MITIGATION OF SALT STRESS IN TOMATO WITH SALICYLIC ACID AND JASMONIC ACID

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CERTIFICATE

*This is to certify that the thesis entitled, **"MITIGATION OF SALT STRESS IN TOMATO WITH SALICYLIC ACID AND JASMONIC ACID"** submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by **SONIKA KHAN SITHI,** Registration No. **16-07534** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission

Dated: DECEMBER, 2017
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Dedicated To

My Beloved Parents

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ABSTRACT

A study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2016 to February 2017. The experiment consisted of two factors: Factor A (salinity level): S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}; Factor B (mitigation level): M_0 = 0, M_1 = 1 mM of Salicylic Acid, M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid with 10 µm of Jasmonic acid. The experiment was laid out in Randomized Complete Block Design with 4 replications. Various morphological, yield and yield contributing characters varies due to increasing salinity and application of salicylic acid and Jasmonic acid singly or in combination have significantly mitigate this effect. In terms of salinity, the highest yield per hectare (81.04 t) was recorded from S_0, while the lowest yield (17.40 t) was recorded from S_3. In terms of mitigation levels, the highest yield per hectare (46.55 t) was found from M_3, whereas the lowest yield (43.84 t) was recorded from M_0. In combination, the highest yield per hectare (83.32 t) was recorded from S_0M_3, whereas the lowest yield (16.45 t) was recorded from S_3M_0. Therefore, combined application of salicylic acid with Jasmonic acid seems to mitigate salt stress in tomato.

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ABBREVIATIONS AND ACRONYMS

Abbreviations	Expansions
ABA	= Abscisic acid
AEZ	= Agro- Ecological Zone
Anon.	= Anonymous
AOS	= Active Oxygen Species
ASC	= Ascorbic acid
BARI	= Bangladesh Agricultural Research Institute
BAU	= Bangladesh Agricultural University
BBS	= Bangladesh Bureau of Statistics
BINA	= Bangladesh Institute of Nuclear Agriculture
Cm	=Centi-meter
cm^2	=Centimeter square
CO_2	=Carbon di oxide
CV	= Coefficient of Variance
cv.	=Cultivar(S)
DAS	=Days after sowing
DAT	=Days after Transplanting
^0C	= Degree Centigrade
Df	=Degree of freedom
dSm^{-1}	= Deci simen per meter
JA	= Jasmonic acid
SA	=Salicylic acid
EC	= Electrical conductivity
et al.	= And others
FAO	= Food and Agriculture Organization

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CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most important vegetable crops grown throughout the world including Bangladesh. Tomato is cultivated in almost all over the country for its adaptability to wide range of soil and climate in Bangladesh (Ahmed,1995). Tomato ranks next to potato and sweet potato in respect of vegetable production in the world (Hossain *et al*., 2010). It ranks fourth in respect of production and third in respect of area in Bangladesh (BBS 2016). Tomato is a major component in the daily diet, having several nutrients and can be used in making soups, conserves, pickles, ketchup, sauces, juices etc. Ripe tomatoes having antioxidant-lycopene, which acts as an anti-carcinogen and prevents cancer (Agarwal and Rao, 2000) and also prevent so many diseases. Due to increasing consumption of tomato products, the crop is becoming promising. Tomato is sensitive to a number of environmental stresses, especially extreme temperature, drought, salinity and inadequate moisture stresses (Kalloo,1993). Among various abiotic and biotic stresses, salt stress is highly putting constrains to tomato production in Bangladesh.

Salinity is one of the most devastating abiotic stress factors which caused reduction in plant growth and development as well as productivity and thus pose serious threat to agriculture (Flowers and Colmer,2008). The higher demand for foods of increased global population is putting a strain on food production in such a way that will force the use of saline soil for agricultural production (Ashraf,2009).Salinity induced osmotic and ionic toxicity cause physiological, morphological and biochemical modifications and thus resulting growth inhibition and crop yield reduction (Ashraf and Foolad, 2007). It is also well known that under salt exposure plant showed detrimental response in water status and cell turgidity, photosynthetic efficiency and carbon allocation and utilization (Abdul-Jaleel *et al.,* 2007; Kim and Lee, 2001). Various studies show that Tomato undergoes various damages with adverse effects of salinity (Bradbury and Ahmad, 1990; Liang et al., 1996).

One viable strategy of overcoming the salt-induced injurious effects on plant growth is the exogenous application of growth regulators, osmo- protectants and stress signaling molecules (Farooq *et al*., 2010). Application of salicylic acid (SA) and jasmonic acid (JA) effectively alleviates the salt-induced damage in plant (Farooq *et al*., 2010).

Salicylic acid (SA) is a phenolic compound. It is one kind of plant growth regulator, non-enzymatic antioxidant and acts as an important signal molecule for modifying plant responses to environmental stresses. Salicylic Acid protects plant growth and induces antioxidant defense system under salt stress (Nazar *et al.,* 2011).SA plays important role in flowering induction, plant growth and development, synthesis of ethylene, opening and closure of stomata and respiration of plants (Raskin, 1992). Plants undergoes damages caused by oxidative stresses through increasing antioxidants enzymes activities, are diminished by SA application (El-Tayeb; 2005, Idrees et al., 2011). SA has received much attention due to its function in plant's responses to environmental stresses. Exogenous SA alters the activities of antioxidant enzymes and increases plant tolerance to abiotic stress by decreasing generation of ROS.

Jasmonic acid (JA) acts as a vital signaling molecule in biotic stress responses and development (Wasternack, 2015). JAs mediate several aspects of plant development, including root growth, seed germination, pollen viability, stomatal closure and senescence (Cheong and Choi, 2003; Haga and Iino, 2004; Wasternack and Hause, 2013; Riemann et al., 2013). Many studies reveals that JA is also involved in salt stress mitigation. However, the mechanisms by which JA alleviates salt tolerance are still unknown but studies show that increased levels of JA under drought or salt stress are consistent with the induction of genes for JA synthesis (Kiribuchi et al., 2005). Exogenous JA application may change the balance of endogenous hormones, such as ABA, which provides an important clue for understanding the protection mechanisms against salt stress (Kang *et al.,* 2005).

It has been reported SA and JA improve the morphological and physiological functions in plant to cope with adverse environment (Mohsen Kazemi *et al.*, 2014).Therefore, the effect of SA and JA to minimize the effect of salt toxicity in the reduction of yield and quality of tomato fruits is essential to investigate, especially for saline prone area.

This study focuses on the independent or interactive effect of SA and JA in alleviation of salt toxicity in tomato by improving the morpho-physiology, yield and quality of tomato to different levels of salt stress in Bangladesh.

OBJECTIVES:

- **i.** To observe the morpho-physiology, yield contributing characters and yield of tomato under salt stress.
- **ii.** To examine the effect of salicylic acid and jasmonic acid alone or in combinations on mitigation of salt stress in tomato.

CHAPTER II

REVIEW OF LITERATURE

Salinity becomes severe problem in the coastal region of Bangladesh nowadays. The scientists of Bangladesh are conducting different experiments to adopt different crops in the saline area and tomato is one of them. An attempt has been made to find out the performance of tomato at different levels of salinity as well as to find out the possible ways of mitigation by using salicylic acid, Jasmonic acid and their combination under the salt stressed tomato plants. 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 under the following heads-

2.1. Effect of Salt stress on tomato plants

Ruiz *et al*. (2015) conducted a study to characterize the effects of salinity on tomato fruit skin texture. Tomato plants were irrigated with fresh water (control, ED=1.01 dSm^{-1}) and saline water (up to 12.61 dSm^{-1}). Results showed that saline water improves fruit taste and reduces yields. Salinity additionally leads to toughening of tomato fruit skin, though the causative mechanism for which is unknown. The tougher tomato skin obtained under conditions of salinity is attributed to increased number of hypodermal cell layers rather than to changes in cell wall composition. Results stated that due to salinity strengthening tomato skin and increasing of its thickness happens, which results in increasing firmness and shelf life of tomato fruits under salt stress.

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

Jamal *et al.* (2014) conducted a hydroponic study to find out the growth and yield of tomato in different salinity level as response of tomato (*Lycopersicon esculentum*) to Salinity. T_0, Control; T_1, 4 dSm^{-1}; T_2, 8 dSm^{-1}; T_3, 12 dSm^{-1} and T_4,16 dSm^{-1} treatments were taken as Five salinity levels and the experiment was carried out with completely randomized design (CRD) . Significant results were revealed among growth, yield and yield contributing characters. Result shows Control (T_0) have 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. Salinity had a greater impact on stomatal resistance and chlorophyll content of plants. Stomatal resistance and highest Na and Cl uptake remain best in 16 dSm^{-1} (T_4) treatments. the uptake of K+ was reduced at 16 dSm^{-1} (T_4) and increased at control (0 dSm^{-1}) level.

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

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

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.

Kaveh *et al.* (2011) studied the effect of high salt concentrations in soil and irrigation water which restricted establishment and growth of tomato (*Solanum lycopersicum*). Selection and breeding for salt tolerance can be a wise solution to minimize salinity effects as well as to improve production efficiency while Correcting saline condition in field and greenhouse would be expensive and temporary. In a greenhouse, Effects of four salinity levels in irrigation water (0.5, 2.5, 5, and 10 dsm^{-1}) were investigated on seed germination and seedling emergence, and growth of tomato lines LA3770, R205, CT6, Fla, and ME. Results showed that germination percentage and rate, emergence percentage and rate of all tomato lines were delayed and decreased by salinity. All seedling growth characters were decreased with increasing salinity levels, only exception happened in case of seedling height. At germination and emergence stage, LA 3770 were more tolerant to salinity than others.

Marco *et al.* (2011) conducted a research on the effect of two sources of nitrogen on plant growth and fruit yield of chilli (Capsicum annuum L.) under increased salinity. An organic source extracted from grass clippings in rates of 120 and 200 kg N ha^{-1}, and another inorganic (ammonium nitrate) in rate of

120 kg ha^{-1} were combined with low, moderate and high (1.5, 4.5, and 6.5 dSm^{-1}) salinity levels. Research was conducted under controlled condition in greenhouse and arranged in a randomized complete block design with four replications. Finding of this research was that salinity treatments reduced dry matter production, leaf area, relative growth rate and net assimilation rate but increased leaf area ratio. Mean fresh fruit yields decreased for each N rate and source combinations as soil salinity increased.

Jogendra *et al.* (2011) studied ten genetically diverse genotypes along with their 45F1(generated by di-allel mating) under normal and salt stress conditions. In this study, germination rate, speed of germination, dry weight ratio and Na^+/K^+ ratio in root and shoot, were the parameters assayed on three salinity levels; control, 1.0 % NaCl and 3.0 % NaCl with Hoagland's solution. salt stress negatively affected growth and development of tomato. Germination of tomato seed was reduced, the time needed to complete germination lengthened, root/shoot dry weight ratio was higher and Na+ content increased but K+ content decreased under higher saline level. Result showed that plants which were tolerant at seedling stage also show improved salinity tolerance at adult stage.

Ghorbanpour *et al.* (2011) conducted an experiment on the effect of salinity and drought stress on fenugreek germination indices. Salinity levels of 0 (as control), -3, -6 and -9 bar sodium chloride (NaCl) and polyethylene glycol 6000 (PEG 6000) in osmotic levels at 0 (as control), -3, -6 and -9 bar as drought stress were used. They found that with the increase of stress levels, germination and epicotyls and hypocotyls length reduced. Result showed that salinity and drought cause reduction in germination and growth indices and Fenugreeks have relative resistance to salinity and drought stress in germination stage.

Abari *et al.* (2011) conducted an experiment for studying germination of pepper spp. under salt stress with different NaCl and KCl concentrations.

Seeds of Bindu, Picnic, and Hotmaster after subjected to sulphuric acid and boiling water were grown on medium under eight salinity levels (0, 50, 100, 150, 200, 250 and 300 mM) in a complete randomized design under laboratory conditions. Salinity decreased Germination of both the species.

Abdul Qados (2011) experimented to study the effect of salt stress on plant growth and metabolism of bean plant. Result represent that the decrease of leaf numbers as well as branch numbers occur due to the accumulation of sodium chloride in the cell walls when exposed to higher salt condition.

Azami *et al.* (2010) experimented on the response of six tomato cultivars (*Lycopersicon esculentum* Mill.) to salt stress under in vitro conditions. Parameters like Callus relative growth rate (RGR), dry matter percentage (DM), osmotic potential and proline content were collected and significant differences were found among cultivars in those parameters. Result showed that the reduction in osmotic potential and proline content is to be concluded as the more the salt tolerant genotype.

Niu *et al.* (2010) studied on Salt tolerance of five cultivars of (*Capsicum annuum* L.). Three levels of salinity such as 0.82 dSm^{-1} (control, tap water), 2.5 dSm^{-1}, and 4.1 dSm^{-1} was made by adding NaCl, $MgSO_4$, and $CaCl_2$ to tap water at different amounts. It was concluded that The most salt tolerant cultivars had the lowest leaf Na+ accumulation, where the sensitive one had the highest Na+ in the leaves.

