EFFECT OF GYPSUM ($CaSO_4.2H_2O$) TO MITIGATE THE SALINE STRESS ON TOMATO PLANT [*Solanum lycopersicum*]

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CERTIFICATE

This is to certify that the thesis entitled,**" EFFECT OF GYPSUM ($CaSO_4.2H_2O$) TO MITIGATE THE SALINE STRESS ON TOMATO PLANT [*Solanum lycopersicum*]"**submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **JANNATUL FERDOUS SHURID** Registration No. **18-09136** under my supervision and my guidance. No part of the thesis has been submitted for 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: December, 2020
Dhaka, Bangladesh

Dr. Nazmun Naher
Professor
Supervisor

DEDICATED

TO MY

BELOVED PARENTS

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ABSTRACT

Salinity is one of the most devastating abiotic stress factors which caused reduction in plant growth and development. But gypsum can mitigate the adverse effect of salt stress. So, the experiment was conducted to assess the effect of Gypsum to mitigate the saline effect of Tomato at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during October 2019 to March 2020. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The factors were: Factor A: three levels of salinity viz. S_1-0, S_2-4 and S_3-8 dSm^{-1} and factor B; the different concentration of gypsum viz. C_1-0, C_2-5 and C_3-10 mM. The treatments were applied at 30, 45, 70 days after transplanting (DAT). The highest value of morphological parameters and yield was observed at control level of salinity S_1 (dSm^{-1}). At 75 DAT the highest plant height (79.67 cm), number of flower per plants, fruits per plant and yield per plant was respectively (48.0, 46.3, 3.11 kg). The lowest value was observed at S_3 in all the cases. The yield of tomato was gradually decreasing with the increasing levels of salinity.The highest number of flower per plants (52.0), fruits per plant (49.8), and yield per plant (3.31 kg) was recorded at 5 mM Ca^{2+} treatment. This result showed that, the salt stress reduced the morphological parameters and yield (kg) with the increment of salinity and the exogenous Ca^{2+} application can effectively mitigate the deleterious effect of salt stress in tomato.

ABBREVIATIONS,ACRONYMS AND SYMBOLS

AEZ	Agro-ecological Zone
cm	Centimeter
CEC	Cation exchange capacity
RCBD	Randomized complete block design
EC	Electric Conductivity
g	Gram
ha	Hactor
Kg	Kilogram
LSD	Least Significant Difference
pH	Hydrogen ion concentrations
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Ca	Calcium
$CaCl_2$	Calcium Chloride
No.	Number
CV	Coefficient of Variance
DAT	Days After Transplanting
dSm^{-1}	Decisiemens per meter
DW	Dry Weight
et al.	And others
FAO	Food and Agricultural Organization
mM	Milli mole
NaCl	Sodium Chloride

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CHAPTER I

INTRODUCTION

Salinity is a great problem in the coastal region of Bangladesh, where a vast area remains fallow for long time. Most of the coastal areas are located over medium highlands. As soil salinity increases, salt effects may result in degradation of soils and vegetation. Salinity is one of the most abiotic stress which caused reduction in plant growth and development as well as productivity. Bangladesh has 3 million hectares of land affected by salinity with ECe (Electrical Conductivity) values ranging between 4 and 16 dS/m (Naher *et al*., 2020, Zaman and Bakri, 2003). The extent of salinity problem is about 10% of world land area and 50% of irrigated areas which results in 12 billion US$ loss of agricultural production (Flowers *et al*., 2010). The higher demand for foods of increased global population is putting a strain on. The coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country but the land use in agriculture here is very poor, which is much lower than the country's average cropping intensity. The detrimental effects of salinity on plant growth may be divided into three broad categories: a) reduction in the soil osmotic potential thus reducing the amount of water available to plants b) specific sodium ion toxicity and c) inhibition of nutrient uptake resulting in nutrient imbalance (Ashraf and Foolad, 2007; Ahl and Omer, 2011). But plants have developed a well-organized defense mechanism of biochemical and physiological processes to protect themselves from the salinity-induced damages including antioxidant responses, ionic homoeostasis, and/or osmoregulation (Hasegawa *et al.,* 2000; Parida and Das, 2005). It is well known that the basal or foliar application of Ca^{2+} , Mg^{2+}, K^{+}, proline, glycine-betaine, salicylic acid can mitigate the adverse effects of salinity. Calcium (Ca) is a signaling molecule and second messenger which is increased in the cytosol by activating influx channel both in the plasma membrane and tonoplast and plays a significant role in mediating mechanisms involved in recognition and response to abiotic stresses in plants (Kader and Lindberg, 2010). In addition, Hussain *et al.* (2010) and Lazof and Bernstein, 1999) reported that Ca^{2+} restrict the entry of Na^{+} into the plant cells under sodium stress. The Ca^{2+} has a pivotal participation in salt stress signaling that controls ion homeostasis pathways (Yokoi *et al.*, 2002). Calcium can mitigate the sodium toxicity

of plant. Many authors stated that exogenous calcium alleviates stress in green gram, soybean, linseed (Manivannan *et al.* 2007; Arshi *et al.*, 2010, Khan *et al.*, 2010). In addition, the gypsum ($CaSO_4$. $2H_2O$) has been exogenously applied to the saline soil for improving the soil chemical, leading to enhance the crop productivity (Cha-um *et al.*, 2011).

Tomato (*Solanum lycopersicum*) belonging to the family Solanaceae, is one of the most important, popular, nutritious and palatable vegetables grown in Bangladesh. It was cultivated in almost all home gardens and also in the field due to its adaptability to wide ranges of soil and climate (Ahmed, 1986). Tomato ranks third in terms of world vegetable production (FAO, 2000) and tops the list of canned vegetables. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Due to wider adaptability, it is also grown in Bangladesh. In Bangladesh, it is cultivated in total area of 75602 acres with annual production reaches to 387653 metric tons in 2018-19 (BBS, 2019). Nowadays, tomato is grown round the year. Due to increasing consumption of tomato products, the crop is becoming promising. In Bangladesh, the yield of tomato not satisfactory in comparison with other tomato growing countries of the World (Aditya *et al*., 1997). The low yield of tomato in Bangladesh however is not an indication of low yielding potentially of this crop but of the fact that the low yield may be attributed to a number of reasons, viz. unavailability of quality seeds of high yielding varieties, land for production based on fertilizer management, pest infestation and improper irrigation facilities as well as production in abiotic stress conditions. The environmental stresses resulting from drought, temperature, salinity, air pollution, heavy metals, pesticides and soil pH are major limiting factors in crop production (Hernandez *et al.*, 2001; Lawlor and Cornic 2002;Alqudah *et al*., 2011).

Tomato plant is sensitive to moderate levels of salinity depending on cultivar or growth stage and it holds an important position in agriculture. Salinity affects almost all the physiological and biochemical aspects of the plant development and reduces yield and quality of tomato from nutritional value and food safety (Foolad, 2004; Sengupta and Majumder, 2009; Koushafaret *et al*. 2011). It was reported that yield decrease of tomato for 2.5, 3.5 and 7.6 dS m^{-1} salinity level was 0, 10 and 50%,

respectively. Many other studies showed that the reductions in fruit weights by 10% with 5.0 - 6.0 dS m^{-1}, by 30% with 8.0 dS m^{-1} and by 40% with over 10.0 dS m^{-1} magnitude salinity (Reina-Sànchez *et al.,* 2005, Cuartero *et al.*, 2006). Irrigation with saline water may increase sugar and organic acid content of cherry tomatoes (De Pascale *et al*., 2007) and the flavor of processed tomatoes (Albacete *et al*., 2008). Therefore, salt tolerant cultivars are required to be screened out for the vast coastal regions to overcome the threat posed by salinity.

However, information on role of calcium in regulating the physiological and biochemical process in response to salinity induced stress in tomato are largely lacking. Bangladesh is an over populated country and to fulfill the current need of tomato for added population, the yield of tomato needs to be increased and saline prone area must be undertaken under tomato cultivation through proper use of mitigating substance to mitigate the salt toxicity of soil.

Therefore, keeping this view in consideration, the experiment was conducted to fulfill the following objectives

OBJECTIVES

1. To assess the morphological, and yield contributing attributes of tomato under salt stress; and

2. To determine the dose of gypsum to be applied in saline condition to mitigate the effect of salt stress in tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important vegetables crops grown under field and greenhouse condition, which received much attention to the researchers throughout the world. An attempt has been made to find out the performance of tomato at different levels of salinity as well as to find out the possible mitigation ways by using calcium in the saline stressed tomato plants. To facilitate the research works different literatures have been reviewed in this chapter under the following headings.

2.1 Tomato

The English word "tomato" comes from the Spanish word, *tomate*, which in turn comes from the Nahuatl (Aztec language) word *tomatl*. It first came to in print in 1595. Native versions of tomato were small, like cherry tomatoes and most likely yellow rather than red (Fillipone, 2014).

Gentilcore (2010) reported that Mexico has been considered the most likely center of origin of tomato. Italy and Spain are the secondary centers of diversification. The cultivated tomato originated in the Peru-Ecuador-Bolivia area of the South American (Vavilov, 1951). It is believed that during the British regime the tomato was introduced in Indian subcontinent. It is coped to a wide range of climates. In tomato (*Solanum lycopersicum* L.), one cultivated species and 12 wild relatives have been reported (Peralta *et al*., 2006).

According to "International Plant Name Index" and "Slow Food ® Upstate", in 1753, Linnaeus put the tomato in the genus *Solanum* and named as *Solanum lycopersicum*. In 1768 Philip Miller moved it to its own genus, naming it *Lycopersicon esculentum*. This name came into wide use, but was in violating the plant naming rules. Genetic evidence has now shown that Linnaeus was correct to place the tomato in the genus *Solanum*, making *Solanum lycopersicum* the correct name (Peralta *et al*., 2006). Both names, however, will probably be found in the literature for some time.

Tomato adds flavor to the foods and it is also rich in medicinal value. It is widely employed in cannery and made into soups, conserves, pickles, ketchup, sauces, juices

etc. More than 7% of total vitamin-C of vegetable origin comes from tomato in Bangladesh. It contains 94 g water, 0.5 g minerals, 0.8 g fiber, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate and other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B-1, 0.06 mg vitamin B-2 and 27 mg vitamin C in each 100 g edible ripen tomato (BARI, 2010).

2.2 Salinity

Salinity is a measure of dissolved salts in sea water. Soil salinity is the salt content in the soil, the process of increasing the salt content is known as salinization ("Soil salinity" in Water Wiki., the on-line Knowledge and Collaboration Tool). Soil salinity causes due to the excess accumulation of salts at the soil surface. Salts may rise to the soil surface by capillary transport from a salt-laden water table and then accumulate due to evaporation.

Nizam *et al*. (2019) found that, the salt stress reduced the yield parameters and yield of tomato with the increase of salinity. They found the lowest yield from 8 dSm^{-1} and highest value from control. Ca^{2+} significantly increased the yield contributing characters as well as yield of tomato in both saline and non-saline conditions. The highest number of fruits $plant^{-1}$ (50.8) and the highest yield $plant^{-1}$ (3.88 kg) was produced from 0 dSm^{-1} Na x 10 mM Ca^{2}.

Salt stress is a polymorphous stress that affects plant growth. It reduces yield through three direct ways: First, the presence of salt reduces the ability of the plant to take up water which leads to reduction in the growth rate. This is referred to as the osmotic effect of salt stress, which starts immediately after the salt concentration around the roots increases over a threshold level. These condition and slower response due to the accumulation of ions is in leaves. This ion-specific phase of plant response to salinity starts when accumulated salt reaches toxic concentrations in the leaves and the third one is nutritional stress (Gomez-Cadenas *et al*., 1998). Within many species, documented genetic variation exists in the rate of accumulation of Na^{+} and Cl^{-} in leaves, as well as in the degree to which these ions can be tolerated (Munns and Tester, 2008). For most species, Na^{+} appears to reach a toxic concentration before Cl does. However, for some Cl^{-} considered being the more toxic ion (Lopez-Climent *et al*., 2008).

The negative effects of salinity have been attributed to increase in Na^+ and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both Na^+ and Cl^- are the major ions produce many physiological disorders in plant, Cl^- is the most dangerous (Tavakkoli *et al*., 2010). Salinity at higher levels causes both hyper ionic and hyperosmotic stress and can lead to plant demise. The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction including photosynthesis which ultimately leading to plant death (Hasanuzzaman and Fujita, 2012; Mahajan and Tuteja, 2005).

2.3 Mechanism of salt tolerance

The salt tolerance of a plant may be referred as the degree to which the plant can withstand, without significant adverse effects, moderate or high concentrations of salt in water on its leaves or in the soil within reach of its roots. Salt tolerance is a relative term. Researchers who assess and describe such phenomena often rely on definitions of degrees of tolerance that are specific to their particular studies. There is physiological evidence that control of Na^+ invasion of the tissues is a key determinant of salt tolerance (Niu *et al*., 1995). There is an ongoing debate regarding whether Na^+ enters the cells by K^+ transport systems and, if so, what kind of K^+ transport systems could be involved (Walker *et al*., 1996). Based on present knowledge, two kinds of transport systems are likely to play a major role in Na^+ transport: transporters of the HKT1 family, with the Arabidopsis member suspected of transporting Na^+ more efficiently than K^+ (Uozumi *et al*., 2000) and the Na^+/H^+ ratio which is suspected to play a role in sequestering Na^+ in the vacuole (Garbarino and DuPont, 1988).

2.4 Plant response to salinity

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants because most of the crop plants are sensitive to salinity caused by high concentrations of salts in the soil (Jacobsen *et al.*, 2012). One of the initial effects of salt stress on plant is the reduction of growth rate. The first phase of the growth response is due to the osmotic effect of the soil solution containing salt, and produces a package of effects similar to water stress (Munns 2002; Nahar and Hasanuzzaman,

2009). The mechanisms by which salinity affects growth of a plant depend on the time scale over which the plant is exposed to salt. Munns (2002) summarized the sequential events in a plant grown in saline environment. He stated that "In the first few seconds or minutes, water is lost from cells and shrinked. Over hours, cells recover their original volume but the elongation rates are still reduced which led to lower growth rates of leaf and root. Over days, cell division rates are also affected, and contribute to lower rates of leaf and root growth. Over weeks, changes in vegetative development and over months changes in reproductive development can be seen". Later on Munns R., Tester M. (2008) developed the 'two-phase growth response to salinity' for better understanding the temporal differences in the responses of plants to salinity. The first phase of growth reduction is a quicker process which is due to osmotic effect. The second phase, on the other hand, is much slower process which is due to the salt accumulation in leaves, leading to salt toxicity in the plants. The later one may results in death of leaves and reduce the total photosynthetic leaf area which reduce the supply of photosynthate in plants and ultimately affect the yield. During phase 2, leaves of more sensitive genotype are died and the photosynthetic capacity of the plant is greatly reduced which imposes an additional effect on growth. Upon addition of salt at one step, the growth rate plummets to zero or below and takes 1–24 h to regain the new steady rate, depending on the extent of the osmotic shock (Munns, 2002; Dorais *et al*., 2008; Amoah and Onumah, 2011). Tomato as crop is moderately sensitive to salinity (Foolad, 2004; Maggio *et al*., 2007) and undoubtedly, salinity affects almost all the physiological and biochemical aspects of the plant development and reduce yield and quality of tomato from nutritional value and food safety (Favati *et al*., 2009; Kaouther *et al*., 2012). The effect of salinity concentration on plant growth has been studiedin different tomato cultivars. From agronomic and physiological point of view as regards salinity response of this crop there are several studies (Maggio *et al*. 2011; Lovelli *et al*., 2012). Extensive research is necessary to develop growing conditions in moderate salinity to produce good vegetative growth.

