MITIGATION OF SALT STRESS IN TOMATO BY FOLIAR APPLICATION OF POTASSIUM NITRATE

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MITIGATION OF SALT STRESS IN TOMATO BY FOLIAR APPLICATION OF POTASSIUM NITRATE

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CERTIFICATE

This is to certify that thesis entitled, "**MITIGATION OF SALT STRESS IN TOMATO BY FOLIAR APPLICATION OF POTASSIUM NITRATE**" 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 HORTICULTURE**, embodies the result of a piece of bonafide research work carried out by **MD. SUJAN**, Registration No. 14-05836 under my supervision and 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: June, 2021
Place: Dhaka, Bangladesh

Khairul Kabir
Associate Professor
Supervisor

Dedicated to

My

Beloved Parents

LIST OF ABBREVIATIONS

FULL WORD	ABBREVIATION	FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ	Hectare	ha
Agriculture	Agric.	Least Significant Difference	LSD
Agricultural	Agril.	Meter Squares	m^2
Anonymous	Anon.	Muriate of Potash	MoP
Bangladesh Agricultural Research Institute	BARI	Miligram	mg
Bangladesh Bureau of Statistics	BBS	Mililiter	ml
Centi-meter	cm	Milimolar	mM
Coefficient of variation	CV	Sodium	Na
Degree Celsius	^oC	Sodium Chloride	NaCl
Degrees of freedom	d.f.	Non-significant	NS
Days After Transplanting	DAT	Parts per million	ppm
Decisiemens per meter	dSm^{-1}	Sher-e-Bangla Agricultural University	SAU
And others	*et al.*	Ton per hectare	$t\ ha^{-1}$
Food and Agriculture Organization	FAO	Triple Super Phosphate	TSP
Gibberellic Acid	GA_3	Variety	var.
Potassium	K	Per cent	%
Kilogram	Kg		

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The Author

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ABSTRACT

A pot experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from October 2019 to March 2020 to find out the effect of salinity levels and potassium nitrate on morphological, yield and yield contributing characters of tomato. The materials used for the experiment were BARI Tomato 19. In this experiment, the treatments consisted of five different salinity levels viz,, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1} and three different levels of potassium nitrate viz., M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM. The experiment was setup in a two factor Randomized Complete Block Design (RCBD) with three replications. Data were taken from plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, days to first flowering, number of flower $cluster^{-1}$, number of flower cluster $plant^{-1}$, number of flowers $plant^{-1}$, number of dropped flower $plant^{-1}$, number of fruit $plant^{-1}$, fruit length, fruit diameter, dry matter content of fruit, individual fruit weight, fruit weight $plant^{-1}$. When single effect was considered, salinity adversely affected most of the growth and yield parameters, but application of potassium nitrate elevated all the mentioned parameters. When combined effect was considered, the maximum plant height (121.4 cm), number of branches $plant^{-1}$ (8.13), leaves $plant^{-1}$ (39.33), minimum days to first flowering (38.33 days), cluster $plant^{-1}$ (8.92), flower $cluster^{-1}$ (8.67), flower $plant^{-1}$ (77.34), fruit $plant^{-1}$ (53.67), the highest individual fruit weight (69.11 g) and fruit yield $plant^{-1}$ (3.71 kg) were found from L_0M_2 (10 mM KNO_3 with no salinity stress condition), whereas the opposite value was obtained from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination. The experimental results showed that different levels of salinity significantly affect the morphological characters and yield of tomato. Exogenous application of potassium nitrate significantly increased the morphological characters, yield contributing characters and yield of tomato in both saline and non-saline conditions. Among the different concentration of potassium nitrate, tomato showed better response with 10 mM concentration of potassium nitrate.

CHAPTER I

INTRODUCTION

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Tomato (*Lycopersicon esculentum* Mill.), a popular solanaceous vegetable crop, widely grown many parts of the world due to its excellent adaptability to wider range of soil and climatic conditions. Worldwide, it is the second most important vegetable crop next to potato (Kumar *et al.,* 2015). Due to wider adaptability, it is also one of the economically important vegetable crops in Bangladesh. In Bangladesh, it is cultivated in total area of 69697 ha with annual production reaches to 387653 metric tons in 2018-19 (BBS, 2020). It is an excellent source of minerals (notably potassium, calcium and magnesium), carboxylic acids and oxalic acids (Herndndez-Suirez *et al.,* 2007; Caputo *et al.,* 2004), antioxidants, such as lycopene, β-carotene, lutein, phytophene, phytofluene, vitamin C and E (Ray *et al.,* 2011; Capanoglu *et al.,* 2010; Hemandez-Suarez *et al.,* 2007), folic acid, niacin and trace elements e.g. selenium, copper, manganese, iron and zinc (Molla *et al.,* 2012). Surprisingly, tomato is low in fat, as well as cholesterol-free. Therefore, consumption of tomato and tomato products reduced the risk of cardiovascular disease and certain types of cancer, such as cancers of prostate, lung and stomach (Giovannucci, 1999). However, minerals and phytochemical contents of tomato are dramatically affected by the environmental factors and agronomic practices (Hernandez-Suarez *et al.,* 2007). Tomato is sensitive to a number of environmental stresses, especially extreme temperature, drought, salinity and inadequate moisture stresses (Flowers and Colmer, 2008). Among various abiotic and biotic stresses, salt stress is highly putting constraints to tomato production in Bangladesh.

Salinity is one of the most brutal environmental factors limiting the productivity of crop plants. It has been estimated that worldwide 20% of total cultivated and 33% of irrigated agricultural lands are negatively affected by high salinity (Akladious and Mohamed, 2018) and salinized areas are increasing at a rate of 10% annually and more than 50% of the arable land would be salinized by the year 2050 (Hasanuzzaman *et al.,* 2014). The problem of salinity is further accelerated by converting fertile land of agriculture into other uses especially in urban areas which results in serious threats to fulfill 70% more production to meet the feeding of 9.3 billion population in 2050 (Shabala, 2013). Salt stress is a complex mechanism which affects almost every physiological and biochemical pathway in the plants (Cuartero *et* *al.,* 2006; Nabati *et al.,* 2011; Latif and Mohamed, 2016). It also affects the water and nutrients uptake of the plants (Sofy *et al.,* 2020). Salt stress affect all the major processes like photosynthesis, protein synthesis, energy and lipid metabolism, osmotic stress etc. due to excess sodium and chloride ion in soil solution that decrease osmotic potential of soil solution and water uptake by the root (Apel and Hirt, 2004).

Salinity disturbs the physiology of plants by changing the metabolism of plants, it also injures cells due to ion toxicity that reduce growth of plants, leaf area, and accumulation of dry matter content and also reduces net rate of CO_2 assimilation (Munns and Tester, 2008). Salt induced osmotic stress is responsible for the oxidative stress caused by reactive oxygen species. The toxic effect of reactive oxygen species can counter acted by enzymatic as well as non-enzymatic antioxidative system such as: superoxide dismutase, catalase, ascorbate peroxidase, glutathione reductase, ascorbic acid, phenolic compounds etc. (Shi and Zhu, 2008; Sharma and Dietz, 2009; Ashraf, 2009 and Ahmed *et al.,* 2008). It is well known that the basal or foliar application of K^+, Ca^{2+}, Mg^{2+}, proline, glycine-betaine, salicylic acid can mitigate the adverse effects of salinity. Potassium is one of the important macronutrients required for the growth, development, yield, and quality of plants, and it also plays a key role in the survival of plants under abiotic stress conditions, as stress negatively affects the physiological processes of plants such as root and shoot elongation, enzyme activity, water and assimilate transport, synthesis of protein, photosynthetic transport, and chlorophyll content (Yin and Vyn, 2003; Kanai *et al.,* 2011). Under saline field conditions, plants suffer a deficiency of potassium mainly because of the excess of Na^+ in the rooting medium, which acts as an antagonist and decreases the availability of potassium (Rodriguez-Navarro, 2000); thus, under salinity stress, plants face the problem of K deficiency. Therefore, under salinity stress, improving the K-nutritional status of plants alleviates the detrimental effects of Na^+ by different mechanisms, including K^+, Na^+ discrimination (Rubio *et al.,* 2009). As higher levels of NaCl cause K deficiency, this may be one of the factors of oxidative stress. Hence, under salt stress, improving the K-nutritional status of the plants could be used as a tool to minimize oxidative cell damage, at least by the reduced formation of reactive oxygen species during photosynthesis and by the inhibition of NADPH oxidase generating O_2 (Shin and Schachtman, 2004). Kaya *et al*. (2003) reported that foliar application of K fertilizer could be effective in correcting salinity-induced K-deficiency, significantly decreasing salinity-induced damage to membranes and increasing biomass production in tomato and strawberry.

Considering the above facts, the experiment has been undertaken with the following objectives:

- To investigate the morpho-physiology, yield contributing characters and yield response of tomato to salt stress
- To identify the effect of potassium nitrate on the morpho-physiology, yield contributing characters and yield response of tomato
- To examine the role of potassium nitrate on mitigation of salt stress in tomato.

CHAPTER II

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Tomato is one of the important vegetable crops in Bangladesh and other countries of the world and it has drawn attention by the researchers for its various way of consumptions. It is adapted to a wide range of climates ranging from tropics to within a few degrees of the Arctic Circle. However, in spite of its broad adaptation, production is concentrated facing in a diverse biotic factor and abiotic stress conditions. But very few researcheswork available related to growth, yield and development of tomato due to stress especially salt and also the mitigation of salt stress. The research work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works and research findings related to the salt stress and also the mitigation of salt stress in vegetable crops as well as tomato, so far been done at home and abroad, have been reviewed in this chapter.

Salinity is one of the major constraints to plant growth and development across the globe that leads to the huge crop productivity loss. Salinity stress causes impairment in plant's metabolic and cellular processes including disruption in ionic homeostasis due to excess of sodium (Na^+) ion influx and potassium (K^+) efflux. This condition subsequently results in a significant reduction of the cytosolic K^+ levels, eventually inhibiting plant growth attributes. K^+ plays a crucial role in alleviating salinity stress by recasting key processes of plants. In addition, K^+ acquisition and retention also serve as the perquisite trait to establish salt tolerant mechanism. In addition, an intricate network of genes and their regulatory elements are involved in coordinating salinity stress responses. Furthermore, plant growth regulators (PGRs) and other signaling molecules influence K^+-mediated salinity tolerance in plants. Recently, nanoparticles (NPs) have also been found several implications in plants with respect to their roles in mediating K^+ homoeostasis during salinity stress in plants. The present review describes salinity-induced adversities in plants and role of K^+ in mitigating salinity-induced damages. The review also highlights the efficacy of PGRs and other signaling molecules in regulating K^+ mediated salinity tolerance along with nano-technological perspective for improving K^+ mediated salinity tolerance in plants (Kumari *et al.,* 2021).

Aslam *et al.* (2021) reported that the exogenous application of potassium (K) enhanced abiotic resistance and increase yield of crops. They explored the impact of foliar-applied K at 500 ppm on the physiological and biochemical traits, antioxidant activities, and growth attributes of sunflower grown under salt stress (140 mM NaCl). The findings indicated that foliar applied K markedly improved the stomatal conductance, transpiration rate, water use efficiency, CO_2 assimilation rate, total soluble proteins, chlorophyll pigments, and upregulated antioxidant system, which are responsible for the healthy growth of sunflower hybrids grown under salinity stress. The shoot and root lengths, plant fresh and dry weights, and achene weight were significantly increased by K application. Overall, foliar applied K significantly improved all of the aforementioned attributes and can attenuate the deleterious influences of salinity stress in sunflower.

Nkrumah *et al.* (2021) carried out an experiment to examine the effects of Salicylic acid (SA) and Potassium nitrate (KNO_3) on plant height and flowering time of groundnut (*Arachis hypogaea* L.) under induced stresses of salinity, drought and combined salinity and drought. Three watering regimes namely; normal, moderate and severe were used. For salinity stress, 50 mM NaCl, 100 mM NaCl, 150 mM NaCl and combination of water and salinity regimes were used. 50 µm KNO_3 and 50 µm SA were separately applied to plants under water, salinity and combined water and salinity stresses. The mean plant height at 100 mM salt concentration were 42.29 cm for KNO_3, 42.27 cm for SA, compared with 40.98 cm for control ($F= 2.73$; $P \leq 0.008$). In combined severe watering and 150 mM NaCl treatment, flowering time was 57 DAP (days after planting) compared to 34 DAP in control plants. When KNO_3 and SA were applied to severe watering and 150 mM NaCl combined stress induced plants, flowering time was 51 DAP and 53 DAP for KNO_3 and SA treated plants respectively. In conclusion, the exogenous application of plant growth regulators such as SA and KNO_3 reduce impact of water stress on groundnut and effectively improve yield.

Kul *et al.* (2020) reported that biochar as an organic amendment has the potential to remediate salt affected soils, thereby alleviating salt stress on tomato (*Solanum lycopersicum*) plants. The results of the study showed that biochar was efficient in improving overall plant performance under salt stress condition.

Adhikari *et al.* (2020) reported that Potassium sulfate showed better positive effect on the antioxidant activities, polyphenol, flavonoid, carotenoid, and chlorophyll contents compared to those of potassium chloride although the contribution was not noteworthy in comparison to the fertilizer unsprayed plants. The results of this study implied that foliar applications of 2.5% potassium fertilizers could not help reduce the negative effect of salinity stress at the early stage of soybean growth.

Aini *et al.* (2019) conducted an experimentto investigate the effect of K fertilizer on the growth and yield of tomato plants at different levels of salinity. The experiment was conducted in a greenhouse located in the rural area of Bendosari in Kediri, East Java, and using factorial randomized block design. The first factor was NaCl concentration (0, 3000, 6000 and 9000 ppm) while the second factor was the dosage of ZK fertilizer (75, 150 and 225 kg/ha). The results showed that salinity level reduced growth and yield of tomato while the dosage of ZK fertilizer did not affect. Salinity level on 3000 ppm reduced leaf area 20.35 %, shoot dry weight 27.18%, root dry weight 28 %, number of fruits 24.14 %, fruit weight per fruit 29.82 % and fruit weight per plant 12.42 %.

Mahajan *et al.* (2019) reported that foliar application, KNO_3 at 5.0 gL^{-1} registered significantly ($P \leq 0.05$) higher dry leaf yield of *Stevia rebaudiana* compared with control. Exogenous application of K^+ under moderate salinity stress-maintained ion balance in cytosol, particularly K:Na. Thus, the salinity tolerance of stevia can be elevated to some extent through exogenous application of K^+.

Nizam *et al.* (2019) conducted an experiment to investigate the role of Ca in mitigating salt stress induced response in tomato. They found that Ca^{2+} significantly increased the yield contributing characters as well as yield of tomato in both saline and non-saline conditions. However, for combined effect, highest number of fruits plant^{-1} (50.8) and the highest yield plant^{-1} (3.88 kg) was produced from 0 dS m^{-1} Na × 10 mM Ca^{2+}. This result suggests that, exogenous Ca^{2+} can effectively mitigate the deleterious effect of salt stress in tomato.

Mridha (2018) conducted a pot experiment at the net house of Agro-Environmental Chemistry Laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period from November 2017- August 2018 to find out the alleviation of adverse effects of salt stress in tomato by foliar application of salicylic acid. The study showed that salinity adversely affected most of the growth and yield parameters and nutrient content except Na.

Among the plant nutrients, potassium (K) is one of the vital elements required forplant growth and physiology. Potassium is not only a constituent of the plant structure butit also has a regulatory function in several biochemical processes related to protein synthesis, carbohydrate metabolism, and enzyme activation. Several physiological processes depend on K, such as stomatal regulation and photosynthesis. In recent decades, K was found to provide abioticstress tolerance. Under salt stress, K helps to maintain ion homeostasis and to regulate the osmoticbalance (Hasanuzzaman *et al.*, 2018).

Hossein (2018) conducted an experiment in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2017 to April 2018 to study the effect of salinity levels and magnesium on morphological, yield and yield contributing characters of tomato.The study showed that salt stress adversely affected the plant height, number of branches per plant, number of leaves per plant, stem diameter, fruit length and breadth, single fruit weight and total yield.

Nasrin (2017) conducted a pot experiment was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2016 to March 2017. The experimental results showed that different levels of salinity significantly affect the morphological characters and yield of tomato. Exogenous application of salicylic acid significantly increased the morphological characters, yield contributing characters and yield of tomato in both saline and non-saline conditions.In case of salinity the highest yield (3.03 kg) wasfound in non-saline condition and the lowest (0.59 kg) from 16 dS/m concentration of NaCl.

Elhindi *et al.* (2016) carried out an experiment to study the effect of foliar application of K as potassium nitrate (KNO_3) ability to mitigate the negative impacts of salinity on coriander (*Coriander sativum* L.) plants. The study showed that salt stress affected adversely the growth rate, relative content of leaf water, the plant contents of protein and chlorophyll, attributes of gas exchange containing net CO_2 assimilation rate, transpiration rate, stomatal conductance and substomatal CO_2 concentration, essential oil content and leaf K^+, Mg^{2+}, P, Ca^{2+}, N as well as Na^+/K^+ ratio, while it enhanced the electrolyte leakage, the plant contents of proline and Na^+. They found that plants that were treated with KNO_3 perform better in salt stress condition compared to control.