Humayun *et al.* (2010) conducted an experiment to evaluate 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 by He reported that 70 mM and 140 mM concentrations of NaCl decreased 1000 seed weight and yield significantly.

Nawaz *et al.* (2010) conducted a research to study the salt tolerance induction in two cultivars of sorghum by exogenous application of different levels (0, 50 mM and 100 mM) of proline. Conclusion showed that germination percentage, growth and chlorophyll contents were adversely affected by Salt treatments (100 mM) in both the cultivars. Applications of proline alleviated the adverse effects of salt stress and to low concentration i.e. 50 mM was more effective than high concentration of proline (100 mM) in both cultivars.

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

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

Taffouo *et al.* (2010) conducted a research on six cultivars of tomato. Three concentrations of salt solution 50, 100 and 200 mM NaCl and the control were used in irrigation. The results showed that the salt treatments increased significantly Na^+ concentrations in roots, stems and leaves of plants, whereas K^+ and Ca^{2+} concentrations and K^+/Na^+ selectivity ratio of plants were decreased in all tomato cultivars. Total chlorophyll concentration of tomato leaves is significantly reduced under salt stress in all cultivars except for Lindo at 50 and 100 mM NaCl and Ninja at 50 mM NaCl. The total chlorophyll, the dry weight of seedlings (roots dry weight, stems dry weight and leaf dry weight), the plant height and the mineral nutrient concentrations (Na^+, K^+ and Ca^{2+}) decreased due to increased salt solution.

Unlukara (2010) studied the effects of irrigation water salinity on eggplant growth, yield, water consumption and mineral matter accumulation in leaves and fruits in a greenhouse experiment. Five saline irrigation water with electrical conductivities of 1.5, 2.5, 3.5, 5.0, 7.0 dSm^{-1} and tap water as a control treatment were used. The fruit yield results revealed that eggplant was moderately sensitive to salinity. Plant water consumption and water use efficiency decreased with increasing salinity. The crop yield coefficient was 2.3. Salinity caused a decrease in K content and increased Cl content of leaves. Although mineral concentration of the leaves did respond to increased mineral concentration of irrigation water, mineral concentration of fruits did not .

Ahmet *et al.* (2009) conducted an experiment to study the predictive screening parameters at early development stages of tomato plants, where 18 tomato cultivars were grown in nutrient solution with 12 dSm^{-1} NaCl. Different morphologic and physiologic changes happened due to increase in NaCl concentrations. Almost all growth parameters were decreased under salt stress. Result also showed that the amount of Na^{+} was increased and the amount of Ca^{2+} and K^{+} ions were decreased due to rise in NaCl applications.

Datta *et al.* (2009) evaluated the impact of salt stress under different salinity levels (0, 25, 50, 75, 100, 125, 150 mM NaCl) on five varieties of wheat. The experiment concluded that root and shoot length, fresh weight and dry weight of root and shoot were reduced significantly for Regarding biochemical analysis, the sugar, proline content increased with increasing salinity level where as protein content decreased in the physiologically active leaves of different treatments for all the varieties of wheat.

Rafat and Rafiq (2009) stated by 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).

Magan *et al.* (2008) conducted a research to study the effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in

Mediterranean climatic conditions. Results stated that under salt stress huge reduction in flower number occurs.

Fanasca *et al.* (2007)The combined effects of electrical conductivity (an EC of 2.5 dS m^{-1} or 8 dS m^{-1} in the root zone) and fruit pruning (three or six fruit per truss) on tomato fruit quality were studied in a greenhouse experiment, Taste-related attributes [dry matter content (DM), total soluble solids content (SSC), titratable acidity (TA), glucose, fructose and citric acid content] and health-promoting attributes (lycopene, *β*carotene, vitamin C, and total anti-oxidant activity) of tomato fruits were determined. Though The quality of tomato fruits was improved by high EC. Results showed that EC and fruit pruning both had a strong effect on fruit size; however, EC had a much stronger impact on taste and health-related fruit quality attributes.

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

Guiseppe (2006) reported that salinity improved fruit quality by increasing dry matter content and total soluble solid TSS content in plants.

Hajer *et al.* (2006) conducted experiment on tomato under saline condition and reported the effect of NaCl salinity stress on the growth of tomato plants was reflected in lower fresh and as well as dry weights.

Jamil *et al.* (2006) conducted a study to analyze the response of four vegetables species, treated with different concentrations of salt solution. Outcomes indicated that salinity caused significant reduction in germination percentage, germination rate, root and shoot lengths and fresh root and shoot weights.

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

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

Agong *et al.* (2003) evaluated Thirteen tomato (Lycopersicon esculentum) cultivars which were subjected to salt treatment under hydroponics . Salt applications ranged from 0 to 2% NaCl, with the resultant EC values of 1.4 to 37 dS/m were taken. The cultivars were cultured in the experimental solutions for up to four weeks in the greenhouse. Significant genotypic and/or salt treatment effects were registered on plant height, leaf area, dry matter yield, flower cluster and total flowers; and Na+ and Cl- accumulation in tomato tissues.

Mohammad *et al.* (1998) conducted a pot experiment where tomato seedlings (cv. riogrande) were grown in 500 ml glass jars containing Hoagland's solutions. These Hoagland's solutions were salinized by four levels of NaCl salt (0, 50, 100 and 150 mM NaCl) and/or enriched with three P levels (0.5, 1 and 2 mM P). The treatment of the experiment had nine combinations. Result showed that increasing salt stress results in decreasing shoot weight, plant height, number of leaves per plant.

Khavari and Mostofi (1998) observed that rise in salinity levels, reduced chlorophyll content of leaves at all growth stage in tomato. They also reported that reduction rate of chlorophyll content was greater at vegetative growth stage than maturity stage.

Vanleperen (1996) conducted experiment to find out the effect of salinity on tomato. They found out that the number of cluster per plant was reduced both with high salinity and long salinization periods in case of tomato.

Belda and Ho (1993) carried out a study on Salinity effects on the network of vascular bundles during tomato fruit development. They reported that xylem development in tomato fruit was reduced due to salinity and only a small proportion of the water input come via the xylem ultimately the individual fruit size as well as weight were reduced.

Yasseen *et al.* (1987) carried out study on *solanum lycopersicum* plants subjected to salinity showed a reduction in the growth parameters; such reduction in morphological parameters might have been due to the NaCl-induced inhibition of cell division and cell elongation.

yosef (1982) states that salt depressed the P^H of fruits from saline-treated plants. The fruit pH was, however, slightly decreased in accordance with the increase in total acidity.

2.2 Effect of mitigation agent on tomato plant

- **Salicylic acid**

Eman *et al.* (2018) carried out an investigation on Gladiolus grandifloras. The aim of this work was to study the effect of different levels of methyl jasmonate at rates of (zero, 50, 75 and 100 ppm) and salicylic acid at rates of (zero, 50, 100 and 150 ppm) on the vegetative growth, flowering and Corm Production of Gladiolus grandifloras, L. From the obtained results it was concluded that treating Gladiolus plants with combination of salicylic acid at 150ppm and methyl jasmonate at 75 ppm improve the vegetative growth, flowering characteristics, Corm Production and the contents of total chlorophyll in the leaves of Gladiolus plants.

D. Jini, B. Joseph (2017) investigated on how application of salicylic acid (SA) improved the growth and yield under salt stress conditions and its physiological mechanisms for salt tolerance. Germination and growth rates decreased by the salt stress were significantly increased by the SA application (SA + NaCl). The treatment of SA to the high and low saline soils enhanced the growth, yield and nutrient values of rice. It was revealed that the increased accumulation of Na^+ and Cl^- ions by the salt stress were reduced by SA application.

Mohsen Kazemi *et al.* (2014) conducted a study, which was aimed to understand the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits by The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, also reduced blossom end rot incident. While, MJ (1 mM) application significantly decreased vegetative growth and increased reproductive growth. The combination of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content as well as improved the yield and fruit quality of tomato.

Babar *et al.* (2014) carried out an experiment to alleviate the salinity-induced harmful effect on biomass production and physiochemical attributes of fenugreek by foliar application of salicylic acid. They experimented on Two varieties named Deli Kabul and Kasuri, which were grown in two different growth medium; one media were treated with (100 mM NaCl) and another one remain untreated i.e. 0 mM NaCl. They found that shoot fresh weight and net CO_2 assimilation rate were higher in Deli Kabul and both remained lower in Kasuri and Foliar application of SA mitigated growth biomass reduction in both plants. Similarly, CO2 assimilation rate, transpiration rate, stomatal conductance reduced due to salinity and Exogenous application of salicylic acid helped to mitigate this reduction in gas exchange attributes of the plants.

Laila Khandaker *et al.* (2011) conducted a study at Gifu University, Japan, by to determine the effect of foliar salicylic acid (SA) applications on growth, yield and bioactive compounds of red amaranth grown under greenhouse conditions. 3 different concentrations (10^{-3}, 10^{-4} and 10^{-5} M) of SA was applied at three times at 7-day intervals one week after sowing. plant height, stem length, number and size of leaves, root length, fresh and dry matter weight; along with bioactive compounds like beta-cyanins, chlorophyll, total polyphenol and antioxidant activity were also determined from the leaves of treated and control plants were recorded from plants on 28 days after sowing. Foliar SA applications of several doses enhanced the plant growth, yield and leaf's bioactive compounds compared to the control. The highest yield, antioxidant activity, amount of beta-cyanins, chlorophyll and total polyphenol was observed in 10^{-5} M SA treatment in red amaranth.

Humayun *et al.* (2010) investigated 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) of soybean cv. Hwangkeumkong. Plant length, biomass, chlorophyll content, number of pods, 100 seed weight and yield was significantly decreased when exposed to 70 mM and 140 mM concentrations of NaCl. The endogenous GA and free SA content decreased under salt stress, whereas while endogenous ABA and JA contents were increased significantly. They observed that growth and yield components of soybean was affected by salt stress significantly.

Sibgha *et al.* (2008) experimented to study the adverse effects of salt stress on sunflower plants and its amelioration by foliar application of exogenous SA. Two lines of sunflower (Hisun-33 and SF-187) were grown under normal or saline (120 mM NaCl) conditions. Different levels of salicylic acid (0, 100, 200, 300 mg L-1) were applied as a foliar spray. Result showed that both the cultivars were equally responsive to the stress and growth of the both lines was reduced significantly. But application of 200 mg L-1 of SA caused an increase in biomass and photosynthetic rate of both cultivars under control and saline conditions, particularly in line SF187.

Mohsina *et al.* (2008) experimented to study the effect of salicylic acid seed priming on growth and some biochemical attributes in wheat (*Triticum aestivum* L.) under saline conditions. Wheat seeds of cv. Inqlab and S-24 were soaked in water and 100 mg /L salicylic acid solution for 24 hours, and then sown in sand which was exposed to 0, 50 or 100 mM NaCl. Result indicated that all growth parameters i.e. shoot and root length, shoot and root dry weights were decreased significantly with the increase of salinity. Whereas this adverse effect of salinity on growth parameters were alleviated througth salicylic acid treatment. Salinity decreased the chlorophyll a and b content and chlorophyll a/b ratio in both the lines, but reduction in chlorophyll a/b ratio was lower in salt tolerant wheat line S-24, which could be a useful marker for selection of salt tolerant wheat.

Kaydan *et al.* (2007) showed that seed soaking pre-treatment using salicylic acid, positively affected the osmotic potential, shoot and root dry mass, K+/Na+ ratio and photosynthetic pigments (chlorophyll a, chlorophyll b and carotenoids) concentration in wheat tissues, under both salt and non-salt treatments.

El-Tayeb (2005) studied the interactive effect of salinity and salicylic acid on barley. The result indicated that foliar application of 1.0 mM SA increased RWC, fresh and dry weights, water content, soluble protein, total free amino acids, proline content, photosynthetic pigments, and phosphorus and peroxidase activity of barley seedlings under varying salt treatments.

Tari *et al.* (2002) reported that tomato plants tolerated 100 mM NaCl at low levels of SA concentration (10-7 to 10-4 M range) by a substantial increase in photosynthetic rate, transpiration rate and stomatal conductance.

Coronado *et al.* (1998) investigated and find out a significant increase in biomass of shoots and roots of soybean were observed due to application of SA.

Eris (1983) experimented on pepper seedlings and found out that stomatal conductance or resistance was increased and transpiration rate was reduced in due to foliar application of SA.

