The growth and yield components of potato were influenced by the different salinity level. The results have been summarized in different table, figures and appendices. The analysis of variance of data at different parameters are also given in the Appendix II-VIII. The results of each parameter have been presented, discussed and interpreted in this chapter.

4.1. Morphological parameters

4.1.1. Plant height

Different salinity levels affected plant height significantly during the growth periods. Plant height decreased with increasing the salinity levels. The plant height of the potato variety was measured at 30, 50, 70 DAP (Days After Planting) and at harvest varied significantly due to application of salt. It was evident from Table 1. The highest plant height 38.40 cm was found from T_0 (control) followed by 30.43 cm from T_1 (2 ds/m) at the harvest. Then the height of plant gradually reduced with increasing of salinity level as 29.7 cm, 28.67 cm and 28.67 cm with T_2, T_3 and T_4 (4 ds/m, 6 ds/m and 8 ds/m respectively) treatment at the harvest. On the other hand, the shortest plant height as 14.90 cm at harvest was observed in T_8 (16 ds/m) followed by 17.17 cm with T_7 (14 ds/m) treatment at harvest.

Levy, (1986) reported that the Plant height was significantly affected by salinity. Within the first 20 days after the application of treatment, plant height was reduced by about 17% in treatments T_3 and T_4 compared to the control treatment. This inhibition of plant growth remained more or less constant throughout the entire growth period. However, withholding of irrigation for 2 weeks reduced plant height by 25% (T_5).

Alam *et al*. (2004) reported that the critical level of salinity was about 6 dS/m for rice seedling growth. The most common salinity effect was stunting of plant growth, resulting leaf withering was less apparent and the growth parameters such as dry matter, seedling height, root length and emergence of new roots decreased significantly at electrical conductivity value of 6-8 dS/m. Seedling height, root length, seedling dry weight were highly correlated with the saline stress tolerance index, that measuring varietal ratings for salt tolerance at the early stage of growth via these traits was likely to be effective.

Table 1. Plant height of potato influenced by different salinity levels at different days after planting

Treatment	Plant height (cm)			
	30 DAS	50 DAS	70 DAS	At harvest
T_0	20.78 a	27.23 a	35.23 a	38.40 a
T_1	20.00 a	23.87 b	29.74 b	30.43 b
T_2	18.45 a	22.75 b	28.31 b	30.39 b
T_3	16.51 ab	20.30 bc	26.47 bc	29.71 b
T_4	15.97 b	19.97 bc	26.14 bc	28.67 b
T_5	14.18 c	17.83 d	23.03 d	23.75 c
T_6	12.54 d	14.73 e	18.22 e	18.35 d
T_7	12.23 d	14.24 e	16.54 ef	17.17 d
T_8	10.75 e	13.27 e	14.51 f	14.90 d
$LSD_{0.05}$	2.4267	3.604	3.671	3.437
CV (%)	8.24	10.43	11.79	10.89

T_0 = 0 ds/m, T_1 = 2 ds/m, T_2 = 4 ds/m, T_3 = 6 ds/m,T_4= 8 ds/m, T_5 = 10 ds/m, T_6 = 12 ds/m, T_7 = 14 ds/m, T_8 = 16 ds/m

∗ Different letters indicate significant variance

4.1.2. Number of leaves/plant

A significant variation was recorded for producing the number of leaves per plant at different DAP with defferent level of salinity (Figure 1-4). Number of leaves/plant decreased with increasing the salinity level. The highest 20.23 number of leaves were produced by T_0 (control) treatment followed by 18.68, 18.03 in T_1 and T_2 (2 ds/m and 4 ds/m respectively) treatment at harvest. The lowest number of leaves were observed 6.01, 7.54, 7.07 and 5.30 at 30, 50, 70 DAP and at harvest respectively in T_8 treatment. The number of leaves was

significantly higher in control plant. Which was gradually decreased with increasing in salinity levels.

When the plant is exposed to saline stress for extended periods, it has been noted that ion toxicity and water deficiency occurs in old leafs, with carbohydrate deficiency and associated symptoms in young leaves. A salt-specific effect appears as salt injury in the old leaves, leading to their death. Loss of only a few leaves does not affect plant growth, but if the rate of leaf death approaches the rate of new leaf production, a substantial drop in the supply of assimilates to the growing leaves can occur with increasing of salinity. It leads to a significant suppression in plant growth. In this experiment, leaf death which reduced leaf number was responsible for the decrease in leaf area.

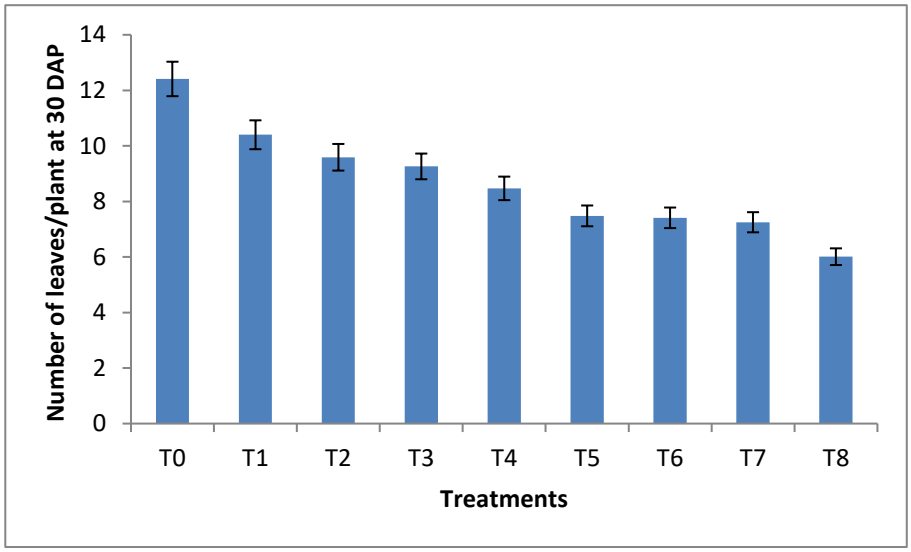

Figure 1: Effect of different level of salinity on number of leaves/plant of potato at 30 DAP