Amjad *et al.* (2016) conducted an experiment to check the efficacy of potassium in alleviating oxidative stress under salt stress, salt-tolerant (Indent-1) and salt-sensitive (Red Ball) tomato (*Lycopersicon esculentum* Mill.) genotypes were exposed to three levels of sodium chloride (NaCl) (0, 75, 150 mM) and two levels of potassium (4.5 and 9 mM) in solution and foliar form. Thirty days of treatments revealed that increasing NaCl stress increased lipid peroxidation (malondialdehyde, MDA) and correspondingly the activity of antioxidant enzymes (superoxide dismutase, SOD; catalase, CAT; and glutathione reductase GR) in both genotypes. However, higher potassium (K) level in solution or foliar spray during the salt-induced stress decreased MDA and antioxidant activity and increased the growth in salt-tolerant genotype than in the salt-sensitive genotype. Decrease in MDA concentration, activity of antioxidant enzymes, and increase in the growth of tomato plants by the application of potassium under salt stress suggest that potassium is an effective ameliorating agent against salt-induced oxidative damage.

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 T_0 (Control), T_1 (4 dS m^{-1}), T_2 (8 dS m^{-1}), T_3 (12 dS m^{-1}) and T_4 (16 dS m^{-1}) treatments, respectively and were carried out with completely randomized design (CRD). Significant results were revealed among growth, yield and yield contributing characters. Control (T_0) 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.

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. He attained the response of tomato to salinity and revealed that the significant variation was found with different level of salinity for leaf area. The highest leaf area (946.80 cm^2) was observed in salinity control while the lowest (410.80 cm^2) was recorded with 16 dS m^{-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.

Amjad *et al.* (2014) reported that potassium plays a key role in the survival of tomato plants under saline conditions in mitigating the adverse effects of sodium. The effect of application of potassium to soil (0, 3.3, and 6.6 mmol/kg) and leaves (4.5 and 9 mM) on tomato yield and quality under 3 salinity treatments (0, 7.5, and 15 dS m^{-1}), using 2 salt-tolerant (Indent-1 and Nagina) and 2 salt-sensitive (Peto-86 and Red Ball) genotypes, was studied in a pot experiment. Potassium application positively affected plant growth and yield, especially in salt-tolerant genotypes. It was concluded that the application of potassium increases yield and quality of tomato fruits in saline soil, and it could be used as an effective practice to produce even a salt-sensitive species like tomato under saline conditions.

Parvin (2013) conducted a pot experiment in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2013 to March 2014 to study the salt stress mitigation in tomato by exogenous application of calcium (Ca^{2+}). The experimental results showed that salt stress significantly affects morphology, physiology, yield contributing characters and yield of tomato. Plant height, leaf number and branch number per plant were reduced with increased levels of salinity mostly at 6 and 8 dSm^{-1}. Salinity also adversely affected the leaf and stem dry weight (gm), leaf area (cm^2), leaf chlorophyll content, number of flowers plant^{-1}, number of dropped flower plant^{-1}, number of fruit plant^{-1} and also fruit weight plant^{-1} mostly at 8 dSm^{-1}. Salt treatment greatly increased the uptake of Na^+ and decreased both potassium K^+ and Ca^{2+} uptake in the leaves of tomato.

Alaa El-Din Sayed Ewase (2013) conducted a pot experiment of coriander where coriander was grown by four levels of NaCl salt (0, 1000, 2000, 3000 and 4000 ppm of NaCl). The results indicate that all growth parameters were reduced by increasing the NaCl concentration. Coriander plants were found to resist salinity up to the concentration of 3000 ppm NaCl only.

Nizam (2013) carried out a pot experiment at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2013 to April 2014. A factorial experiment was conducted based on RCBD with five NaCl levels (0, 2, 4, 6 and 8 dS/m) and three $CaCl_2$ levels (0, 5 and 10 mM), respectively. The results of this experiment showed that, the salt stress reduced the morphological parameters and yield (kg) of tomato with the increment of salinity. The lowest plant height (81.5 cm), number of branch (18.0), SPAD value (21.3), fruit weight (55.4 g) and yield per plant (1.42 kg) was recorded at 8 dS/m NaCl and the highest value was observed at control.

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

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 $CaCl_2$ 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. Tomato in its response to nutrient solution, salinized with sodium chloride and calcium chloride. The results obtained from this experiment show that salinity stress caused a significant reduction in plant growth, leaf number and fruit weight.

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 dS m^{-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. Hence, these varieties can be regarded as a breeding material for development of new tomato varieties for tolerance to salinity in saline areas of Bangladesh.

Hajiboland *et al.* (2010) conducted an experiment where plants treated with the arbuscular mycorrhizal fungi *Glomus intraradices* (+AMF) showed beneficial effect in salt condition. Tomato (*Solanum lycopersicum* L.) cultivars Behta and Piazar were cultivated in soil without salt (EC= 0.63 dS/m), with low (EC= 5 dS/m), or high (EC= 10 dS/m) salinity. Growth and plant yield reduction affected by salinity can be the reason of variation in photosynthetic products translocation toward root, decrease of plant top especially leaves, partial or total enclosed of stomata, chlorophyll content, direct effect of salt on photosynthesis system and ion balance.

Nawaz *et al.* (2010) reported that applications of salt in the growth medium caused reduction in shoot length of sorghum cultivars. Under saline conditions 50 mM proline was more effective to reduce the effect of NaCl than 100 mM proline in both cultivars. Proline level 50 mM showed 26.58% and 11.78% increased shoot length as compared to NaCl stresses plants. However, high concentration of proline (100 mM) was not so much effective as compared to low concentration i.e. 50 mM.

Hamayun (2010) reported that, the adverse effects of NaCl induced salt stress on growth attributes and endogenous levels of gibberellins (GA), abscisic acid (ABA), jasmonic acid (JA) and salicylic acid (SA) soybean cv. Hwangkeumkong was showed. Chlorophyll content was significantly decreased in response 70 mM and 140 mM concentrations of NaCl.

Taffouo *et al.* (2010) conducted research on six cultivars of tomato. Three concentrations of salt solution 50, 100 and 200mM NaCl and the control were used in irrigation. The results showed that total chlorophyll concentration of tomato leaves is significantly reduced under salt stress in all cultivars at 50 and 100 mM. The total chlorophyll and the plant height decreased due to increased salt solution.

Rafat and Rafiq (2009) reported that, total chlorophyll content in tomato plant proportionally decreased with the increase in salinity levels up to 0.4% sea salt solution (EC 5.4 dSm^{-1}).

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

Jafari (2009) studied the interactive effects of salinity, calcium and potassium on physio-morphological traits of sorghum (*Sorghum biclolor* L.) in a green-house 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). Salinity substantially reduced the plant growth as reflected by a decrease in the plant height, shoot and root weight.

Munns and Tester (2008) observed that osmotic effect, which develops due to increasing salt concentration in the root medium, is a primary contributor in growth reduction in the initial stages of plant growth. This stage can be characterized by reduction in generation of new leaves, leaf expansion, development of lateral buds leading to fewer branches or lateral shoots formation in plants.

Memon *et al.* (2007) conducted a pot experiment on silty clay loam soil at Sindh Agriculture University, in Tando Jam, Pakistan. Sarokartuho variety of Sorghum (*Sorghum bicolor* L.) was continuously irrigated with fresh (control) and marginally to slightly saline EC 2, 3, 4 and 5 (dSm^{-1}) waters. Increasing water salinity progressively decreased plant height and fodder yield (fresh and dry weight) per plant. It was reported that under severe salt stress, photosynthesis of tomato deeply reduced, so in this way stressed plants had a lower amount of fixed carbon to utilize for plant growth (Jamil *et al.,* 2007).

Amini and Ehsanpour (2006) reported decrease in chlorophyll content in tomato cultivar due to salt stress.

Hajer *et al.* (2006) conducted two different experiments separately on tomato under saline condition and reported that fruit yield decreased with increased salinity separately.

Ali *et al.* (2005) conducted a pot experiment with three salinity levels (0, 6 and 9 dSm^{-1}) and observed that 1000-seed weight decreased with increased salinity level in sesame.

A significant decline in the net photosynthesis is an immediate effect of stomatal closure coupled with photorespiration in plants exposed to high salinity stress. This short-term response to salinity exposure lasts for 24-48 hr and completely ceases photosynthesis (Parida *et al.,* 2005).

Soil salinity affects plant growth and development by way of osmotic stress, injurious effects of toxic Na^+ and Cl^- ions and to some extend Cl^- and SO_4^{2-} of Mg^{2+} and nutrient imbalance caused by excess Na^+ and Cl^- ions (Sairam *et al.,* 2004).

Mostafa (2004) observed that at low and moderate salinity levels, sugars and consequently the total carbohydrates are decreased. Soluble protein is generally decreased in response to salinity (Abdel-Latef, 2005).

Salinity arrests the cell cycle transiently by reducing the expression and activity of cyclins and cyclin-dependent kinases that results in fewer cells in the meristem, thus limiting growth (West *et al.*, 2004).

Salinity adversely affects reproductive development by inhibiting micro-sporogenesis and stamen filament elongation, enhancing programmed cell death in some tissue types, ovule abortion and senescence of fertilized embryos. In Arabidopsis, 200 mM NaCl stress causes as high as 90% ovule abortion (Sun *et al.*, 2004).

Debnath (2003) worked with mustard to know the effect of different levels of salinity (0, 5, 7, 10 and 15 dSm^{-1}) on yield attributes and dry matter partitioning and reported that harvest index decreased with increased salinity levels.

High concentration of Na^+ and Cl^- ions in soil solution reduced the uptake of K^+ ions which ultimately caused K^+ deficiency in plants. K^+ deficiency result in chlorosis and then necrosis in plant leaves (Gopal and Dube, 2003).

Cicek and Cakirlar (2002) observed the effect of salinity on physiological attributes of maize cultivars. They found that salinity caused a marked decrease in shoot length, fresh and dry weight, leaf area of maize plants.

Javaid *et al.* (2002) investigated the salinity effect (0, 20, 50 and 75 mM NaCl) on plant height in four rice variety and reported that salinity affects the morphological characters of the studied plants and plant height decreased with increased salinity levels. Similar results were also reported by Thakral *et al.* (2001) in twenty-nine Ethiopian mustard (*Brassica carinata*) and by Uddin *et al.* (2005) in *B. campestris.*

Chakraborti and Basu (2001) studied salt tolerance ability in 9 sesame varieties under saline condition and reported that capsules $plant^{-1}$, seeds $capsule^{-1}$ and seed yield decreased under saline condition in all studied varieties of sesame.

Babu and Thirumurugan (2001) conducted a pot experiment to study the effect of salt priming on growth and development of sesame under induced salinity condition. Salinity was induced by addition of 35, 70 and 140 mM NaCl solution to create three levels of salinity and observed that plant height decreased with the increased salinity level. Similar results were also observed by many researchers in sesame by Ragiba (2000).

Potassium (K) uptake by plant roots is often suppressed by sodium (Na) in the growth medium, whose damage may be moderated by calcium (Ca^{2+}). There is a debate if K influx could be used as an index to salinity tolerance and the reliability of its determination by the ion depletion method. Silberbush (2001) studied two sorghum varieties (Hegari and NB-9040), that differ in their salt tolerance, grew for 28 days in nutrient solutions with 0, 25, 50 and 75 mm NaCl. Depletion of K^+ concentration in the solutions was then determined over time, and K net influx was calculated from K^+ concentration depletion between two-time steps. The procedure was repeated four times. K influx data of the four reps were fitted by the least-squares procedure to the equation is the calculated coefficients. For each variety, the fitted equation indicated a decrease in K influx affinity to C with the increase in the NaCl concentration in the growth solution. This effect was obtained in the salinity sensitive NB9-040 in lower NaCl concentration than in the tolerant Hegari.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted during the period from October 2019 to March 2020 to study the mitigation of salt stress in tomato by foliar application of potassium nitrate used as a form of KNO_3. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Location of the experimental site

The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. It was located in 23°74′N latitude and 90°35′E longitudes. The altitude of the location was 8.6 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207, which have been shown in the Appendix I.

3.2 Climate condition of the experimental site

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. The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season October 2019 to March 2020 have been presented in Appendix IV-VI.

3.3 Characteristics of soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with adequate irrigation facilities and remains fallow during previous growing season. The nutrient status of the farm soil under the experimental pot was collected and analyze in the Soil Resource Development Institute (SRDI), Dhaka and result has been presented in Appendix II-III.

3.4 Planting materials

BARI Tomato 19, developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh was used as planting material. The seeds were healthy, well matured and free from other crop seeds and inert materials.

3.5 Preparation of soil and filing of pots

A total of 45 earthen pots were prepared with 10 kg air dried soil. The size of the pot was 30 cm top diameter with a height of 25 cm. Plant parts, inert materials, visible insects and pests were removed from soil by sieving. Collected soil was dried under the sun. The dry soil was thoroughly mixed with well rotten cowdung and fertilizers before filling the pots. The pots were placed in the shade.

3.6 Pot preparation

A ratio of 1:3 well rotten cowdung and soil were mixed and pots were filled 10 days before transplanting. Silt loam soils were used for pot preparation. All 45 pots were filled on October 2019. Weeds and stubbles were completely removed from the soil.

3.7 Experimental treatments and design

Five levels (0, 2, 4, 6 and 8 dS m^{-1}) of saline water irrigation were imposed to tomatoplant. Three levels (0, 5 and 10 mM) of potassium were applied to the leaves of tomato plant as foliar application. The experiment was set up in a two factor Randomized Complete Block Design (RCBD) with three replications. Thus 45 experimental pots were placed in ambient air at the Horticulture Farm premises of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

3.8 Treatments of the experiment

Factor A: Different levels of NaCl

i. L_0: 0 dS/m (Control)

ii. L_1: 2 dS/m

iii. L_2: 4 dS/m

iv. L_3: 6dS/m

v. L_4: 8 dS/m

Factor B: Different levels of Potassium Nitrate (KNO_3)

i. M_0: 0 mM (Control)

ii. M_1: 5 mM

iii. M_2: 10 mM

There were 15 (5 × 3) treatments combination such as L_0M_0, L_0M_1, L_0M_2, L_1M_0, L_1M_1, L_1M_2, L_2M_0, L_2M_1, L_2M_2, L_3M_0, L_3M_1, L_3M_2, L_4M_0, L_4M_1, L_4M_2.

3.9 Application of manures and fertilizer in the pot

The required amount of fertilizers (N, P, K, and S kg ha^{-1}) and manure (cowdung) was calculated for each pot considering the dose of 1hectare soil at the depth of 20 cm as per recommendation of Fertilizer Recommendation Guide, 2012. As per such recommendation, 15.0 g of urea, 7.0 g of triple super phosphate (TSP), 3.0 g of muriate of potash (MoP), 2.0 g of gypsum and 100.0 g of cowdung pot^{-1} was applied. One third of urea and entire amount of cowdung, TSP and MoP 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.

3.10 Imposition of salinity treatments

Tomato plants were treated with 0, 2, 4, 6 and 8 dSm^{-1} salinity levels per pot containing 10 kg of soil. These total amounts of salts were applied through irrigation water as per required.

3.11 Preparation of stock solution

Saline water was synthesized by using a mixture of 1.17 g salt/L of water for 2 dSm^{-1}, 2.34 g salt/L of water for 4 dSm^{-1}, 3.51 g salt/L of water for 6 $dSm^{-1}$and 4.68 g salt/L of water for 8 dSm^{-1} so that their composition was almost alike with the average composition of the ground water. For this experiment, Analytical Grade (AR Grade) of NaCl was used to prepare the stock solution. As a salt stress mitigation agent, K^+ was used in the form of KNO_3 at 0 mM, 5 mM (0.51 g KNO_3 add to water to make the solution 1litre) and 10 mM (1.01 g KNO_3 add to water to make the solution 1litre) concentration as foliar application at 30, 50 and 70 DAT.

3.12 Sowing of seeds

The seeds of BARI Tomato 19 were sown on the 2^{nd} week of October 2019 by hand in pot to raise the seedling. Proper care was taken following recommended measures for the development of healthy seedlings.

3.13 Raising of seedling

A common procedure was followed in raising of seedlings. Tomato seedlings were raised in pots at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the pot was 30 cm in top area and 25 cm in bottom area. The soil of the pot was prepared by drying the soil and made into loose friable. All weeds and stubbles were removed from the soil and 5 kg well rotten cowdung was added to the soil during pot preparation. The seeds were sown in the pot at 10 October, 2019. Germination was visible 4 days after sowing of seeds. After sowing, seeds were covered with light soil to a depth of about 0.6 cm. Sevin dust was applied @ 4 kg ha^{-1} around each pot as precautionary measure against ants and worm. The establishment of the seedlings took place within 7 to 8 days after sowing. Companion was applied to the seedling @ 2g/l water to prevent damping off diseases. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in the pots.