- **Jasmonic acid**

Parvaiz *et al.* (2018) investigated the effects of exogenous application of jasmonic acid (JA) and nitric oxide (NO) on growth, antioxidant metabolism, physio-biochemical attributes and metabolite accumulation, in tomato (Solanum lycopersicum L.) plants exposed to salt stress. They Treated the plants with NaCl (200 mM) resulted in considerable growth inhibition in terms of biomass, relative water content, and chlorophyll content. All these parameters were significantly improved upon application of JA and NO under both normal and NaCl-stress treatments. JA and NO either applied individually or in combination boosted the flavonoid, proline and glycine betaine synthesis under NaCl treatments and protected tomato plants from NaCl-induced damage by up-regulating the antioxidant metabolism, osmolyte synthesis, and metabolite accumulation.

Abdul *et al.* (2016) conducted a research which defines about the effect of foliar application of methyl jasmonate (MeJA) on physiological and biochemical processes in tomato under both saline and non-saline conditions. Two tomato genotypes Rio Grande (tolerant) and Savera (sensitive) were grown in pots having sand as growth medium. The salinity substantially decreased the physiological and biochemical parameters. Different doses of MeJA (0.0, 10, 20, 30, 40, 50, 60 µM) were applied on both control and salt stressed tomato plants. Methyl Jasmonate (MeJA) significantly ameliorated the deleterious effects of salinity on tomato plants by inducing the physiological and biochemical resistance. Different parameters responded to MeJA at various extents.

Alireza Pazoki (2015) carried out an experiment to investigate the effects of different salinity levels (0, 25, 50 and 75 mM NaCl), salicylic acid (0 and 0.7 mM) and Jasmonic acid (0 and 100 μM) on some pigment contents in Lemon balm (*Melissa officinalis* L.). The results indicated that pigment contents such as chl a, chl b and chl a+b significantly decreased and carotenes and xanthophylls increased when exposed to salt stress. On the contrary application of salicylic acid and Jasmonic acid significantly increased all pigment contents. Consequently, it showed that salicylic acid and Jasmonic acid could reduce the harmful effects of salt stress on Lemon balm.

Kazan *et al.* (2015) studied diverse roles of jasmonates and ethylene in abiotic stress tolerance. They found that jasmonate (JA) can play relevant functions in abiotic stress response.

Yoon *et al.* (2009) reported that Pre-treatment with JA in soybean reduced the inhibitory effect of high salt concentrations on growth and photosynthesis.

Sheteawi (2007) reported that foliar application of jasmonic acid on soybean under salt stress conditions reduced the damaging influence of salt and gained to the higher photosynthesis and yield.

Wasternack *et al.* (2002) reported that Jasmonic acid (JA) and its methyl ester methyl jasmonate (MeJA) collectively termed as jasmonates acts as cell signaling molecule and its regulatory phenomenon were responsible to affect seed germination, tuberization, senescence, root growth, reproductive growth and fruit ripening in plants.

Chapter III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2016 to March 2017 to study the mitigation of salt stress in tomato by using exogenous salicylic acid and Jasmonic acid. This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, transplanting of seedling, intercultural operations, harvesting, data collection and statistical analysis. The materials and methods those were used and followed for conducting the experiment have been presented under the following headings.

3.1 Experimental site

This study was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh. The location of the experimental site is 23°74′N latitude and 90°35′E longitude at an altitude of 8.6 meter above the sea level.

3.2 Characteristics of soil that used in pot

The soil of the experimental area belongs to the Modhupur Tract (Anon., 1989) under AEZ No. 28. The characteristics of the soil under the experiment were analyzed in the Laboratory of Soil science Department, SAU, Dhaka and details of soil characteristics have been presented in Appendix I. The soil of the pot was medium high in nature with adequate irrigation facilities and remained fallow during the previous season. The soil texture of the experiment was sandy loam.

3.3 Climatic condition of the experimental site

The experimental site was situated under the subtropical monsoon climatic zone. This zone having heavy rainfall during Kharif season (April to September) and during Rabi season (rest month of the year) having limited rainfall. Enough sunshine and moderately low temperature prevail during Rabi season (October to March), 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 November 2016 to March 2017 have been presented in Appendix II.

3.4 Planting materials

Seedlings of 30 days of BARI Tomato-15 were used in the study. Tomato seedlings were grown at the nursery of Horticulture Farm in Sher-e-Bangla Agricultural University. BARI Tomato-15 is a high yielding winter variety of Tomato, which was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. It was released in 2009. It’s total duration is about 100-110 days after transplanting. The experiment was conducted in a two side open plastic shade house.

3.5 Treatments of the experiment

The experiment consisted of two factors:

- Factor A: salinity level (4 levels of salt concentration)
    1. S_0 = 0 dSm^{-1}
    2. S_1 = 4 dSm^{-1}
    3. S_2 = 7 dSm^{-1}
    4. S_3 = 10 dSm^{-1}

- Factor B:Mitigation level
    1. M_0 = 0 (Control)
    2. M_1 = 1 mM of Salicylic Acid
    3. M_2 = 10 µm of Jasmonic Acid
    4. M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

There were total 16 (4×4) Treatment Combinations, such as:
S_0M_0, S_0M_1, S_0M_2, S_0M_3, S_1M_0, S_1M_1, S_1M_2, S_1M_3, S_2M_0, S_2M_1, S_2M_2, S_2M_3, S_3M_0, S_3M_1, S_3M_2, S_3M_3.

3.6 Experimental design

The two factor experiment was laid out in Randomized Completely Block Design (RCBD) with four replications. There were 64 pots all together. The total area was 16.5 m × 6.4 m. The experimental area was divided into four equal blocks. Each block was divided into 16 pots where 16 treatment combinations were allotted at random. The distance between two blocks and two pots were 1.0 m and 0.5 m respectively.

3.7 Pot preparation

A ratio of 1:3 well rotten cow dung and soil were mixed. 64 pots were filled 15 days before transplanting with silt loam soils. Those pots were filled on 7 November 2016. Weeds and stubbles were completely removed from the soil and brought into desirable fine tilth by hand mixing. The soil was treated with insecticides (Cinocarb 3G @ 4kg/ha) at the time of final pot preparation to protects young plants from the attack of soil inhibiting insects such as cutworms and mole cricket.

3.8 Raising the Seedling

Tomato Seedlings were raised in one seedbed on a relatively high land at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the seedbed was 3m × 1 m. The soil was well prepared with spade and made into loose friable and dried mass to obtain fine tilth. Weeding and removing of stubbles were done when necessary and 5 kg well rotten cowdung was applied during seedbed preparation. The seeds were sown in the seedbed at 22 october, 2016 to get 30 days old seedlings. Germination occurs within 3 days after seeds sowing. After sowing, seeds were covered with light soil to a depth of about 0.6 cm. Sevin was applied as precautionary measure against ants and worm around the seedbed. Seedlings emergence was visible within 5 to 6 days after sowing. Necessary shading by banana leaves was provided over the seedbed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were provided when necessary and required and no chemical fertilizer was used in this seedbed.

3.9 Uprooting and Transplanting the Seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 22 November 2016 , each pot containing only one seedling. The seedbed was irrigated before uprooting from the seedbed, which helps to minimize damage to roots by ensuring maximum retention of roots. The seedlings were also irrigated after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedlings from scorching sunlight.

3.10 Application of the treatments

Tomato plants were treated with 0, 4, 7 and 10 dSm^{-1} salinity levels which were maintained by adding 0, 25.6, 51.2, 76.8 g of sodium chloride (NaCl) respectively per pot containing 10 kg of soil. These total amounts of salts were applied through irrigation water in three splits at 35, 55 and 75 days after transplanting. As a salt stress mitigation agent, salicylic acid and jasmonic acid was used both as singly or in combination at 1 mM of salicylic acid, 10 µm of jasmonic acid and combined application of 10 µm of jasmonic acid and 1 mM of salicylic acid concentration with irrigation water at 35, 55 and 75 DAT.

3.11 Intercultural operations:

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.

3.11.1 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.

3.11.2 Staking

When the plants were well established, staking was given to each plant by bamboo sticks. This is done to give support to keep the plant erect.

3.11.3 Weeding

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

3.11.4 Earthing-up

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

3.11.5 Plant Protection Measures

Spraying Diathane M-45 fortnightly @2 gm per L of water at the early vegetative stage was done as precautionary measure against disease attack of tomato during foggy weather . Ridomil gold was also applied @ 2 gm per L of water against blight disease of tomato. Blossom end rot (Ca deficiency) , a physiological disorder, was observed due to extremely stress condition. So Ca is also used as $CaNO_3$ @ 2 gm per L of water.

3.11.6. Harvesting Fruits were harvested at 3 days interval during early ripe stage when they developed slightly red color. Harvesting was started from 10 february 2017 and was continued up to 1st week of march 2017.

3.12. Data recording Experimental data were recorded from 35 days after transplanting and continued until harvest. The following data were recorded during the experimental period.

- **Morphological characters**

  01. Plant height (at different days after transplanting)

  02. Number of Leaf per plant (at different days after transplanting)

  03. Number branches per plant (at different days after transplanting)

  04. Leaf Area per plant (cm^2)

- **Physiological and Yield contributing characters**

  05. Chlorophyll content -SPAD reading

  06. Days required to 1st flowering

  07. No. of flower clusters per plant

  08. No. of flowers per cluster per plant

  09. No. of fruits per plant

  10. Volume of fruits

  11. Shelf life of tomato fruits

  12. Vit-C content of fruits

  13. P^H of fruits

  14. Total soluble solid content

  15. Dry matter content of fruits

- **Yield related characters**

  16. Length of fruit

  17. Diameter of fruit

  18. Weight of individual fruit

  19. Total Fruit Weight per plant (kg)

  20. Yield (t/ha)

Detailed Procedures of Data Recording

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

- Morphological characters

3.12.1 Plant height (cm)

Plant height was measured at 35, 55 and 75 DAT. The height of the plant was determined in centimeter by measuring the distance from the soil surface to the tip of the highest leaf.

3.12.2 Number of branches per plant

The total number of branches per plant was counted from each plant at 35, 55 and 75 DAT. There is no option to make average value from collected value due to only one plant was maintained per pot.

3.12.3 Number of Leaves per plant

Leaf number was counted at 35, 55 and 75 DAT. The number of leaves per plant was counted from each plant.

3.12.4 Leaf Area per plant (cm^2)

Leaf area was measured immediately after removal of leaves from plants to avoid rolling and shrinkage using CL-202 Leaf Area Meter, (USA). Mature leaves were taken measured at flowering stage (at 55 DAT) and were expressed in cm^2.

- Physiological and yield contributing characters

3.12.5 Chlorophyll content-SPAD reading

Leaf chlorophyll content was measured by using a hand-held chlorophyll content SPAD meter (CCM-200, Opti-Science, USA). For each evaluation, five leaves from five different positions of per plant was selected, then their SPAD value was recorded (at 55 DAT). The average of the value from each plant was used for analysis.

3.12.6 Days required to 1st flowering

Total number of days from the date of transplanting to the date of visible flower initiation was recorded.

3.12.7 Number of flower clusters per plant

The number of flower clusters produced per plant was counted and recorded in each plant.

3.12.8 Number of flowers per cluster per plant

The number of flowers per plant was counted and recorded.

3.12.9 Number of fruits per plant

The number of fruits per plant was counted from the plant.

3.12.10 Volume of fruits

The fruit Volume of tomato was measured by water displacement. Pure water was employed in a measurement container to determine the actual volume of tomato fruits. The measurement container of 100gm was taken and 50gm of water was poured to it. The tomato fruit was put into the container. The level of water rises high as volume of fruit was added to it. Increased volume was deducted from the previous volume. By repeating the same procedure, volume of fruits from each plant was collected.

3.12.11 Shelf life of tomato fruits

Shelf life of tomato fruits was measured by storing half ripe tomatoes in a shaded, cool place, and observed till it rotten.

3.12.12 Vitamin C content of tomato fruits

Vitamin-C was measured by using Oxidation Reduction Titration Method. Single fruit was taken and exatract of tomato was filtrated by Whatman No.1 filter paper. After that, It was mixed with 3% metaphosphoric acid solution. The titration was conducted in presence of glacial acetic acid and metaphosphoric acid to inhibit aerobic oxidation with dye solution (2, 6-dichlorophenol indophenol). The solution was titrated with dye. The observations mean will give, the amount of dye required to oxidize definite amount of L-ascorbic acid solution of unknown concentration, using L-ascorbic acid as known sample. It was measured in Biochemistry Lab of Sher-e-Bangla Agriculture University, Dhaka.

3.12.13 pH of tomato fruits

Fully ripened fruits were collected from each of the treatment and blended it in liquid form. All the samples were taken in clean and transparent plastic pots. Electric P^H meter (model H 12211 P^H/OPR meter of Hanna Company) was adjusted in buffer solution of P^H 7.0; later on again it was adjusted in buffer solution containing P^H 4.0. Finally, Electric P^H meter was inserted in first sample and data was recorded. The same procedure was repeated to measure P^H of all other samples.

3.12.14 Total soluble solid content

Total soluble solid contents were measured by using brix meter. This is measured juice of ripe tomato.