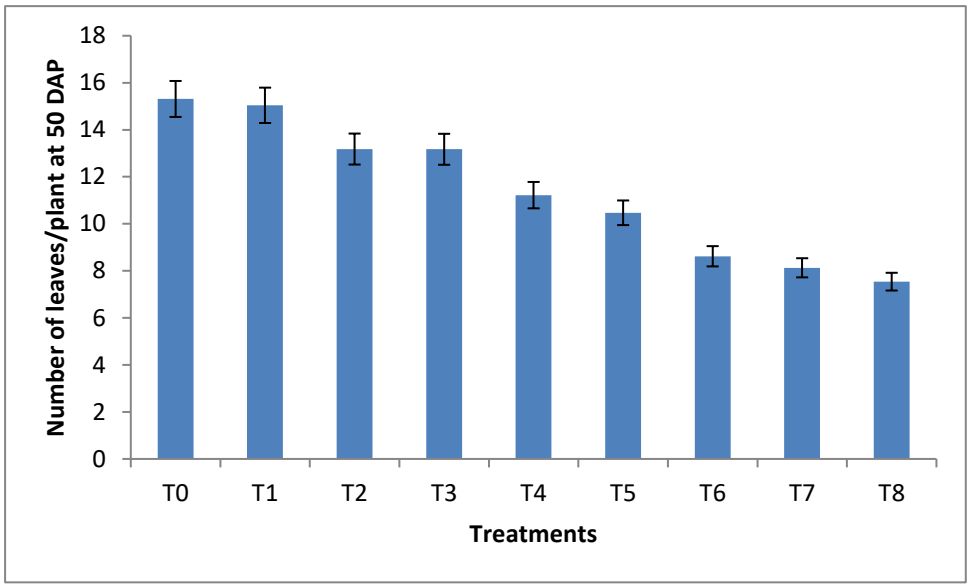

Figure 2: Effect of different level of salinity on number of leaves/plant of potato at 50 DAP

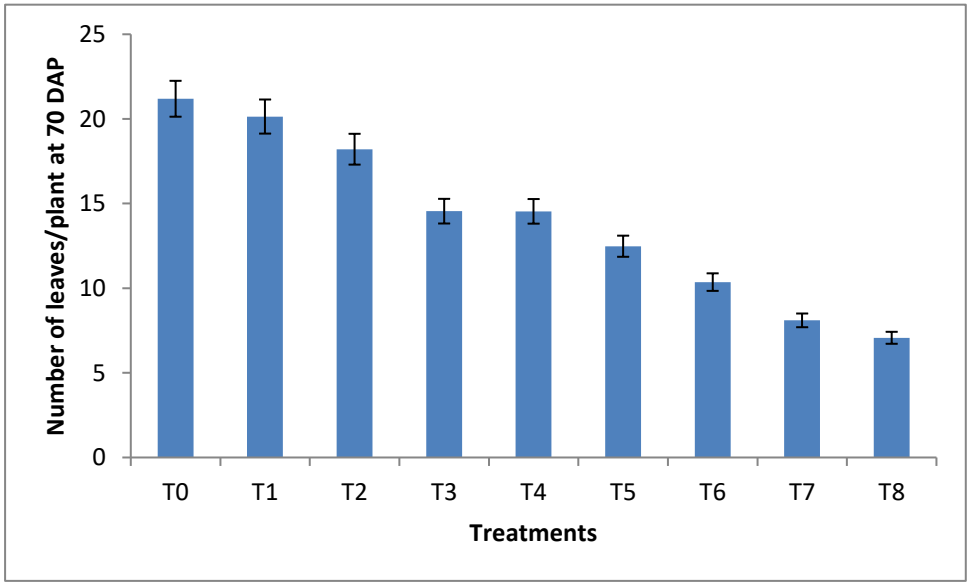

Figure 3: Effect of different level of salinity on number of leaves/plant of potato at 70 DAP