3.14 Transplanting of seedlings

Healthy and uniform 35 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 16 November, 2019. This allowed an accommodation of 1 plant in each pot. The seedlings were watered after transplanting. Shading was provided using polythene sheath for three days to protect the seedling from the hot sun and removed after seedlings were established. They (transplants) were kept open at night to allow them receiving dew. Each pot allows two seedlings in the pot and one seedling is removed from pot after healthy establishment of seedlings.

3.15 Intercultural operation

After raising seedlings, various intercultural operations such as weeding, earthing up, irrigation pest and disease control etc. were accomplished for better growth and development of the tomato seedlings.

3.15.1 Weeding

Weeding and mulching were executed as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust.

3.15.2 Gap filling

When the tomato seedlings were well established, the soil around the base of each seedling was pulverized. Gap filling was done by healthy seedlings of the same stock material grown in nearby plot where initial planted seedlings failed to survive.

3.15.3 Earthing up

Earthing up was done at 20 and 40 days after transplanting on the basement of plant by taking the soil from the boundary side of pots by hand.

3.15.4 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.

3.15.5 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.

3.15.6 Plant protection measures

Plant protection measures were done whenever they were necessary. Malathion 57EC was applied at the rate of 2 ml/L as preventive measure against insect pests like cut worms, leaf hoppers and fruit borers. The insecticides were applied fortnightly as a routine work from a week after transplanting to a week before first harvesting. Dithane M-45 was applied @ 2 g/L at the early stage against late blight of tomato.

3.16 Harvesting of fruits

Fruits were harvested at 3 days interval during early ripe stage when they attained slightly red color. Harvesting was started from February, 2020 and was continued up to March, 2020.

3.17 Parameter studied

Data on the following parameters were recorded

1. Plant height (cm)
2. Number of branch Plant^{-1}
3. Number of leaves Plant^{-1}
4. Days to first flowering
5. Number of flower cluster plant^{-1}
6. Number of flowers per cluster
7. Number of flowers per plant
8. Number of dropped flower plant^{-1}
9. Number of fruits plant^{-1}
10. Fruit length (cm)
11. Fruit diameter (cm)
12. Dry matter content of fruit (%)
13. Individual fruit weight (g)
14. Fruit weightplant^{-1} (kg)

3.18 Data recording

3.18.1 Plant height (cm)

The height of the plants was measured from each pot after 30 days of transplanting and continues up to 70 days after transplanting at 20 days interval. The height was measured from the soil surface to the tip of the plant in centimeter by a measuring scale.

3.18.2 Number of branch Plant^{-1}

Total number of branches per plant was counted from the plant of each of unit pot. Data recorded at 20 days interval started from the 30 days of planting up to70 days.

3.18.3 Number of leaves Plant^{-1}

Total number of leaves per plant was counted from the plant of each of unit pot. Data was recorded at 20 days interval started from the 30 days of planting upto 70 days.

3.18.4 Days to 1st flowering

Date of first flowering was recorded, and the number of days required for first flowering was calculated.

3.18.5 Number of flower cluster plant^{-1}

Total number of clusters of individual plant was counted and recorded.

3.18.6 Number of flowers cluster^{-1}

Total number of flowers per cluster was counted and recorded.

3.18.7 Number of flower plant^{-1}

Total number of flowers of individual plant was counted and recorded.

3.18.8 Number of dropped flower plant^{-1}

The number of dropped flower plant^{-1} was calculated by subtracting the total number of fruits plant^{-1} from the total number of flowers plant^{-1}.

3.18.9 Number of fruits plant^{-1}

The number of fruits of individual plant was counted and recorded.

3.18.10 Fruit length (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 5 individual fruits from individual plant three times and their average was taken and expressed in cm.

3.18.11 Fruit diameter (cm)

Diameter of fruit was measured at middle portion of 5 individual fruits from individual plant three times with a slide caliper. Their average was taken and expressed in cm.

3.18.12 Dry matter content of fruit (%)

After harvesting fresh weight of 100 gm fruit was taken from each treatment and sun dried then sliced into pieces and were put into envelop and placed in an oven maintaining at 70^0 C for 72 hours. The samples were then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken in gram and dry matter percent was calculated by the following formula:

$$Dry\ matter\ content\ of\ fruit\ (\%) = \frac{\text{Dry weight of fruit}}{\text{Fresh weight of fruit}} \quad x\ 100$$

3.18.13 Individual fruit weight (g)

The fresh weight of 5 individual fruits from individual plant was recorded by an electric balance three times and the mean value was calculated by the following formula:

$$Individual\ fruit\ weight = \frac{\text{Total weight of fruits per plants}}{\text{Total number of fruits per plant}}$$

3.18.14 Fruits weightplant^{-1} (kg)

Fruit yield per plant was calculated by taking the weight of total number of fruits per plant and expressed in kilogram (kg).

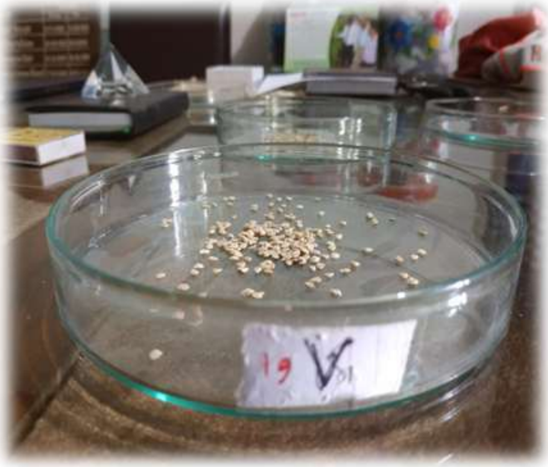


Plate 1. Seed of BARI Tomato 19

Plate 2. Raising of seedlings on pot

Plate 3. Seedling transplanting in the pot

Plate 4. Experimental site

Plate 5. KNO_3 and NaCl used as treatments

Plate 6. Intercultural operation in the experimental field

Plate 7. Application of KNO_3

3.19 Statistical analysis

The data obtained for different characters were statistically analyzed by using MSTAT-C computer package program to find out the significance of the difference for salt stress and potassium nitrate on yield and yield contributing characters of tomato. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

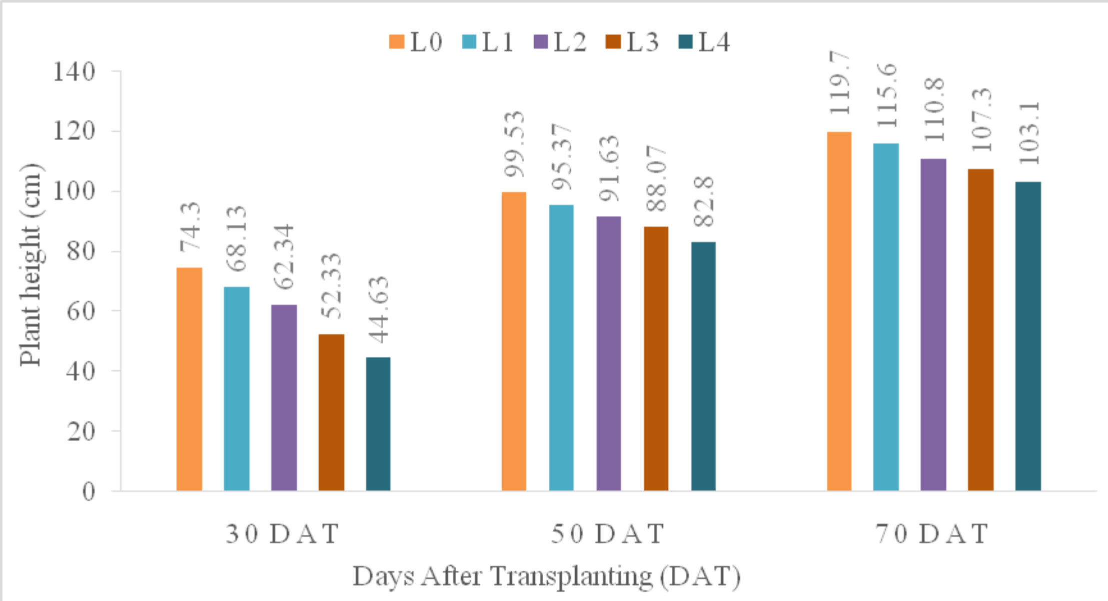
RESULTS AND DISCUSSION

CHAPTER IV
RESULTS AND DISCUSSION

This chapter comprises the presentation and discussion of the results obtained from the effect of potassium nitrate to alleviate salt stress in tomato. The effects due to different levels of salt stress, and application of potassium nitrate and their interaction on the growth, yield and yield contributing characters have been presented in figures and tables. A summary of the analyses of variances (ANOVA) of the data in respect of all the parameters have been shown in Appendices VII to XIII. The results have been presented and discussed and possible interpretations have been given under the following headings:

4.1 Plant height (cm)

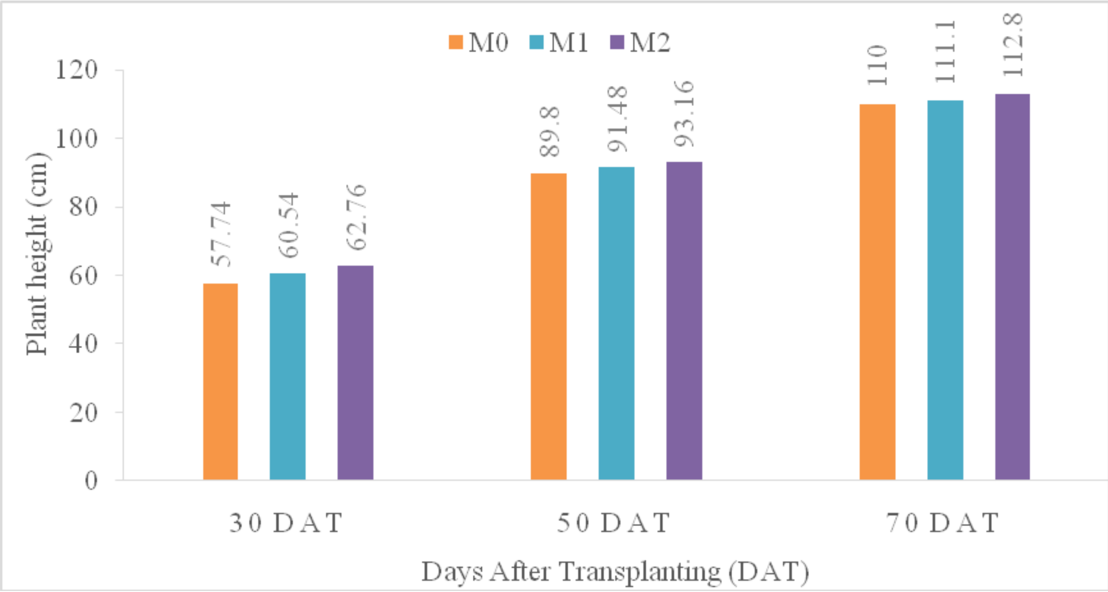
The effect of salinity on the growth of tomato plant is first shown in plant height. Naturally plant height increased with increasing age but decreased with increasing salinity in tomato. Plant height of tomato varied significantly at 30, 50 and 70 DAT due to different levels of salinity (Figure 1 and Appendix VII). At 30 DAT, the highest plant height (74.30 cm) was recorded in case of L_0 (control) treatment and the lowest value (44.63 cm) was found from L_4 (8 dS/m). At 50 DAT, the tallest plant (99.53 cm) was recorded from L_0 treatment and the shortest plant (82.80 cm) was observed in case of L_4 treatment. Similarly, at 70 DAT, the tallest plant (119.7 cm) was found from L_0 (control) where the shortest plant (103.1 cm) was found from L_4 (8 dS/m salinity). Result showed that plant height gradually decreased with increased levels of salinity and the highest declaration occurs in L_4 treatment. Data revealed that the salt stress reduced the morphological parameters such as plant height of tomato. Plant salt tolerance is generally thought of in terms of the inherent ability of the plant to withstand the effects of high salt concentration in the rhizosphere. Similar results were also recorded by many other authors like Hossein (2018) in tomato, Nasrin (2017) in tomato, Alaa El-din (2013) in coriander, Ashraf and Mcnilly (2004) in *Brassica*, Islam *et al.* (2011) in tomato and Ramoliya and Pandey (2007) in *Rhamnaceae*, etc. Salinity affects cell growth directly by lowering the osmotic potential of the soil solution and affects growth by lowering cell turgor pressure. Sudden decreases in turgor pressure responsible for the inhibition of growth induced by rapid increase in external solute concentrations (Volkamar *et al.*, 1998). This reduction may be due to inhibitory behavior of salt stress on cell division and cell expansion (Hernandez *et al.*, 2003). Due to plant height decreasing, most yield components were decreased and therefore fruit yield was reduced (Ashraf and Mcneilly, 2004).



(Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1})

Figure 1. Effect of salinity levels on plant height of tomato at different days after transplanting. ($LSD_{0.05}$= 3.44, 6.86 and 8.55 for 30 DAT, 50 DAT and 70 DAT, respectively)

Plant height of tomato varied significantly due to different levels of potassium nitrate at different days after transplanting (DAT) (Figure 2 and Appendix VII). At 30 days, the longest plant (62.76 cm) was recorded from M_2 (10 mM of KNO_3), while the shortest plant (57.74 cm) was recorded from M_0 (KNO_3 controlled condition) (Figure 2). At 50 DAT, the longest plant (93.16 cm) was recorded from M_2 treatment, while the shortest plant (89.90 cm) from M_0 treatment. Similarly, at 70 DAT, the longest plant was recorded from M_2 (112.8 cm) treatment and the shortest plant from M_0 (110.0 cm). Similar results were also recorded by many other authors like Mahajan *et al.* (2019). He found that application of KNO_3 at 5.0 g L^{-1} registered maximum height (70.18 cm) which are significantly ($P \leq 0.05$) different from the water spray as control.



[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 2. Effect of different doses of potassium nitrate on plant height of tomato at different days after transplanting. ($LSD_{0.05}$= 3.44, 6.86 and 8.55 for 30 DAT, 50 DAT and 70 DAT, respectively)

The results of the present study showed that the interaction effect between salinity stress and potassium nitrate as mitigation agent on plant height was significant at 30, 50 and 70 DAT (Table 1 and appendix VII). At 30 DAT, the highest plant height (77.40 cm) was found from L_0M_2 (10 mM KNO_3 with no salinity stress condition) and the lowest plant height (41.40 cm) was recorded in case of L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition). At 50 DAT, the tallest plant was found from L_0M_2 (102.2 cm) where the shortest plant was recorded from L_4M_0 (80.30 cm). Similarly, at 70 DAT, the highest plant height was found from L_0M_2 (121.4 cm) where the lowest value was recorded from L_4M_0 (101.8 cm). Similar results were also recorded by many other authors like Mahajan *et al.* (2019). He observed that averaged across the KNO_3 levels, plants treated with high concentration of NaCl ($\geq$ 80 mM) showed significantly ($P \leq 0.05$) lower plant height as compared with the plants irrigated with non-saline water as control and the interaction effects between salinity levels and KNO_3 on plant height were significant.