3.12.15 Dry matter content of fruit

After harvesting, randomly selected 100 g fruit sample from each treatment combination were collected and sliced into very thin pieces and dried. Then those were put into envelop and placed in oven maintaining at 70° C for 72 hours. The sample was then transferred into desiccators and allowed to cool down at room temperature. The final weight of the sample was taken in gram.

The dry matter contents of fruit were computed by simple calculation from the weight recorded by the following formula:

$$\text{Dry matter contents of fruit} = \frac{\text{Dry weight of fruits (gm)}}{\text{Fresh weight of fruits (gm)}} \times 100$$

- yield related characters:

3.12.16 Length of fruit (cm)

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

3.12.17 Diameter of fruit (cm)

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

3.12.18 Weight of individual fruit

Among the total number of fruits during the period from first to final harvest, fruit was considered for determining the individual fruit weight by the following formula:

$$\text{Weight of individual fruit (gm)} = \frac{\text{Total weight of fruits (gm)}}{\text{Total number of fruits}}$$

3.12.19 Fruit weight per plant (kg)

Fruit weight of tomato per plant was calculated from the whole fruit per plant and was expressed in kilogram (kg).

3.12.20 Yield (t\ha)

Yield per hectare of tomato fruits was calculated by converting the weight of plant yield into hectare on the basis of total plant population of tomato per hectare and expressed in ton.

3.13 Statistical analysis The data obtained from different parameters were statistically analyzed following the analysis of variance (ANOVA) technique by using MSTAT-C computer package program. The significance of the difference among the treatment combinations of means was estimated by least significant difference at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER VI

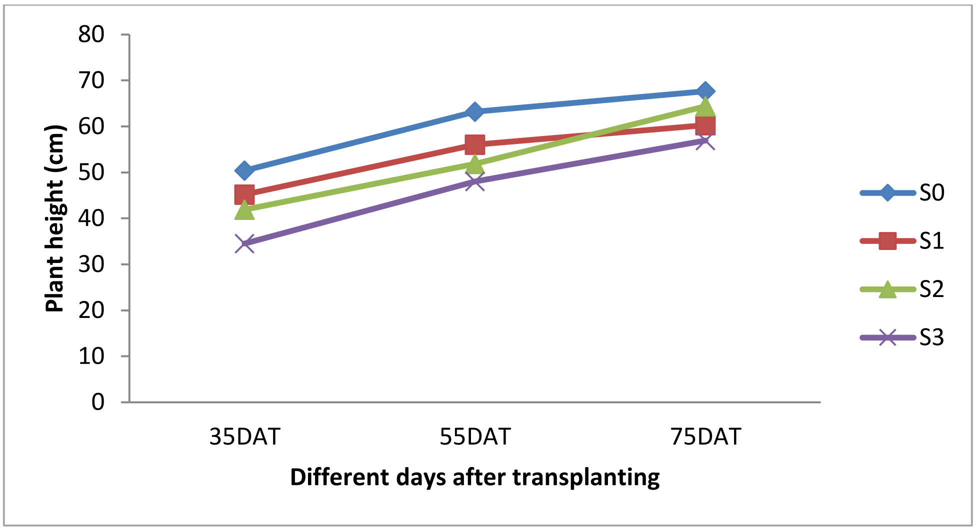
RESULTS AND DISCUSSION

This experiment was aimed to study the effect of salt stress and mitigation of salt stress in tomato with the application of salicylic acid and Jasmonic acid. Different morphological, physiological, yield and yield contributing characters were analyzed and the analysis of variance (ANOVA) of that data is given in the appendices. The results of the study were presented in both tables and figures; and discussed below:

1. Plant height:

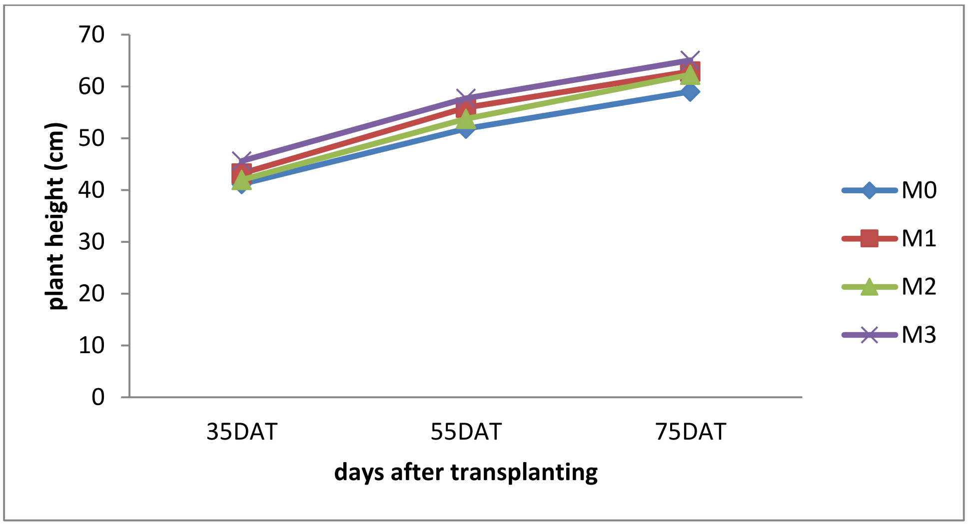
Naturally plant height increased with the increasing age, but due to salinity decreased gradually in tomato. Data shows that plant height of tomato was reduced significantly at different DAT with the increase of salinity. Plant height of tomato varied significantly for different levels of salt stress at 35, 55 and 75 days after transplanting (DAT) (Appendix III). Figure.1 revealed that, at 35, 55 and 75 DAT, the height of tomato plant was recorded highest (50.41 cm, 63.19 cm, 67.63 cm) from S_0, followed by S_1 (45.14 cm, 56.06 cm, 60.25 cm) and S_2 (41.91 cm, 51.88 cm, 64.38 cm) respectively. The lowest value was observed from S_3 (34.53 cm, 48.03 cm, 56.94 cm) at 35, 55 and 75 DAT respectively. Shalaby (2015) have reported the same i.e morphological traits like plant height reduced due to increasing salinity. Jamal *et al.,* (2014), Siddiky *et al.* (2012) and Ahmet et al. (2009) have reported the same.

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on height of tomato plant at 35, 55 and 75 (Appendix III). Figure.2 revealed that, at 35, 55 and 75 DAT, the height of tomato plant was recorded highest (45.63 cm, 57.69 cm, 65.06 cm) from M_3 , followed by M_1 (43.22 cm, 55.88 cm, 62.88 cm) and M_2 (41.98 cm, 53.75 cm, 62.25 cm) respectively. The lowest value was observed from M_0 (41.15 cm, 51.84 cm, 59.01 cm) at 35, 55 and 75 DAT respectively. Combination of SA and JA improves vegetative growth, states alireza (2015), Mohsen Kazemi *et al.* (2014).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 1. Effect of salinity levels on plant height (cm) at different DAT



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 2. Effect of mitigation levels on plant height (cm) at different DAT

Combined effect of salinity and mitigation agent showed different significant variation on height of tomato plant at 35, 55 and 75 (Appendix III). From table 1, it showed that highest result was recorded from S_0M_3 (52.75 cm, 71.00 cm, 71.50 cm) at 35, 55 and 75 DAT respectively. Whereas the lowest value was observed from S_3M_0 (30.98 cm, 44.88 cm, 51.28 cm) at 35, 55 and 75 DAT respectively.

Table No. 01. Combined effect of salinity and salicylic acid with jasmonic acid as mitigation agent on plant height (cm) at different days after transplanting (DAT).

Treatment	**Plant height at different DAT**		
	30 DAT	50 DAT	70 DAT
S_0M_0	48.50 c	57.50 cd	65.25 c
S_0M_1	50.38 b	65.75 b	67.00 b
S_0M_2	50.00 b	58.50 c	66.75 b
S_0M_3	52.75 a	71.00 a	71.50 a
S_1M_0	44.25 f	54.75 e	58.50 gh
S_1M_1	45.50 d	56.50 d	60.50 e
S_1M_2	45.00 e	56.25 d	59.50 f
S_1M_3	45.83 d	56.75 d	62.50 d
S_2M_0	40.88 i	50.25 h	61.00 e
S_2M_1	42.00 h	52.25 fg	65.00 c
S_2M_2	41.75 h	51.75 g	64.75 c
S_2M_3	43.00 g	53.25 f	66.75 b
S_3M_0	30.98 k	44.88 j	51.28 i
S_3M_1	35.00 j	49.00 hi	59.00 fg
S_3M_2	31.17 k	48.50 i	58.00 h
S_3M_3	40.95 i	49.74 hi	59.50 f
LSD value$_{(0.05)}$	0.46	1.32	0.55
CV %	1.53	3.40	1.25

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

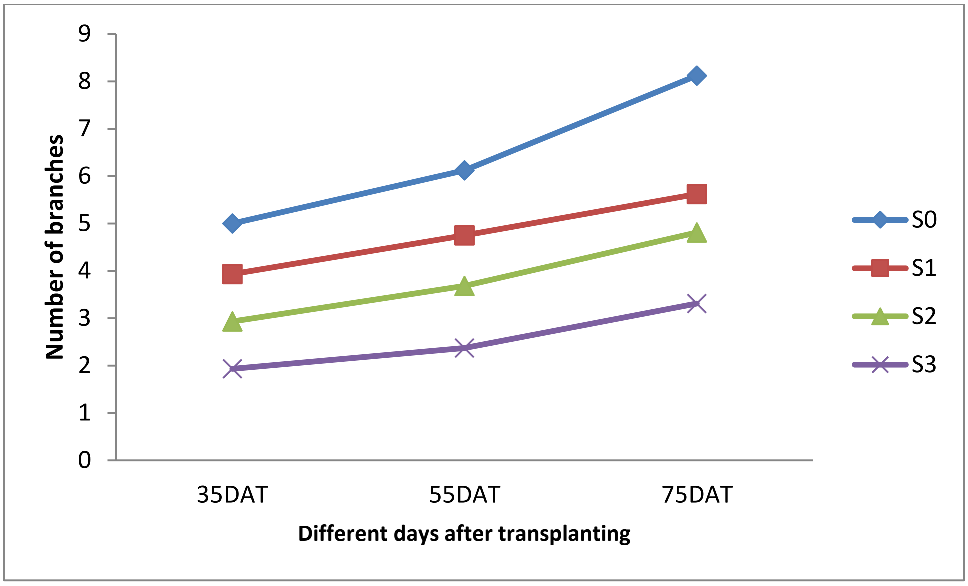
S_0 = 0 dSm^{-1},	M_0 = 0 (Control),
S_1 = 4 dSm^{-1},	M_1 = 1 mM of Salicylic Acid,
S_2 = 7 dSm^{-1},	M_2 = 10 µm of Jasmonic Acid,
S_3 = 10 dSm^{-1}	M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

2. Number of branches per plant

Number of branches of tomato varied significantly for different levels of salt stress at 35, 55 and 75 days after transplanting (DAT) (Appendix IV). Figure.3 revealed that, the total number of branches of tomato plant was recorded highest (5.000 cm, 6.125 cm, 8.125 cm) from S_0 as control at 35, 55 and 75 DAT respectively; followed by S_1 (3.938 cm, 4.750 cm, 5.625 cm) and S_2 (2.938 cm, 3.688 cm, 4.813 cm) respectively. On the contrary, the lowest value was observed from S_3 (1.938 cm, 2.375 cm, 3.313 cm) at 35, 55 and 75 DAT respectively. The result was consistant with Abdul Qados (2011) and Ahmet *et al.* (2009).