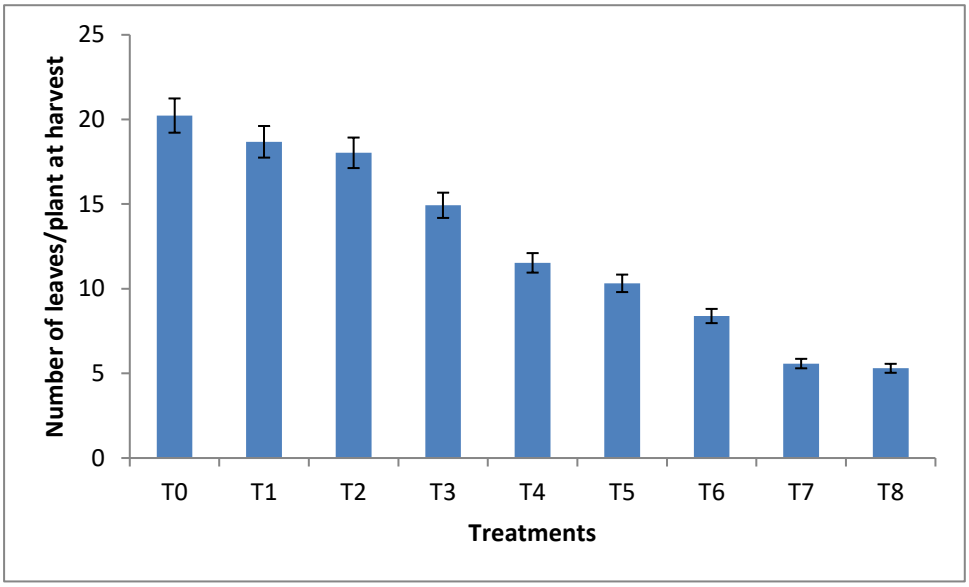

Figure 4: Effect of different level of salinity on number of leaves/plant of potato at harvest

4.1.3. Number of branches/plant

The impact of different salinity levels on the number of branches is shown in (Figure 5-8). The number of branches/plant was measured at 30, 50, 70 DAP and at harvest respectively varied significantly due to the application of different level of salt. For T_6, T_7 and T_8 treatments it was observed the number of branches/plant decreased in salt treated treatment in comparison to the control treatment. T_0 (control treatment) was found to produce the highest number of branches. The number of branches were recorded as 9.27, 8.57, 7.53, 6.43 and 5.53 in T_0, T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 (0 ds/m, 2 ds/m, 4 ds/m , 6 ds/m, 8 ds/m, 10 ds/m, 12 ds/m, 14 ds/m and 16 ds/m respectively) treatment at harvest respectively. T_8 (16 ds/m) treatment produced the lowest number of branches. With increasing the DAP with treatment, the number of branches was decreased gradually.

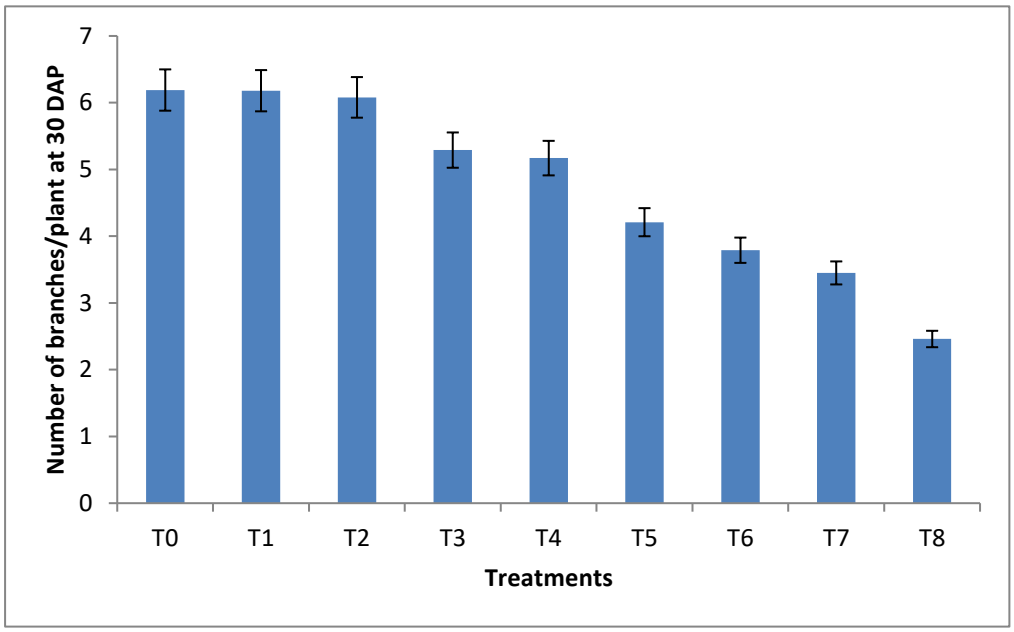

Figure 5: Effect of different level of salinity on number of branches /plant of potato at 30 DAP

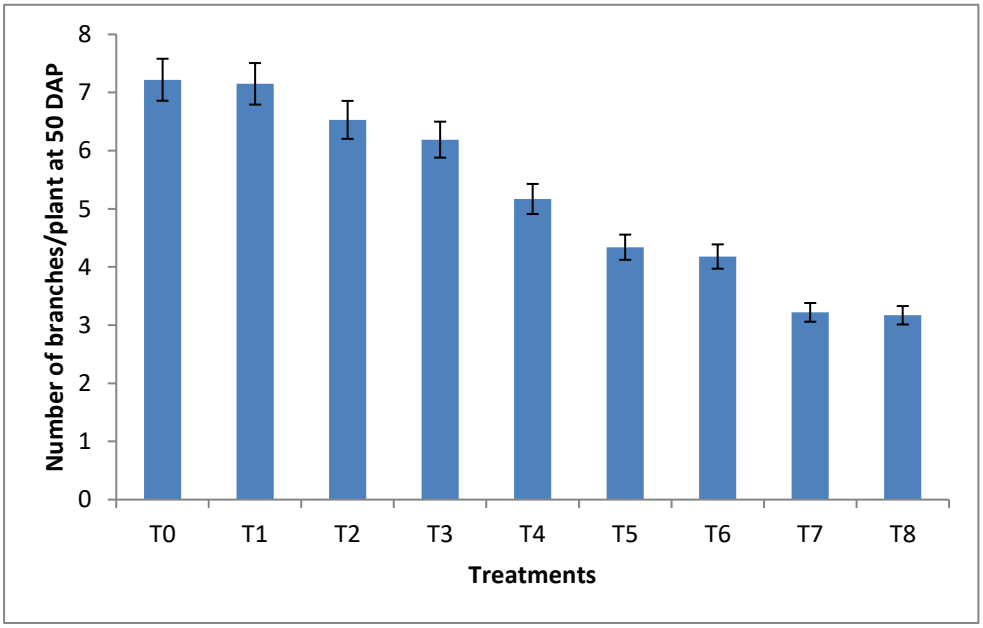

Figure 6: Effect of different level of salinity on number of branches /plant of potato at 50 DAP