2.5 Effect of salinity on morphological characters of plant

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

Hasanuzzaman *et al*. (2009) accomplished a field experiment to investigate that in plants, where Na^+ and Cl^- build up in the transpiring leaves over a long period of time, resulting in high salt concentration and leaf death. Leaf injury and death are attributed to the high salt load in the leaf that exceeds the capacity of salt compart mentation in the vacuoles, causing salt to build up in the cytoplasm to toxic levels (Munns *et al*., 2006; Ghanem *et al*., 2011).

Iseri *et al*. (2014) conducted an investigation with aim to whether sodium chloride seed priming and irrigation at seedling stage enhance response of 5-leaf stage tomato plants (*Solanum lycopersicum* Mill.) to high salt stress. They found that, priming reduced mean germination time, and increased final germination percentage together with energy of germination. Increased root and hypocotyl lengths as well as increases in fresh weights supported enhanced seedling vigor. Chlorophyll content, chlorophyll to carotenoid ratios, and lipid peroxidation and electrolyte leakage were less affected in primed plants. Moreover, improvement of the accumulation of osmo regulating defense molecules, such as proline and anthocyanin, and of the inductions of the anti-oxidative enzyme system points out to higher adaptive response of these plants against deleterious effects of salt.

Kusvuran *et al.* (2007) reported that formerly, most of tomato growth was mainly in soil, while at present cultivation has switched to greenhouse soilless cultures. The principal salinity problem is the accumulation of Na and Cl, as these elements are

abundantly present in many irrigation waters and absorbed by most crops. As a result, Na and Cl accumulate in the root environment, and high concentrations can readily be reached in small volumes of growing media as used in the soilless culture systems. It has been found that salt concentrations (mostly sodium and chloride) in leaves reach toxic levels in sensitive genotypes much faster than in salt-tolerant genotypes. This has been attributed primarily to the ability of roots to exclude the salt from the xylem sap flowing to the shoot.

Shimul *et al*. (2014) operated a study on the effects of different salinity level on growth of tomato and observed that plant height of tomato genotypes decreased significantly with decreasing level of salinity. They attained the response of tomato to salinity and revealed that the significant variation was found with different level of salinity for leaf area. Highest leaf area (946.80 cm^2) was observed in salinity control while lowest (410.80 cm^2) was recorded with 16 dSm^{-1}.

Murshed *et al.* (2014) reported that the response of antioxidant systems of tomato fruits to oxidative stress induced by salt stress treatments was different depending on the fruit development stage. The study also states that increasing salinity results in delayed flowering.

Hala and Ghada (2014) similarly showed that volume along with length and diameter of tomato fruits were reduced under increasing salinity.

Alaa El-Din Sayed Ewase (2013) carried out a pot experiment to study the effect of salinity stress on plants growth of Coriander (*Coriandrum sativum* L.) by the selection method. For this purpose, four treatments of different concentrations of NaCl were used, namely: 0, 1000, 2000, 3000 and 4000 ppm of NaCl. The results showed that all growth parameters were reduced by increasing the NaCl concentration and Coriander plants were found to resist salinity up to the concentration of 3000 ppm NaCl only.

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

Hossain and Nonami (2012) stated plant height, number of flower cluster, fruit number and yield were not adversely affected up to 8 dSm^{-1} but ripening was delayed. Increased yield over the control was noted with salt concentrations of 4 and 6 dSm^{-1}.

Edris *et al*. (2012) reported that salinity treatment strongly affected the yield in cherry tomato. Abdul Qados (2011) studied the effect of salt stress on plant growth and metabolism of bean plant. Result represents that the decrease of leaf numbers as well as branch numbers occur due to the accumulation of sodium chloride in the cell walls when exposed to higher salt condition.

Shalaby *et al.* (2015) conducted a field experiment to investigate growth parameters and fruit yield of tomato response to salt stress at irrigation water levels during different growth stages under drip and gated-pipe irrigation systems in arid environmental conditions. The irrigation system was comprised 9 irrigation treatments combined between salt stress using well water of 9.15 dSm^{-1} and irrigation water levels of 100, 75, and 50 % from crop evapotranspiration (ETc) subjected during development, flowering and harvesting stages as well as control treatment. The results showed that the plant height, fresh, dry weight, leaf water potential and fruit yield of tomato plants at the harvesting stage were subjected to studied salt stress and irrigation water depth levels during development.

Siddiky *et al.* (2012) conducted a field experiment to screen out a number of Bangladeshi tomato (*Lycopersicon esculentum L.)* varieties for salinity tolerance. Three levels of salinity were 2.0-4.0 dSm^{-1}, 4.1-8.0 dSm^{-1} and 8.1-12.0 dSm^{-1} taken and Significant varietal and/or salinity treatment effects were registered on plant height, leaf area, plant growth, yield, dry matter per plant, Na^+ and Cl accumulation in tomato tissues. They used different varieties and among them BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2 consistently showed superior biological activity at moderate salinity (4.1-8.0 dSm^{-1}), based on dry matter biomass production thus displaying relatively greater adaptation to salinity. All plant parameters of tomato varieties were reduced compared to the control under salt stressed condition. Only exception was number of fruits of BARI Tomato 14, BARI Hybrid Tomato 5 and BARI Tomato 2.

Ghorbanpour *et al.* (2011) conducted an experiment on the effect of salinity and drought stress on fenugreek germination indices. Salinity levels of 0 (as control), -3, -

6 and -9 bar sodium chloride (NaCl) and polyethylene glycol 6000 (PEG 6000) in osmotic levels at 0 (as control), -3, -6 and -9 bar as drought stress were used. They found that with the increase of stress levels, germination and epicotyls and hypocotyls length reduced. Result showed that salinity and drought cause reduction in germination and growth indices and Fenugreeks have relative resistance to salinity and drought stress in germination stage.

Gorai *et al.* (2010) and Jampeetong and Brix (2009) reported that, various plant growths and development processes viz. seed germination, seedling growth, flowering and fruiting are adversely affected under salt stressed condition salinity, ultimately reduced yield and quality.

El-Midaoui *et al.* (1999) conducted a greenhouse experiment with three sunflower cultivars (cv. Oro 9, Flamme pinto and Ludo) under four salinity levels of 0, 50, 75 and 100 mM NaCl. They reported that plant growth was adversely affected by increasing salinity. Similar results were also reported by Steduto *et al.* (2000) in sunflower.

Uddin *et al.* (2005) studied salt tolerance on nine *Brassica juncea* varieties along with one *Brassica carinata* variety. They also found that number of branch decreased with increased salinity in all the studied Brassica species.

BINA (2008) studied the screening of wheat varieties for growth and yield attributes contributing to salinity tolerance and reported that wheat varieties of high yielding and tolerant group recorded a higher value of number of effective tillers plant^{-1}.

Saberi *et al.* (2011) conducted an experiment where two forage sorghum (*Sorghum bicolor* L. Moench) varieties (Speed feed and KFS4) were grown under salinity levels of 0, 5, 10 and 15 dSm^{-1}. Maximum number of leaves was produced in non-saline soil (13.5 leaves plant^{-1}) with normal irrigation (12.4 leaves plant^{-1}). Low soil water and high salinity reduced the number of leaves as well as the number of tillers produced. The maximum total leaf area was obtained in the control treatment but with increasing salinity and infrequent irrigation, this parameter was found to decrease.

2.6 Salinity effect on yield and yield contributing characters of plant

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

Shameem *et al.* (2012) performed an experiment of tomato plants, to evaluate the effects salinity on fruit yield and quality and observed 8 tomato genotypes with different salinity level 10, 15 dS m^{-1} at early development stages. It was observed that the tomato genotype 0178590 adapted to salinity, based on number of fruits, number of flowers, K^+ concentration and K^+/Na^+ ratio.

Khavarinejad and Mostofi (1998) reported that the chlorophyll content reduced with higher salinity levels at all growth stage where the reduction rate was greater at vegetative growth stage than maturity stage in tomato.

Parida and Das (2005) carried out a study to understand salt tolerance and salinity effects on plants. They found that plant growth hampers due to salt stress, which ultimately resulting a considerable decrease in fresh and dry weights of leaves, stems and roots of tomato. Increase in salinity levels also results in significant reductions in shoot weight, plant height and root length. Salt stress leads to changes in growth, morphology and physiology of the root and that adversely affected water and ion uptake and the production of signals that sends information to shoot and ultimately the yield was reduced.

Sixto *et al.* (2005) observed that due to higher levels of salinity, vegetative growth parameters were reduced significantly in *Populus nigra*. Increase in salinity levels results in decreasing root, stem and shoot developments, fresh and dry stem and root weights, leaf area and number and ultimately the yield of plants.

Basirat *et al.* (2011) stated that an increase of 1 dS m^{-1} electrical conductivity resulted in a yield reduction of about 9-10%. At low EC yield reduction was caused mainly by reduction in the average fruit weight and reduced yield was found for reduced number of fruits at high EC. Chookhampaeng *et al.* (2007) concluded that the fruit yield,

number of fruits and fruit weight of tomato cultivars significantly decreased with increased in salinity level.

Hossain *et al.* (2006) worked with rice to know the effect of different levels of salinity (0, 6, 9, and 15 dS m^{-1}) on yield attributes and dry matter partitioning and reported that harvest index decreased with increased salinity levels. Similar result was also reported by Rana (2007) in rice. Hajer *et al.* (2006) reported that salinity reduced fresh and dry weights of tomato. Shibli *et al.* (2007) found that growth and consequent fresh and dry weights are less impaired by salinity; this would indicate greater salt tolerance ability to the variety. At low transpiration treatment, yield loss was only 3.4% per EC unit in accordance with the reduction of fruit weight. It was concluded that transpiration control in a greenhouse has the same importance for tomato production as salinity control in root environment and depressed transpiration may reduce the negative effect of salinity on tomato yield.

Azarmi *et al.* (2010) conducted an experiment on the effects of salinity on morphological and physiological changes and yield of tomato on growth, yield and quality of greenhouse tomato grown in hydroponics culture. The results of this experiment showed that growth parameters and yield reduced with increasing salinity, but qualitative properties were improved by salinity.

Jamal *et al.* (2014) conducted an experiment to find out the growth and yield of tomato in different salinity level. Five salinity levels were accounted at T0 (Control), T1 (4 dSm^{-1}), T2 (8 dSm^{-1}), T3 (12 dSm^{-1}) and T4 (16 dSm^{-1}) treatments respectively and were carried out with completely randomized design (CRD). Significant results were revealed among growth, yield and yield contributing characters. Control (T0) showed the best performance in plant height, number of fruits $plant^{-1}$, fruit weight, leaf area $plant^{-1}$, total chlorophyll content and plant dry matter compared to the other salinity level.

Belda and Ho (1993) conducted an experiment on tomato and reported that salinity reduced the xylem development in tomato fruit but since the tomato fruit has a very low transpiration rate, only a small proportion of the water input come via the xylem (Ho *et al.*, 1987) thus reduced the individual fruit size as well as weight.

Lolaei (2012) stated the effects of salinity and supplied calcium chloride on growth and leaf ions concentration of tomato (*Lycopersicon esculentum* L.) were investigated

in Gorgan, Iran. A factorial experiment was conducted based on RCBD with four NaCl levels (0, 50, 100, and 150 mM) and four CaCl2 levels (0, 100, 200 and 300 mg L^{-1}). Data of growth, yield and leaf's Ca, K, and Na content were subjected to analyze of variance. The results showed that fruit yield decreased under salinity stress. Increasing Ca^{2+} concentration in the nutrient solution increased the fruit yield. Leaf Ca^{2+}, K^{+}, and N content decreased under salinity stress.

Johnson *et al.* (1992) reported that individual fruit weight decreased with increased salinity due to the reason of high salinity lowering the water potential in the tomato plant which will reduce the water flow into the fruit and therefore the rate of fruit expansion.

Bybordi (2010) studied the salinity stress effects resulted from sodium chloride on germination and vegetative growth, elements concentration and proline accumulation in five canola cultivars. The outcomes of this research showed that different salinity levels adversely effected germination percentage, germination speed, shoot and root length. In this pot experiment, salt stress showed adverse effect on plant height, leaf area, dry matter and seed yield.

Qaryouti *et al.* (2007) had reported that the total yield of tomato (*Lycopersicon esculentum* M. cv. Durinta F1) was significantly reduced at salinity equal and above 5 dSm^{-1}. He noted a 7.2% yield reduction per unit increase in salinity.

Grunberg *et al.* (1995) reported that fruit set could be decreased because of low number of pollen grains $flower^{-1}$ in plant under salt stress, extra flower production would be inhibited (Saito and Ito, 1974).

2.7 Effect of application of exogenous Calcium (Ca) on plant growth and salinity mitigation

Through the positive and negative impacts of calcium chloride on the dry weight of shoot and root and growth conditions of plant to reduce the destructive effects of salinity stress reported by Tabatabaeian (2014). By maintaining the proper amount of calcium ions in the soil, toxicity of sodium ions is controlled. Results showed that increase of salinity caused a significant reduction in relative water content of tissues, cytoplasmic membrane stability and chlorophyll concentration in leaves. Dry weight yield of roots and shoots also decreased with increasing the salinity so that all the

characters were lowest in 90 mmol of sodium chloride concentration. The results showed that the growth terms of calcium chloride and chloride + calcium chloride solutions were better, as the 10 mmol concentration of calcium chloride has a significant impact on improving the damage caused by the salinity.

Tomato 'Trust' was grown by Hao and Papadopoulos (2004) on rockwool with nutrient solutions containing two levels of calcium (150 and 300 mgL^{-1}) in factorial combination with three levels of magnesium (20, 50, and 80 $mg \cdot L^{-1}$) in winters, to investigate the effects of calcium and magnesium on growth, biomass partitioning, and fruit production. Plants grown at 20 $mg \cdot L^{-1}$ Mg started to show Mg deficiency symptoms (leaf chlorosis) at 8 weeks after planting. The chlorophyll content of middle and bottom leaves increased with increasing Mg concentration in the nutrient solution. At 300 $mg \cdot L^{-1}$Ca, total fruit yield and fruit dry matter increased linearly with increasing. The Mg effects on total and marketable fruit yield were mainly due to its influence on fruit yield in the late growth stage. Incidence of blossom-end rot (BER) at 150 $mg \cdot L^{-1}$Ca increased linearly with increasing Mg concentration while it was not affected by Mg concentration at 300 $mg \cdot L^{-1}$Ca.

An experiment has done by Boscaiu *et al.* (2011) in *Juncus acutus* and *J. maritimus* to study the response of salt stress during seed germination and vegetative growth. They reported that $Ca^{2+}$and Mg^{2+}could contribute to protecting the plants from salt stress. Seedlings of tomato (*Lycopersicon esculentum* cv. L-402) with low calcium efficiency and cv. Jiangshu 1 with high calcium efficiency were cultured in Hoagland solution by Huang *et al*. (2003). The amount of calcium supply was decreased from the flowering stage. Reducing Ca application at the flowering stage resulted in a decrease of Ca content in fruits of cv. L-402 but not of cv. Jiangshu 1. Mg contents in fruits of the two cultivars increased, while K contents were not different. Ca contents in proximal parts of the fruit were higher than in distal parts of fruit in both cultivars.