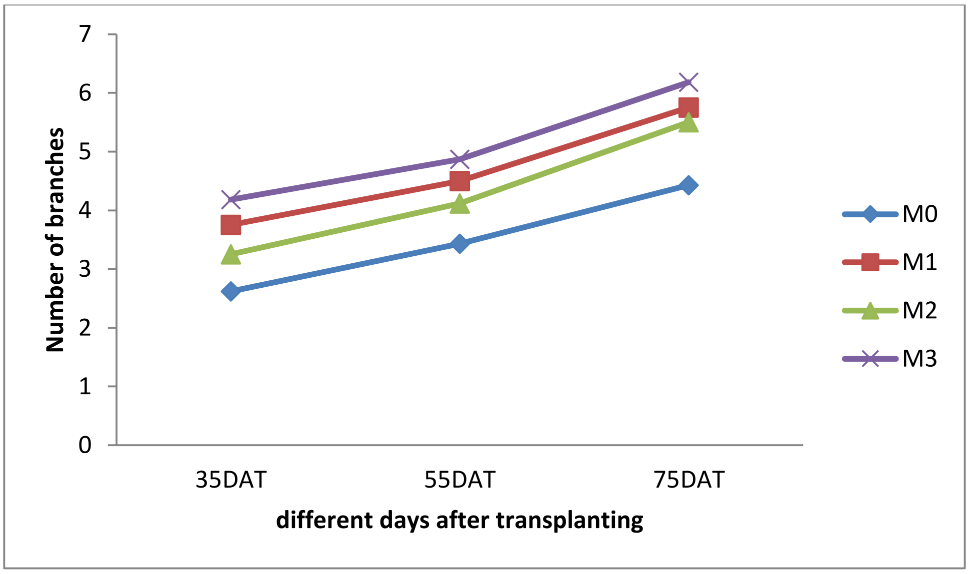
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on total Number of branches of tomato plant at 35, 55 and 75 days after transplanting (DAT) (Appendix IV). Figure.4 revealed that, at 35, 55 and 75 DAT, total number of branches of tomato plant was recorded highest (4.188 cm, 4.875 cm, 6.188 cm) from M_3 ; followed by M_1 (3.750 cm, 4.500 cm, 5.750 cm) and M_2 (3.250 cm, 4.125 cm, 5.500 cm) respectively, which were statistically similar to each other. On the contrary, the lowest value was observed from M_0 (2.625 cm, 3.438 cm, 4.438 cm) at 35, 55 and 75 DAT respectively. Similar result was found from Mohsen Kazemi *et al.* (2014)

Combined effect of salinity and mitigation agent showed different significant variation on total number of branches of tomato plant at 35, 55 and 75 (Appendix IV). Table 2 showed that highest result was recorded from S_0M_3 (5.750 cm, 6.750 cm, 8.750 cm) at 35, 55 and 75 DAT respectively. Whereas the lowest value was observed from S_3M_0 (1.250 cm, 1.500 cm, 2.250 cm) at 35, 55 and 75 DAT respectively.



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 3. Effect of salinity levels on number of branches at different DAT



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 4. Effect of mitigation levels on number of branches at different DAT

Table No. 02. Combined effect of Salinity and Salicylic acid with Jasmonic acid as mitigation agent on number of branches at different days after transplanting (DAT)

Treatment	Number of branches at different DAT		
	30 DAT	50 DAT	70 DAT
S_0M_0	4.00 c	5.25 b	7.00 b
S_0M_1	5.50 a	6.25 a	8.50 a
S_0M_2	4.75 b	6.25 a	8.25 a
S_0M_3	5.75 a	6.75 a	8.75 a
S_1M_0	3.00 ef	4.00 cd	4.50 fg
S_1M_1	4.00 c	5.25 b	6.00 cd
S_1M_2	4.00 c	4.50 c	5.50 de
S_1M_3	4.75 b	5.25 b	6.50 bc
S_2M_0	2.25 gh	3.00 ef	4.00 gh
S_2M_1	3.25 de	3.75 d	5.00 ef
S_2M_2	2.50 fg	3.50 de	5.00 ef
S_2M_3	3.75 cd	4.50 c	5.25 e
S_3M_0	1.25 i	1.50 h	2.25 j
S_3M_1	2.25 gh	2.75 fg	3.50 hi
S_3M_2	1.75 hi	2.25 g	3.25 i
S_3M_3	2.50 fg	3.00 ef	4.25 g
LSD value$_{(0.05)}$	0.56	0.53	0.60
CV %	23.08	17.85	15.64

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M_0 = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

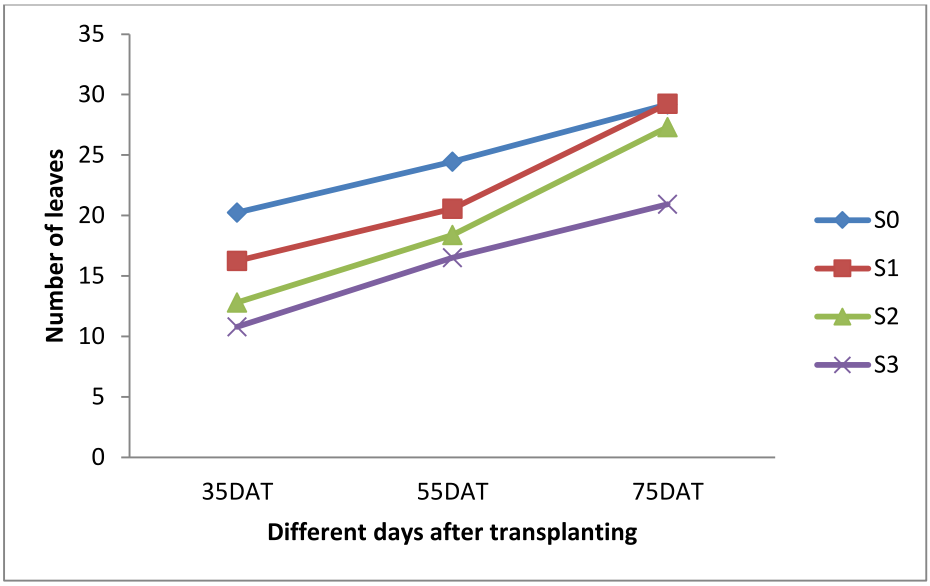
S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

3. Number of leaves per plant

The total number of leaves per tomato plant varied significantly for different levels of salt stress at 35, 55 and 75 days after transplanting (DAT) (Appendix V). Figure.5 revealed that, the total number of leaves per tomato plant was recorded highest (20.25 cm, 24.44 cm) from S_0 as control at 35 and 55 respectively; followed by (16.25 cm and 20.56 cm) and S_2 (12.81 cm and 18.38 cm) respectively. At 75 DAT, the maximum number of leaves per plant was recorded 29.19 cm from S_0 which was statistically similar to 29.19 cm (S_1); followed by 29.25 cm (S_2). On the contrary, the lowest value was observed from S_3 (10.79 cm, 16.50 cm, 20.94 cm) at 35, 55 and 75 DAT respectively. Similar result was found from Jogendra *et al.,* (2011), Ahmet *et al.*, (2009) and Sixto *et al.* (2005).

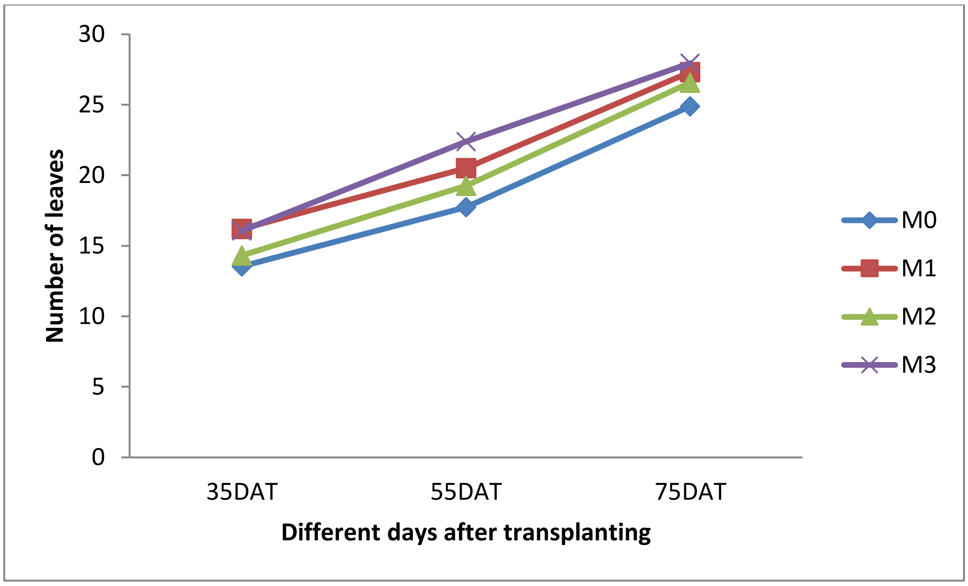
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on the total number of leaves per tomato plant at 35, 55 and 75 days after transplanting (DAT) (Appendix V). Figure.6 revealed that, at 35 DAT, the total number of leaves per tomato plant was recorded highest (16.19 cm) from M_2 which was statistically similar to (16.06 cm) from M_3; followed by (14.31 cm) from M_2. The lowest value (13.54 cm) was observed from M_0. Figure also shows that the highest number of leaves per tomato plant was recorded (22.38 cm and 27.94 cm) from M_3 at 55 and 75 DAT respectively; followed by (20.50 cm and 27.31 cm) from M_1 and (19.25 cm and 26.56 cm) from M_2. The lowest value was observed from M_0 (17.75 cm and 24.88 cm) at 55 and 75 DAT respectively. Eman *et al.* (2018) states the same.

Combined effect of salinity and mitigation agent showed different significant variation on the total number of leaves per tomato plant at 35, 55 and 75 (Appendix V). Table 3 shows that highest result was recorded from S_0M_3 (22.25 cm, 28.00 cm, 30.75 cm) at 35, 55 and 75 DAT respectively. Whereas the lowest value was observed from S_3M_0 (8.675 cm, 14.00 cm, 19.50 cm) at 35, 55 and 75 DAT respectively.



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no.5.Effect of salinity levels on number of leaves per plant at different DAT



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 6. Effect of mitigation levels on number of leaves per plant at different DAT

Table No. 03. Combined effect of Salinity and Salicylic acid with Jasmonic acid as mitigation agent on number of leaves at different days after transplanting (DAT)

Treatment	Number of leaves at different DAT		
	30 DAT	50 DAT	70 DAT
S_0M_0	18.25 b	22.00 d	25.50 e
S_0M_1	22.25 a	24.75 b	30.50 a
S_0M_2	18.25 b	23.00 c	30.00 ab
S_0M_3	22.25 a	28.00 a	30.75 a
S_1M_0	15.25 cd	19.00 hi	28.25 d
S_1M_1	16.75 bc	20.75 e	29.25 bc
S_1M_2	16.25 bc	20.25 ef	29.50 bc
S_1M_3	16.75 bc	22.25 d	30.00 ab
S_2M_0	12.00 e	16.00 k	26.25 e
S_2M_1	13.00 e	19.50 gh	28.00 d
S_2M_2	13.25 de	18.50 i	26.25 e
S_2M_3	13.00 e	19.50 gh	28.75 cd
S_3M_0	8.675 f	14.00 m	19.50 h
S_3M_1	12.75 e	17.00 j	21.50 f
S_3M_2	9.500 f	15.25 l	20.50 g
S_3M_3	12.25 e	19.75 fg	22.25 f
LSD value$_{(0.05)}$	2.03	0.72	0.80
CV %	18.97	5.08	4.21

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M_0 = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

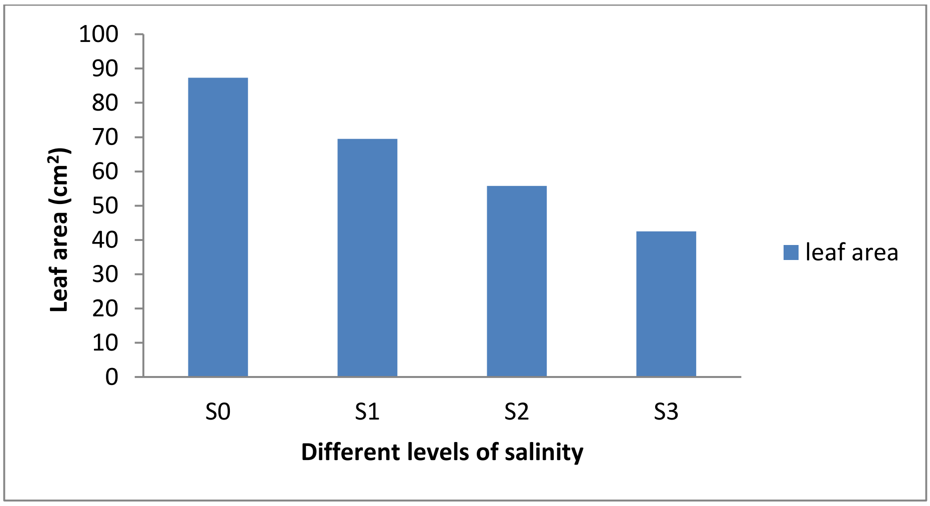
S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

4. Leaf area (cm^2)

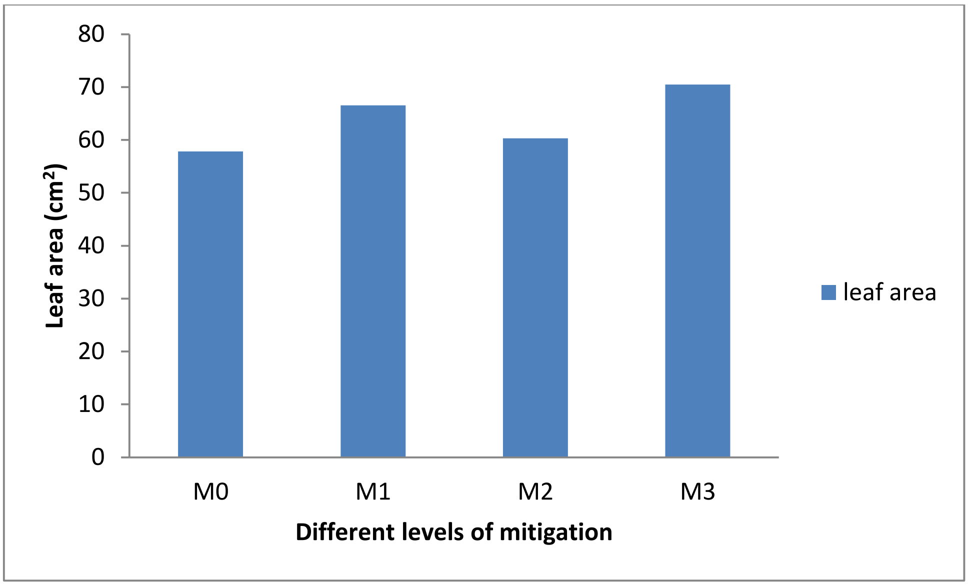
The leaf area of tomato varied significantly for different levels of salt stress(Appendix VI). Figure.7 reveals that, leaf area of tomato was recorded highest (87.36 cm^2) from S_0 as control at 55 DAT; followed by S_1 (69.52 cm^2) and S_2 (55.76 cm^2) respectively. On the contrary, the lowest value was observed from S_3 42.49 at 55 DAT. Azami *et al.* (2010) also showed that total leaf area of tomato (*Lycopersicon esculentum* Mill.) decreased with increasing salinity . Jamal *et al.*, (2014), Siddiky *et al.*, (2012) and Marco et al. (2011) have reported the same.