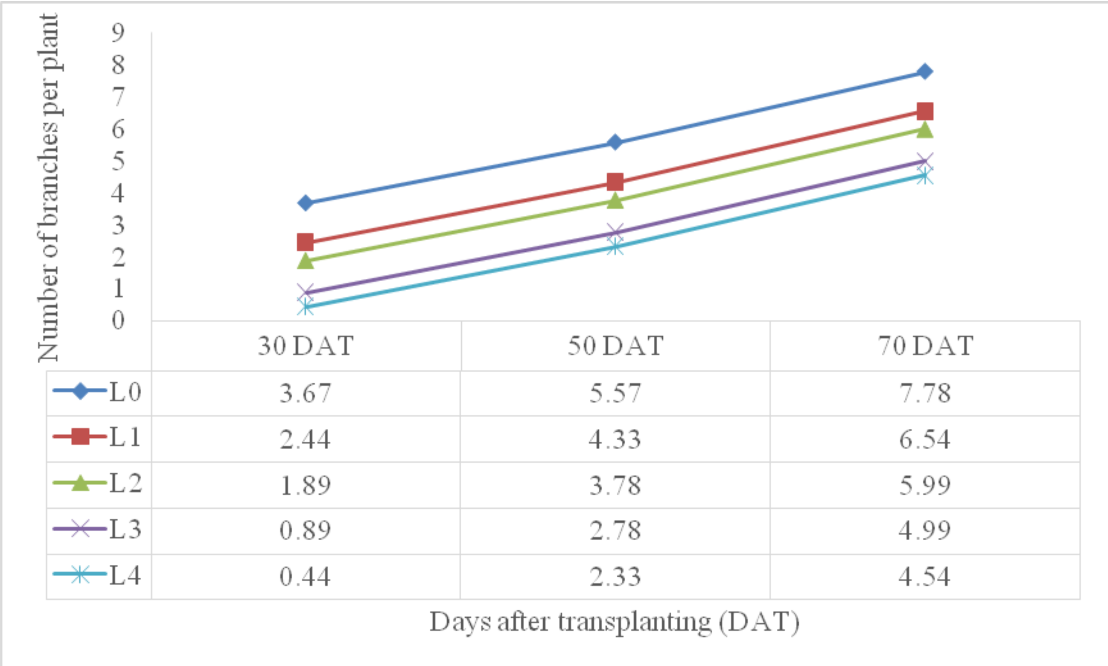
Table 1. Combined effect of salinity levels and potassium nitrate doses on plant height of tomato at different days after transplanting (DAT)

Treatment combination	Plant height (cm) at different days after transplanting		
	30 DAT	50 DAT	70 DAT
L_0M_0	71.30 bc	97.80 abc	118.2 abc
L_0M_1	74.20 ab	98.60 ab	119.4 ab
L_0M_2	77.40 a	102.2 a	121.4 a
L_1M_0	59.40 f	94.40 bcd	114.4 abcde
L_1M_1	63.30 e	95.30 abcd	115.3 abcde
L_1M_2	64.30 e	96.40 abcd	117.2 abcd
L_2M_0	66.80 de	90.30 cdefg	109.2 cdefg
L_2M_1	68.20 cd	91.40 bcdef	110.3 bcdefg
L_2M_2	69.40 cd	93.20 bcde	112.8 abcdef
L_3M_0	49.80 hi	86.20 efgh	106.2 efg
L_3M_1	51.80 h	88.80 defg	107.4 defg
L_3M_2	55.40 g	89.20 defg	108.4 cdefg
L_4M_0	41.40 k	80.30 h	101.8 g
L_4M_1	45.20 j	83.30 gh	103.3 fg
L_4M_2	47.30 ij	84.80 fgh	104.3 fg
CV (%)	3.46	4.55	4.67
LSD $_{(0.05)}$	3.44	6.86	8.55

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

4.2 Number of branch plant^{-1}

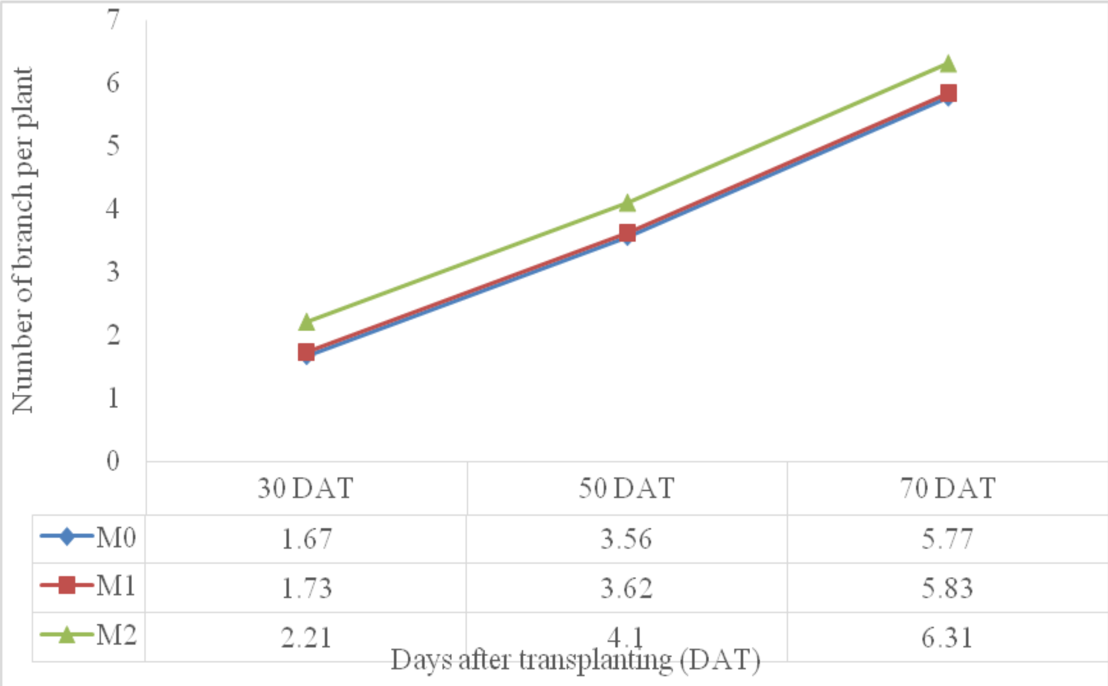
Number of branches per plant of tomato varied significantly due to different levels of salinity at different days after transplanting (DAT) (Figure 3 and Appendix VIII). At 30, 50 and 70 DAT, the maximum number of branches per plant (3.67, 5.57 and 7.78) was recorded from L_0 treatment (Salinity controlled condition). On the other hand, the minimum number (0.44, 2.33 and 4.54) was recorded from L_4 (8 dS/m of NaCl) treatment. From the result, it can be said that number of primary branches plant^{-1} reduced with increasing salinity. Similar results were also recorded by many other authors like Hossein (2018), Mridha (2018) and Nasrin (2017) in tomato. Uddin *et al.* (2005) also found that number of branches decreased with the increased salinity in *Brassica* species. Biswas *et al.* (2015) recorded maximum number of branches (16.0 plant^{-1}) from BARI Tomato 14 under salinity. Agong *et al.* (2003) reported that salt treatment at 2% NaCl stimulated chlorophyll production, but caused severe depression on the production of number of branches.



[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1}]

Figure 3. Effect of salinity levels on branch number plant^{-1} of tomato at different days after transplanting. ($LSD_{0.05}$= 0.16, 0.13 and 0.18 for 30 DAT, 50 DAT and 70 DAT, respectively)

Number of branches per plant of tomato showed significant differences due to application of different levels of potassium nitrate at different days after transplanting (DAT) (Figure 4 and Appendix VIII). At 30, 50 and 70 DAT, the maximum number of branches per plant (2.21, 4.1 and 6.31) was recorded from M_2 treatment (10 mM of KNO_3). On the other hand, the minimum number (1.67, 3.56 and 5.77) was recorded from M_0 (KNO_3 controlled condition) treatment. From the result, it can be said that number of primary branches plant^{-1} reduced with increasing salinity. Mahajan *et al.* (2019) observed that application of KNO_3 at 5.0 g L^{-1} increased the number of branches (7.17 and 7.33 No. Plant^{-1}) which are significantly ($P \leq 0.05$) different from the water spray as control.



[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 4. Effect of different level of potassium nitrate on number of branch of tomato at different days after transplanting. ($LSD_{0.05}$ = 0.16, 0.13 and 0.18 for 30 DAT, 50 DAT and 70 DAT respectively)

Combined effect of saline water and potassium nitrate showed statistically significant variation for number of branches per plant at different days after transplanting (Table 2 and appendix VIII). At 30 DAT, the highest number of branches per plant (4.03) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination and the lowest number of branches per plant (0.33) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) and L_4M_1 (8 dSm^{-1} NaCl with 5 mM KNO_3) treatment combination. Similarly, at 50 and 70 DAT the similar trend of combined effect between saline water and potassium nitrate showed on number of branches per plant of tomato (Table 2). At 50 DAT, the highest number of branch (5.92) was recorded from L_0M_2 treatment combination and the lowest number of branches per plant (2.22) was recorded from L_4M_0 and L_4M_1 treatment combination which was statistically similar with L_4M_2 (8 dSm^{-1} NaCl with 10 mM KNO_3) and L_3M_0 (6 dSm^{-1} NaCl with no KNO_3 condition). Beside this, at 70 DAT, the highest number of branch (8.13) was recorded from L_0M_2 treatment combination and the lowest number of branches per plant (4.43) was recorded from L_4M_0, which was statistically at par with L_4M_1 treatment combination. Similar results were also recorded by many other authors like Mahajan *et al.* (2019) and Elhindi *et al.* (2016). Elhindi *et al.* (2016) reported that there was a significantly negative relationship between the salinity and branch number of coriander plants. These negatively affected parameters under salinity were significantly increased under foliar KNO_3 applications. Mahajan *et al.* (2019) reported that the interaction effects between salinity levels and KNO_3 on plant height were significant.

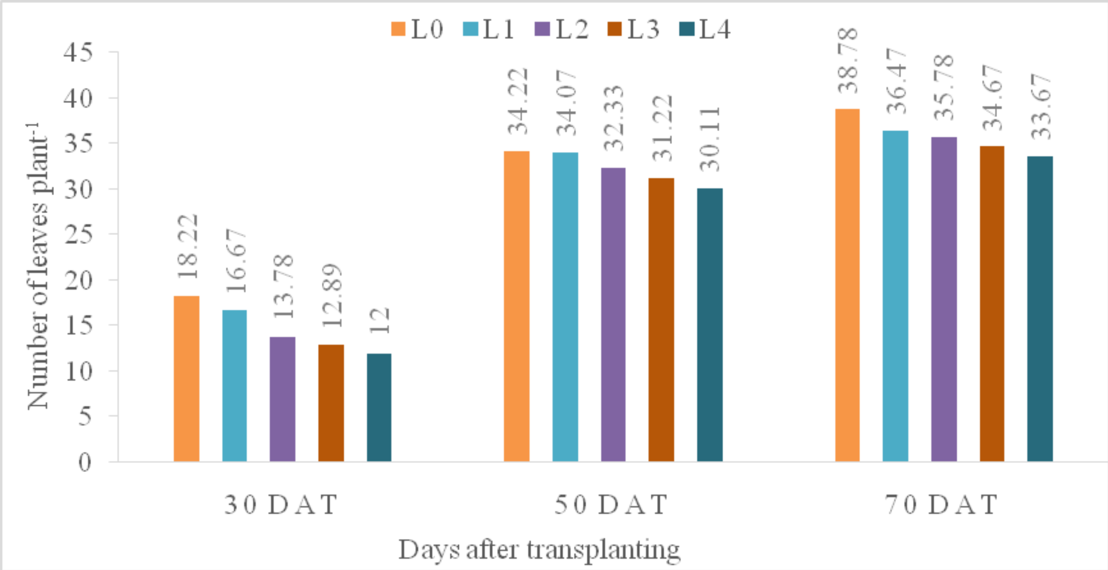
Table 2. Interaction effect of salinity and potassium nitrate levels on number of branches plant^{-1} at different days after transplanting of tomato

Treatment combination	Branches plant^{-1} at different days after transplanting		
	30 DAT	50 DAT	70 DAT
L_0M_0	3.33 c	5.22 c	7.43 c
L_0M_1	3.67 b	5.56 b	7.77 b
L_0M_2	4.03 a	5.92 a	8.13 a
L_1M_0	2.33 e	4.22 e	6.43 e
L_1M_1	2.33 e	4.22 e	6.31e
L_1M_2	2.67 d	4.56 d	6.77 d
L_2M_0	1.67 f	3.56 f	5.77 f
L_2M_1	1.67 f	3.56 f	5.47 g
L_2M_2	2.33 e	4.22 e	6.39 e
L_3M_0	0.67 h	2.56 h	4.61 h
L_3M_1	0.67 h	2.56 h	4.77 h
L_3M_2	1.33 g	3.22 g	5.43 g
L_4M_0	0.33 i	2.22i	4.43i
L_4M_1	0.33 i	2.22i	4.57 i
L_4M_2	0.67 h	2.56 h	4.77 h
CV (%)	4.96	4.06	4.29
LSD $_{(0.05)}$	0.16	0.13	0.18

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

4.3 Number of leaves plant^{-1}

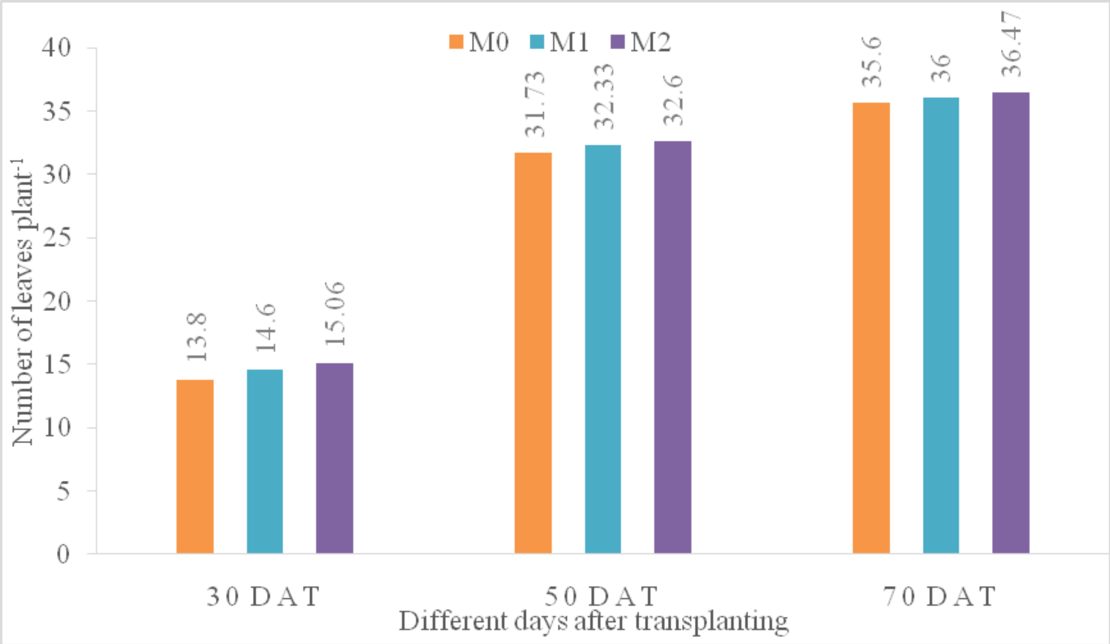
The leaf number is the very important character for plant growth and development as leaf is the main photosynthetic organ. Salinity adversely affected the production of leaf number per plant in tomato. The results of this experiment showed that different concentration of salt have significant effect on number of leaves per plant of tomato at different DAT at 30, 50 and 70 DAT (Figure 5 and Appendix IX). At 30 DAT, the highest number of leaves plant^{-1}(18.22) was found from L_0 (salinity-controlled condition) and the lowest value (12.00) was observed with L_4 (8 dS/m of NaCl) treatment. Similarly, at 50 DAT, the highest number of leaves plant^{-1}(34.22) was recorded in case of L_0 treatment which was statistically similar with the treatment L_1 (2 dSm^{-1} of NaCl) and the lowest value (30.11) was found from L_4 treatment. At 70 DAT, the highest number of leaves plant^{-1} was recorded from L_0 (38.78) and the lowest value was observed in case of L_4 (33.67) treatment. From the result, it was revealed that the salinity significantly reduced the number of leaves plant^{-1} of tomato at different days after transplanting (DAT). These results have been confirmed by the results of Karen *et al.* (2002), with their study on *Cirer arietinum* L. and Raul *et al.* (2003), with their study on the leaf of the teprary bean (*Phaseolus acutifolius* L.), cowpea (*Vigna unguiculata* L.), and wild bean (*Phaseolus filiformis* L). They mention that, the treatment of sodium chloride reduced the number of leaves compared with control plants. According to Hernandez *et al.* (2003) salt stress inhibited the cell division and cell expansion, consequently leaf expansion and as a result leaf area and leaf number are reduced. Alaa El-Din (2013) also observed the similar observation. He reported that number of leaves plant^{-1} decreased with the increase of NaCl concentration in coriander. Reduced leaves number plant^{-1} under salinity stress also observed by Hossein (2018), Mridha (2018), Nasrin (2017), Parvin (2013), and Nizam (2013) in tomato and Jafari *et al.*, (2009) in sorghum. Mohammad *et al.*, (1998) found that salinity stress accompanied by significant reduction in number of leaves plant^{-1}.



[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1}]

Figure 5. Effect of salinity levels on number of leaves plant^{-1} of tomato at different days after transplanting. ($LSD_{0.05}$= 0.86, 2.52 and 2.78 for 30 DAT, 50 DAT and 70 DAT, respectively)

A significant effect of potassium on the number of leaves plant^{-1} of tomato at 30, 50 and 70 DAT were found (Figure 6 and Appendix IX). At 20 DAT, the highest number of leaves plant^{-1} (15.06) was found from M_2 treatment (10 mM of KNO_3) and the lowest value (13.80) from M_0 (KNO_3 controlled condition) treatment. Similarly, at 50 DAT, the highest number of leaves plant^{-1} (32.60) was recorded from M_2 treatment and the lowest one (31.73) from M_0 treatment. At 70 DAT, the highest number of leaves (36.47) was observed in case of M_2 treatment where the lowest value (35.60) was recorded from M_0 treatment. From this experiment it was found that, the number of leaves was gradually increased with the increase in age with the supplementation of potassium along with salt. Thus, these results suggested that the potassium application increased the number of leaves by reducing the effect of salt. This fact was supported by other authors likeAmjad *et al.* (2014) in tomato, Elhindi *et al.* (2016) in coriander and Adhikari *et al.* (2020) in soybean.