Gobinathan (2009) reported that *Pennisetum* plants were grown with NaCl and $CaCl_2$ in order to study the effect of $CaCl_2$ on NaCl induced oxidative stress in terms of osmolyte concentration, proline (PRO)-metabolizing enzymes. The plants were treated with solutions of 100 mM NaCl, 100 mM NaCl with 5 mM $CaCl_2$ and 5 mM $CaCl_2$ alone. They found that NaCl-stressed plants showed increased glycine betaine (GB) and PRO contents, decreased proline oxidase (PROX) activity and increased glutamyl kinase (GK) activity when compared to control. Addition of $CaCl_2$ to NaCl-

stressed plants lowered the PRO concentration by increasing the level of PROX and decreasing the gama-GK activities. Calcium ions increased the GB contents and appears to confer greater osmo protection by the additive role with NaCl in GB accumulation.

Yildirim *et al*. (2008) found that salinity reduced plant macro and micro nutrient contents except for Na and Cl content of plant shoots and roots. The foliar application of KNO_3, Mg $(NO_3)_2$, Ca $(NO_3)_2$ increased the concentration of N, K, Mg, Ca, S and P content under salinity stress. It is not surprising that supplementary KNO_3, Mg $(NO_3)_2$, Ca $(NO_3)_2$ enhanced concentrations of N, K, Ca and Mg which are helpful for the growth and development of plant.

Al-Moshileh (2004) reported that the application of chelated calcium (10% calcium) at the rates of 0, 250 and 500 mg Ca^{2+} kg^{-1} soil on potato plants irrigated with saline water (1000, 3000, 6000 and 9000 ppm NaCl) was studied in a pot experiment. The results indicated that the vegetative growth characters such and tuber yield were significantly decreased as the salinity level of irrigated water increased. Plants given 500 mg Ca^{2+} kg^{-1} soil had a higher yield than plants without applying calcium or with 250 mg Ca^{2+} kg^{-1} soil.

Song *et al.* (2006) reported that high levels of external Ca are essential for the maintenance of high root uptake and shoot accumulation of Ca and K on saline soils and thus for avoiding salinity damage in plants as shown in rice plants.

Manaa *et al*. (2013) reported that salinity is a major abiotic stress that adversely affects plant growth and productivity when conducting an experiment to find out the effects of salinity and calcium on fruit proteome variations of two tomato genotypes (Cervil and Levovil). Their results showed a protective effect of calcium that limited the impact of salinization on metabolism, ripening process, and induced plant salt tolerance.

Chaum *et al.* (2012) reported that Calcium (Ca) is a signaling molecule that plays an active role in regulating various mechanisms involved in recognition and response to abiotic stresses in plants. Two rice genotypes viz. Pokkali, salt tolerant and IR29 salt susceptible, grown on liquid Murashige and Skoog medium (MS) supplied by 1.98 mM $CaCl_2$ (control) were compared to 2 (3.96 mM), 4 (7.92 mM) and 8 (15.84 mM) folds exogenous $CaCl_2$ pretreatment subsequently exposed to 200 mM NaCl salt

stress. In IR29 salt susceptible rice, leaf area of salt-stressed seedling was significantly recovered by exogenous application of 7.92 mM $CaCl_2$, which was greater by 1.38-folds over that in 1.98 mM $CaCl_2$ application. Exogenous $CaCl_2$ (7.92 mM) enhanced proline accumulation in both Pokkali (3.26 µmol g^{-1} FW) and IR29 (4.37 µmol g^{-1} FW) genotypes, and reduced relative electrolyte leakage thereby indicating its positive role in membrane stability. Treatment of 7.92 mM $CaCl_2$ significantly enhanced the photosynthetic abilities, including maximum quantum yield of PSII (Fv/Fm), photon yield of PSII, photochemical quenching (qP) and net photosynthetic rate (Pn), in two genotypes of salt-stressed rice seedlings, especially in salt susceptible IR29 genotypes.

An experiment done by Grigore *et al*. (2014) in adult *Plantago crassifolia* plants with to investigate the possible role of calcium and magnesium salts in the responses of this species to salt stress. They found that addition of low concentrations of $CaCl_2$ or $MgCl_2$ to the plants simultaneously with the NaCl treatments did not affect vegetative growth or flowering, but completely prevented the NaCl dependent inhibition of reproductive development: the number, mean weight and germination rate of the seeds. They concluded that both divalent cations have a protective role against the effects of salt stress in plants.

Voogt (1998) stated that in the nutrient uptake processes K, Mg and Ca are strongly antagonistic resulting in a deficiency of the depressed nutrient. According to the Bergmann (1992), it is well known that a deficiency of one element could imply a relative or absolute excess of the others resulting in an unbalanced diet for the plants. Schimanski (1981) found that magnesium may strongly modify the uptake of Ca^{2+} and K^+ while K^+ and Ca^{2+} can restrict the uptake and translocation of Mg^{2+} from the roots to the upper plant parts.

Jaleel *et al.* (2008) reported that, in a pot culture experiment, the effect of calcium chloride ($CaCl_2$) as an ameliorating agent on sodium chloride (NaCl) stress was studied in *Dioscorea rotundata* plants. Plants were raised in pots and exposed to salinity stress (80 Mm NaCl) with or without 5 mM $CaCl_2$. NaCl-stressed plants showed decreased protein and total sugars, and increased free amino acid and proline content. When NaCl treatment was combined with $CaCl_2$, overall plant metabolism was altered, with increased antioxidant enzyme activity, paving the way for partial amelioration of oxidative stress caused by salinity.

Jafari (2009) studied the interactive effects of salinity, calcium and potassium on physio-morphological traits of sorghum (*Sorghum biclolor* L.) in a greenhouse experiment. Treatments included 4 levels of NaCl (0, 80, 160, and 240 mM NaCl), 2 levels of $CaCl_2$ (0 and 20 mM), and 2 levels of KCl (0 and 20 mM). Number of leaves was significantly affected by NaCl, while elevated calcium promoted total number of leaves, particularly at high levels of NaCl. The interaction effect of Ca^{2+} and K^+ improve leaf generation only at 160 mM NaCl. Salt stress, increased mortality of leaves exposed to salinity. Application of Ca^{2+} and K^+ didn't make up the adverse effects of salinity, in comparison to control.

Calcium nutrition plays an important role in the maintenance of a high growth rate under saline conditions (Marschner, 1995). Several reports showed a significant role of Ca in improving the salt tolerance of plants. In studies on the soybean and cucumber, an additional supply of Ca to salt-stressed plants improved the salt tolerance of plants by reducing Na uptake and transport (Dabuxilatu and Ikeda, 2005). According to Husain *et al.* (2004), the major role of Ca in increasing the salt tolerance of plants is related to its inhibitory effect on the xylem loading of Na and thus decreases in shoot Na concentration.

From the above review of literature, it may conclude that salinity has marked effect on growth and development of tomato plant and calcium has the capacity to mitigate this detrimental effect.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in pots at the research field of Agroforestry and Environmental Science department at Sher-e-Bangla Agricultural University (SAU), Dhaka-1207. This chapter consists of materials used and methods followed during the experimental period are narrated below.

3.1. Experimental site

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. The experiment was carried out during rabi season (October 2019 to March 2020). It is located in $23^0$74/ N latitude and $90^0$35/ E longitude and an elevation of 8.2 m from the sea level (Anon., 1989).

3.2 Climate

The experimental site is situated in the subtropical monsoon climatic zone, which is characterized by heavy rainfall during the months from April to September (Kharif season) and scanty of rainfall during rest of the year (Rabi season). Plenty of sunshine and moderately low temperature prevail during October to March (Rabi season), which are suitable for growing of tomato in Bangladesh.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) under AEZ No.28 and was dark. It was medium high land and the soil series was Tejgoan (FAO, 1988). The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq/100g soil, respectively. The characteristics of the soil under the experiment were analyzed in the Laboratory of Soil science Department, SAU, Dhaka.

3.4 Plant materials used in the experiment

BARI Tomato - 2 was used in this experiment. 30 days seedlings of this variety were used. The seedlings of tomato were grown at the nursery of research field of Agroforestry and Environmental Science department in Sher-e-Bangla Agricultural University. BARI Tomato 2, a high yielding variety of Tomato was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. It was released in 1985.

3.5 Raising of seedlings

For raising tomato seedlings, the soil was well prepared and converted into loose friable. All weeds and dead stubbles were removed and the soil mixed with well rotten cow dung. Hundred seeds of tomato were shown in an iron tray of 91.5 cm × 61.0 cm.

3.6 Pot preparation

Earthen pots were used in this experiment. The height of each pot was 20cm and width 35cm. The collected soil was well pulverized and dried in the sun. Plant propagates, inert materials, visible insects and pests were removed from the soil. The soil was thoroughly mixed with well rotten cow dung at the rate of ton ha^{-1}. Then each pot was filled with 10 kg of soil.

3.7 Fertilizer application

The required amount of fertilizers ($N_{155}P_{34}K_{47}S_{9}Zn_{1.4}B_{0.6}$ kg ha^{-1}) and manure (cow dung @ 10 t ha^{-1}) was estimated on the basis of initial soil test result following Fertilizer Recommendation Guide (BARC, 2012). As per such recommendation urea 28g, triple super phosphate (TSP) 12g, muriate of potash (MP) 6.64 g, gypsum 4.0 g, zinc sulphate 0.28 g, boric acid 0.25g and 1.18 g cow dung pot^{-1} was applied. One third of urea and entire amount of cow dung, TSP MoP, gypsum, boric acid and zinc sulphate were mixed with the soil in each pot before sowing. Rest of the urea was applied as side dressing at 25 and 45 days after transplanting.

3.8 Uprooting and Transplanting of Seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 16 December, 2019 maintaining two seedlings in each pot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to roots with ensuring maximum retention of roots.

3.9 Design and layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with two factors and three replications. The total number of unit pots was 27 (9×3). Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height.

3.10 Treatment of the experiment

Two factors were used in the experiment,viz. 3 doses of saline water for irrigation and 3 doses of Ca^{2+}

Factor A. 3 doses of saline water coded as

1. $S_{1:}$ 0 dSm^{-1}

2. $S_{2:}$ 4 dSm^{-1}

3. $S_{3:}$ 8 dSm^{-1}

Factor B. 3 doses of Ca^{2+}coded as

1. $C_{1:}$ 0 mM
2. $C_{2:}$ 5mM
3. $C_{3:}$ 10mM

There were 9(3×3) treatment combinations as follows:

S_1C_1, S_1C_2, S_1C_3, S_2C_1, S_2C_2, S_2C_3, S_3C_1, S_3C_2 and S_3C_3.

3.11 Application of the treatments

Tomato plants were treated with 0, 4 and 8 dsm^{-1} salinity levels which were maintained by adding 0, 27and 58 g of sodium chloride (NaCl) respectively per pot. These total amounts of salts were applied through irrigation water in three splits at 30, 45 and 70 DAT. The soil salinity was tested by EC (Electrical conductivity) meter. As a Na^{+} stress mitigation agent, Ca^{2+} was used in the form of $CaSO_{4,}$ $5H_2O$ at 0, 5 and 10 mM concentration with irrigation water at 30, 45 and 70 DAT.

3.12 Intercultural operations

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

3.12.1. Gap filling

Very few seedlings were damaged after transplanting and new seedlings from the same stock replaced these.

3.12.2 Staking

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

3.12.3 Irrigation

Light watering was provided with water cane immediately after transplanting the seedlings and this technique of irrigation was used as every day at early morning and sometimes also in evening throughout the growing period. But the frequency of irrigation became less in harvesting stage. Irrigation in those days when treatment was applied was done at evening as salt was applied with irrigation water. The amount of irrigation water was limited up to that quantity which does not leached out through the bottom. As such the salinity status was maintained in the desired level.

3.12.4 Weeding

Weeding was done whenever it was necessary, mostly in vegetative stage.

3.12.5. Plant protection measures

Plant protection measures were done whenever it was necessary.

Insect pests

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

Diseases

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

3.13. Harvesting

Fruits were harvested at 3 day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 13 March 2020 and was continued up to 16 April 2020.

3.14 Data collection

Data on the following parameters were recorded:

A.Measurement of morphological characters

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

B. Measurement of yield and yield contributing characters

1. Number of Flower Cluster $Plant^{-1}$

1) Number of Flowers $Cluster^{-1}$
2) Number of Flowers $Plant^{-1}$
3) Number of Fruits $Plant^{-1}$
4) Number of Fruits Cluster $plant^{-1}$

5) Fruit length (cm)
6) Fruit diameter (cm)
7) Total fruit yield Plant^{-1} (kg)

3.15 Detailed Procedures of Recording Data

A. Morphological characters

1. Plant height (cm)

Plant height was measured at 35, 50, and 75 DAT. The height of the plant was determined in centimeter by measuring the distance from the soil surface to the tip of the highest leaf.

2. No. of branches plant^{-1}

The total number of branches plant^{-1} was counted from each plant at 35 DAT, 50 DAT and 75 DAT.

3. Leaf No. plant^{-1}

Leaf number was counted at 35, 50, and 75 DAT. The number of leaves plant^{-1} was counted from each plant.

B. Measurement of yield and yield contributing characters

1. **No. of flower clusters plant^{-1}**

The number of flower clusters produced plant^{-1} was counted and recorded.

2. No. of flowers cluster^{-1}

The number of flower cluster^{-1} was counted on the basis of flower cluster plant^{-1}.

3. No. of flowers plant^{-1}

The number of flower plant^{-1} was counted and recorded.

4. No. of fruits per cluster^{-1}

The number of fruits cluster^{-1} was counted from the plant.

5. No. of fruits per plant^{-1}

The number of fruits plant^{-1} was counted and recorded.

6. Length of fruit (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 10 fruits from each plant and their average was taken and expressed in cm.

7. Diameter of fruit (cm)

Diameter of fruit was measured at middle portion of 10 fruits from each plant with a slide calipers. Their average was taken and expressed in cm.

8. Yield plant^{-1}

Yield of tomato per plant was recorded as the whole fruit per plant harvested in different time and was expressed in kilogram.

3.16 Data analysis

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using the software STATISTIX 10 and the mean differences were adjudged by least significant difference (LSD) test at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter includes the presentation and discussion of the results obtained from the present study. The results of the study have been presented in tables and figures for easy discussion, comparison and understanding. Results of each parameter have been discussed and possible interpretation, where ever necessary have been provided under the following headings:

4.1 Plant height (cm)

Plant height is one of the most important parameter, which is positively correlated to the yield of tomato.

4.1.1. Effect of salinity on tomato plant height (cm) plant^{-1}

Salinity strongly influenced on tomato plant height. The plant height varied significantly ($p \leq 0.01$) due to the effect of salinity stresses observed at 35, 50 and 75 DAT with statistically significant variation. The highest plant height 34.11 cm was found from S_1 (0 dSm^{-1}, control), the lowest 29.89 cm was recorded from S_3 (8 dSm^{-1}) and 32 cm was from 4 dSm^{-1} at 35 day after transplanting (DAT). At 50 DAT the highest plant height was observed 59.18 cm from S_1, the lowest was 57.73 cm from S_3 (8 dSm^{-1}) and 58.45 cm was from 4 dSm^{-1}. At 75 DAT the highest plant height was measured 79.68 cm from S_1 (0 dSm^{-1}) and the lowest was 77 cm from S_3, besides this results 4 dSm^{-1} showed 77.62 cm. The results of this study showed that salinity significantly reduced the plant height of tomato at different days after transplanting (DAT). With increasing the dose of salinity, the plant height decreasing significantly. The natural plant height increased with increasing age but decreased with increasing salinity in tomato. Similar results were also recorded by many other authors like Rahman *et al*. (2018); Naher *et al.* (2020); Naher *et al*. (2011) and Mohammad *et al.* (1998) in tomato, Jafari (2009) and Nawaz (2010) in sorghum, Milne (2012) in

lettuce, Alaa El-din Sayed Ewase (2013) in coriander etc. The reduction of plant height may be due to inhibitory behavior of salt stress on cell division and cell expansion (Hernandez *et al*., 2003). From previous research and findings, now it is well established that the salinity strongly regulated the plant growth and development by decreasing plant height, leaves number, leaf area, branches number etc. (Nawaz *et al*., 2010; Islam 2004; Mohammad *et al*., 1998). The reduction of the plant height due to reduction in internodal distance with increased salinity may be a result of a combination of osmotic ion effects of Cl^- and Na^+ (Al- Rwahy, 1989; Zhu *et al*., 2001).