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on leaf area of tomato at 55 DAT (Appendix VI). Figure.8 reveals that, at 55 DAT, leaf area of tomato was recorded highest (70.49 cm^2) from M_3 at 55 DAT; followed by M_1 (66.53 cm^2) and M_2 (60.3 cm^2) respectively. On the contrary, the lowest value was observed from M_0 (57.80 cm^2) at 55 DAT. Eman et al. 2018 states that leaf number and area increases due to combined application of SA and JA.



$S_0 = 0$ dSm^{-1}, $S_1 = 4$ dSm^{-1}, $S_2 = 7$ dSm^{-1}, $S_3 = 10$ dSm^{-1}

Fig no. 7. Effect of salinity levels on leaf area (cm^2) of tomato plant



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 8. Effect of mitigation levels on leaf area (cm^2) of tomato plant

Combined effect of salinity and mitigation agent showed different significant variation on leaf area of tomato (Appendix VI). Table 4 shows that highest result was recorded from S_0M_3 (100.3 cm^2) at 55 DAT, Whereas the lowest value was observed from S_3M_0 (35.91 cm^2) at 55 DAT respectively.

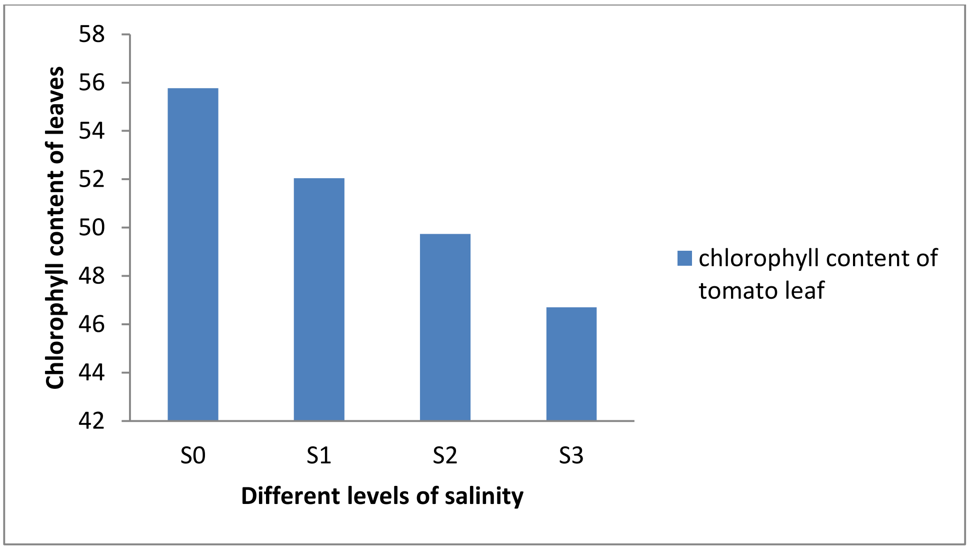
5. **Leaf chlorophyll content-SPAD reading**

The Leaf chlorophyll content varied significantly for different levels of salt stress(Appendix VI). Figure.9 reveals that, leaf chlorophyll content was recorded highest (55.77 SPAD units) from S_0 as control at 55 DAT; followed by S_1 (52.04 SPAD units) and S_2 (49.74 SPAD units) respectively. On the contrary, the lowest value was observed from S_3 (46.70 SPAD units) at 55 DAT. The results were consistent with Jamal et al., (2014), Nawaz *et al.*, (2010) and Taffouo *et al.* (2010).

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on leaf chlorophyll content at 55 DAT (Appendix VI). Figure.10 reveals that, leaf chlorophyll content was recorded highest (52.08 SPAD units) from M_3 at 55

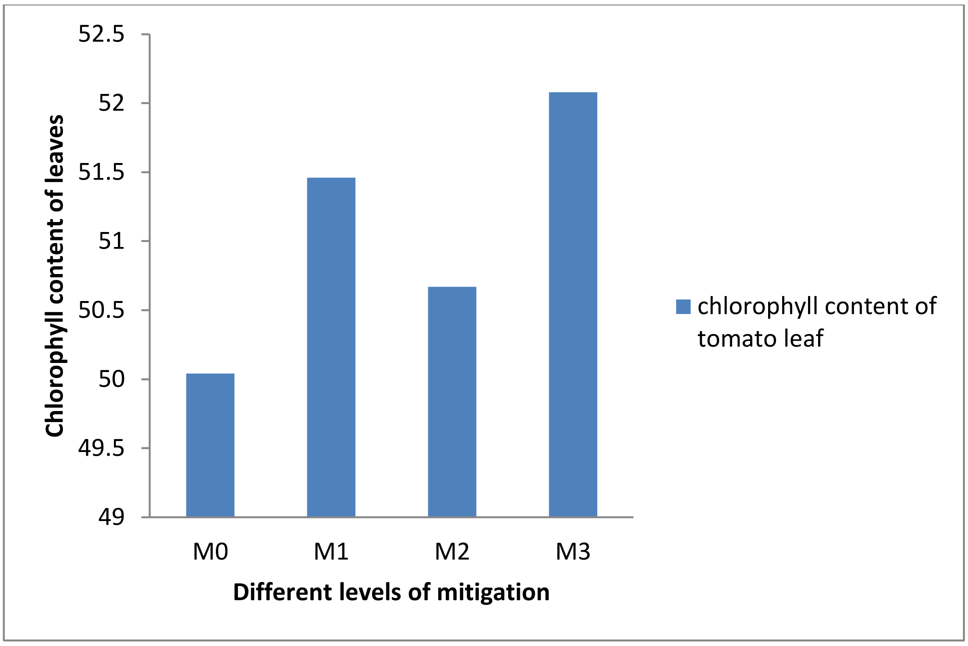
DAT; followed by M_1(51.46 SPAD units) and M_2 (50.67 SPAD units) respectively. On the contrary, the lowest value was observed from M_0 (50.04 SPAD units) at 55 DAT. Similar result was found from Parvaiz *et al.* (2018)

Combined effect of salinity and mitigation agent showed different significant variation on leaf chlorophyll content (Appendix VI). Table 4 shows that highest result was recorded from S_0M_3 (57.38 SPAD units) at 55 DAT. Whereas the lowest value was observed from S_3M_0 (45.10 SPAD units) at 55 DAT respectively.



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 9 . Effect of salinity levels on chlorophyll content -SPAD reading of tomato leaves



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no.10. Effect of mitigation levels of chlorophyll content -SPAD reading of tomato leaves.

Table No. 04. Combined effect of Salinity and Salicylic acid with Jasmonic acid as mitigation agent on leaf area(cm^2) and chlorophyll content of tomato leaf.

Treatment	Parameters	
	Leaf area (cm^2)	chlorophyll content of tomato leaf
S_0M_0	75.66 d	54.31 c
S_0M_1	90.10 b	56.63 b
S_0M_2	83.34 c	54.75 c
S_0M_3	100.3 a	57.38 a
S_1M_0	65.89 h	51.85 d
S_1M_1	71.69 f	52.06 d
S_1M_2	66.50 g	51.88 d
S_1M_3	74.02 e	52.38 d
S_2M_0	53.75 l	48.89 g
S_2M_1	55.88 j	49.76 f
S_2M_2	54.50 k	49.60 f
S_2M_3	58.91 i	50.70 e
S_3M_0	35.91 o	45.10 j
S_3M_1	48.45 m	47.40 h
S_3M_2	36.89 n	46.45 i
S_3M_3	48.70 m	47.85 h
LSD value$_{(0.05)}$	0.51	0.55
CV %	1.14	1.52

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M$_0$ = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

6. Days required to 1st flowering

Days required from transplanting to 1st flowering varied significantly for different levels of salt stress (Appendix VIII). Figure.11 reveals that, the maximum date required to flowering was recorded (29.94) from S_3 as control; followed by S_2 (26.94) and S_1 (26.19) both are statistically similar to each other. On the contrary, the lowest value was observed from S_0 (23.88). Murshed *et al.* (2014) reported that salinity delayed flowering.

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on Days required from transplanting to 1st flowering of tomato plant (Appendix VIII). Figure.12 reveals that, the maximum date required to flowering was recorded highest (28.06) from M_3; which are statistically similar to M_2 (27.75) and M_1 (27.31) respectively. On the contrary, the lowest value was observed from M_0 (23.81). Yoon *et al.* (2009) reported JA increases growth and yield related characters.

Combined effect of salinity and mitigation agent showed different significant variation on Days required from transplanting to 1st flowering of tomato plant (Appendix VIII). Table 5 shows that highest result was recorded from S_3M_3 (30.50).Whereas the lowest value was observed from S_0M_0 (18.75).

7. Number of flower clusters per plant

Number of flower clusters per tomato plant varied significantly for different levels of salt stress (Appendix VIII). Figure.13 reveals that, total number of flower clusters per tomato plant was recorded highest (72.59) from S_0; followed by S_1 (65.56) and S_2 (56.65) respectively. On the contrary, the lowest value was observed from S_3 (51.81). Agong et al. (2003) found that salt stress negatively affects yield contributing characters in tomato.

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on total number of flower clusters per tomato plant (Appendix VIII). Figure.14

reveals that, total number of flower clusters per tomato plant was recorded highest (62.71) from M_3; followed by M_1(62.14) and M_2 (61.19) respectively. On the contrary, the lowest value was observed from M_0 (60.55).

Combined effect of salinity and mitigation agent showed non-significant variation on total number of flower clusters per tomato plant. Table 5 shows that highest result was recorded from S_0M_3 (74.07), which was statistically similar to S_0M_1 (73.70). Whereas the lowest value was observed from S_3M_0 (50.88).

8. Number of flowers per cluster per plant

Number of flowers per cluster varied significantly for different levels of salt stress (Appendix VIII).. Figure.15 reveals that, total number of flowers per cluster per tomato plant was recorded highest (6.564) from S_0; followed by S_1 (6.275) and S_2 (6.019) where both were statistically similar to each other. On the contrary, the lowest value was observed from S_3 (4.963). similar results were found from Magan *et al.,* (2008), Agong *et al.* (2003)

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on total number of flowers per cluster per tomato plant (Appendix VIII).. Figure.16 reveals that, total number of flowers per cluster per tomato plant was recorded highest (6.408) from M_3; followed by M_1 (6.175) and M_2 (5.933). On the contrary, the lowest value was observed from M_0 (5.304).

Combined effect of salinity and mitigation agent showed different non-significant variation on total number of flowers per cluster per tomato plant(Appendix VIII).. Table 5 shows that highest result was recorded from S_0M_3 (7.008), which was statistically similar to S_0M_1 (6.975). Whereas the lowest value was observed from S_3M_0 (4.57), which was statistically similar to S_3M_2 (4.825).

Table no. 05. Effect of Salinity and salicylic acid and Jasmonic acid as mitigation agent on days required to flowering, flower cluster per plant, flower per cluster.

Treatment	Parameters		
	days to flowering	Flower cluster per plant	Flower per cluster
Salinity level (dS m-1)			
S_0	23.88 c	72.59 a	6.564 a
S_1	26.19 b	65.56 b	6.275 b
S_2	26.94 b	56.65 c	6.019 b
S_3	29.94 a	51.81 d	4.963 c
LSD value$_{(0.05)}$	0.8480	0.42	0.26
Different level of Salicylic acid (SA) and Jasmonic acid (JA)			
M_0	23.81 b	60.55 d	5.304 c
M_1	27.31 a	62.14 b	6.175 ab
M_2	27.75 a	61.19 c	5.933 b
M_3	28.06 a	62.71 a	6.408 a
LSD value$_{(0.05)}$	0.8480	0.42	0.26
CV%	4.45	0.98%	6.14%

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M_0 = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Table No. 06. Combined effect of Salinity and SA with JA as mitigation agent on days required to flowering, days to flowering, days to fruiting and days to harvest of tomato fruits.