[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 6. Effect of different level of potassium nitrate on number of leaves plant^{-1} of tomato at different days after transplanting. ($LSD_{0.05}$= 0.16, 0.51 and 1.18 for 30 DAT, 50 DAT and 70 DAT, respectively)

Combined effect of saline water and potassium nitrate showed statistically significant variation for number of leaves per plant at 30, 50 and 70 DAT (Table 3 and Appendix IX). At 30 DAT, the highest number of leaves per plant (19.33) was found from L_0M_2 (10 mM KNO_3 with no salinity stress condition) which was statistically similar with L_0M_1 (5 mM KNO_3 with no salinity stress condition) and the lowest value (11.67) was found from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition). At 50 DAT, the highest number of leaves per plant (34.67) was found from L_0M_2 and the lowest value (29.33) found from L_4M_0. Similarly, at 70 DAT, the highest number of leaves per plant (39.33) was found from L_0M_2 (10 mM KNO_3 with no salinity stress condition) and the lowest value (33.33) was found from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination. From this result, it was found that leaf number gradually increased with the increasing age and the supplementation of potassium nitrate along with salt.

Table 3. Interaction effect of salinity and potassium levels on number of leaves plant^{-1} at different days after transplanting of tomato

Treatment combination	Number of leaves plant^{-1} at different days after transplanting		
	30 DAT	**50 DAT**	**70 DAT**
L_0M_0	16.67 b	33.67 abc	38.33 abc
L_0M_1	18.67 a	34.33 ab	38.67 ab
L_0M_2	19.33 a	34.67 a	39.33 a
L_1M_0	14.67 d	33.00 abcde	36.67 abcdef
L_1M_1	15.67 c	33.33 abcd	37.33 abcde
L_1M_2	16.33 bc	33.33 abcd	37.67 abcd
L_2M_0	13.33 fg	32.00 abcdef	35.33 cdefg
L_2M_1	13.67 ef	32.33 abcde	35.67 bcdefg
L_2M_2	14.33 de	32.67 abcde	36.33 abcdefg
L_3M_0	12.67 ghi	30.67 def	34.33 efg
L_3M_1	13.00 fgh	31.33 cdef	34.67 defg
L_3M_2	13.00 fgh	31.67 bcdef	35.00 defg
L_4M_0	11.67 j	29.33 f	33.33 g
L_4M_1	12.00 ij	30.33 ef	33.67 fg
L_4M_2	12.33 hij	30.67 def	34.00 fg
CV (%)	3.60	4.75	4.69
LSD $_{(0.05)}$	0.86	2.52	2.78

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

4.4 Days to 1st flowering

Days to 1st flowering of tomato varied significantly due todifferent levels of salt stress under the present trial (Appendix X and Table 4). The minimum days to 1st flowering (39.78 days) was found from L_0 (Salinity controlled condition). On the other hand, the maximum days (44.89 days) was attained from L_4 (8 dS/m of NaCl) treatment. Mizrahi (1982) reported that salinityshortened the time of fruit development by 4 to 15%. Murshed *et al.* (2014) reported that salinity delayed flowering. Higher levels of salinity delays flowering in tomato which was also confirmed by Hossein (2018), Mridha (2018), Nasrin (2017), Parvin (2013), Nizam (2013) and Islam *et al.* (2011).

Although days to 1st flowering has no significant effect at different levels of potassium nitrate (Appendix X). The minimum days from transplanting to 1st flowering (41.87 days) was recorded from M_2 treatment (10 mM of KNO_3), while the maximum days (43.13 days) was recorded from M_0 (KNO_3 controlled condition) treatment.

Combined effect of saline water and potassium nitrate showed statistically significant variation for days from transplanting to 1st flower initiation (Appendix X and Table 5). The maximum days from transplanting to 1st flower initiation was (46.33 days) recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) which was statistically identical with L_4M_1 (45.67 days) and the minimum days from transplanting to 1st flower initiation was (38.33 days) recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination (Table 5).

4.5 Number of flower cluster plant^{-1}

Different levels of salt stress varied significantly in terms of number of flower cluster per plant of tomato (Appendix X). Data revealed that the highest number of flower cluster per plant (8.68) was found from L_0 (salinity-controlled condition) which was closely followed (8.45) by L_1 treatment, while the lowest number (6.91) was recorded from L_4 (8 dS/m of NaCl) treatment (Table 4). Higher levels of salinity reduced number of flower clusterin tomato which was also confirmed by Hossein (2018), Mridha (2018), Nasrin (2017), Parvin (2013), and Nizam (2013).Agong *et al.* (2003) found that significant genotypic and/or salt treatment effects were registered on yield contributing characters of tomato.

Significant variation was observed for number of flower cluster per plant of tomato for different levels of potassium nitrate (Appendix X). The highest flower cluster per plant (7.98) was found in M_2treatment (10 mM of KNO_3) treated plants which was statistically identical with M_1 (7.92) treatment and control treated plants showed the lowest flower cluster per plant (7.67) (Table 4).

Combined effect of different levels of salt stress and potassium nitrate showed significant differences on number of flower cluster per plant (Appendix X). The highest number of flower cluster per plant (8.92) was observed from L_0M_2 (10 mM KNO_3 with no salinity stress condition) which was statistically similar with L_0M_1 (5 mM KNO_3 with no salinity stress condition) and L_0M_0 (salt and potassium nitrate-controlled condition), while the lowest number (6.57) was attained from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) (Table 5).

4.6 Number of flowers cluster^{-1}

Different levels of salt stress varied significantly in terms of number of flowers per cluster of tomato (Appendix X). The highest number of flowers per cluster (7.89) was recorded from L_0 (salinity-controlled condition). On the other hand, the lowest number (5.44) was recorded from L_4 (8 dS/m of NaCl) treatment which was statistically similar with L_3 treatment (6.00) (Table 4). Luo *et al.* (2013) reported that salt stress of NaCl, stronger inhibitory effect on tomato growth. Biswas *et al*. (2015) reported the maximum number of flowers (6.1cluster^{-1}) from BARI Tomato 14.

Significance differencewas recorded due to different levels of potassium nitrate for number of flowers per cluster per plant (Appendix X). The maximum number of flowers per cluster per plant was (7.20) recorded from M_2 treatment (10 mM of KNO_3), while the minimum number of flowers per cluster per plant (6.20) was recorded from M_0 (KNO_3 controlled condition) treatment which was statistically similar with M_1 (6.47) treatment.

Combined effect of saline water and potassium nitrate showed statistically significantvariation for number of flowers per cluster per plant (Appendix X). The maximum number of flowers per cluster per plant (8.67) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination, while the minimum number of flowers per cluster per plant (5.0) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination (Table 5).

4.7 Number of flowers plant^{-1}

Number of flowers per plant of tomato varied significantly due to different levels of salt stress under the present trial (Appendix XI). The highest number of flowers per plant (68.49) was found from L_0 (Salinity controlled condition), while the lowest number (37.59) was observed from L_4 (8 dS/m of NaCl) treatment which was statistically identical (44.88) with L_3 (Table 4). This result says that salinity decreases the number of flowers which ultimately reduces fruit number and yield. Reduced flowers number plant^{-1} under salinity stress also observed by Mridha (2018), Nasrin (2017), Parvin (2013), and Nizam (2013) in tomato.

Statistically significant variation was recorded for different levels of potassium nitrate on number of flowers per plant of tomato (Appendix XI). The highest number of flowers per plant (57.46) was recorded from M_2 treatment (10 mM of KNO_3), which was followed (51.24) by M_1, again the lowest number (47.55) was observed from M_0 (Table 4).

Combination effect of saline water and potassium nitrate showed statistically significant variation for number of flowers per plant (Appendix XI). The maximum number of flowers per plant (77.34) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination, while the minimum number of flowers per plant (32.85) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination (Table 5).

Table 4. Effect of salt stress and potassium nitrate on yield contributing characters of tomato

Treatments	Days required 1^{st} flowering	Number of cluster/plant	Number of flower/cluster	Number of flower/plant
Salt stress				
L_0	39.78 c	8.68 a	7.89 a	68.49 a
L_1	41.44 bc	8.45 ab	7.11 b	60.08 b
L_2	42.11 abc	8.06 b	6.67 b	53.76 b
L_3	44.22 ab	7.48 c	6.00 c	44.88 c
L_4	44.89 a	6.91 c	5.44 c	37.59 c
CV (%)	4.86	4.40	5.67	6.99
LSD $_{(0.05)}$	3.40	0.57	0.62	4.92
Potassium nitrate				
M_0	43.13 a	7.67 b	6.20 b	47.55 b
M_1	42.47 a	7.92 a	6.47 b	51.24 ab
M_2	41.87 a	7.98 a	7.20 a	57.46 a
CV (%)	4.86	4.40	5.67	6.99
LSD $_{(0.05)}$	3.40	0.57	0.62	4.92

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

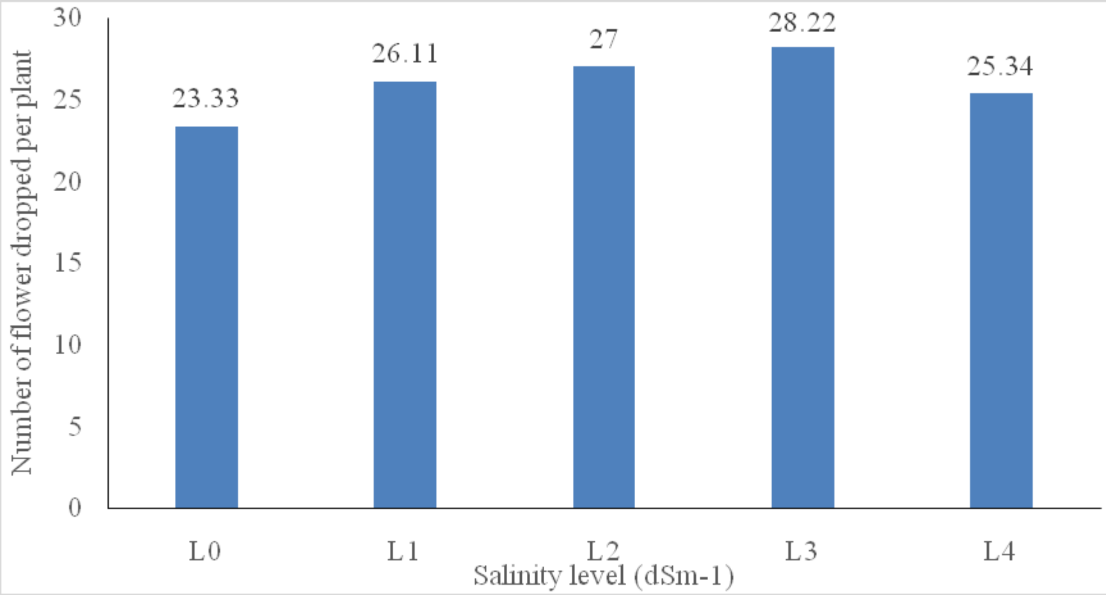
Table 5. Combine effect of salt stress and potassium nitrate on yield contributing characters of tomato

Combinations	Days required 1st flowering	Number of cluster/plant	Number of flower/cluster	Number of flower/plant
L_0M_0	39.67 fgh	8.69 a	7.67 bc	66.65 bc
L_0M_1	39.33 gh	8.87 a	8.00 b	70.96 b
L_0M_2	38.33 h	8.92 a	8.67 a	77.34 a
L_1M_0	41.33 cdefgh	8.29 ab	7.00 cde	58.03 de
L_1M_1	40.67 defgh	8.47 ab	7.00 cde	59.29 de
L_1M_2	40.33 efgh	8.50 ab	7.33 cd	62.31 cd
L_2M_0	43.33 abcdef	7.86 bcd	6.33 efg	49.75 efgh
L_2M_1	42.67 abcdefg	7.92 bc	6.33 efg	50.13 efg
L_2M_2	41.67 bcdefgh	8.03 bc	6.67 def	53.56 def
L_3M_0	44.67 abc	7.39 cde	6.00 fgh	44.34 ghi
L_3M_1	44.33 abcd	7.47 cde	6.00 fgh	44.82 ghi
L_3M_2	43.67 abcde	7.57 cd	6.33 efg	47.91 efgh
L_4M_0	46.33 a	6.57 f	5.00 i	32.85 i
L_4M_1	45.67 a	6.92 ef	5.33 hi	36.88 hi
L_4M_2	45.33 ab	7.23 de	5.67 gh	40.99 ghi
CV (%)	4.86	4.40	5.67	6.99
LSD (0.05)	3.40	0.57	0.62	4.92

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

4.8 Number of dropped flower plant^{-1}

Significant variation was recorded for number of flowers drop of tomato due to different levels of salinity (Figure 7 and Appendix XI). The highest number of flower drop (28.22) was obtained from L_3 (6dS/m of NaCl) treatment, while the lowest number of flower drop (23.33) was obtained from L_0 (Salinity controlled condition). From this result, it is clear that Salinity increased the number of dropped flowers with increased levels of salinity resulting the lower number of fruits plant^{-1}as well as yield.This fact was supported by other authors like Hossein (2018) in tomato.

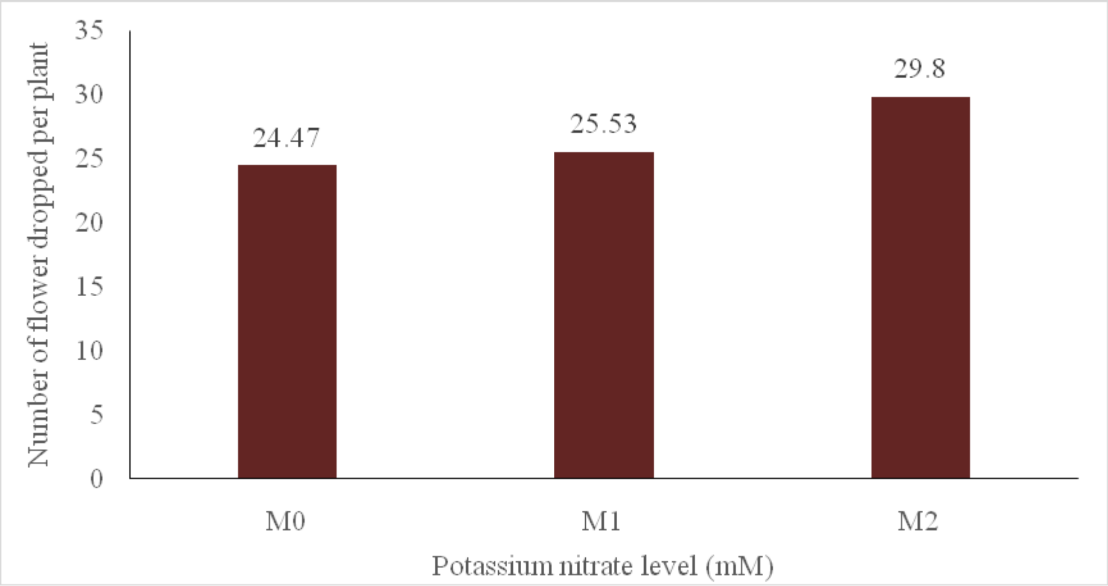


[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1}]

Figure 7. Effect of salinity levels on number of flowers dropped per plant of tomato. ($LSD_{0.05}$= 2.20)

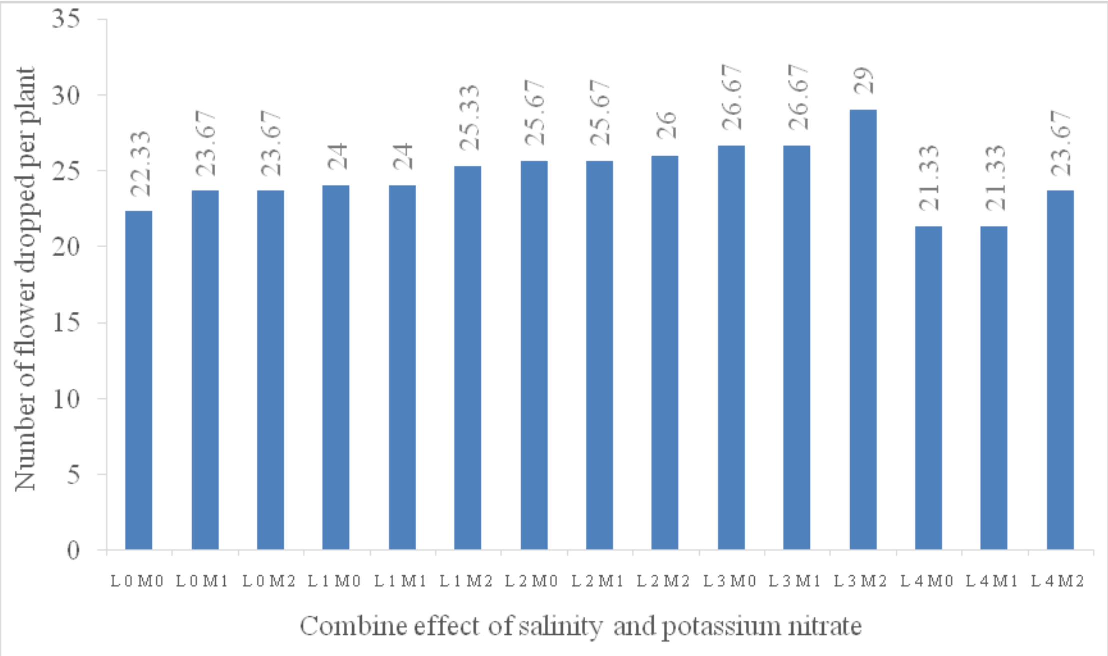
Statistically significant variation was found for number of dropped flowers plant^{-1} of tomato due to application of different levels of potassium nitrate (Figure 8 and Appendix XI). The highest number of dropped flowers plant^{-1} (29.80) was found from M_2treatment (10 mM of KNO_3). The lowest value (24.47) was observed from M_0 (KNO_3 controlled condition) treatment which was statistically similar with M_1 (25.53) treatment. The results obtained from this experiment showed that the highest flower dropping was happened with 10 mM KNO_3 application where this concentration of potassium is also responsible for the highest number of flower plant^{-1} and thus produced the highest fruit yield plant^{-1}.