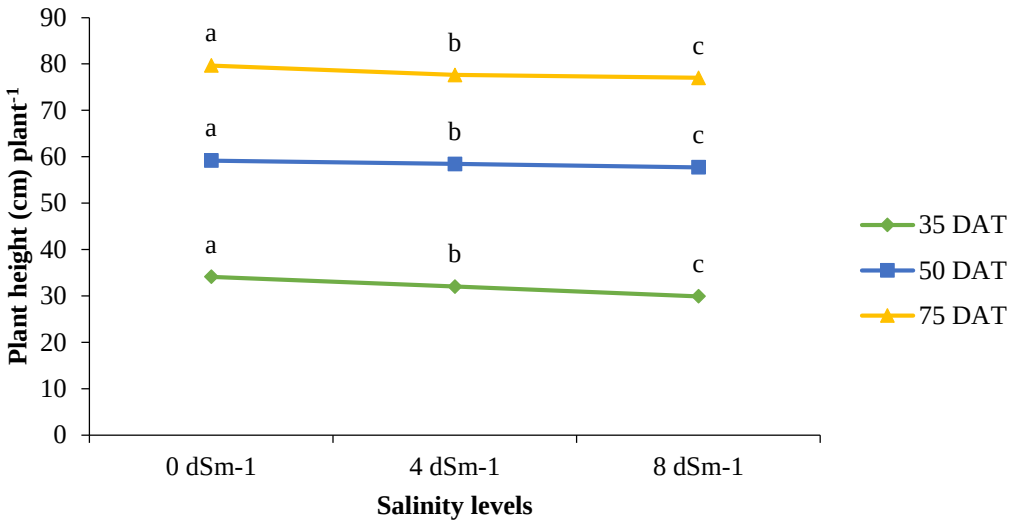

Figure 1. Effect of salinity levels on plant height (at different days after transplanting)

4.1.2. Effect of Calcium on tomato plant height plant^{-1} (cm)

In this study, different dose of calcium such as 0 (C_1), 5 mM (C_2) and 10 mM (C_3) were used to investigate the effect of calcium to reduce the saline toxicity in plant height. As shown in Figure 2. After added calcium to the plants the plant height changed significantly. Statistically significant variation was recorded for different levels of calcium sulphate on plant height of tomato at 35, 50 and 75 DAT. At 35 DAT the highest plant height was observed 34.11 cm from 5 mM (C_2) and the lowest was 30.89 cm from 10 mM (C_3). At 50 DAT, numerically the highest plant height was found 59.68 cm from C_2 (5mM)) where the lowest value was recorded from C_3, 57.81 cm which was statistically similar with treatment C_1 (57.88 cm). At 75 DAT, the tallest plant was recorded from C_2 (80.111 cm), the shortest plant was found From C_1 (76.57 cm) and 77.62 cm plant height recorded from 10 mM (C_3). From this experiment it was observed that calcium increased the plant height as compared with control where the highest result was found from 5mM concentration of calcium. Nizam *et al*. (2019) and Manivannan *et al.* (2007) also reported that calcium increased the plant height.

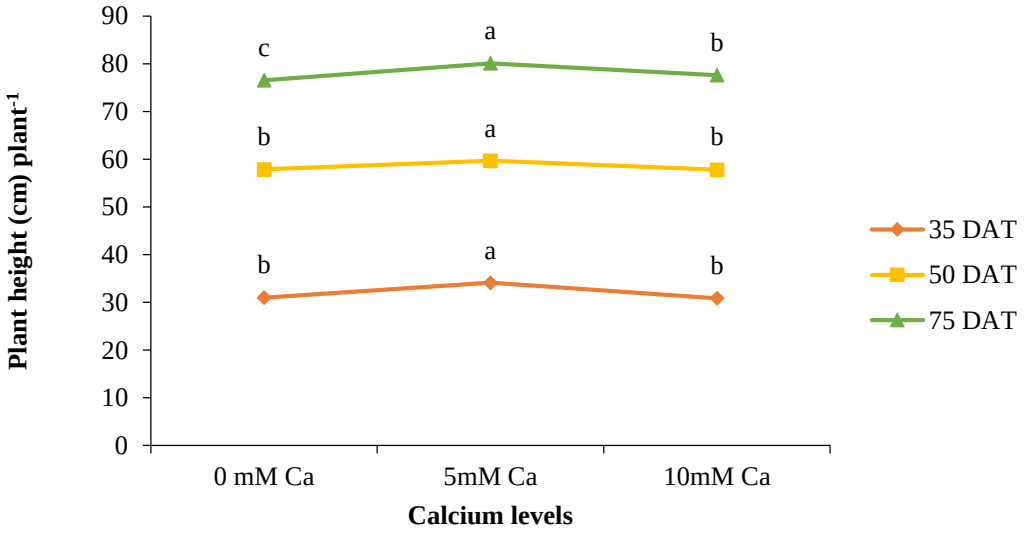

Figure 2. Effect of Calcium levels on plant height (at different days after transplanting)

4.1.3. Interaction Effect of Salinity and Calcium on Plant Height plant^{-1} (cm)

Combined effect of different levels of salt stress and calcium sulphate showed significant differences on plant height of tomato at 35, 50 and 75 DAT. At 35, 50 and 75 DAT, the tallest plant (35.3 cm, 60.2 cm and 81.3 cm) was found from S_1C_2 (0 dS/m × 5.0 mM Ca^{2+}) treatment combination, while the shortest (28.0 cm, 57.0 cm, 75.1 cm) was found from S_3C_1 (8 dSm^{-1} salt × control, Ca^{2+}) treatment combination (Table 1). The result showed that 5mM calcium has significant effect on plant height.

Table 1. Interaction effect of salinity and calcium levels on plant height (at different days after transplanting) of tomato

Treatment Combinations (salinity× calcium)	Plant height (cm) at different days after transplanting		
	35	50	75
$S_1 \times C_1$	33.0 c	59.3 bc	79.26 bc
$S_1 \times C_2$	35.3 a	60.23 a	81.30 a
$S_1 \times C_3$	34.0 b	57.96 d	78.46 cd
$S_2 \times C_1$	32.0 d	57.3 e	75.33 f
$S_2 \times C_2$	34.3 b	59.73 ab	79.96 b
$S_2 \times C_3$	29.67 e	58.3 d	77.56 de
$S_3 \times C_1$	28.0 f	57.0 e	75.10 f
$S_3 \times C_2$	32.6 cd	59.06 c	79.06 bc
$S_3 \times C_3$	29.0 e	57.13 e	76.83 e
CV (%)	**1.22**	**0.61**	**0.72**

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.2. Number of leaves plant^{-1}

The leaf number is the very important character for plant growth and development as leaf is the main photosynthetic organ.

4.2.1. Effect of Salinity levels on number of leaves plant^{-1}

Salinity have significant effect on number of leaves per plant at different DAT such as 35, 50 and 75 DAT (Figure 3). Number of leaves in each plant was decreased due to increasing level of salt. At 35 DAT maximum numbers of leaves plant^{-1} (12.0) was found in case of 0 dSm $^{-1}$ (S_1) the lowest value (11.44) from 8 dSm^{-1} (S_3) and 4 dSm^{-1} (S_2) showed 11.6 number of leaves. At 50 DAT highest number of leaves (23.66) was recorded from S_1, the lowest value (20.33) was found from S_3 and 21.1 value found from 4 dSm^{-1}. At 75 DAT, 41.1 value was found from 4 dSm^{-1} (S_2) the highest number of leaves plant^{-1} (43.66) was recorded from S_1 (0 dSm $^{-1}$) and the lowest value (40.22) was found in case of S_3. Similar observation was also observed by Nizam *et al*. (2019); Naher (2014) in tomato. Alaa El-Din Sayed Ewase (2013) who reported that number of leaves plant^{-1} decreased with the increase of NaCl concentration in coriander. Mohammad *et al.* (1998) also reported increasing salinity stress accompanied by significant reduction in number of leaves plant^{-1}. Jafari (2009), Saberi *et al.* (2011b), Islam (2004), and Angrish *et al.* (2001) also obtained reduced leaves number plant^{-1} under salinity stress. Reduction in number of leaves per plant is a common phenomenon under salinity stress in various plant species (Zhu *et al.*, 2001). Hassine and Lutts (2010) and Bakht *et al.* (2011) investigated the *Solanum tubersum*, *Atriplex halimus* and *Zea mays*, respectively under saline conditions and found a marked reduction in internodal distance in response to salt stress. This reduction in internodal distance and number of leaves may be due to the reduction in turgor potential, necessary for cell elongation (Iqbal and Ashraf, 2005) and turgor pressure, which were reduced under salt stress (Ashraf and Harris, 2004).

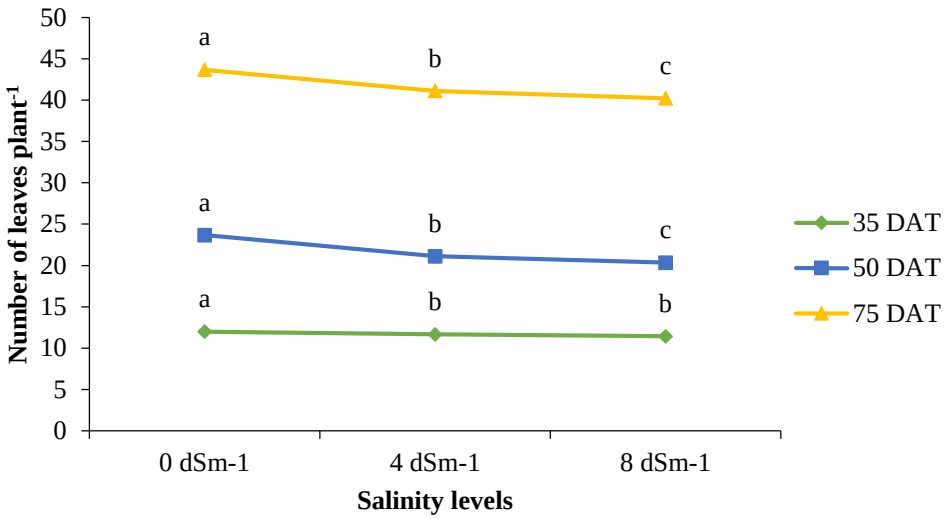

Figure 3. Effect of salinity levels on number of leaves (at different days after transplanting)

4.2.2. Effects of Calcium levels on number of leaves plant^{-1}

Different levels of calcium varied significantly on number of leaves per plant of tomato at 35, 50 and 75 DAT (Figure 4). At 35 DAT the highest number of leaves was observed 12.88 from C_2, the lowest was 10.667 from C_1 (0mM) and C_3 (10mM) showed 11.56 value. At 50 DAT, numerically the highest number of leaves was found 23.88 from 5mM (C_2)where the lowest value was recorded from C_1 20.33 which was statistically similar with treatment C_3 (20.88). At 75 DAT, the highest value was recorded from C_2 (43.88) and the lowest was found From C_1 (40.33), which was statistically similar with treatment C_3 (40.77). From this experiment it was found that, the number of leaves was gradually increased with the increase in age with the supplementation of calcium along with salt. Thus these results suggested that the calcium application increased the number of leaves by reducing the effect of salt. This fact was supported by other authors like Tzortzakis (2010) in leafy vegetables, Lolaei *et al.* (2012) in tomato.

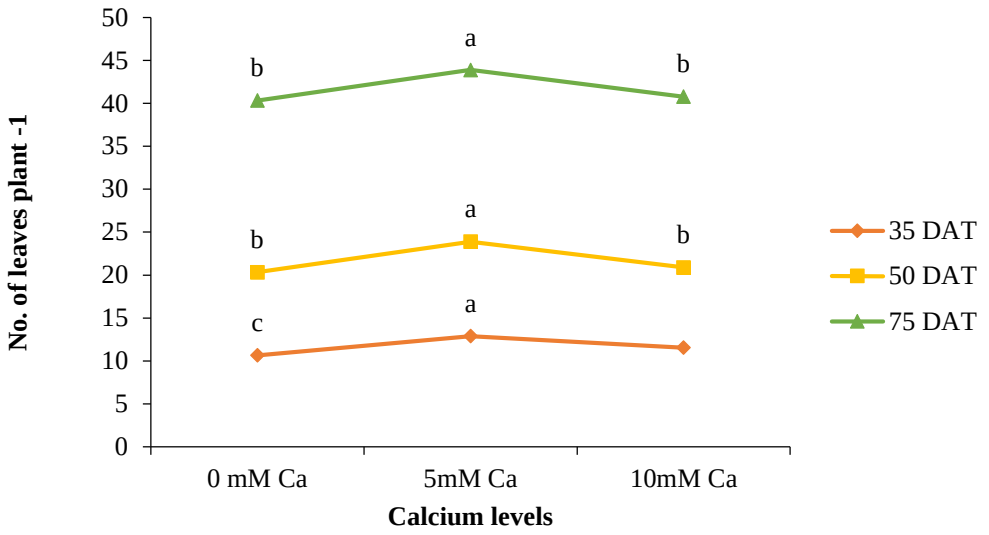

Figure 4. Effect of Calcium levels on number of leaves (at different days after transplanting)

4.2.3. Interaction Effect of Salinity and Calcium on Number of leaves plant^{-1}

The results of the present study showed that, the interaction effect between salinity stress and calcium as mitigation agent on number of leaves plant^{-1} was significant at 35, 50 and 75 DAT (Table 2). At 35 DAT, the highest number of leaves plant^{-1} was (13.0) found from (0 dSm^{-1}× 5 mM), which statistically similar with (4 dSm^{-1}× 5mM) S_2C_2 and the lowest value was recorded in case of S_2C_3 (11.00). At 50 DAT highest number of leaves plant^{-1} was found from S_1C_2 (25.33) where the lowest value was recorded from S_3C_3 (18.33). At 75 DAT, the highest number of leaves plant^{-1} was found from (0 dSm^{-1}× 5mM)S_1C_2 (45.33) where the lowest value was recorded from (8 dSm^{-1}× 10mM) S_3C_3 (38.0). 5mM calcium increased the number of leaves of tomato than 10mM Ca with or without saline.