Treatment	Parameters			
	days to flowering	Flower cluster per plant	Flowers per cluster	Total number of fruits
S_0M_0	18.75 i	71.00 c	5.575 g	56.67 c
S_0M_1	25.00 fg	73.70 a	6.975 a	57.13 b
S_0M_2	25.75 ef	71.57 b	6.700 bc	56.58 c
S_0M_3	26.00 e	74.07 a	7.008 a	58.47 a
S_1M_0	22.50 h	64.70 g	5.493 g	44.58 g
S_1M_1	27.00 d	65.85 e	6.500 cd	45.92 e
S_1M_2	27.50 cd	65.28 f	6.258 de	45.53 f
S_1M_3	27.75 cd	66.40 d	6.850 ab	46.55 d
S_2M_0	24.50 g	55.63 j	5.575 g	41.63 j
S_2M_1	27.50 cd	56.92 i	6.125 ef	43.03 i
S_2M_2	27.75 cd	56.50 i	5.950 f	42.78 i
S_2M_3	28.00 c	57.55 h	6.425 d	43.83 h
S_3M_0	29.50 b	50.88 n	4.575 i	39.50 l
S_3M_1	29.75 ab	52.10 l	5.100 h	40.55 k
S_3M_2	30.00 ab	51.42 m	4.825 i	38.63 m
S_3M_3	30.50 a	52.83 k	5.350 gh	41.58 j
LSD value$_{(0.05)}$	0.8480	0.4284	0.2607	0.3355
CV%	4.45	0.98	6.14	1.01

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M_0 = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

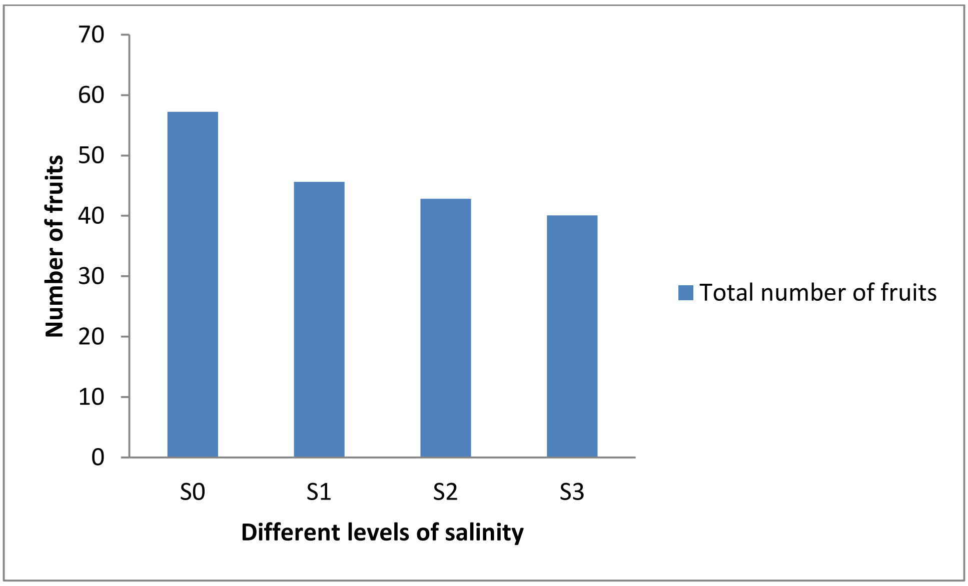
S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

9. Total Number of fruits per plant

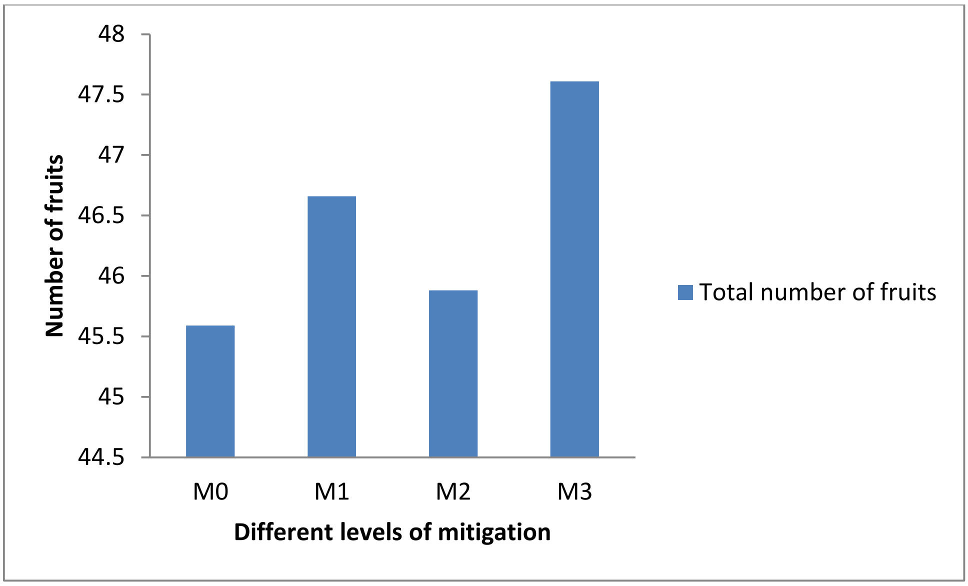
Total Number of fruits per tomato plant varied significantly for different levels of salt stress. Figure.11 reveals that, total number of fruits per tomato plant was recorded highest (57.21) from S_0; followed by S_1 (45.64) and S_2 (42.80) respectively. On the contrary, the lowest value was observed from S_3 (40.06). similar results were found from Jamal *et al.*, (2014), Sixto et al. (2005).

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on total number of fruits per tomato plant. Figure.12 reveals that, total number of fruits per tomato plant was recorded highest (47.61) from M_3; followed by M_1 (46.66). On the contrary, the lowest value was observed from M_0 (45.59), which are statistically similar to M_2 (45.88). similar result was found from Alireza Pazoki (2015).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 11. Effect of salinity levels on total number of fruits per plant



M_0 = 0 (Control), `M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no.12. Effect of mitigation levels on total number of fruits per plant

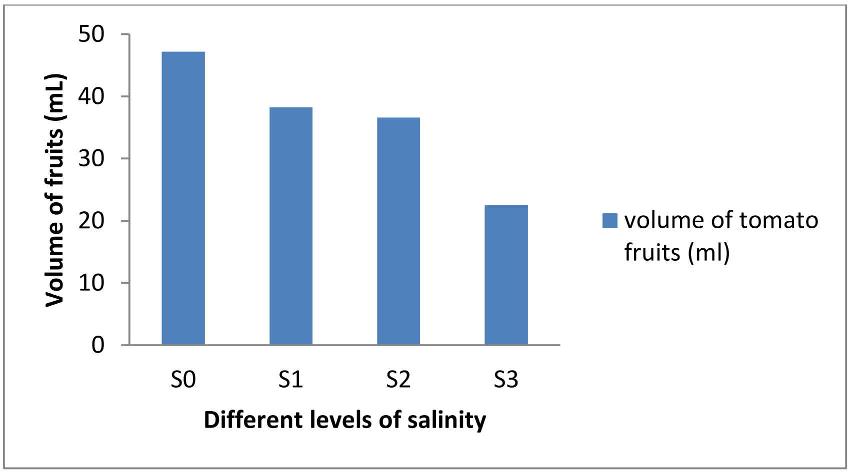
Combined effect of salinity and mitigation agent showed different significant variation on total number of fruits per tomato plant. Table 5 shows that highest result was recorded from S_0M_3 (58.47).Whereas the lowest value was observed from S_3M_0 (84.00),

10. Volume of fruits

Volume of fruits varied significantly for different levels of salt stress. Figure.13 reveals that, the volume of fruits was recorded highest (47.18) from S_0; followed by S_1 (38.26) and S_2 (36.59) respectively (Appendix VI). On the contrary, the lowest value was observed from S_3 (22.52). Hala 2014 reported that salt stress decreases fruit volume.

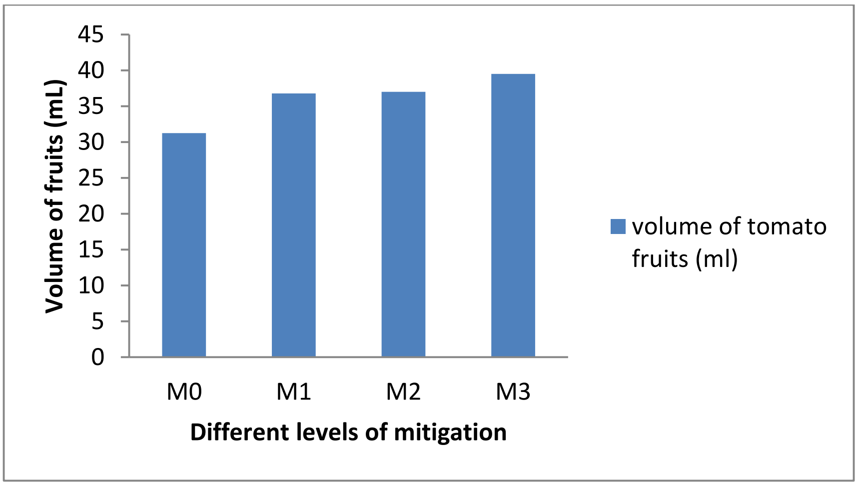
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on volume of fruits (Appendix VI). Figure.14 reveals that, the Volume of fruits was recorded highest (39.50) from M_3; followed by M_1 (36.79) and M_2 (37.02), where both were statistically similar to each other. On the contrary, the lowest value was observed from M_0 (31.25).

Combined effect of salinity and mitigation agent showed different significant variation on Volume of fruits (Appendix VI). Table 7 shows that highest result was recorded from S_0M_3 (51.35).Whereas the lowest value was observed from S_3M_0 (20.00).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 13. Effect of salinity levels on volume of tomato fruits (ml) of tomato plant



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

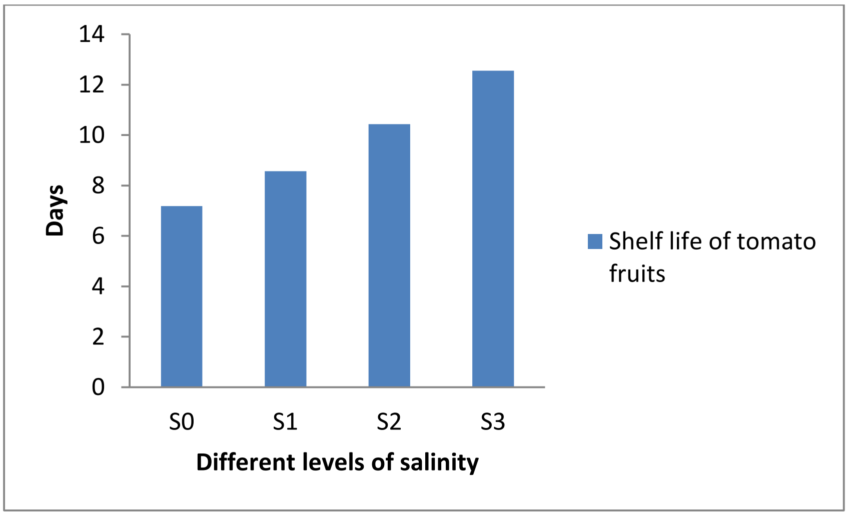
Fig no.14. Effect of mitigation levels on volume of tomato fruits (ml) of tomato plant.

11. Shelf life of tomato fruit

Shelf life of tomato fruits varied significantly for different levels of salt stress. Figure.15 reveals that, the shelf life of fruits was recorded highest (12.56 days) from S_3; followed by S_2 (10.44 days) and S_1(8.563 days) respectively (Appendix VI). On the contrary, the lowest value was observed from S_0 (7.188 days). Ruiz *et al*. (2015) reported that salt stress can be effective for increasing shelf life of tomato.