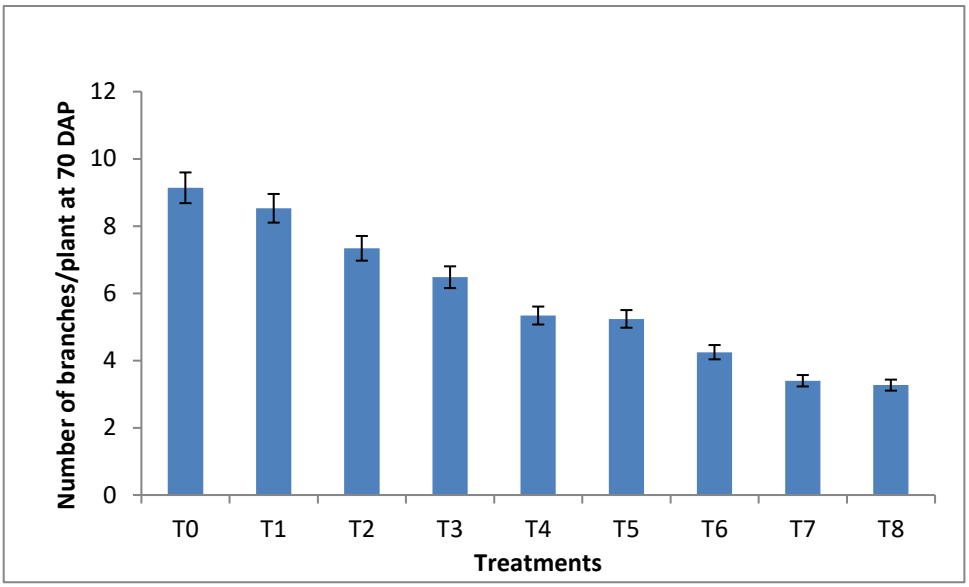

Figure 7: Effect of different level of salinity on number of branches /plant of potato at 70 DAP

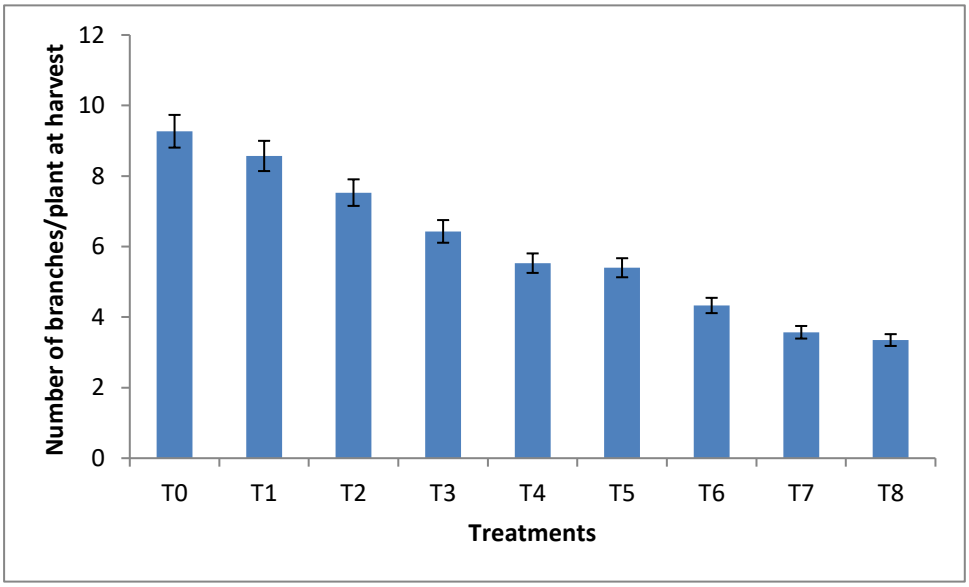

Figure 8: Effect of different level of salinity on number of branches /plant of potato at harvest

4.2. Physiological parameters

4.2.1. Leaf area index

A significant variation in leaf area index was observed in different salinity levels (Table 2). Leaf area decreased with increasing salinity levels. The maximum leaf area index 21.74 cm^2 was obtained from T_0 (control) at 50 DAP and the minimum leaf area index 13.63 cm^2 was found from T_8 (16 ds/m) at harvest. Resulting showed that leaf area index decreased gradually with the increasing of salinity levels at different DAP.

Jefferies (1993) reported that salinity or drought significantly reduced the final size of potato leaves. A marked decrease in leaf area was observed when the crop was irrigated with the more saline water 62% (Table 2). The greatest effect was obtained in T_8, in which leaf area was reduced by 86%.