Table 2. Interaction effect of salinity and calcium levels on number of leaves plant^{-1} (at different days after transplanting) of tomato

Treatment Combinations (salinity× calcium)	No.of leaves plant^{-1} at different days after Transplanting		
	35	**50**	**75**
$S_1 \times C_1$	11 c	22.33 b	42.33 c
$S_1 \times C_2$	13 a	25.33 a	45.33 a
$S_1 \times C_3$	12 b	23.33 b	43.33 b
$S_2 \times C_1$	11 c	19.33 d	39.33 e
$S_2 \times C_2$	13 a	23 b	43 bc
$S_2 \times C_3$	11 c	21 c	41 d
$S_3 \times C_1$	10 d	19.33 d	39.33 e
$S_3 \times C_2$	12.66 a	23.33 b	43.33 b
$S_3 \times C_3$	11.66 b	18.33 d	38 f
CV (%)	**2.18**	**3.01**	**1.39**

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.3. Number of branches of tomato plant

4.3.1. Effects of salinity levels on number of branches plant^{-1}

Number of branches plant^{-1} of tomato was significantly affected by the different levels of salinity at 35, 50 and 75 DAT (Figure 5). At 35 DAT maximum numbers of branches plant^{-1} (5) was found in case of S_1 (0 dSm $^{-1}$), the lowest value (4) from S_3 and 4.11 value recorded from 4 dSm^{-1} (S_2). At 50 DAT, 4 dSm^{-1} (S_2) showed 4.3, highest number of branches (6.11) was recorded from S_1 and the lowest value (4) was found from (8 dSm^{-1}) S_3. At 75 DAT, the highest number of branches plant^{-1} (7.11) was recorded from S_1 and the lowest value (5.88) was found in case of (8 dSm^{-1}) S_3. Uddin *et al.* 2005 also found that number of branch decreased with the increased salinity in *Brassica* species. Similar observation was also found in rice where tiller

number decreased in response to salinity which was reported by Mortazainezhad *et al.* 2006. Many other authors like LingHe *et al.* 2000; Burman *et al.* 2002; WeonYoung *et al.* 2003; Islam, 2004; Rashid, 2005; Karim, 2007 also reported the similar results in rice.

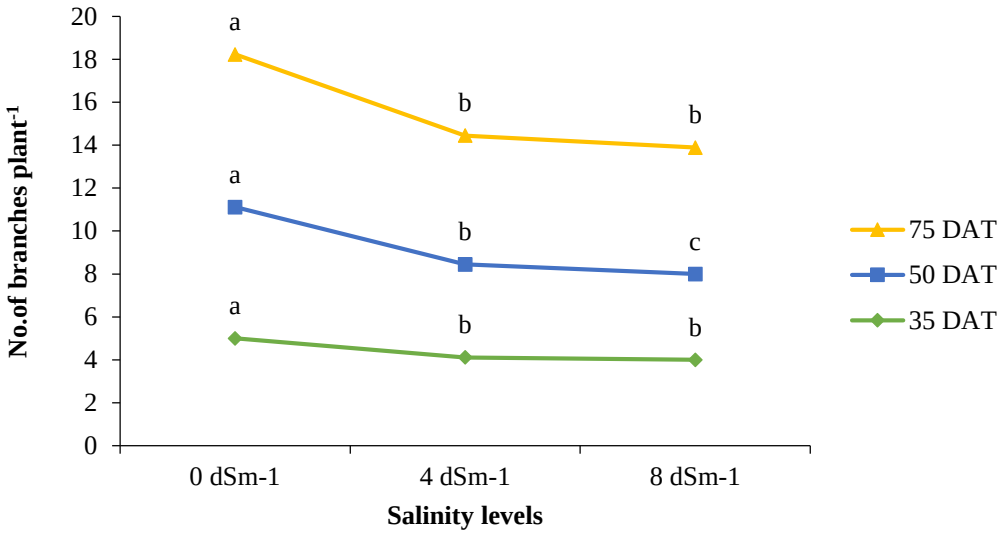

Figure 5. Effect of salinity levels on number of branches (at different days after transplanting)

4.3.2. Effects of calcium levels on number of branches plant^{-1}

A significant effect of calcium was found on the number of branches plant^{-1} of tomato at 35, 50 and 75 DAT (Figure 6). At 35 DAT the highest number of branches was observed 7.67 from C_2 (5mM), the lowest was 5.33 from C_1 (0mM) and 3.6 result found from C_3 (10mM). At 50 DAT, the highest value was found 5.67 from C_2 (5mM) where the lowest value was recorded from C_1 (4.33) which was statistically similar with treatment C_3 (4.44). At 75 DAT, the highest value was recorded from C_2 (5.44) and the lowest was found from C_3 (3.67). From this experiment it was found that, the number of branches was gradually increased with the increase in age with the supplementation of calcium along with salt and 5mM Ca has significant effect than 0mM, 10 mM.

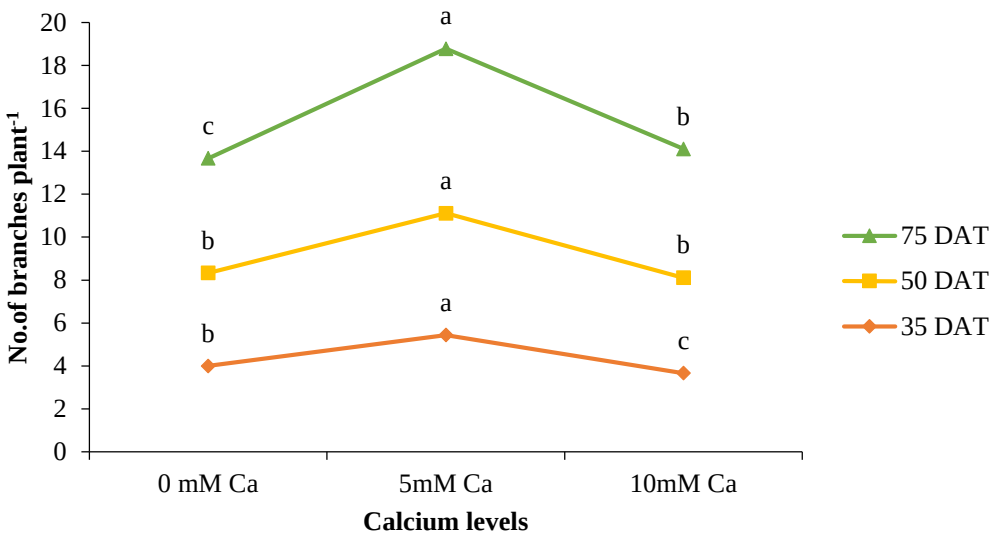

Figure 6. Effect of calcium levels on number of branches (at different days after transplanting)

4.3.3. Interaction Effect of Salinity and Calcium on Number of branches of plant^{-1}

The combined effect of salinity and calcium on number of branches plant^{-1} of tomato exhibited a significant effect at 35, 50 and 75 DAT. At 35 DAT, the highest number of branches plant^{-1} was found from S_1C_2 (0 dSm^{-1}× 5 mM) (6) and the lowest value was recorded in case of S_2C_3 and S_3C_1 (4 dSm^{-1}× 10 mM) and (8 dSm^{-1}× 0 mM) (3.00). At 50 DAT highest number of branches plant^{-1} was found from S_1C_2 (7) where the lowest value was recorded from S_3C_1 and S_2C_3 (3). At 75 DAT, the highest number of branches plant^{-1} was found from S_1C_2 and S_3C_2 (8) where the lowest value was recorded from S_3C_1 (4). 5mM increased the value with or without salinity.

Table 3. Interaction effect of salinity and calcium levels on number of branches plant^{-1} (at different days after transplanting) of tomato

Treatment Combinations (salinity× calcium)	No. of branches plant^{-1} at different days after Transplanting		
	35	**50**	**75**
$S_1 \times C_1$	5 c	6 b	7 b
$S_1 \times C_2$	6 a	7 a	8 a
$S_1 \times C_3$	4 d	5 c	6.33 c
$S_2 \times C_1$	4 d	4 e	5 e
$S_2 \times C_2$	5.33 b	5 d	7 b
$S_2 \times C_3$	3 e	4 e	6 cd
$S_3 \times C_1$	3 e	3 f	4 f
$S_3 \times C_2$	5 c	5 d	8 a
$S_3 \times C_3$	4 d	4 e	5.67 d
CV (%)	**4.40**	**4.00**	**4.56**

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.4. Number of flower clusters plant^{-1}

4.4.1. Effect of salinity on Number of flower clusters plant^{-1}

There was a significant difference in number of flower clusters plant^{-1} at different levels of salinity (Figure 7). The highest number of flower clusters plant^{-1} (7.78) of tomato was found in control plants 0 dSm^{-1}(S_1) the lowest number of cluster was recorded from 8dSm^{-1} (S_3) and 7 was from4 dSm^{-1} (S_2) of salinity. This report was similar to other studies ((Rahman *et al.* 2018; Nazmun *et al.* 2011; Admans and Ho, 1989 and Van leperen, 1996) in case of tomato. Agong *et al*. (2003) found that significant genotypic and/or salt treatment effects were registered on yield contributing characters of tomato.

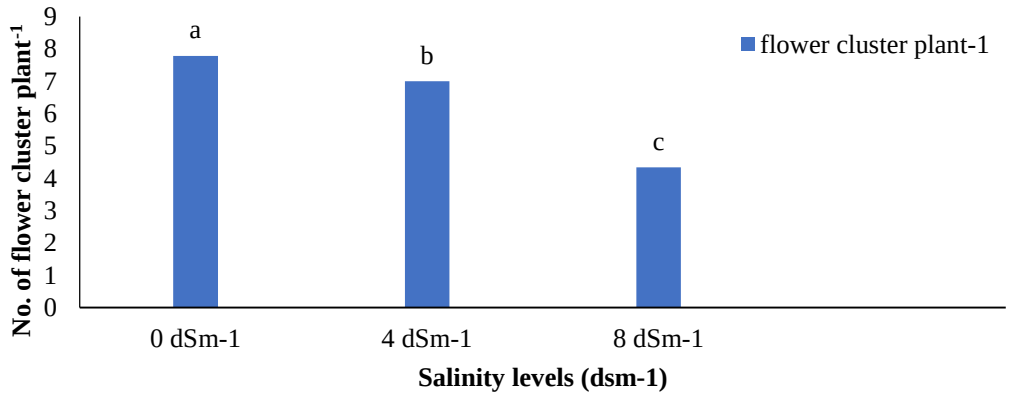

Figure 7. Effect of salinity levels on number of flower cluster plant^{-1}

4.4.2. Effect of calcium on Number of flower clusters plant^{-1}

Significant variation was observed for number of flower clusters plant^{-1} of tomato for different levels of calcium (figure 8). The highest flower clusters plant^{-1} (8.00) was found in C_2 (5mM) treated plants and C_3 (10mM) treated plants showed the lowest flower clusters plant^{-1} (5.44). 5.6 value was recorded from C_1 (0mM). From this result it was clear that calcium 5mM increase the number of flower clusters plant^{-1}.

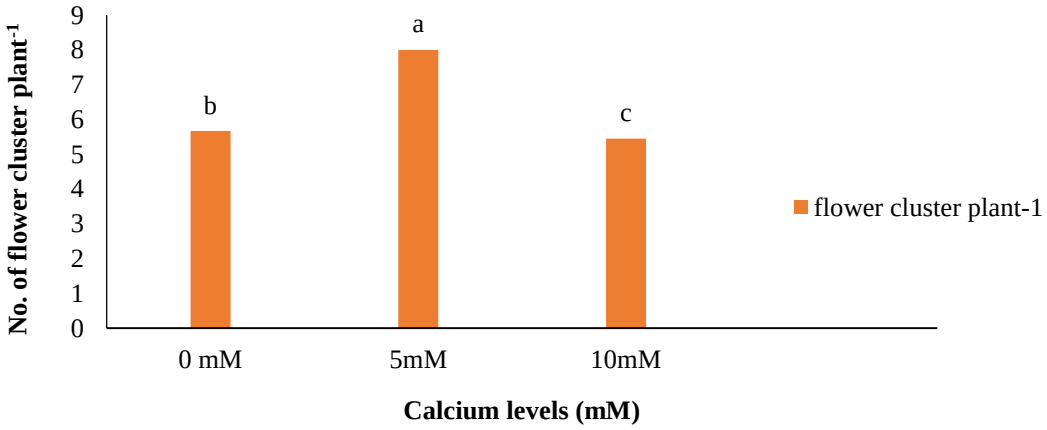

Figure 8. Effect of calcium levels on number of flower cluster plant^{-1}

4.4.3. Interaction effect of salinity and calcium on number of flower cluster plant^{-1}

Number of flower clusters plant-^{1} varied significantly for the interaction of salinity and calcium levels (Table 4). The highest number of flower clusters plant^{-1} (9.00) was found from S_1C_2 (0 dSm^{-1}× 5 mM), which was statistically similar with (4 dSm^{-1}× 5 mM) S_2C_2, while the lowest number (3) was obtained from S_3C_3 (8 dSm^{-1}× 10 mM). This result showed that, the 8 dSm^{-1} salinity decreased the number of flower clusters .5mM calcium increased the number of flower cluster with or without salinity.

Table 4. Interaction effect of salinity and calcium on number of flower cluster plant^{-1}

Salinity Levels	Calcium		
	C_1	**C_2**	**C_3**
S_1	7	9	7.3
S_2	6	9	6
S_3	4	6	3
CV (%)	**3.02**		
LSD (5%)	**0.333**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.5. Number of flowers cluster^{-1} and flowers plant^{-1}

4.5.1. Effect of salinity on Number of flowers cluster^{-1}

Different levels of salinity significantly effects on number of flowers cluster^{-1}(Figure 9). The highest number of flowers cluster^{-1}(6.22) was observed from S_1 (0 dSm^{-1}) treatment and the lowest number (4.0) was found from S_3. 5.6 result found from 4 dSm^{-1} (S_2). Salinity reduced the flowers cluster^{-1}. Luo *et al*. (2013) reported that salt stress of NaCl, stronger inhibitory effect on tomato growth.

4.5.2. Effect of salinity on Number of flowers plant^{-1}

Number of flowers plant^{-1} of tomato showed significant differences with different levels of salinity (Figure 9). The highest number of flowers plant^{-1} (48.778) was observed from S_1 (0dSm^{-1}), where the lowest number (39.778) was recorded from S_3 (8dSm^{-1}). 41 value was from 4 dSm^{-1} (S_2). Number of flowers plant^{-1} gradually reduced with the increased levels of salinity.

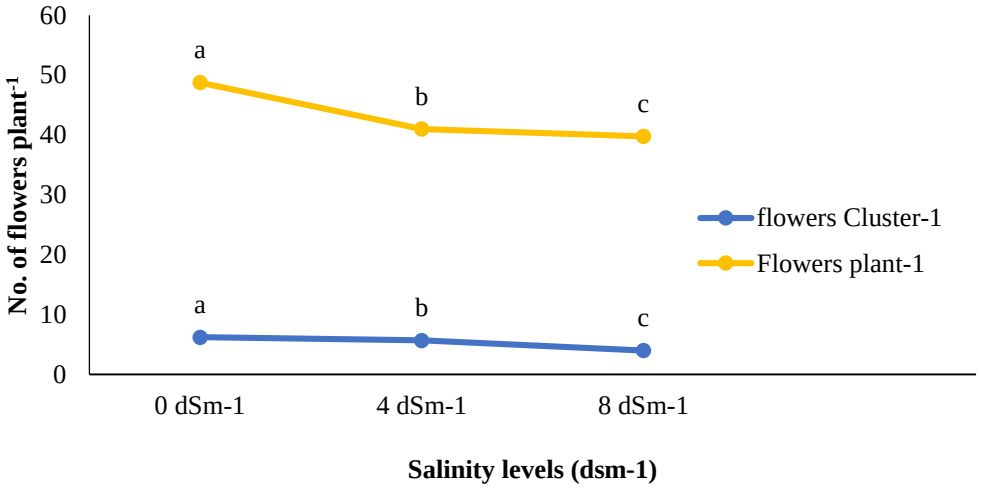

Figure 9. Effect of salinity levels on number of flowers cluster $^{-1}$ and flowers plant^{-1}

4.5.3. Effect of calcium on Number of flowers clusters^{-1}

Different levels of calcium varied significantly for number of flowers cluster^{-1} of tomato (figure 10). The highest number of flowers cluster^{-1} (6.33) was found from C_2 (5mM) treatment and the lowest number was (4.66) recorded from C_1 (0mM). 4.88 was found from C_3 (10mM). Number of flowers clusters^{-1} increased with 5mM of calcium.