Interaction effect of salinity and potassium nitrate showed significant differences in case of number of dropped flowers plant^{-1} (Figure 9 and Appendix XI). The highest number of dropped flowers plant^{-1}(29.00) was recorded from L_3M_1 and the lowest value (21.33) was observed from L_4M_0.



[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 8. Effect of different level of potassium nitrate on number of dropped flowers plant^{-1} of tomato. ($LSD_{0.05}$= 2.20)



[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

Figure 9. Combine effect of salinity and potassium nitrate level on number of dropped flowers plant^{-1} of tomato. ($LSD_{0.05}$= 2.20)

4.9 Number of fruits plant^{-1}

Number of fruits per plant of tomato showed significant differences in response to different levels of salinity (Table 6 and Appendix XI). The highest number of fruits per plant (45.16) was recorded from L_0 (salinity-controlled condition) which was followed by L_1 (33.97) and L_2 (26.76). On the other hand, the lowest number of fruits per plant (12.25) was observed from L_4 (8 dS/m of NaCl) treatment which was followed L_3 (16.66). Similar results were found from Jamal *et al.*, (2014) and Sixto *et al.* (2005). Reduction in fruit number per cluster in tomato due to the increase of salinity levels was also found by Hossein (2018), Mridha (2018), Nasrin (2017), Parvin (2013), Nizam (2013) and Siddiky *et al.* (2012). Salinity reduced the number of fruits per plant which was also related with the number of flower/plant and ultimately reduced the fruit yield which is also supported by Olympios *et al.* (2003). Salinity adversely affects reproductive development by inhibiting microosporogenesis, stamen filament, ovule abortion and senescence of fertilized embryo.

Statistically significant variation was recorded for number of fruits per plant of tomato after the application of different levels of potassium nitrate (Table 6 and Appendix XI). The highest number of fruits per plant (27.66) was observed from M_2 (10 mM of KNO_3) treatment which was followed by M_1 (25.71) and the lowest value (23.08) from M_0 (control) treatment. These results were also confirmed by Elhindi *et al.* (2016) in case of coriander that KNO_3 increases total number of fruits per plant.

Number of fruits per plant showed statistically significant variation for the combined effect of saline water and potassium nitrate (Table 7 and Appendix XI). The maximum number of fruits per plant (53.67) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination which was followed by L_0M_1 (47.29) and L_0M_0 (44.32) while the minimum number of fruits per plant (11.52) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination which was followed by L_4M_1 (15.55), L_4M_2 (17.32), L_3M_1 (17.67) and L_3M_2 (18.15).

4.10 Fruit length (cm)

Significant variation was recorded for the fruit length of tomato due to different levels of salinity (Table 6 and Appendix XII). The highest fruit length (9.33 cm) was obtained from L_0 (salinity-controlled condition) which was followed by L_1 (8.85 cm), while the lowest fruit length (6.69 cm) was obtained from L_4 (8 dS/m of NaCl) treatment. It was observed that due to its inhibitory effect on cell expansion relatively large size fruits were obtained from control plants and gradual small size fruits were obtained from increased salinity levels. Hossein (2018), Mridha (2018), Nasrin (2017), Hala and Ghada(2014), Parvin (2013), and Nizam (2013) have reported the same effect in tomato. Cuartero and Fernandez (1999) reported that the cell division phase of salt treated fruit is normal but salt have a deleterious effect on cell expansion phase due to low water content in the fruit. According to Johnson *et al.,* (1992), supply of water into the fruit under saline conditions is restricted by a lower water potential in the plant.

Application of different levels of potassium nitrate on tomato for fruit length has significant effect (Table 6 and Appendix XII). The highest fruit length (8.62 cm) was recorded from M_2 (10 mM of KNO_3) treatment and the lowest fruit length (7.34 cm) was found from M_0 (control) treatment.

Combined effect of saline water and potassium nitrate showed statistically significant variation for length of fruits (Table 7 and Appendix XII). The maximum length of fruits (10.0 cm) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination which was followed by L_0M_0 (9.33 cm) and L_0M_1 (9.43 cm), while the minimum length of fruits per plant (6.10 cm) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination which was followed by L_4M_1 (6.33 cm) and L_4M_2 (6.67 cm).

4.11 Fruit diameter (cm)

Significant variation was recorded for fruit diameter of tomato due to different levels of salinity (Table 6 and Appendix XII). The highest fruit diameter (6.11 cm) was obtained from L_0 (salinity-controlled condition) which was statistically similar with L_1 (5.73 cm) and L_2 (5.56 cm), while the lowest fruit diameter (4.48 cm) was obtained from L_4 (8 dS/m of NaCl) treatment which was statistically similar with L_3 (4.90 cm) treatment. Fruit size was decreased by salinity. Similar result was found in tomato from Hossein (2018), Mridha (2018), Nasrin (2017), Hala and Ghada (2014), Parvin (2013), and Nizam (2013). High salinity can reduce the fruit growth rate and final fruit size by an osmotic effect. Epheuvelink (2005) explained that high salinity induces lower water potential in the plant which reduces the water flow in the fruit and therefore the rate of fruit expansion is restricted. Posada and Rodriguez (2009) reported that fruits of salt-stressed plants had reduced diameter.

Statistically significant variation was recorded due to different levels of potassium nitrate on diameter of fruit of tomato (Table 6 and Appendix XII). Data revealed that the highest diameter of fruit (5.92 cm) was recorded from M_2 (10 mM of KNO_3) treatment, whereas the lowest diameter (4.88 cm) was foundfrom M_0 (control) treatment which was statistically similar with M_1 (5.27 cm).

Diameter of fruit showed significant differences due to combined effect of different levels of salt stress and potassium nitrate (Table 7 and Appendix XII). The highest diameter of fruit (6.70 cm) was observed from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination which was followed by L_0M_1 (6.43 cm) and the lowest diameter (4.07 cm) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination which was followed by L_4M_1 (4.36 cm) and L_4M_2 (4.43 cm).

Table 6. Effect of different levels of salinity and potassium nitrate on total number of fruits per plant, fruit length and fruit diameter of tomato

Treatments	Fruit/plant	Fruit length (cm)	Fruit diameter (cm)
Effect of different levels of salinity			
L_0	45.16 a	9.33 a	6.11 a
L_1	33.97 b	8.85 ab	5.73 a
L_2	26.76 c	7.99 bc	5.56 a
L_3	16.66 d	7.44 cd	4.90 b
L_4	12.25 e	6.69 d	4.48 b
CV (%)	6.14	6.76	6.31
$LSD_{(0.05)}$	3.67	0.90	0.56
Effect of different levels of potassium nitrate			
M_0	23.08 b	7.34 b	4.88 b
M_1	25.71 ab	8.23 ab	5.27 b
M_2	27.66 a	8.62 a	5.92 a
CV (%)	6.14	6.76	6.31
$LSD_{(0.05)}$	3.67	0.90	0.56

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

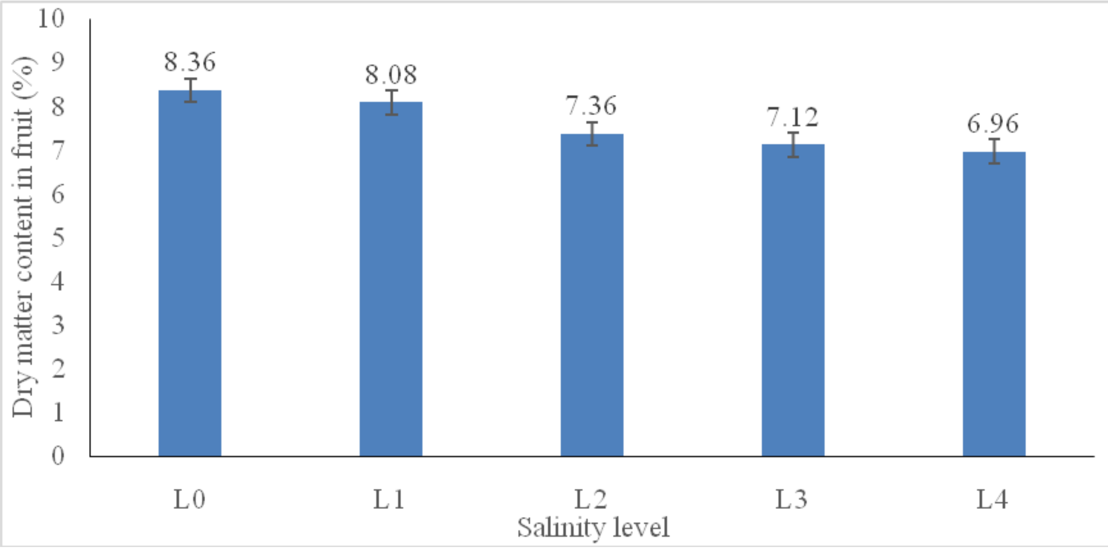
Table 7. Combined effect of different levels of salinity and potassium nitrate on total number of fruits per plant, fruit length and fruit diameter of tomato

Treatment Combinations	Fruit/plant	Fruit length (cm)	Fruit diameter (cm)
L_0M_0	44.32 bc	9.33 ab	6.10 bc
L_0M_1	47.29 b	9.43 ab	6.43 ab
L_0M_2	53.67 a	10.00 a	6.70 a
L_1M_0	34.03 de	8.67 bc	5.63 cde
L_1M_1	35.29 de	8.70 bc	5.67 cde
L_1M_2	36.98 cd	8.83 bc	5.89 bcd
L_2M_0	36.05 cd	7.97 cde	5.33 def
L_2M_1	24.08 gh	8.30 cd	5.43 def
L_2M_2	24.46 fg	8.33 cd	5.53 cdef
L_3M_0	27.56 ef	7.30 ef	4.72 gh
L_3M_1	17.67 hij	7.30 ef	4.93 fgh
L_3M_2	18.15 hij	7.67 de	5.13 efg
L_4M_0	11.52 k	6.10 g	4.07 i
L_4M_1	15.55 hij	6.33 fg	4.36 hi
L_4M_2	17.32 hij	6.67 fg	4.43 hi
CV (%)	6.14	6.76	6.31
LSD $_{(0.05)}$	3.67	0.90	0.56

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

4.12 Dry matter content of fruit (%)

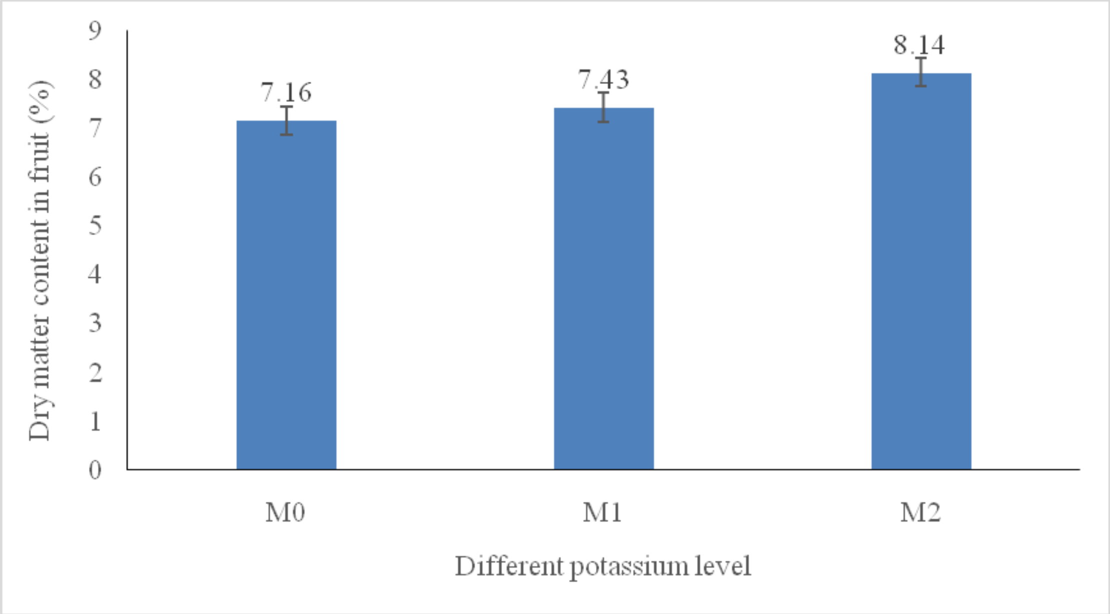
Percent dry matter content in fruit varied significantly due to different level of saline water (Figure 10 and Appendix XII). The highest dry matter content in fruits (8.36 %) was recorded from L_0 (salinity-controlled condition) which was followed by L_1 (8.08 %) treatment. On the other hand, the lowest dry matter content in fruits (6.96 %) was recorded from L_4 (8 dS/m of NaCl) treatment which was statistically identical with L_3 (7.12 %) treatment. The findings of Patil *et al.* (2006) were partially in consonance with the present findings. They reported that dry matter production reduced with increasing salinity. Similar result also found by Hossein (2018) in tomato and Zhani *et al.* (2012) in case of chili. Posada and Rodriguez (2009) reported that fruits of salt-stressed plants had reduced total dry matter.



[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1}]

Figure 10. Effect of different level of salt stress on dry matter content of fruit. ($LSD_{0.05}$= 0.77)

Dry matter content in fruit of tomato showed significant differences due to different levels of calcium nitrate (Figure 11 and Appendix XII). The highest dry matter content in fruit (8.14%) was found from M_2 (10 mM of KNO_3) treatment and the lowest (7.16%) was recorded from M_0 (control) treatment. Amjad *et al.* (2014) reported that plants in the control treatment (0 mM K) showed significantly lower values of these fruit dry matter content than the K-treated plants at all 3 saline levels (0, 7.5, and 15 dS m^{-1}). Application of potassium both in soil (3.3 and 6.6 mmol/kg) and foliar (4.5 and 9 mM) form had significant differences within different concentrations; it significantly increased the TSS and fruit dry matter in all genotypes compared to the control (0 mM K).



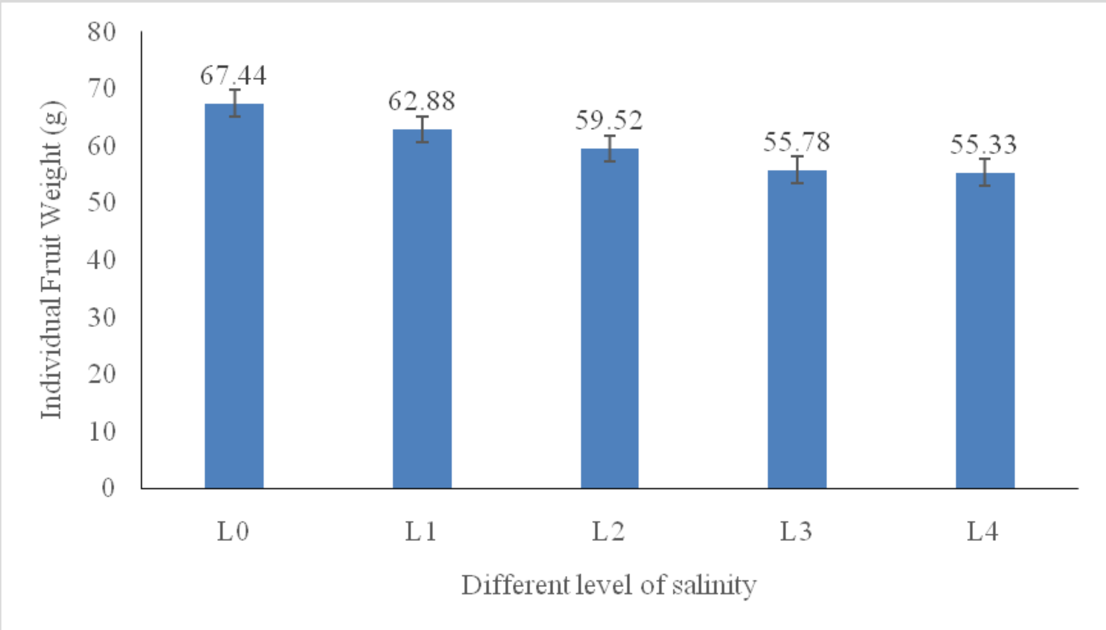
[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 11. Effect of different level of potassium nitrate on dry matter content of fruit. ($LSD_{0.05}$= 0.77)

A statistically significant variation for the percent of dry matter content in fruits was recorded in case of combined effect of saline water and potassium nitrate (Appendix XII and Table 8). The highest dry matter content in fruits (8.87%) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination which was followed by L_0M_1 (8.57%) while the lowest dry matter content in fruits per plant (6.13%) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination which was followed by L_4M_1 (6.36%) and L_4M_2 (6.67%).