Table 2. Leaf area index of potato influenced by different salinity levels

Treatment	Leaf area index (cm^2)	
	50 DAS	At harvest
T_0	14.91 a	21.74 a
T_1	10.01 b	16.37 b
T	9.94 b	16.31 b
T_3	8.69 c	15.45 c
T_4	8.29 c	14.81 d
T_5	6.95 d	13.65 d
T_6	6.87 d	13.79 e
T_7	6.38 e	13.68 e
T_8	6.24 f	13.63 e
$LSD_{0.05}$	0.356	0.714
CV (%)	6.587	8.472

T_0 = 0 ds/m, T_1 = 2 ds/m, T_2 = 4 ds/m, T_3 = 6 ds/m,T_4= 8 ds/m, T_5 = 10 ds/m, T_6 = 12 ds/m, T_7 = 14 ds/m, T_8 = 16 ds/m

* Different letters indicate significance variance

4.2.1. SPAD value

Photosynthesis is the most important biochemical event on earth. Photosynthesis converts massive amount of sunlight into electrical and then chemical energy (Hall and Rao, 1999). The SPAD value of potato plants showed statistically significant variation among the different salinity levels (Table 3). SPAD value decreased with increasing salinity. The highest SPAD value (55.60) was measured from T_0 treatment and the minimum SPAD value (38.20) was measured from T_8. Khatun *et al* (2016) studied on SPAD value of potato plant and she observed, the highest SPAD value (53.07) was in T_0 (control) treatment and the minimum value (50.79) was T_3 (12dS/m) treatment.

4.2.2. Chlorophyll content in leaves

Chlorophyll content of potato leaves showed statistically significant variation among the different salinity levels (Table 3). Decrease in chlorophyll content in leaves was occurred as a result of the increasing of salt application. The highest chlorophyll content (2.64 mgg^{-1}) was measured from T_0 (control) treatment and the minimum chlorophyll content (0.91mgg^{-1}) was measured from T_8 (16 ds/m) treatment.

The result (Table 3) revealed that different salinity levels and the interaction between salinity had a significantly effect on chlorophyll a, b and carotenes content. By increasing salinity levels from 0 to 16 ds/m, these three photosynthetic pigments reduced. Maximum reduction was observed when plants were exposed to high salinity level (16 ds/m).

Mostafa Heidari (2012) indicated that chlorophyll content in leaves was affected by salinity and this effect depends on the levels of salinity. By increasing salinity levels from 0 to 6 ds/m, chlorophyll a, b and carotenes content in two basil genotypes decreased.

The loss of chlorophyll under salt stress could be related to photo-inhibition or ROS formation (Kato and Shimizu, 1985). The reduction in photosynthesis under salinity can be attributed to a decrease in chlorophyll content.

Salinity reduces the chlorophyll content in salt susceptible plants and increases it in salt tolerant plants. Salinity reducing growth in radish (*Raphanus sativus* L.) at high salinity level could be attributed to a reduction in leaf area expansion and hence to a lower light interception (Marcelis and Hooijdonk, 1999).

4.2.3. Membrane leakage in leaves

Statistically significant variation was found in respect of membrane in different salinity level (Table 3). Cell membrane leakage exhibited negative correlation with fresh and dry weight, leaf area, leaf water content and total protein content. There was also a significant positive correlation between cell membrane injury and RNA degradation. This results indicate continous increased in cellular membrane leakage with increasing salt concentration. The highest membrane leakage (93.51 %) was obtained from T_8 treatment which was statistically different from all other treatments. The lowest membrane stability (52.29%) was observed in T_0 (control) treatment.

Wahid *et al* (2007) reported that specific expression of stress proteins is an important adaptive manifestation in maintaining the integrity, native configuration and topology of cellular membranes components to ensure their normal functioning under salinity stress. The decrease in protein content and protein molecular weights that salinity exposure affect protein activities in the plant. M. Mumtaz Khan *et al* (2013) demonastrated that the electrolyte leakage was enhanced with increasing salinity levels as compared to the control plants. It was also observed the same increasing trend of electrolyte leakage in salt sensitive cucumber cultivar as compared to the salt tolerant cultivar.

Nassery (1975, 1979) reported that the effect of NaCl was attributed to the non-specific membrane damage and loss of membrane integrity. However, it

was showed that NaCl (>50mM) specifically induces efflux of K^+. Analysing K^+ efflux from wheat, barley, bean, and chick pea roots, demonstrated that this reaction is sensitive to Ca^{2+} and that it is not induced by osmotic stress.

4.2.4. Proline accumulations

The influence of different salinity levels was significant on the proline accumulation (Table 3). Proline accumulations increased with increasing salinity levels. Proline accumulates more in the leaves of plants that are more tolerant to salinity stress than in salt sensitive plants. The highest proline accumulation (16.12 $\mu mol^{-1}FW$) was obtained from T_8 treatment (16 ds/m) followed by T_7 treatment (14 ds/m). The lowest proline accumulation (0.82 μmol^{-1} FW) was observed in T_0 (control) treatment.

Leaf proline content increased during the growth period, being between two and three-folds higher in plants at T_8 (16 ds/m) treatment compared to T_0 treatment (control plants). After 70 days of salt stress, both TAA and proline content did not differ between is T_7 (14 ds/m) and T_8 (16 ds/m) treatments. For all sampling dates, the 16 ds/m salt concentration significantly enhanced free radical scavenging activity compared to control and the T_1 ds/m NaCl.

Mostafa Heidari (2012) reported that salinity had only significant effect on proline content. By increasing salinity levels from 0 to 6 ds/m, proline accumulation in leaves of basil plants increased.

Proline, sucrose, and other organic sugars in quinoa contribute to osmotic adjustment during stress and protect the structure of macromolecules and membranes during extreme dehydration (Prado *et al.*, 2000). Melonid *et al.* (2001) suggested that proline also serves as an important source of nitrogen in plant metabolism, as a readily available source of energy and as a reducing agent.