4.5.4. Effect of calcium on Number of flowers plant^{-1}

Significant variation was observed for number of flower plant^{-1} of tomato for different levels of calcium (figure 10). The highest flower plant^{-1} (52) was found in C_2 (5mM) treated plants and control treated plants showed the lowest flower plant^{-1} (45).

47.7 was statistically similar with C_1, found from C_3 (10mM). Application of calcium increased the number of flowers plant^{-1}.

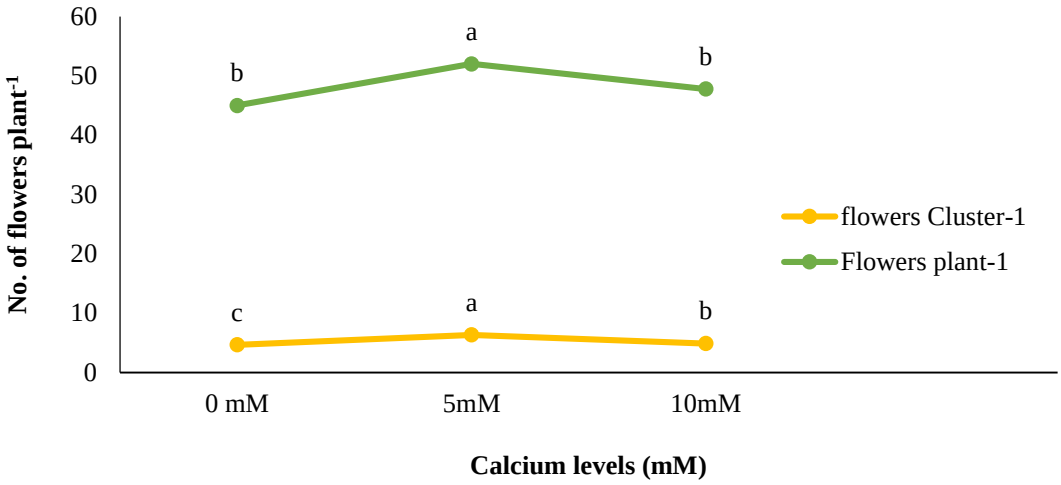

Figure 10. Effect of calcium levels on number of number of flowers cluster $^{-1}$ and flowers plant^{-1}

4.5.5. Interaction Effect of Salinity and Calcium on Number of flowers cluster^{-1} plant^{-1}

Interaction effect of salinity and calcium showed significant differences for number of flowers cluster^{-1} (Table 5). The highest number of flowers cluster^{-1} (7) was recorded from S_1C_2 (0 dSm^{-1}× 5 mM) which was statistically similar to S_2C_2 (4 dSm^{-1}× 5 mM) (7). On the other hand, the lowest number (3) was obtained from S_3C_1 (8 dSm^{-1}× 0 mM)

4.5.6. Interaction Effect of Salinity and Calcium on Number of flowers plant^{-1}

Interaction effect of salinity and calcium showed significant differences for number of flowers plant^{-1} (Table 6). The highest number of flowers plant^{-1} (63.00) was recorded from S_1C_2 which was statistically similar to S_2C_2 (63.00). On the other hand, the lowest number (12.00) was obtained from S_3C_1 (8 dSm^{-1}× 0 mM) which was statistically similar to S_3C_3 (8 dSm^{-1}× 10 mM) (12.00). This result showed that, 8dSm^{-1} decreased the value with or without calcium.

Table 5. Interaction effect of salinity and calcium on number of flowers cluster^{-1} plant^{-1}

Salinity Levels	Calcium		
	C_1	**C_2**	**C_3**
S_1	6.00	7.00	5.66
S_2	5.00	7.00	5.00
S_3	3.00	5.00	4.00
CV (%)	**3.63**		
LSD (5%)	**0.3331**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

Table 6. Interaction effect of salinity and calcium on number of flowers plant^{-1}

Salinity Levels	Calcium		
	C_1	**C_2**	**C_3**
S_1	42.00	63.00	41.33
S_2	30.00	63.00	30.00
S_3	12.00	30.00	12.00
CV (%)	**1.07**		
LSD (5%)	**0.6662**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.6. Number of fruits cluster plant^{-1}

4.6.1. Effects of salinity levels on number of fruit cluster plant^{-1}

Significant variation was recorded for the number of fruits cluster plant^{-1} of tomato due to different levels of salinity (Figure 11). The highest number of fruits cluster plant^{-1} (8.44) was obtained from S_1 (0 dsm^{-1}), while the lowest number (7.00) was obtained from S_3 (8 dSm^{-1}). 7.33 was obtained from 4 dSm^{-1} (S_2).

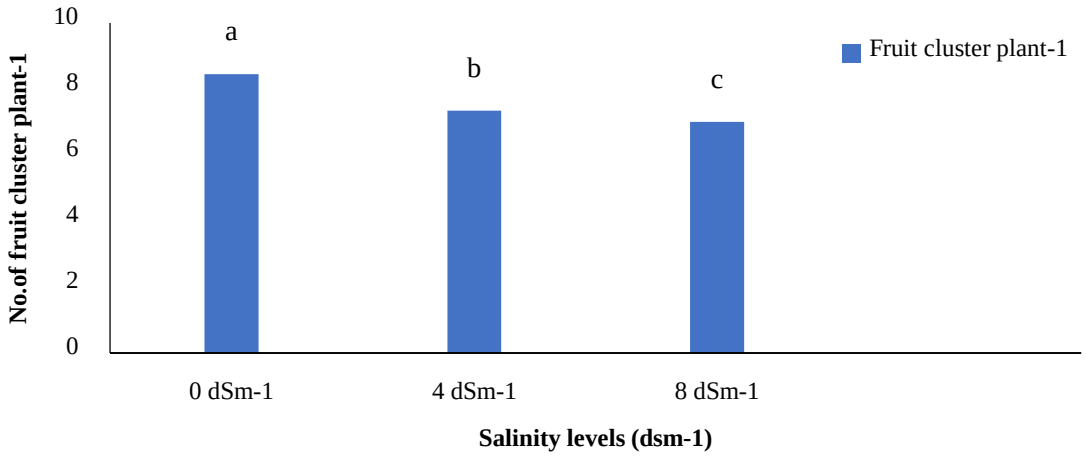

Figure 11. Effect of salinity levels on number of fruit cluster plant^{-1}

4.6.2. Effects of calcium levels on number of fruit cluster plant^{-1}

Statistically significant variation was recorded for number of fruit cluster plant^{-1} after the application of different levels of calcium (Figure 12). The highest number of fruit cluster plant^{-1} (9.44) was observed from C_2 and the lowest value (6.33) from C_1. 6.33 was found from C_1 (0mM). Number of fruit cluster plant^{-1} increased with the increased levels of calcium. This trend was also related with the number of flowers plant^{-1}.

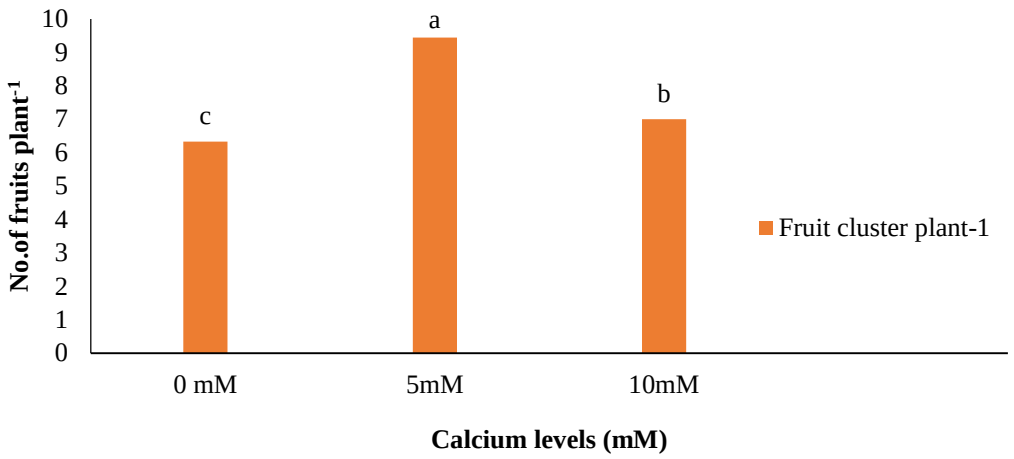

Figure 12. Effect of calcium levels on number of fruit cluster plant^{-1}

4.6.3. Interaction Effect of Salinity and Calcium on Number of fruit cluster plant^{-1}

Interaction effect of salinity and calcium showed significant differences in case of number of fruit cluster plant^{-1} (Table 7). The highest number of fruit cluster plant^{-1} (10.33) was recorded from S_1C_2 (0 dSm^{-1}× 5 mM) and the lowest value (5.00) was observed from S_3C_1 (8 dSm^{-1}× 0 mM).

Table 7. Interaction effect of salinity and calcium on number of fruit cluster plant^{-1}

Salinity Levels	Calcium		
	C_1	**C_2**	**C_3**
S_1	8.00	10.33	7.00
S_2	6.00	9.00	6.00
S_3	5.00	9.00	7.00
CV (%)	**2.53**		
LSD (5%)	**0.3331**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.7. Number of fruits plant^{-1}

4.7.1. Effects of salinity levels on number of fruits plant^{-1}

Application of different levels of saline water on tomato for number of fruits plant^{-1} has significant effect (Figure 13). The highest number of fruits plant^{-1} (46.33) was obtained from (0 dSm^{-1}) S_1, while the lowest number (22.77) was obtained from (8 dSm^{-1}) S_3. 38.8 was found from 4 dSm^{-1} (S_2). From the result, it is clear that fruits plant^{-1} decrease with increasing level of salinity. Salinity reduced the number of fruits plant^{-1} which was also consistent with the number of flowers plant^{-1} and ultimately reduced the fruit yield which is also supported by Hamayun (2010). Similar result was obtained by Naher *et al*. (2020); Cuartero and Munoz (1999) in tomato. Grunberg *et al*. (1995) reported that fruit set could be decreased because of low number of pollen grains/flower in plants under salt stress; extra flower production would be inhibited (Saito and Ito, 1974). According to Sun and Hauster (2004), salinity adversely affects reproductive development by inhibiting micro osporogenesis and stamen filament elongation, enhancing programmed cell death, ovule abortion and senescence of fertilized embrayo.

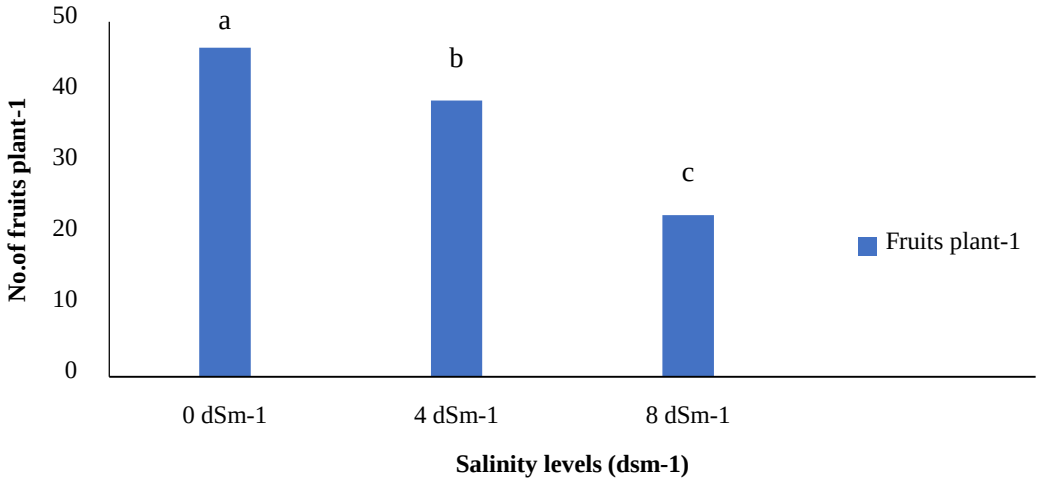

Figure 13. Effect of salinity levels on number of fruits plant^{-1}

4.7.2. Effects of calcium levels on number of fruits plant^{-1}

Influence of different levels of calcium on number of fruits plant^{-1} of tomato varied significantly (Figure 14). The highest number of fruits plant^{-1} (49.88) was recorded from C_2 (5mM) and the lowest number (35.77) was found from C_3 (10mM). 39.3 was obtained from C_1 (0mM) This result showed that, 5mM Ca level was better than 10mM.

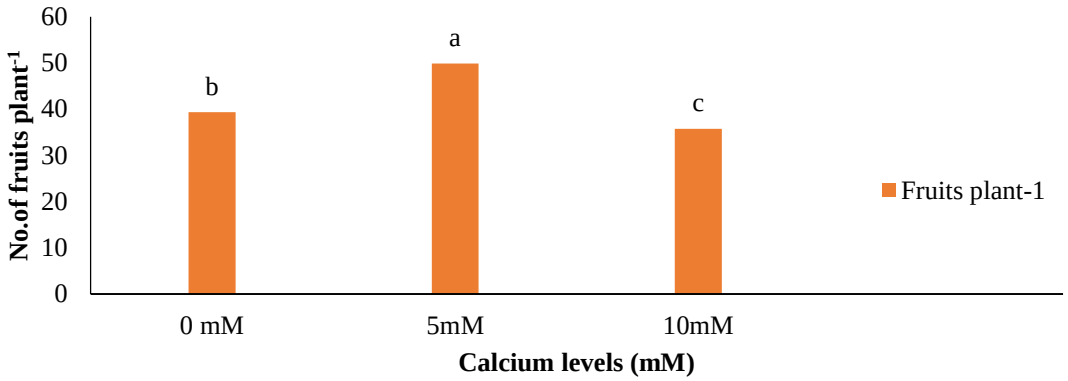

Figure 14. Effect of calcium levels on number of fruits plant^{-1}

4.7.3. Interaction Effect of Salinity and Calcium on Number of fruits plant^{-1}

Combined effect of different levels of salt stress and calcium showed significant differences on number of fruits per plant. The highest number of fruits per plant (61.00) was observed from S_1C_2 (0 dSm^{-1}× 5 mM) treatment combination, which was statistically similar to (4 dSm^{-1}× 5 mM) S_2C_2 (60.66). The lowest number (20.00) was attained from S_3C_1 (8 dSm^{-1}× 0mM) treatment combination, which was statistically similar to (8 dSm^{-1}× 10 mM) S_3C_3 (60.66) (Table 8).

Table 8. Interaction effect of salinity and calcium on number of fruits plant^{-1}

Salinity Levels	Calcium		
	C_1	C_2	C_3
S_1	40.00	61.00	38.00
S_2	28.00	60.66	28.00
S_3	20.00	28.00	20.33
CV (%)	**1.22**		
LSD (5%)	**0.7633**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.8. Length of fruit (cm)

4.8.1. Effects of salinity levels on length of fruit (cm)

Length of fruit of tomato varied significantly for different levels of salt stress. The highest length of fruit (5.76cm) was recorded from S_1 (0 dSm^{-1}) which was statistically similar (5.73cm) with S_2 (4 dSm^{-1}). On the other hand, the lowest length (5.08cm) was recorded from (8 dSm^{-1}) S_3 (Figure 15). Fruits length decreased with increasing the salinity.