4.13 Individual fruit weight (g)

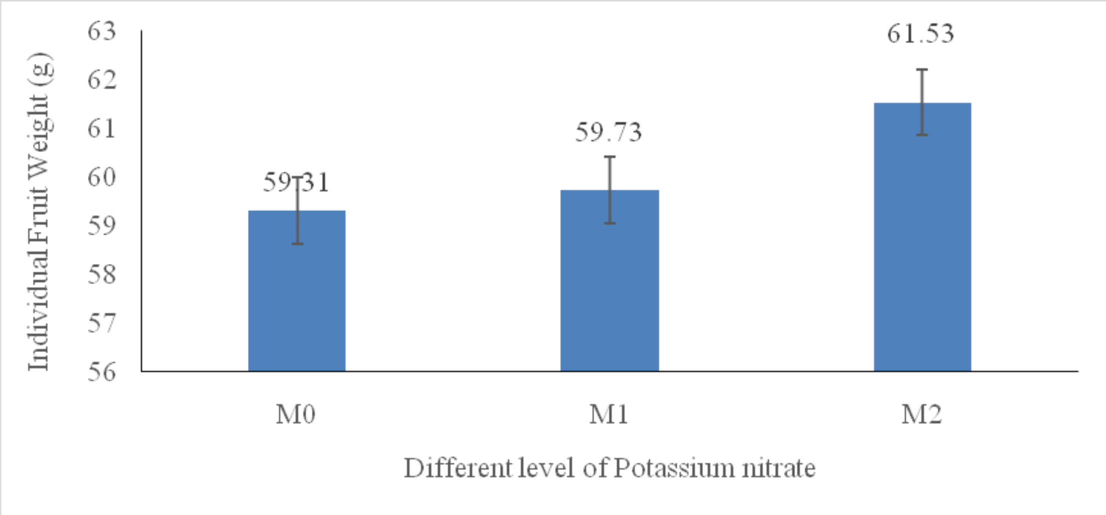
Individual fruit weight of tomato varied significantly due to influence of the different levels of salinity (Figure12 and Appendix XIII). The highest individual fruit weight (67.44 g) was found from L_0 (salinity-controlled condition). The lowest weight (55.33 g) was obtained from L_4 (8 dS/m of NaCl) treatment which was statistically similar with L_3 (55.78 g). The results obtained from this experiment showed that salinity stress caused a significant reduction in fruit weight in tomato which was also reported by Hossein (2018), Mridha (2018), Nasrin (2017), Hala and Ghada (2014), Parvin (2013), Nizam (2013) and Lolaei *et al.* (2012). This behavior also responsible for reduction of fruit weights $plant^{-1}$. Salinity reduced the individual fruit weight by inhibiting the cell division and rate of fruit expansiondue to the lower water potential in the plant which will reduce the water flow into the fruit as reported by Jonson *et al.* (2008). It was reported that the low water content of fruit appeared to be the result of an osmotic effect rather than a toxic effect of NaCl. It was studied that salinity reduced xylem development in tomato fruit (Belda and Ho, 2003) but since the tomato fruit has a very low transpiration rate, only a small proportion of the water input came via the xylem (Hossain,2006). Decreased fruit weight with increasing salinity were reported by Singh *et al*. (2015) and Cho and Chung (2007).



[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1}]

Figure 12. Effect of different level of salt stress on individual fruit weight of tomato. ($LSD_{0.05}$= 6.19)

Statistically significant variation was recorded for different levels of potassium nitrate on weight of individual fruit of tomato (Figure 13 and Appendix XIII). The highest weight of individual fruit (61.53 g) was recorded from M_2 (10 mM of KNO_3) treatment, whereas the lowest weight (59.31g) was attained from M_0 (control).



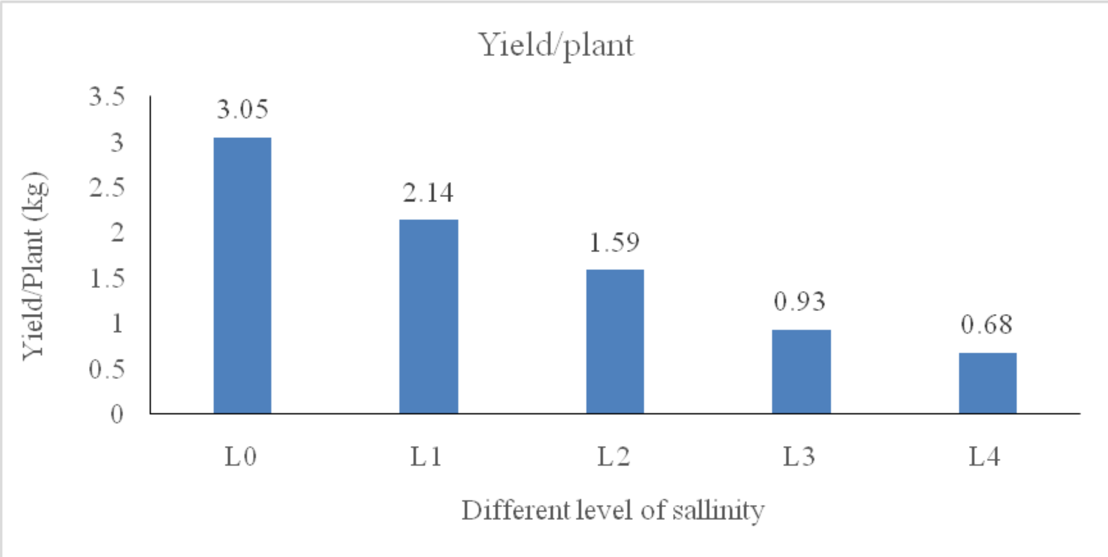
[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 13. Effect of different level of potassium nitrate on individual fruit weight of tomato. ($LSD_{0.05}$= 6.19)

A statistically significant variation was recorded in case of combination effect of saline water and potassium nitrate for the weight of individual fruit per plant (Table 8 and Appendix XIII). The maximum weight of individual fruit (69.11 g) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination which was followed by L_0M_1 (67.11 g), while the minimum weight of individual fruit (52.78 g) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination which was statistically identical with L_4M_1 (54.22 g) treatment combination.

4.14 Fruits weight plant^{-1} (kg)

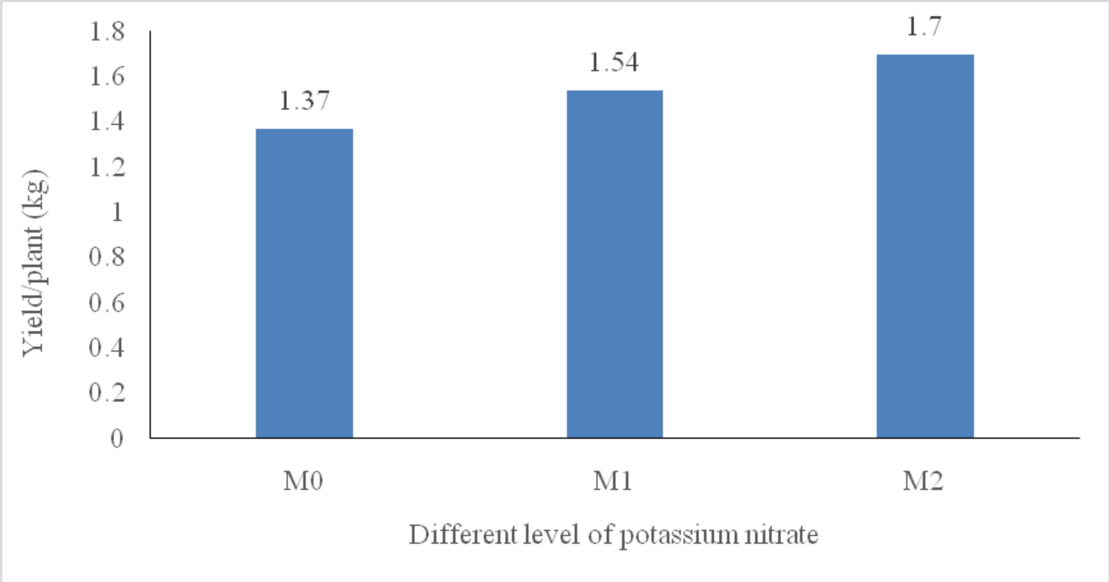
Fruits weight plant^{-1} varied significantly due to different levels of salinity (Figure 14 and Appendix XIII).The highest fruits weight (3.05 kg) was observed from L_0 (salinity-controlled condition) and the lowest value (0.68 kg) was recorded from L_4 (8 dS/m of NaCl). Number of fruits plant^{-1} and individual fruit weight were decreased with increased levels of salinity and that's why fruit weight plant^{-1} also decreased under high salinity. The reason of plant yield reduction affected by salinity might be the variation in photosynthetic products translocation toward root, decrease of plant top especially leaves, partial or fully enclosed stomata, direct effect of salt on photosynthesis system and ion imbalance Hajiboland *et al.* (2010). Similar observation was also reported by Hossein (2018), Mridha (2018), Nasrin (2017), Hala and Ghada (2014), Parvin (2013), Nizam (2013) and Lolaei (2012) in tomato, Siddiky *et al.* (2012) and Humayun (2010) also explained the same result. Similar observations were also reported by Ali *et al.* (2007) in eggplant, Hakim *et al.* (2014) in rice. 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).



[Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1}]

Figure 14. Effect of different level of salt stress on fruit weight of tomato per plant. ($LSD_{0.05}$= 0.35)

A statistically significant difference was recorded due to different levels of potassium nitrate for yield per plant (Figure 15 and Appendix XIII). The highest yield (1.7 kg) was recorded from M_2 (10 mM of KNO_3) treatment, while the lowest yield (1.37 kg) was recorded from M_0 (control). Fruit weight was increased with the supply of potassium nitrate and the highest result was recorded from 10 mM of KNO_3. This result indicated that potassium nitrate reduced the toxic effect of salinity and increased the fruit weight in tomato which agrees with the result of Amjad *et al.* (2014) in tomato; Adhikari*et al.* (2020) in soybean; and Elhindi *et al.* (2016) in coriander.



[Here, M_0= 0 mM (Control), M_1= 5 mM and M_2= 10 mM]

Figure 15. Effect of different level of potassium nitrate on fruit weight of tomato per plant. ($LSD_{0.05}$= 0.35)

Combined effect of saline water and potassium nitrate showed statistically significant variation for yield per plant of tomato (Table 8 and Appendix XIII). The highest yield per plant (3.71 kg) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) treatment combination which was followed by L_0M_1 (3.17 kg), while the lowest yield per plant (0.61 kg) was recorded from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination which was statistically similar withL_4M_1 (0.84 kg) treatment combination.

Table 8. Combine effect of different levels of salinity and potassium nitrate on dry matter content in fruit, individual fruit weight and fruit weight per plant of tomato

Treatment combination	Total dry matter content of fruit (%)	Single fruit weight (g)	Yield/plant (kg)
L_0M_0	8.38 abc	66.11 abc	2.93 c
L_0M_1	8.57 ab	67.11 ab	3.17 b
L_0M_2	8.87 a	69.11 a	3.71 a
L_1M_0	8.17 abcd	62.33 abcd	2.12 e
L_1M_1	8.17 abcd	62.77 abcd	2.22 e
L_1M_2	8.33 abc	63.55 abcd	2.35 d
L_2M_0	7.33 def	57.44 de	1.38 g
L_2M_1	7.63 cde	59.67 cde	1.46 g
L_2M_2	7.70 bcde	61.44 bcd	1.69 f
L_3M_0	6.97 efg	56.44 de	1.00 h
L_3M_1	7.13 efg	56.77 de	1.03 h
L_3M_2	7.23 ef	56.78 de	1.07 h
L_4M_0	6.13 h	52.78 e	0.61 i
L_4M_1	6.36 gh	54.22 e	0.84 i
L_4M_2	6.67 fgh	56.33 de	0.98 hi
CV (%)	6.19	6.25	8.13
LSD $_{(0.05)}$	0.77	6.19	0.35

[In a column means having similar letter(s) is/ are statistically identical and those having dissimilar letter(s) differ significantly as per as 0.05 (%) level of probability; Here, L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1}, L_4= 8 dSm^{-1} and M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM]

CHAPTER V

SUMMARY AND CONCLUSION

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The experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from October 2019 to March 2020 to study the effect of salinity levels and potassium nitrate on morphological, yield and yield contributing characters of tomato. The materials used for the experiment were BARI Tomato 19. In this experiment, the treatments consisted of five different salinity levels viz., L_0= 0 dSm^{-1} (Control), L_1= 2 dSm^{-1}, L_2= 4 dSm^{-1}, L_3= 6 dSm^{-1} and L_4= 8 dSm^{-1} and three different levels of potassium nitrate viz., M_0= 0 mM (Control), M_1= 5 mM, M_2= 10 mM. The experiment was setup in a two factor Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameters, physiological parameters and yield with yield contributing characters of tomato were recorded. The collected data were statistically analyzed for evaluation of the treatment effect. A significant variation among the treatments was found while different salinity levels and potassium nitate levels were applied in different combinations.

Summary

Significant variations were observed due to different levels of salinity in different growth and yield contributing parameters of tomato. At 30, 50 and 70 DAT, the tallest plant (74.30, 99.53 and 119.7 cm) was recorded from L_0 (Salinity controlled condition), whereas the shortest plant (44.63, 82.80 and 103.1 cm) from L_4 (8 dS/m), respectively. At 30, 50 and 70 DAT, the maximum number of branches was recorded (3.67, 5.57 and 7.78) from L_0 treatment, respectively where the minimum number of branches per plant (0.44, 2.33 and 4.54) from L_4 treatment, respectively. At 30, 50 and 70 DAT, the maximum number of leaves per plant was recorded (18.22, 34.22 and 38.78) from L_0 treatment and the minimum number of leaves per plant (12.00, 30.11 and 33.67) from L_4, respectively.The maximum days from transplanting to 1^{st} flowering (44.89) was recorded from L_4 and minimum days (39.78) from L_0 treatment. The highest number of flower cluster per plant (8.68), number of flower/cluster (7.89) and number of flower/plant (68.49) was found from L_0 and the lowest (6.91, 5.44 and 37.59) from L_4 treatment, respectively. The highest number of flower drop (28.22) was obtained from L_3 and the lowest number (23.33) was found from L_0 treatment. The highest number of fruitsper plant (45.16) was found from L_0 and the lowest number of fruit (12.25) was found from L_4 treatment, respectively. The maximum length (9.33 cm) and diameter of fruit (6.11 cm), maximum dry matter content of fruit (8.36%), the was found from control treatment again while the lowest (6.69 cm, 4.48 cm and 6.96%) from L_4 treatment, respectively. The highest weight of individual fruit (67.44 g) and yield per plant (3.05 kg) was found from L_0 treatment and the lowest weight of individual fruit (55.33 g) and yield per plant (0.68 kg) from L_4 treatment.

Significant variations were observed in different growth and yield contributing parameters of tomato due to application ofdifferent levels of potassium nitrate. At 30, 50 and 70 DAT, the tallest plant (62.76, 93.16 and 112.8 cm) was recorded from M_2(10 mM of KNO_3), whereas the shortest plant (57.74, 89.80 and 110.0 cm) from M_0 (KNO_3 controlled condition), respectively. At 30, 50 and 70 DAT, the maximum number of branches per plant (2.21, 4.1and 6.31) was recorded from M_2 treatment, and the minimum number of branches per plant (1.67, 3.56 and 5.77) from M_0 treatment, respectively. At 30, 50 and 70 DAT, the maximum number of leaves per plant was recorded (15.06, 32.60 and 36.47) from M_2 treatment and the minimum number of leaves per plant (13.80, 31.73 and 35.60) from M_0, respectively. The minimum days from transplanting to 1^{st} flowering (41.87) was recorded from M_2 treatment and the maximum days (43.13) from M_0 treatment. The highest number of flower cluster per plant (7.98), number of flower/cluster (7.20) and flower/plant (57.46) was found from M_2 treatment and the lowest (7.67, 6.20 and 47.55) from M_0, respectively. The highest number of dropped flowers plant^{-1} (29.80) was found from M_2 treatment and the lowest number (24.47) was found from M_0 treatment. The highest number of fruits per plant (27.66) was found from M_2 treatment and the lowest number of fruit (23.08) was found from M_0 treatment, respectively. The maximum length (8.62 cm) and diameter of fruit (5.92 cm), maximum dry matter content of fruit (8.14 %), the was found from M_2 treatmentagain while the lowest (7.34 cm, 4.88 cm and 7.16 %) from M_0 treatment, respectively. The highest weight of individual fruit (61.53 g) and yield per plant (1.7 kg) was found from M_2 treatment and the lowest weight of individual fruit (59.31 g) and yield per plant (1.37 kg) from M_0 treatment.