Table 3. Effect of different salinity levels on SPAD value, Chlorophyl content, Membrane stability, Proline accumulation

Treatment	Physiological attributes			
	SPAD value	Chlorophyll content (mgg^{-1})	Membrane stability (%)	Proline accumulation (μ mol^{-1} FW)
T_0	55.60 a	2.64 a	52.29 g	0.82 h
T_1	52.00 b	2.53 a	74.23 d	2.33 g
T_2	51.30 b	2.26 b	74.39 f	5.00 f
T_3	50.10 b	2.17 b	79.15 de	8.45 e
T_4	49.30 bc	1.98 b	81.57 d	10.12 d
T_5	46.20 d	1.66 c	88.69 c	12.17 c
T_6	44.20 de	1.33 d	91.28 ab	14.10 b
T_7	40.40 f	1.00 e	92.42 a	15.41 a
T_8	38.20 f	0.91 e	93.51 a	16.12 a
$LSD_{0.05}$	2.584	0.231	1.319	1.017
CV (%)	5.391	3.217	8.36	3.87

T_0 = 0 ds/m, T_1 = 2 ds/m, T_2 = 4 ds/m, T_3 = 6 ds/m,T_4= 8 ds/m, T_5 = 10 ds/m, T_6 = 12 ds/m, T_7 = 14 ds/m, T_8 = 16 ds/m

* Different letters indicate significance variance

4.2.6. Na^+ concentrations in potato tuber

The effect of different salinity levels showed a statistically significant variation in the Na^+ concentration in potato tuber (Table 4). The Na^+ concentration increased with the increase the different in salinity levels. The highest Na^+ content (0.246 %) was observed in T_8 (16 dS/m) treatment. The lowest value of Na^+ (0.032 %) was observed under T_0 (control) treatment. These results are agreed with Khatun *et at* (2016) who reported that the highest Na^+ content (0.20%) was observed in T_3 ($12dSm^{-1}$) treatment and the lowest value (0.03 %) was observed under T_0 (control) treatment.

4.2.7. K^+ concentrations in potato tuber

The effect of different salinity levels showed a statistically significant variation in the K^+ concentration in potato tuber (Table 4). With the increasing of the

salinity levels, decreased K^+ concentrations in potato tuber. The highest K^+ content (0.217 %) was observed in T_0 (control) treatment. The lowest value of K^+ (0.011 %) was observed under T_8 (16 dS/m) treatment. These results are supported by Khatun *et at* (2016) who stated that the K concentration of potato was not significantly influenced by different salinity levels. The highest potassium concentration in potato (0.176%) was recorded in T_0 (control) treatment and the lowest value (0.143 %) was recorded in T_3 (12 dS/m) treatment.

Table 4. Effect of different salinity levels on Na^+ and K^+ content of potato

Treatment	% Na and K ion concentration	
	Na^+(%)	K^+(%)
T_0	0.032 f	0.217 a
T_1	0.037 f	0.213 a
T_2	0.073 f	0.193 b
T_3	0.120 e	0.187 b
T_4	0.180 d	0.186 b
T_5	0.194 c	0.165 c
T_6	0.224 b	0.130 d
T_7	0.233 b	0.013 e
T_8	0.246 a	0.011 e
$LSD_{0.05}$	0.114	0.122
CV (%)	3.207	3.048

T_0 = 0 ds/m, T_1 = 2 ds/m, T_2 = 4 ds/m, T_3 = 6 ds/m,T_4= 8 ds/m, T_5 = 10 ds/m, T_6 = 12 ds/m, T_7 = 14 ds/m, T_8 = 16 ds/m

- Different letters indicate significance variance

4.3. Yield contributing parameters

4.3.1. Dry weight of plant (gm)

A significant variation in dry weight of pants were observed in different salinity levels (Table 5). Dry weight of plant decreased with increasing salinity levels. The maximum dry weight of plant (16.99 gm) was obtained from T_0 (control) following by T_1, T_2 and T_3 (16.15, 16.15 and 16.35 gm) treatment respectively. The minimum dry weight of plant (12.21gm) was found T_8 (16 ds/m) treatment. Resulting showed that dry weight of plant decreased gradually with the increased of salinity level.

Table 5. Effect of different salinity levels on yield characters of potato

Treatment	Yield attributes and yield			
	Dry weight of plant (gm)	Dry weight of tuber(%)	Number of tuber/plant	Weight of tuber/plant(gm)
T_0	16.99 a	11.62 a	8.67a	379.13 a
T_1	16.15 b	10.11 b	7.17b	309.31 b
T_2	16.35 b	10.57 a	7.00b	304.98 c
T_3	16.01 b	9.96 c	6.22 b	295.64 d
T_4	15.49 c	9.87 c	6.00 bc	189.86 e
T_5	14.43 c	8.89 d	5.33c	139.97 f
T_6	13.55 d	7.74 d	5.17c	139.51 f
T_7	12.70 e	7.64 e	4.33d	125.71 g
T_8	12.21 f	7.26 f	4.17d	89.24 h
$LSD_{0.05}$	0.425	0.248	0.516	3.147
CV (%)	5.716	7.863	6.381	9.61

T_0 = 0 ds/m, T_1 = 2 ds/m, T_2 = 4 ds/m, T_3 = 6 ds/m,T_4= 8 ds/m, T_5 = 10 ds/m, T_6 = 12 ds/m, T_7 = 14 ds/m, T_8 = 16 ds/m

4.3.2. Dry weight of tuber (%)

Tuber dry weight was significantly influenced by different salinity levels (Table 5). The maximum tuber dry weight (11.62 %) was recorded from T_0 (control) treatment, which was statistically similar with T_1 and T_2 (10.1 % and 10.57%) treatment respectively. The minimum tuber dry weight (7.26 %) was found from the T_8 treatment, which was statistically similar with T_6 and T_7 treatment. Dry matter production of stems and petioles slightly decreased in the 2 ds/m and 4 ds/m salt treatments. The largest decrease in dry matter production was observed in the plants exposed to the higher salt (16 ds/m) treatment.