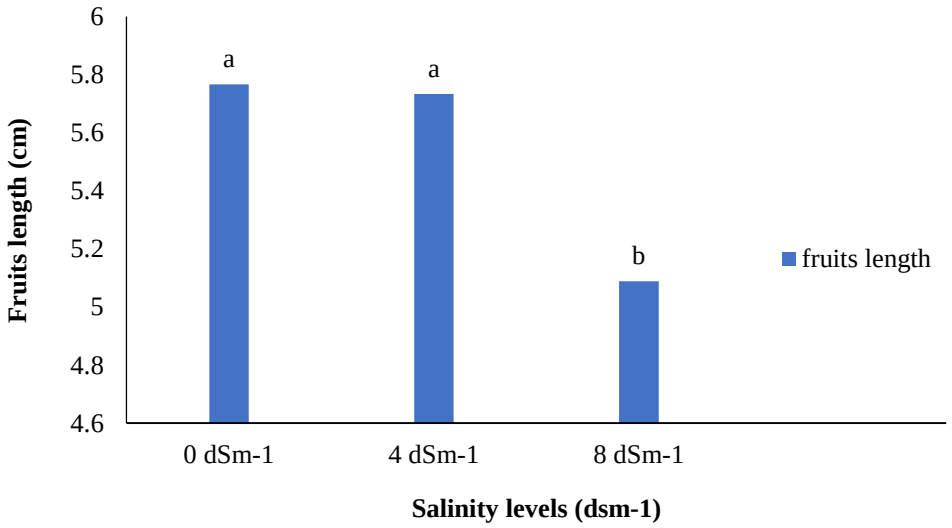

Figure 15. Effect of salinity levels on length of fruits

4.8.2. Effects of calcium levels on length of fruit (cm)

Different levels of calcium showed significant differences on length of fruit of tomato. The highest length of fruit (6.066 cm) was attained from (5mM) C_2, whereas the lowest length (5.04 cm) was recorded from (0 mM) C_1 (Figure 16). 5.3 value was recorded from C_3 (10mM). From this result it was cleared that 5mM Ca was better than control.

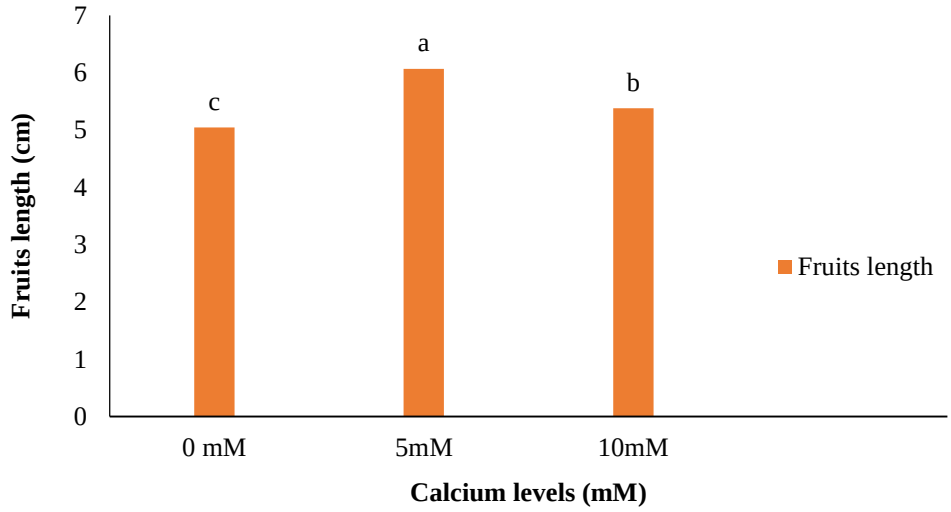

Figure 16. Effect of calcium levels on length of fruits

4.8.3. Interaction Effect of Salinity and Calcium on length of fruit

Combined effect of different levels of salt stress and calcium showed significant differences on length of fruit. The highest length of fruit (6.43 cm) was recorded from (4 dSm^{-1}× 5 mM) S_2C_2, which statistically similar with (0 dSm^{-1}× 5 mM) S_1C_2 (6.36) treatment combination, again the lowest length (4.7 cm) was observed from (8 dSm^{-1}× 0 mM) S_3C_1 treatment combination (Table 9).

Table 9. Interaction effect of salinity and calcium on length of fruit

Salinity Levels	Calcium		
	C_1	C_2	C_3
S_1	5.433	6.366	5.20
S_2	5.00	6.43	5.76
S_3	4.70	5.40	5.16
CV (%)	**3.28**		
LSD (5%)	**0. 3125**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.9. Diameter of fruit (cm)

4.9.1. Effects of salinity levels on diameter of fruit (cm)

Different levels of salt stress varied significantly for diameter of fruit of tomato. The highest diameter of fruit (6.64 cm) was recorded from S_1 which was statistically similar (6.5 cm) with S_2, while the lowest diameter (6.07 cm) was found from S_3 (Figure 17). Posada and Rodriguez (2009) reported that fruits of salt-stressed plants had reduced diameter.

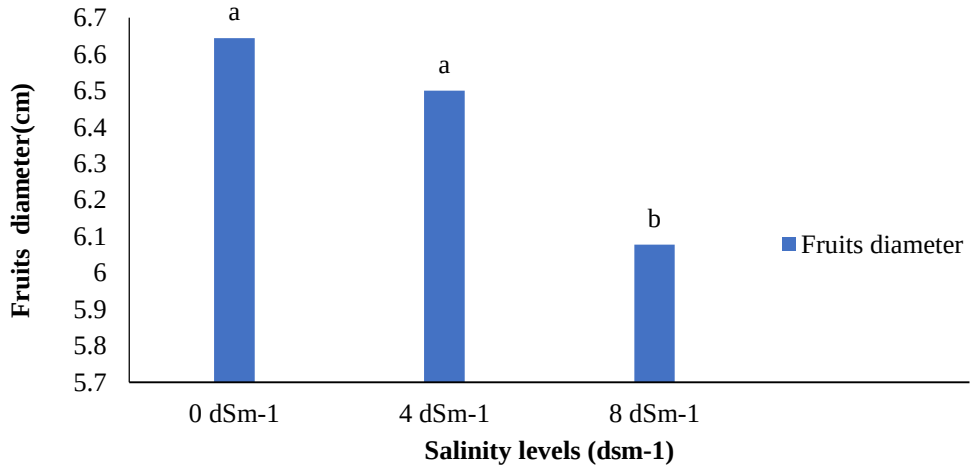

Figure 17. Effect of salinity levels on diameter of fruits

4.9.2. Effects of calcium levels on diameter of fruit (cm)

Statistically significant variation was recorded due to different levels of calcium on diameter of fruit of tomato. Data revealed that the highest diameter of fruit (7.01 cm) was recorded from C_2, whereas the lowest diameter (6.04 cm) was found from (control)C_1, which was statistically identical (6.16cm) with C_3 (Figure 18). This result showed that 5mM Ca increased the diameter of fruits.

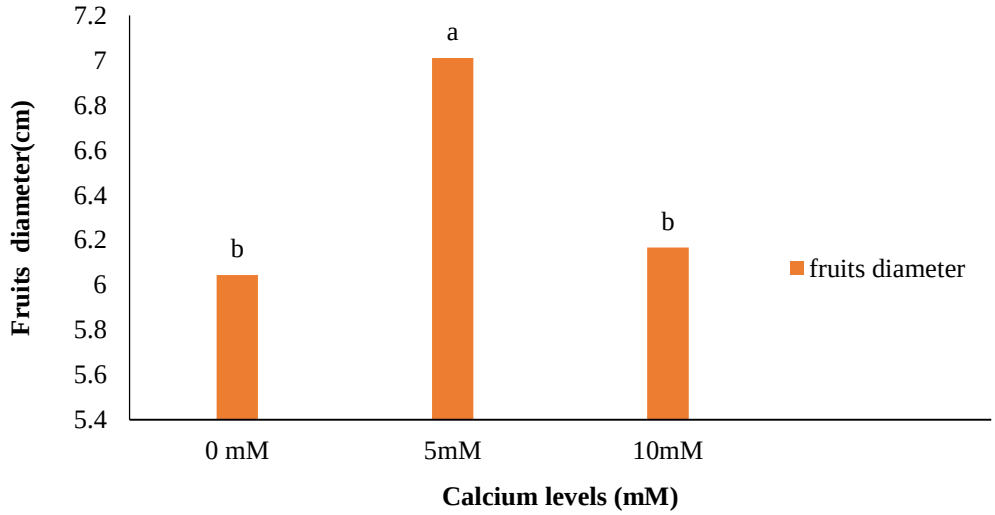

Figure 18. Effect of calcium levels on diameter of fruits

4.9.3. Interaction Effect of Salinity and Calcium on diameter of fruit

Diameter of fruit showed significant differences due to combined effect of different levels of salt stress and calcium. The highest diameter of fruit (7.36 cm) was observed from (4 dSm^{-1}× 5 mM) S_2C_2, which was statistically identical (7.26 cm) with (0 dSm^{-1}× 5 mM) S_1C_2 treatment combination and the lowest diameter (5.70 cm) was recorded from S_3C_1 treatment combination (Table10).

Table 10. Interaction effect of salinity and calcium on diameter of fruit

Salinity Levels	Calcium		
	C_1	C_2	C_3
S_1	6.43	7.26	6.23
S_2	6.00	7.36	5.13
S_3	5.70	6.40	6.13
CV (%)	**2.36**		
LSD (5%)	**0. 2618**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

4.10. Fruit yield $plant^{-1}$(kg)

4.10.1. Effects of salinity levels on fruit yield $plant^{-1}$(kg)

Different levels of salt stress varied significantly in terms of fruit yield per plant of tomato. The highest yield per plant (3.11 kg) was recorded from (control) S_1, while the lowest yield (2.54 kg) was found from (8 dSm^{-1}) S_3 (Figure 19). 2.71 kg yield was obtained from 4 dSm^{-1} (S_2). Most crops tolerate salinity up to a threshold level, above which yields decrease as salinity increases (Maas, 1986). The result showed the gradual decrease of yield with the increased levels of salinity, which was strongly supported by Rahman *et al.*, (2018); Siddiky 2012; Siddiky *et al*. 2015);Naher *et al*. (2020); Hajer *et al.* (2006); Lolaei *et al.* (2012); Khan (2013) and Cuartero and Munoz (1999) in tomato. Tzortzakis (2010) reported that, salinity either of soil or of irrigation water causes disturbance in plant growth and nutrient balance and reduces crop yields. At relatively lower salinity levels, the yield reduction observed is caused mainly by a reduction in the average fruit weight; the declining number of fruits explains the main portion of yield reduction at higher levels of salinity.Tomato yield were subjected to 75 and 150 mM NaCl stress in order to study the effect of salt stress on its antioxidant response and stress indicators by Slathia and Choudhary (2013). The fruit weight of tomato was reported to show a significant variation among different germplasms of tomato, and in general, there was a significant decrease in

fruit yield compared to controls in plants treated with high concentrations of salt (Siddiky 2012; Siddiky *et al*.2015).

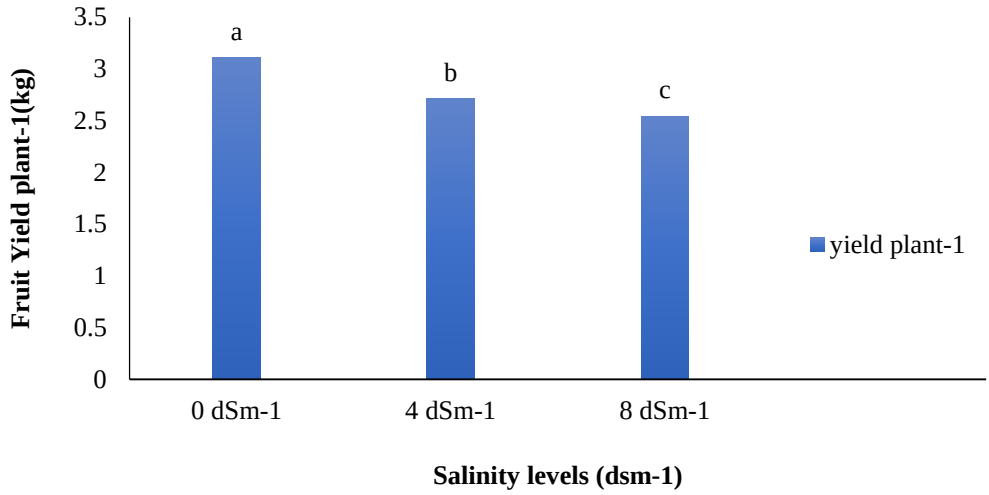

Figure 19. Effect of salinity levels on yield plant^{-1}(kg)

4.10.2. Effects of calcium levels on yield plant^{-1}(kg)

Different levels of calcium showed significant differences on yield per plant of tomato. The highest yield per plant (3.31 kg) was recorded from (5mM) C_2, whereas the lowest yield (2.43 kg) was observed from (0mM) C_1 (Figure 20). 2.62 kg recorded from C_3 (10mM). Hao and Papadopoulos (2004) reported that at 300 mgL^{-1} Ca, total fruit yield increased linearly. These results suggest that the application of calcium increased the tomato fruits yield compared to control but 10mM concentration of calcium gave comparatively lower yield than 5mM. Lolaei *et al.* (2012) reported that, application of Ca^{2+} in the nutrient solution increased the fruit yield of tomato. The present work showed that under both non-saline and saline conditions, the exogenous application of Ca^{2+} alone, through the rooting medium, had an ameliorative effect on yield of tomato.

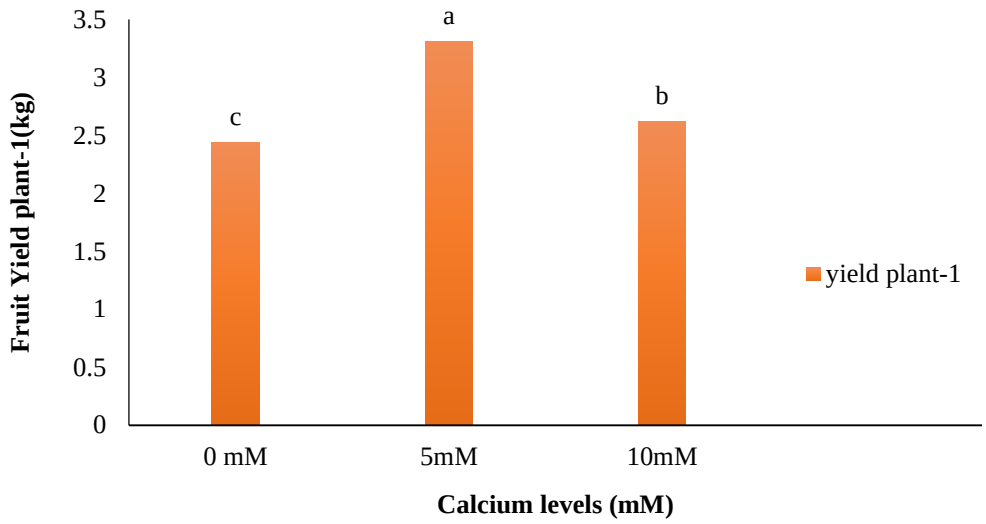

Figure 20. Effect of calcium levels on fruit yield plant^{-1}(kg)

4.10.3. Interactions effects of salinity levels on yield plant^{-1}(kg)

Yield per plant varied significantly due to the combined effect of different levels of salt stress and calcium. The highest yield per plant (3.50 kg) was recorded from (0 dSm^{-1}× 5 mM) S_1C_2 treatment combination and the lowest yield (2.0 kg) was observed from (8 dSm^{-1}× 0 mM) S_3C_1 treatment combination (Table 11).