In combined effect of salt stress and potassium nitrate, at 30, 50 and 70 DAT, the tallest plant (77.40, 102.2 and 121.4 cm) was recorded from L_0M_2 (10 mM KNO_3 with no salinity stress condition) whereas the shortest plant (41.40, 80.30 and 101.8 cm) from L_4M_0 (8 dSm^{-1} NaCl with no KNO_3 condition) treatment combination, respectively. At 30, 50 and 70 DAT, the maximum number of branches per plant (4.03, 5.92 and 8.13) was recorded from L_0M_2, respectively while the minimum number of branches per plant (0.33, 2.22 and 4.43) from L_4M_0, respectively. At 30, 50 and 70 DAT, the maximum number of leaves per plant was recorded (19.33, 34.67 and 39.33) from L_0M_2 treatment combination, respectively and the minimum number of leaves per plant (11.67, 29.33 and 33.33) from L_4M_0 treatment combination, respectively. The maximum days from transplanting to 1st flowering (46.33) was recorded from L_4M_0 treatment combination and the minimum days (38.33) from L_0M_2 treatment combination. The highest number of flower cluster per plant (8.92), number of flower/cluster (8.67) and number of flower/plant (77.34) was found from L_0M_2 treatment combination, respectively while the lowest (6.57, 5.00 and 32.85) from L_4M_0, respectively.

The highest number of fruits per plant (53.67) was found from L_0M_2 treatment combination and the lowest number of fruit (11.52) was found from L_4M_0 treatment, respectively. The maximum length (10.00 cm) and diameter of fruit (6.70 cm)and maximum dry matter content of fruit (8.87 %) was found from L_0M_2 treatment combination treatment again while the lowest (6.10 cm, 4.07 cm and 6.13 %) from L_4M_0 treatment,respectively. The highest weight of individual fruit (69.11 g) and yield per plant (3.71 kg) was found from L_0M_2 treatment and the lowest weight of individual fruit (52.78 g) and yield per plant (0.61 kg) from L_4M_0treatment.

Conclusion

In respect as the above results, it can be concluded that the fruit weight of tomato gradually decreased by the increase of salinity levels and this reduction rate was decreased by foliar application of potassium nitrate. According to result, salinity levels (L_0) showed maximum tallest plant height, leaves number, maximum branch number, days to flower, flower cluster^{-1}, flower plant^{-1}, fruit plant^{-1}, single fruit weight and fruit yield plant^{-1}. On the other hand, (10 mM KNO_3) doses of potassium nitrate application performed excellent among the potassium nitrate treatment applied in terms of all parameters. Besides the combination, salinity (L_0) with 10 mM potassium nitrate application performed the best combination.

Above finding revealed that-

1. Salinity adversely affected morphological characters, yield contributing characters and yield of BARI Tomato 19,
2. Potassium nitrate showed better effect in yield and quality characters under salinity in tomato,
3. Among the different concentration of potassium nitrate, tomato showed betterresponse with 10 mM concentration of potassium nitrate.

Recommendation

Considering the situation 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. Other’s level of potassium nitrate and another stress reducing substances also may be used for further study.
3. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performance.

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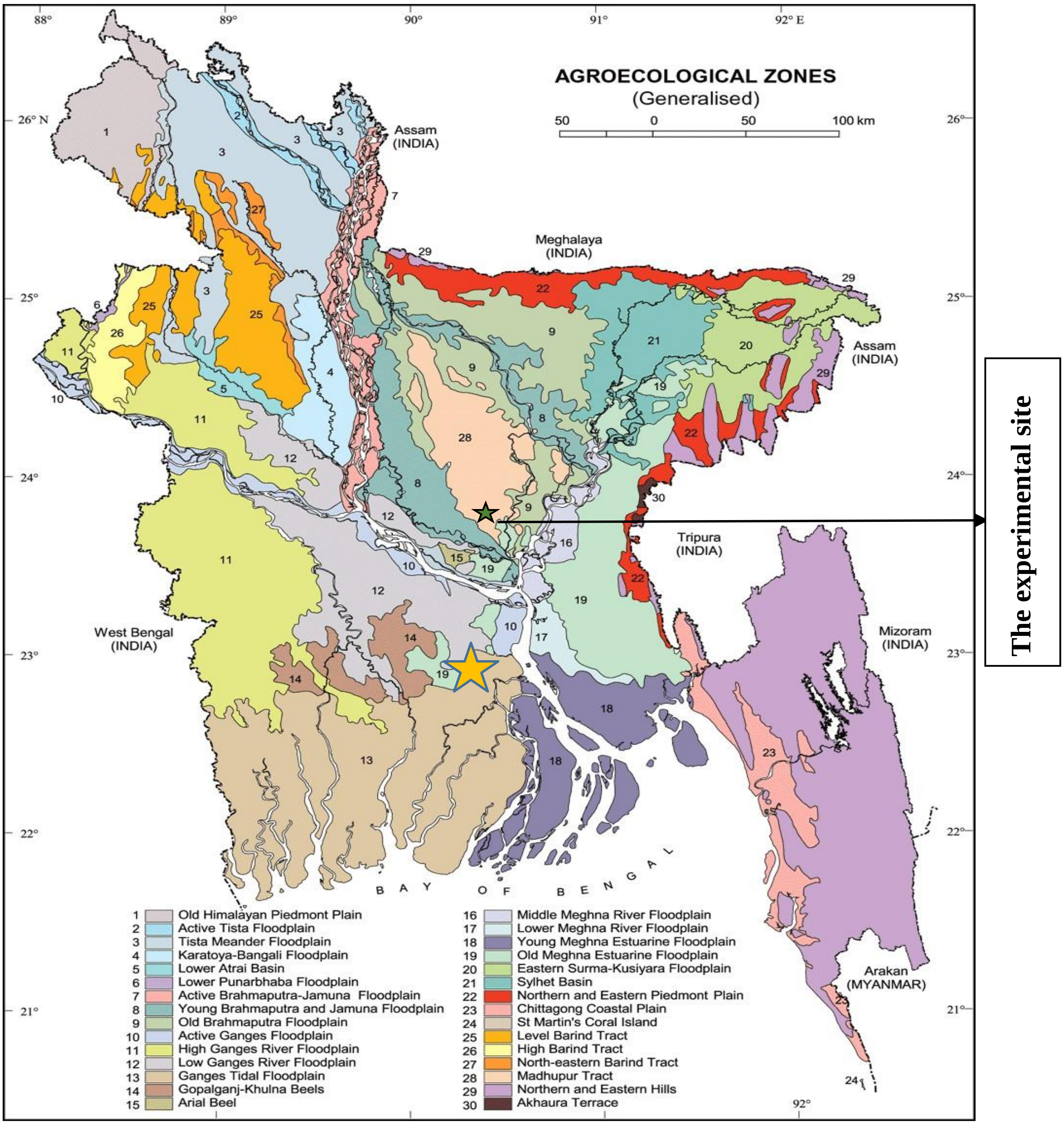
APPENDICES

APPENDICES

Appendix I. Map showing the experimental site



Appendix II. Morphological characteristics of the experimental field

Morphology	Characteristics
Location	Horticulture Farm, SAU, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ-28)
General soil type	Deep Red Brown Terrace Soil
Parent material	Madhupur Clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

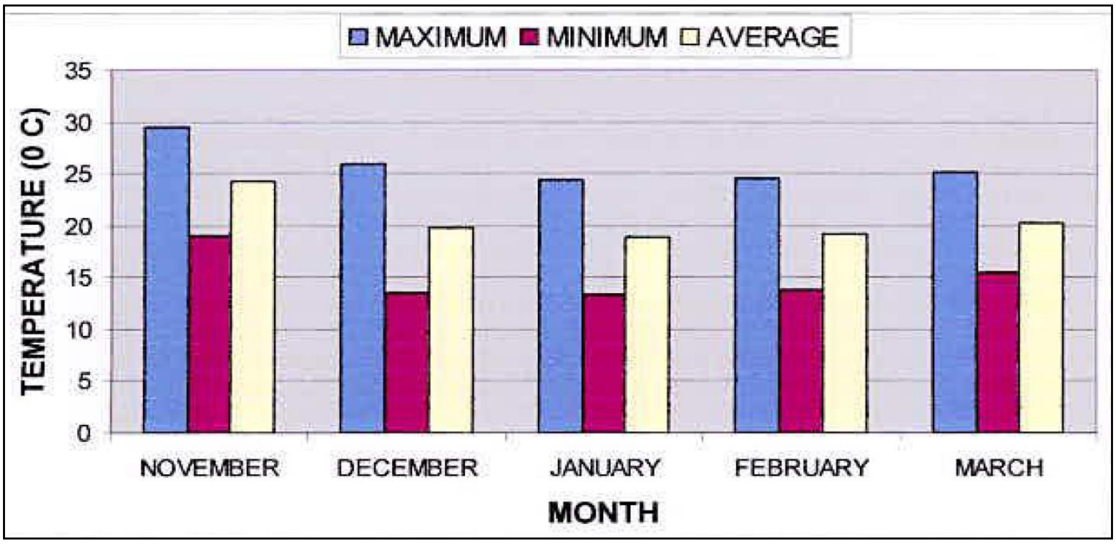
Source: FAO and UNDP, 1988

Appendix III. Initial physical and chemical characteristics of the soil

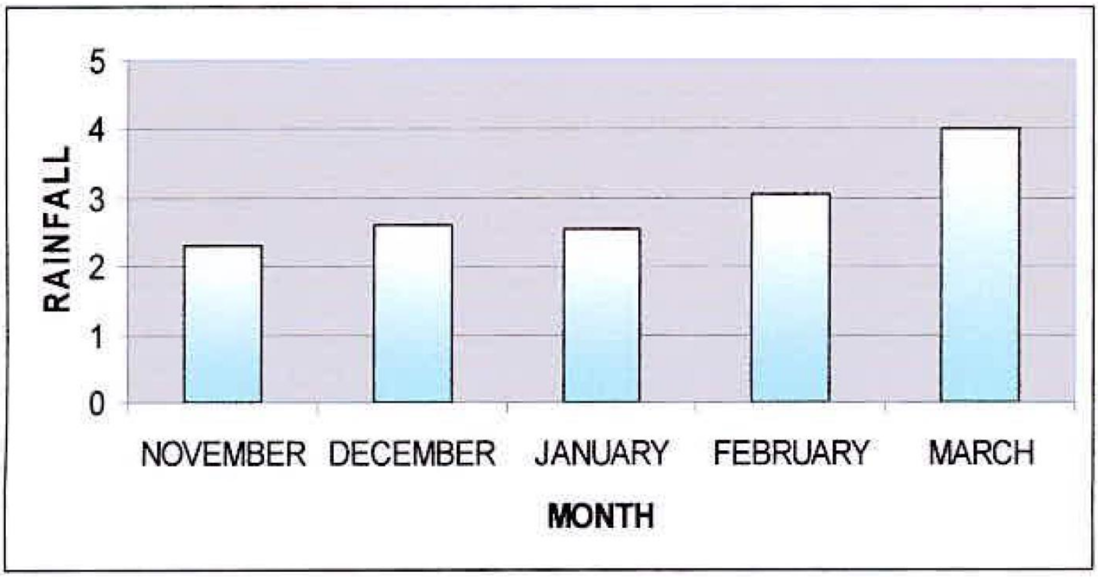
Characteristics		Value
Mechanical fraction:	% Sand (2.0-0.02 mm)	22.26
	% Silt (0.02-0.002 mm)	56.72
	% Clay (<0.002 mm)	20.75
Textural Class		Silt Loam
pH (1:2.5 Soil-water)		5.9
Organic Matter (%)		1.09
Total N (%)		0.06
Available K (ppm)		15.63
Available P (ppm)		10.99
Available S (ppm)		6.07

Source: Soil Resource Development Institute (SRDI), Dhaka.

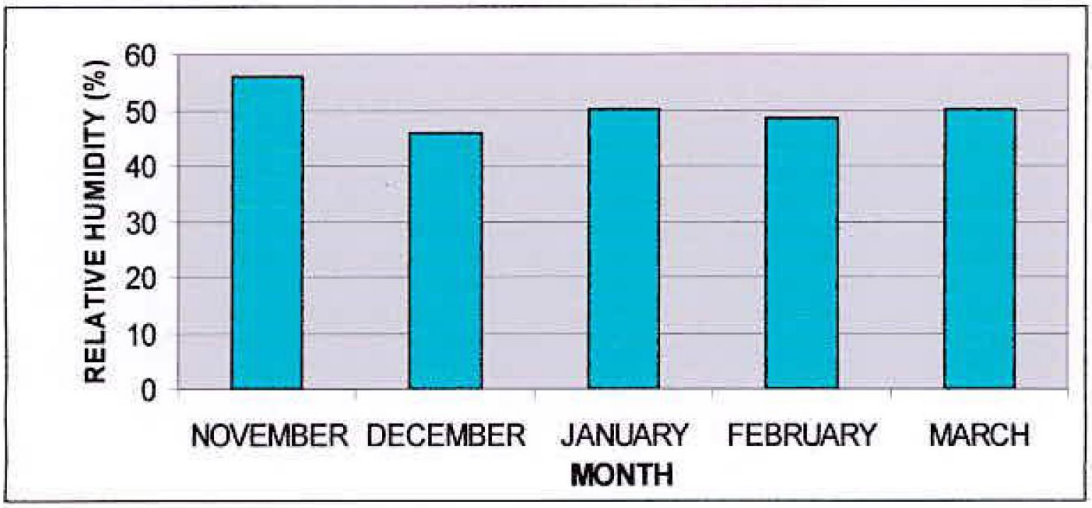
Appendix IV. Monthly average, maximum and minimum air temperature (^{0}C) of the experimental site, Dhaka during the growing time (November, 2019 to March, 2020)



Appendix V. Monthly total rainfall (mm) of the experimental site, Dhaka during the growing period (November, 2019 to March, 2020)



Appendix VI. Monthly average relative humidity (%) of the experimental site, Dhaka during the growing period (November, 2019 to March, 2020)



Appendix VII. Analysis of variance of data on plant height at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean Square of Plant height		
		30 DAT	50 DAT	70 DAT
Replication	2	991.453	2469.005	3680.884
Factor A	4	1283.413	375.704	385.854
Factor B	2	94.948	42.319	30.984
AB	8	2.298	1.824	0.395
Error	28	4.366	17.355	26.988

Appendix VIII. Analysis of variance of data on number of branches per plant at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean Square of branches no. per plant		
		30 DAT	50 DAT	70 DAT
Replication	2	0.657	16.349	81.061
Factor A	4	14.825	7.300	22.411
Factor B	2	1.298	1.355	1.823
AB	8	0.043	0.131	0.046
Error	28	0.009	0.094	0.514

Appendix IX. Analysis of variance of data on number of leaves per plant at different days after transplanting of tomato

Source of variation	Degrees of freedom (df)	Mean Square of leaf no. per plant		
		30 DAT	50 DAT	70 DAT
Replication	2	57.82	310.083	385.878
Factor A	4	54.775	23.561	37.071
Factor B	2	6.115	2.957	2.83
AB	8	0.737	0.124	0.043
Error	28	0.272	2.344	2.857

Appendix X. Analysis of variance of data on days to 1st flowering, cluster/plant and flower/cluster of tomato

Source of variation	Degrees of freedom (df)	Mean Square of		
		Days to 1st flowering	Cluster/plant	Flower/cluster
Replication	2	542.764	18.404	13.141
Factor A	4	39.075	4.711	8.154
Factor B	2	6.035	0.068	4.032
AB	8	12.116	0.325	0.246
Error	28	4.263	0.121	0.141

Appendix XI. Analysis of variance of data on flower/plant, dropped flower/plant and fruit/plant of tomato

Source of variation	Degrees of freedom (df)	Mean Square of		
		Flower/plant	Dropped flower/plant	Fruit/plant
Replication	2	582.193	213.495	422.411
Factor A	4	408.691	37.625	75.856
Factor B	2	269.946	119.413	69.625
AB	8	64.571	8.756	8.808
Error	28	8.939	1.792	4.974

Appendix XII. Analysis of variance of data on fruit length, fruit diameter and dry matter content in fruit

Source of variation	Degrees of freedom (df)	Mean Square of		
		Fruit length	Fruit diameter	Dry matter content in fruit
Replication	2	21.087	8.924	18.238
Factor A	4	10.146	3.891	3.383
Factor B	2	6.438	4.078	3.805
AB	8	0.377	0.091	1.009
Error	28	0.297	0.114	0.22

Appendix XIII. Analysis of variance of data on Individual fruit weight (g) and yield per plant of tomato

Source of variation	Degrees of freedom (df)	Mean Square of	
		Single fruit weight	Yield/plant
Replication	2	1164.77	2.388
Factor A	4	232.685	3.313
Factor B	2	20.862	1.354
AB	8	4.913	0.037
Error	28	14.163	0.046