4.3.3. Number of tuber/plant

Different salinity levels had significant effect on the number of tuber/plant (Table 5). The number of tuber/plant sequentially decreased with the increase of the salt level. At highest salinity level the number of tuber gradually decreased as (5.33, 5.17, 4.33 and 4.17) with T_5, T_6, T_7 and T_8 (10 ds/m, 12 ds/m, 14 ds/m and 16 ds/m) treatment respectively. The highest number of

tuber/plant (8.67) was recorded from the T_0 (control) treatment, which was statistically different from all other treatment. The minimum number of tuber/plant (4.17) was found from the T_8 (16 ds/m) treatment.

4.3.4. Weight of tuber/plant

Weight of tuber/plant was significantly influenced by different salinity levels (Table 5). Total dry matter and tuber production sequentially decreased with the increase of the salinity level. The highest weight of tuber/plant (379.13 gm) was obtained from the T_0 (control) treatment, which followed by T_1, T_2 and T_3 (2 ds/m, 4 ds/m and 6 ds/m) treatment respectively. The minimum weight of tuber/plant (89.24 gm) was found from the T_8 (16 ds/m) treatment which was stastically similar to T_7 (14 ds/m) treatment.

Growth and dry matter production, especially in tubers, were depressed with the increase in the salt level. The salt stress decreased the total and marketable tuber yield due to the decrease in the tuber number per plant and average tuber weight. Tuber specific gravity also decreased by the salt treatments.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the net house at the field of Agricultural Botany Department, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, during the period from November 2016 to March 2017 to find out the effect of salinity on morpho-physiological, yield and quality characters of potato under sodium chloride (NaCl) salt stress. In this experiment, the treatments consisted of nine different levels of salinity viz. T_0=without salt (control), T_1=2 dS/m, T_2=4 dS/m, T_3=6 dS/m,T_4=8 dS/m, T_5=10 dS/m, T_6=12 dS/m, T_7=14 dS/m and T_8=16 dS/m. The experiment was laid out in Completely Randomize Design (CRD) with three replications. Data on different growth parameters, physiological parameters and yield with yield contributing characters of potato were recorded. The collected data were statistically analyzed for evaluation of the treatment effect.

Salinity showed significant differences in all the parameters. In this experiment, potato plant was conducted with sodium chloride (NaCl) contamination by adding salt into the soil. Plant grown on normal soil (control treatment) showed the maximum height more or less over the growth period, whereas the lowest height was recorded from the plant treated with 16 dS/m salinity. The longest plant (20.78, 27.23, 35.23 and 38.40 cm at 30, 50, 70 DAP and at harvest respectively) was recorded in T_0 or controlled condition, whereas the shortest plant (10.75, 13.27, 14.51 and 14.90 cm at 30, 50, 70 DAP and at harvest respectively) in T_8 or 16 dS/m salt. It gradually decreased with increasing salinity level. The maximum number of leaves/plant (12.41, 15.31, 20.19 and 21.23 at 30, 50, 70 DAP and at harvest respectively) was found in T_0 or control treatment while the lowest number of leaves/plant (6.01, 7.54, 7.07 and 5.30 at 30, 50, 70 DAP and at harvest respectively) was observed in T_8 or 16 dS/m of salt. Different salinity levels significantly affected. The number of branch per plant of potato was recorded at 30, 50, 70 DAP and at harvest.

The maximum number of branch per plant (6.19, 7.22, 9.14 and 9.27 at 30, 50, 70 DAP and at harvest respectively) was recorded from the control (T_0) treatment. The minimum number of branch per plant (2.46, 3.17, 3.27 and 3.35 at 30, 50, 70 DAP and at harvest respectively) was observed in T_8 or 16 dS/m of salt. The highest leaf area (14.91 and 21.74 cm^2 at 50 and at harvest respectively) was recorded from the control (T_0) treatment. The lowest leaf area (6.24 and 13.63 cm^2 at 50 and at harvest respectively) was observed in T_8 or 16 dS/m of salt.

Chlorophyll content of the potato showed statistically significant variation among the different salinity levels. The highest chlorophyll content (2.64 mgg^{-1}) was measured from T_0 treatment and the lowest chlorophyll content (0.91mgg^{-1}) was recorded from T_8 treatment. SPAD value of potato showed statistically significant variation among the different salinity levels. The highest SPAD value (55.60) was measured from T_0 treatment and the lowest value (38.20) from T_8 treatment. The influence of different salinity levels was significant on the membrane leakage. The highest membrane leakage (93.51%) was obtained from T_8 treatment and the lowest value (52.29%) from T_0 treatment.

The influence of different salinity levels was significant on the proline accumulation. The highest proline accumulation (16.12 $\mu mol^{-1}FW$) was observed from T_8 treatment and the lowest value (0.82 $\mu mol^{-1}FW$) from T_0 treatment. Number of tubers/plant significantly influenced by different salinity levels. The maximum number of tubers/plant (8.67) was produced from the T_0 treatment and the lowest value (4.170) from the T_8 treatment. Tuber dry weight was significantly influenced by different salinity levels. The maximum tuber dry weight (11.62 %) was produced from the T_0 and the lowest value (4.170%) from the T_8. Yield of tuber was significantly affected by different salinity levels. The highest tuber yield/plant (379.13 gm) was recorded from the T_0 (control) and the lowest value (89.24 gm) from the T_8 treatment.