Table 11. Interaction effect of salinity and calcium on yield plant^{-1}(Kg)

Salinity Levels	Calcium		
	C_1	**C_2**	**C_3**
S_1	2.96	3.50	2.86
S_2	2.33	3.23	2.56
S_3	2.00	3.20	2.43
CV (%)	**3.48**		
LSD (5%)	**0.1682**		

S_1 = 0 dSm^{-1}, without salt, S_2 = 4 dSm^{-1}, S_3 = 8 dSm^{-1}
C_1 = No calcium, C_2 = 5 mM, C_3 = 10 mM

CHAPTER V

SUMMARY, COCLUSION AND RECOMMENDATION

SUMMARY

Salinity is considered as one of the major environmental stress which adversely affect plants growth, metabolism and ultimately yield. So an experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to examine the role of calcium on mitigation of salt stress in tomato. Thirty days seedlings of BARI Tomato- 2 variety were used. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The factors are: Factor A: three levels of salinity viz. S_1 , S_2, S_3 represented as 0 ,4 and 8 dSm^{-1} and factor B is different concentration of Ca^{2+} viz. C_1 , C_2, C_3 considered as 0, 5, 10 mM. The treatments were applied at 30, 45, 70 days after transplanting (DAT). The data collected at 35, 50, 75 days after transplanting. Data on different growth parameters, physiological parameters and yield with yield contributing characters of tomato were recorded. The analysis was done following the software STATISTIX 10. The significance of the difference among the means was evaluated by the Least Significant Difference Test (LSD) at 5% level of probability

A significant variation among the treatments was found while different salinity levels and calcium levels were applied in different combinations. There were significant differences among the influence of different levels of salinity found in case of almost all the parameters. 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 8 dSm^{-1} treated plants.

At 35, 50 and 75 DAT, the highest plant height was34.11, 59.17 and 79.67 cm respectively under a controlled condition whereas the lowest height was 29.88, 57.73 and 77.0 cm at 8dSm^{-1}. The highest number of leaves at 35, 50 and 75 DAT was 12, 23.66 and 43.66 cm under S_1 condition and the lowest was recorded from S_3 condition. At 35 DAT maximum numbers of branches $plant^{-1}$ (5.0) was found in case

of S_1 and the lowest value (4) from S_3. At 50 DAT highest number of branches (6.11) was recorded from S_1 and the lowest value (4.0) was found from S_3. At 75 DAT, the highest number of branches plant^{-1} (7.1) was recorded from S_1 and the lowest value (5.88) was found in case of S_3. The highest number of flowers cluster^{-1}(6.2) was observed from S_1 treatment and the lowest number (4.0) was found from S_3. The highest number of flowers plant^{-1} (48.7) was observed from S_1, where the lowest number (39.7) was recorded from S_3. The highest number of fruits plant^{-1} (46.33) was obtained from S_1, while the lowest number (22.77) was obtained from S_3. The highest yield per plant (3.11 kg) was recorded from S_1, while the lowest yield (2.54 kg) was found from S_3.

Calcium significantly influenced the morphological and yield parameters of Tomato plant. At 35 DAT the highest plant height was observed 34.1 cm from C_2 and the lowest was 30.889 cm from C_3. At 50 DAT, numerically the highest plant height was found 59.678 cm from C_2 where the lowest value was recorded from C_3, (57.8) cm which was statistically similar with treatment C_1 (57.878 cm). At 75 DAT, the tallest plant was recorded from C_2 (80.111 cm) and the shortest plant was found From C_1 (76.567 cm). The highest number of leaves at 35, 50 and 75 DAT was12.8, 23.8and 43.8cm under C_1 condition and the lowest was 10.6, 20.8, and 40.7 recorded from C_1, C_1, and C3 condition respectively. At 35 DAT the highest number of branches was observed 7.67 from C_2 and the lowest was 5.3 from C_1. At 50 DAT, the highest value was found 5.67 from C_2 where the lowest value was recorded from C_1 (4.33) which was statistically similar with treatment C_3. At 75 DAT, the highest value was recorded from C_2 (5.4) and the lowest was found from C_3 (3.67). The highest flower plant^{-1} (52.00) was found in C_2 treated plants and control treated plants showed the lowest flower plant^{-1} (45). The highest number of fruit cluster plant^{-1} (9.44) was observed from C_2 and the lowest value (6.33) from C_1. The maximum number of fruits plant^{-1} (49.88) was recorded from C_2 and the lowest number (35.77) was found from C_3. The highest length and diameter was 6.06 cm and 7.01 cm recorded from C_2 and the lowest was recorded from C_1. The highest yield per plant (3.31 kg) was recorded from C_2, whereas the lowest yield (2.43 kg) was observed from C_1.

The combinations of salinity and calcium significantly influenced almost all the parameters. At 35, 50 and 75 DAT, the tallest plant (35.3 cm, 60.23 cm and 81.30 cm) was found from S_1C_2 (0 dS/m + 5.0 mM Ca^{2+}) treatment combination, while the shortest (28.0 cm, 57.0 cm, 75.1 cm) was found from S_3C_1 (8 dSm^{-1} salt + control,

Ca^{2+}) treatment combination. At 35 DAT, the highest number of leaves plant^{-1} was found from S_1C_2 (13.000) and the lowest value was recorded in case of S_2C_3 (11.00). At 50 DAT highest number of leaves plant^{-1} was found from S_1C_2 (25.33) where the lowest value was recorded from S_3C_3 (18.3). At 75 DAT, the highest number of leaves plant^{-1} was found from S_1C_2 (45.333) where the lowest value was recorded from S_3C_3 (38). At 35 DAT, the highest number of branches plant^{-1} was found from S_1C_2 (6) and the lowest value was recorded in case of S_2C_3 and S_3C_1 (3.00). At 50 DAT highest number of branches plant^{-1} was found from S_1C_2 (7) where the lowest value was recorded from S_3C_1 (3). At 75 DAT, the highest number of branches plant^{-1} was found from S_1C_2 where the lowest value was recorded from S_3C_1 (4.0). The highest number of flower clusters plant^{-1} (9.00) was found from S_1C_2, which was statistically similar with S_2C_2, while the lowest number (3) was obtained from S_3C_3. The highest number of fruits per plant was observed from S_1C_2 treatment combination, which was statistically similar to S_2C_2 (60.66). The lowest number (20.00) was attained from S_3C_1 treatment combination, which was statistically similar to S_3C_3 (60.66). The highest length of fruit (6.43 cm) and diameter of fruit (7.36 cm) was observed from S_2C_2. The highest yield per plant (3.50 kg) was recorded from S_1C_2 treatment combination and the lowest yield (2.0 kg) was observed from S_3C_1 treatment combination.

CONCLUSION

Salinity is one of the brutal environmental factors limiting the productivity of plant. From the result, it may be concluded that,

1. Different morphological and yield contributing characters of tomato was significantly decreased with increasing salinity levels. The highest plant height, leaves plant^{-1}, flower plant^{-1}, fruit plant^{-1} and yield plant^{-1} was found at control the lowest was (77cm, 5.88, 39.7, 22.7, and 2.54) from 8 dS/m salinity.
2. The adverse effect of salinity was minimized by the application of exogenous calcium and increased the yield of tomato. The highest plant height (80.11 cm), number of branch plant^{-1} (5.44), number of flower plant^{-1} (52.0), fruits plant^{-1}(49.8), and yield plant^{-1} (3.31 kg) was recorded at 5 mM Ca^{2+} treatment.

So we can conclude that in the saline effected area by adding 5mM gypsum, the salinity stress of tomato can be minimized.

RECOMMENDATION

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

1. Another experiment may be carried out with various levels of salt stress.
2. Others level of calcium sulphate and another stress reducing substances may also be used for further study; and
3. Similar research work should be conducted by the researchers in wide range of varieties of crops and different agro ecological zones (AEZ) of Bangladesh for regional compliance and other performance.

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APPENDICES

Appendix I: Physical and chemical composition of soil sample

Characteristics	Value
% Sand	28
% Silt	57.46
% Clay	21.7
Textural class	Silt loam
pH	5.6
Organic matter (%)	0.86
Available K (ppm)	25
Available Na (ppm)	70

Appendix II: Analysis of variance tables

Factorial ANOVA Table for Plant Height in 35 days

Source	DF	SS	MS	F	P
Replication	2	0.222	0.1111		
Salinity	2	80.222	40.1111	262.55	0.0000
Treatment	2	60.222	30.1111	197.09	0.0000
Salinity*Treatment	4	16.889	4.2222	27.64	0.0000
Error	16	2.444	0.1528		
Total	26	160.000			

Grand Mean 32.000
CV 1.22

Factorial ANOVA Table for Plant Height in 50 days

Source	DF	SS	MS	F	P
Replication	2	0.5422	0.2711		
Salinity	2	9.3889	4.6944	37.10	0.0000
Treatment	2	20.1867	10.0933	79.77	0.0000
Salinity*Treatment	4	4.6044	1.1511	9.10	0.0005
Error	16	2.0244	0.1265		
Total	26	36.7467			

Grand Mean 58.456
CV 0.61

Factorial ANOVA Table for Plant Height in 75 days

Source	DF	SS	MS	F	P
Replication	2	0.169	0.0844		
Salinity	2	35.349	17.6744	56.36	0.0000
Treatment	2	59.616	29.8078	95.05	0.0000
Salinity*Treatment	4	9.129	2.2822	7.28	0.0015
Error	16	5.018	0.3136		
Total	26	109.280			

Grand Mean 78.100
CV 0.72

Factorial ANOVA Table for Number of leaves in 35 days

Source	DF	SS	MS	F	P
Replication	2	0.2963	0.1481		
Salinity	2	1.4074	0.7037	10.86	0.0010
Treatment	2	22.5185	11.2593	173.71	0.0000
Salinity*Treatment	4	2.3704	0.5926	9.14	0.0005
Error	16	1.0370	0.0648		
Total	26	27.6296			

Grand Mean 11.704
CV 2.18

Factorial ANOVA Table for Number of leaves in 50 days

Source	DF	SS	MS	F	P
Replication	2	9.852	4.9259		
Salinity	2	54.741	27.3704	64.26	0.0000
Treatment	2	65.852	32.9259	77.30	0.0000
Salinity*Treatment	4	10.370	2.5926	6.09	0.0036
Error	16	6.815	0.4259		
Total	26	147.630			

Grand Mean 21.704
CV 3.01

Factorial ANOVA Table for Number of leaves in 75 days

Source	DF	SS	MS	F	P
Replication	2	10.667	5.3333		
Salinity	2	57.556	28.7778	86.33	0.0000
Treatment	2	67.556	33.7778	101.33	0.0000
Salinity*Treatment	4	12.889	3.2222	9.67	0.0004
Error	16	5.333	0.3333		
Total	26	154.000			

Grand Mean 41.667
CV 1.39

Factorial ANOVA table for number of Branches in 35 days

Source	DF	SS	MS	F	P
Replication	2	0.0741	0.03704		
Salinity	2	5.4074	2.70370	73.00	0.0000
Treatment	2	16.0741	8.03704	217.00	0.0000
Salinity*Treatment	4	4.1481	1.03704	28.00	0.0000
Error	16	0.5926	0.03704		
Total	26	26.2963			

Grand Mean 4.3704
CV 4.40

Factorial ANOVA table for number of Branches in 50 days

Source	DF	SS	MS	F	P
Replication	2	0.0741	0.0370		
Salinity	2	23.1852	11.5926	313.00	0.0000
Treatment	2	9.8519	4.9259	133.00	0.0000
Salinity*Treatment	4	2.3704	0.5926	16.00	0.0000
Error	16	0.5926	0.0370		
Total	26	36.0741			

Grand Mean 4.8148
CV 4.00

Factorial ANOVA table for number of Branches in 75 days

Source	DF	SS	MS	F	P
Replication	2	2.248E-29	1.124E-29		
Salinity	2	8.22222	4.11111	49.33	0.0000
Treatment	2	26.0000	13.0000	156.00	0.0000
Salinity*Treatment	4	8.44444	2.11111	25.33	0.0000
Error	16	1.33333	0.08333		
Total	26	44.0000			

Grand Mean 6.3333
CV 4.56

Factorial ANOVA table for number of flower clusters plant^{-1}

Source	DF	SS	MS	F	P
Replication	2	0.0741	0.0370		
Salinity	2	58.7407	29.3704	793.00	0.0000
Treatment	2	36.0741	18.0370	487.00	0.0000
Salinity*Treatment	4	2.8148	0.7037	19.00	0.0000
Error	16	0.5926	0.0370		
Total	26	98.2963			

Grand Mean 6.3704
CV 3.02

Factorial ANOVA table for number of flowers cluster^{-1}

Source	DF	SS	MS	F	P
Replication	2	0.0741	0.0370		
Salinity	2	24.0741	12.0370	325.00	0.0000
Treatment	2	14.7407	7.3704	199.00	0.0000
Salinity*Treatment	4	2.1481	0.5370	14.50	0.0000
Error	16	0.5926	0.0370		
Total	26	41.6296			

Grand Mean 5.2963
CV 3.63

Factorial ANOVA table for number of flowers plant^{-1}

Source	DF	SS	MS	F	P
Replication	2	0.30	0.15		
Salinity	2	4610.30	2305.15	15559.75	0.0000
Treatment	2	3488.30	1744.15	11773.00	0.0000
Salinity*Treatment	4	248.59	62.15	419.50	0.0000
Error	16	2.37	0.15		
Total	26	8349.85			

Grand Mean 35.926
CV 1.07

Factorial ANOVA table for number of fruits cluster plant^{-1}

Source	DF	SS	MS	F	P
Replication	2	0.0741	0.0370		
Salinity	2	10.2963	5.1481	139.00	0.0000
Treatment	2	48.2963	24.1481	652.00	0.0000
Salinity*Treatment	4	7.2593	1.8148	49.00	0.0000
Error	16	0.5926	0.0370		
Total	26	66.5185			

Grand Mean 7.5926
CV 2.53

Factorial ANOVA table for number of fruits plant^{-1}

Source	DF	SS	MS	F	P
Replication	2	0.22	0.11		
Salinity	2	2609.56	1304.78	6710.29	0.0000
Treatment	2	2605.56	1302.78	6700.00	0.0000
Salinity*Treatment	4	625.56	156.39	804.29	0.0000
Error	16	3.11	0.19		
Total	26	5844.00			

Grand Mean 36.000
CV 1.22

Factorial ANOVA table for length of fruits

Source	DF	SS	MS	F	P
Replication	2	0.19185	0.09593		
Salinity	2	2.26074	1.13037	34.68	0.0000
Treatment	2	4.89185	2.44593	75.05	0.0000
Salinity*Treatment	4	1.24370	0.31093	9.54	0.0004
Error	16	0.52148	0.03259		
Total	26	9.10963			

Grand Mean 5.4963
CV 3.28

Factorial ANOVA table for diameter of fruits

Source	DF	SS	MS	F	P
Replication	2	0.01407	0.00704		
Salinity	2	1.56074	0.78037	34.12	0.0000
Treatment	2	4.98741	2.49370	109.04	0.0000
Salinity*Treatment	4	0.97037	0.24259	10.61	0.0002
Error	16	0.36593	0.02287		
Total	26	7.89852			

Grand Mean 6.4074
CV 2.36

Factorial ANOVA table for yield plant^{-1}

Source	DF	SS	MS	F	P
Replication	2	0.02889	0.01444		
Salinity	2	1.52667	0.76333	80.82	0.0000
Treatment	2	3.84222	1.92111	203.41	0.0000
Salinity*Treatment	4	0.37778	0.09444	10.00	0.0003
Error	16	0.15111	0.00944		
Total	26	5.92667			

Grand Mean 2.7889
CV 3.4