Dry weight/plant (16.99 gm) was recorded from the T_0 (control) and the lowest value (12.21gm) from the T_8 treatment.

The effect of different salinity levels showed a statistically significant variation in the Na^+ concentration in potato. The highest Na^+ content (0.246 %) was observed in T_8 (16 dS/m) treatment and the lowest value (0.032%) was obtained from the T_0 treatment. K^+ concentration of potato was not significantly influenced by different salinity levels. The highest potassium concentration in potato (0.217 %) was recorded in T_0 (control) treatment and the lowest value (0.011 %) was obtained from the T_8 treatment.

Considering the above mentioned results, it may be concluded that, the yield of potato was gradually decreased by the increase of salinity levels. But the yield and quality parameters of potato slowly decreased upto 8 dS/m and thereafter drastically reduced by increased salinity level. Therefore, the present experimental results suggest that the Diamond variety of potato would be considered to be cultivated at least 8 dS/m salinity under the adverse effect of salt in the coastal region of Bangladesh.

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

1. Such study is needed in coastal area of Bangladesh for analogy the accuracy of the experiment.
2. Since only an insignificant decreased in yield was observe under cultivation with saline water ($\leq$8 ds/m), treatment T_0-T_4 may be used in the southern area of Bangladesh where fresh water in relatively scarce.
3. Experiments need to be conducted to precisely identify salt sensitive and salt tolerant stage of potato.

REFFERENCES

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APPENDICES

Appendix I: Soil characteristics of the research plot of the Department of Agricultural Botany of Sher-e-Bangla Agriculture University

A. Morphological characteristics

Morphological features	Characteristics
Location	Botany Research farm, SAU, Dhaka
AEZ	Modhupur tract (28)
General soil type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	N/A

Source: Soil Resource Development Institute (SRDI), Farmgate

B. Physical and chemical properties of the initial soil

Characteristics	Value
Practical size analysis	
Sand (%)	15
Silt (%)	55
Clay (%)	29
Silt + Clay (%)	85
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	0.25
Total nitrogen (%)	0.03
Available P (ppm)	20
Exchangeable K(ppm)	0.1
Available S (µgm/gm soil)	9.41
Available B (µgm/gm soil)	0.12
Available Zn (µgm/gm soil)	0.94
Available Cu (µgm/gm soil)	1.93
Available Fe (µgm/gm soil)	240.11
Available Mn (µgm/gm soil)	50.7

Source: Soil Resource Development Institute (SRDI)

Appendix II: Analysis of variance of the data on plant height of potato as influenced by different salinity levels at days of planting

Source	Degrees of Freedom	Mean square of plant height (cm)			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	2.156	1.255	2.053	2.114
Factor A	8	25.66*	30.32*	37.14*	42.76*
Error	16	2.136	2.349	2.788	3.144

*: Significant at 5% level of probability

Appendix III: Analysis of variance of the data on number of leaves per plant of potato as influenced by different salinity levels at days of planting

Source	Degrees of Freedom	Mean square of number of leaves/plant			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.517	0.286	0.841	1.044
Factor A	8	15.66**	16.24**	19.27*	26.76*
Error	16	1.215	1.017	1.871	2.342

**: Significant at 1% level of probability
*: Significant at 5% level of probability

Appendix IV: Analysis of variance of the data on number of branch per plant of potato as influenced by different salinity levels at days of planting

Source	Degrees of Freedom	Mean square of number of branches/plant			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.018	0.154	0.163	0.171
Factor A	8	3.453**	2.854**	3.627*	6.448**
Error	16	0.112	0.217	0.548	0.487

**: Significant at 1% level of probability
*: Significant at 5% level of probability

Appendix V: Analysis of variance of the data on leaf area index of potato as influenced by different salinity

Source	Degrees of Freedom	Mean square of leaf area index	
		50 DAS	At harvest
Replication	2	1.358	1.061
Factor A	8	10.563*	14.28*
Error	16	1.283	2.177

*: Significant at 5% level of probability

Appendix VI: Analysis of variance of the data on physiological attributes of potato as influenced by different salinity

Source	Degrees of Freedom	Mean square of physiological attributes			
		Spade value	Chlorophyll content (mg g^{-1})	Membrane status (%)	Proline accumulation
Replication	2	1.315	0.047	1.214	0.347
Factor A	8	22.59**	4.016**	27.41*	11.24**
Error	16	3.214	0.261	3.216	0.549

**: Significant at 1% level of probability
*: Significant at 5% level of probability

Appendix VII: Analysis of variance of the data on yield and yield of potato as influenced by different salinity level

Source	Degrees of Freedom	Mean square of yield attributes and yield			
		Dry weight/plant at harvest	Dry weight of 100 g tuber	Number of tuber/plant	Weight of tuber/plant
Replication	2	1.274	0.622	0.302	1.415
Factor A	8	8.354**	5.689*	4.229**	26.54*
Error	16	1.086	0.522	0.319	3.126

**: Significant at 1% level of probability
*: Significant at 5% level of probability

Appendix VIII: Analysis of variance of the data on Na^+ and K^+ content of potato as influenced by different salinity level

Source	Degrees of Freedom	Mean square of % Na and K ion concentration	
		Na^+ (%)	K^+ (%)
Replication	2	0.014	0.008
Factor A	8	1.215*	1.067*
Error	16	0.104	0.086

*: Significant at 5% level of probability