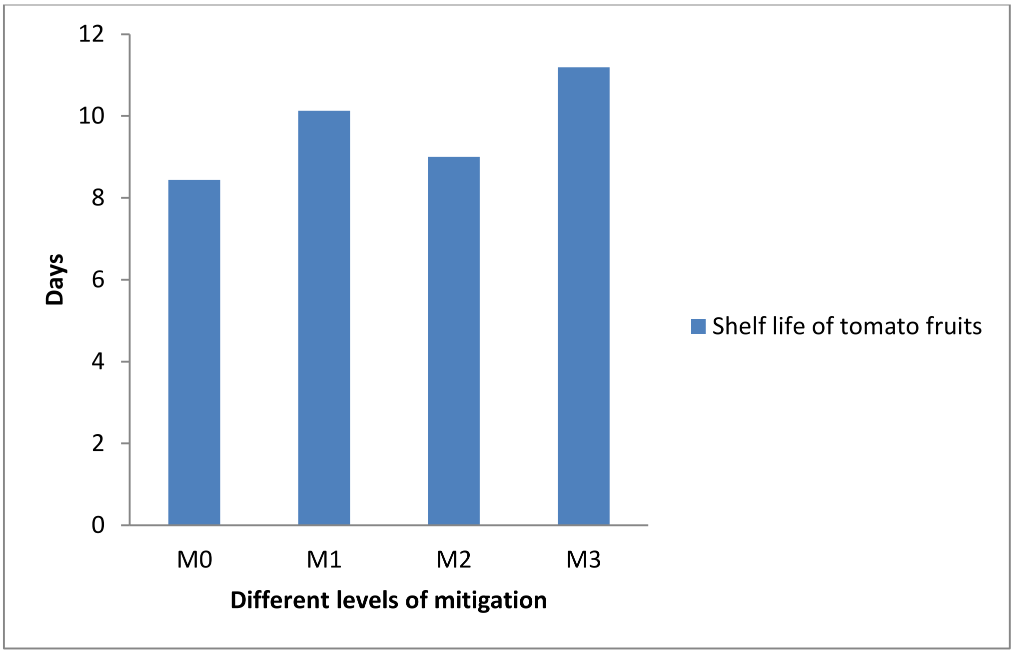
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on Shelf life of tomato fruits (Appendix VI). Figure.16 reveals that, shelf life of tomato fruits was recorded highest (11.19 days) from M_3; followed by M_1 (10.13 days) and M_2 (9.0 days). On the contrary, the lowest value was observed from M_0 (8.438 days).

Combined effect of salinity and mitigation agent showed different significant variation on Shelf life of tomato fruits (Appendix VI). Table 7 shows that highest result was recorded from S_3M_3 (14.25 days).Whereas the lowest value was observed from S_0M_0 (6 days) .



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 15. Effect of salinity levels on shelf life of tomato fruits



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 16. Effect of mitigation levels on shelf life of tomato fruit

Table No. 07. Combined effect of Salinity and SA with JA as mitigation agent on volume of tomato fruits (ml) And Shelf life of tomato leaf.

Treatment	Parameters	
	volume of tomato fruits (ml)	Shelf life of tomato fruits
S_0M_0	42.50 c	6.000 i
S_0M_1	47.38 b	7.500 h
S_0M_2	47.50 b	6.250 i
S_0M_3	51.35 a	9.000 f
S_1M_0	32.50 h	7.500 h
S_1M_1	39.22 f	9.000 f
S_1M_2	39.67 ef	8.000 g
S_1M_3	41.65 d	9.750 e
S_2M_0	30.00 i	9.000 f
S_2M_1	38.05 g	11.00 d
S_2M_2	38.30 g	10.00 e
S_2M_3	40.00 e	11.75 c
S_3M_0	20.00 l	11.25 d
S_3M_1	22.50 k	13.00 b
S_3M_2	22.60 k	11.75 c
S_3M_3	25.00 j	14.25 a
LSD value$_{(0.05)}$	0.4793	0.4819
CV %	1.86	6.99

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

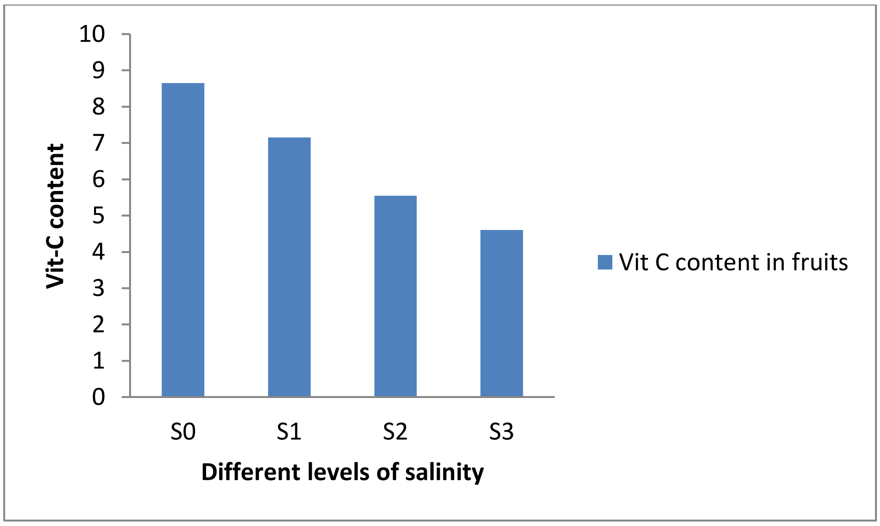
S_0 = 0 dSm^{-1},	M_0 = 0 (Control),
S_1 = 4 dSm^{-1},	M_1 = 1 mM of Salicylic Acid,
S_2 = 7 dSm^{-1},	M_2 = 10 µm of Jasmonic Acid,
S_3 = 10 dSm^{-1}	M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

12. Vitamin C content of fruits

Vit-C content of fruits varied significantly for different levels of salt stress (Appendix VII). Figure.17 reveals that, Vit-C content of fruits was recorded highest (8.650) from S_0; followed by S_1 (7.150) and S_2 (5.550) respectively. On the contrary, the lowest value was observed from S_3 (4.606). Fanasca et al. (2007) have reported the same.

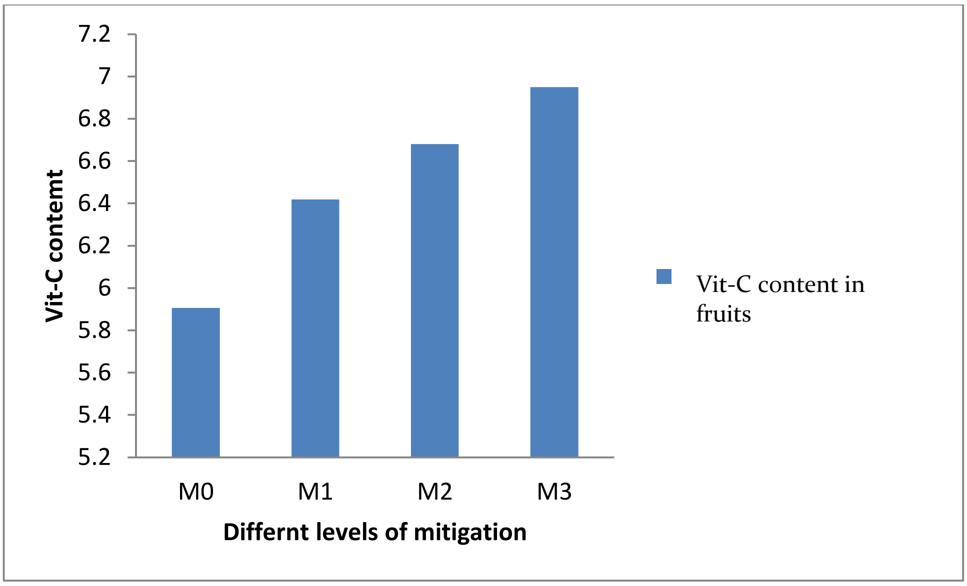
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on Shelf life of tomato fruits (Appendix VII). Figure.18 reveals that, Vit-C content of tomato fruits was recorded highest (6.950) from M_3; followed by M_2 (6.681) and M_1 (6.419). On the contrary, the lowest value was observed from M_0 (5.906).

Combined effect of salinity and mitigation agent showed different significant variation on Vit-C content of tomato fruits (Appendix VII). Table 8 shows that highest result was recorded from S_0M_3 (9.200).Whereas the lowest value was observed from S_3M_0 (3.825).



$S_0 = 0$ dSm^{-1}, $S_1 = 4$ dSm^{-1}, $S_2 = 7$ dSm^{-1}, $S_3 = 10$ dSm^{-1}

Fig no. 17. Effect of salinity level on Vit-C content in fruits of tomato



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

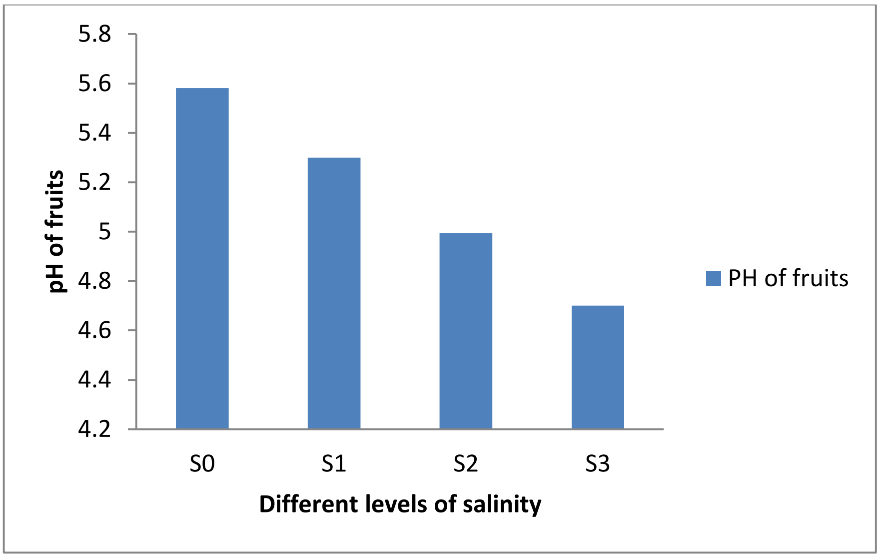
Fig no.18. Effect of mitigation level on Vit-C content in fruits of tomato.

13. P^H of fruits

P^H of tomato fruits varied significantly for different levels of salt stress (Appendix VII). Figure.19 reveals that, P^H of tomato fruits was recorded highest (5.581) from S_0; followed by S_2 (5.300) and S_1 (4.994) respectively. On the contrary, the lowest value was observed from S_3 (4.700). similar results was found from yosef (1982),

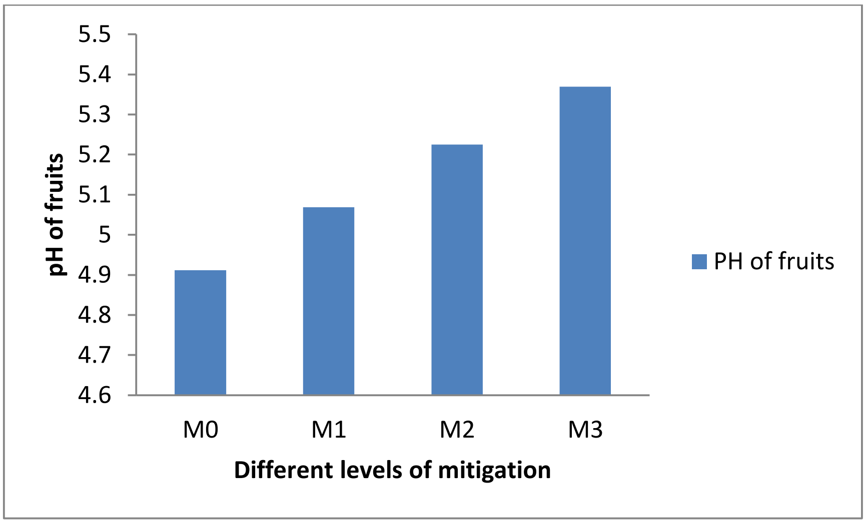
Salicylic acid and Jasmonic acid as mitigation agent had very little significant effect on P^H of tomato fruits (Appendix VII). Figure.20 reveals that, P^H of tomato fruits was recorded highest (5.369) from M_3; followed by M_2 (5.225) and M_1 (5.069). On the contrary, the lowest value was observed from M_0 (4.912).

Combined effect of salinity and mitigation agent showed different significant variation on P^H of tomato fruits (Appendix VII). Table 8 shows that highest result was recorded from S_0M_3 (5.850).Whereas the lowest value was observed from S_2M_0(4.550), which was statistically similar to S_3M_2 (4.600) and S_3M_1 (4.625).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 19. Effect of salinity levels on p^H of tomato fruits



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 20. Effect of mitigation levels on p^H of tomato fruits

Table No. 08. Combined effect of Salinity and SA with JA as mitigation agent on Vit-C contents and shelf life and p^H of tomato fruits.

Treatment	Parameters	
	Vit C content in fruits	p^H oh tomato fruit
S_0M_0	8.200 c	5.300 cd
S_0M_1	8.400 c	5.525 b
S_0M_2	8.800 b	5.650 b
S_0M_3	9.200 a	5.850 a
S_1M_0	6.400 f	4.925 e
S_1M_1	7.200 e	5.200 d
S_1M_2	7.400 de	5.475 bc
S_1M_3	7.600 d	5.600 b
S_2M_0	5.200 ij	4.550 g
S_2M_1	5.400 hi	4.925 e
S_2M_2	5.600 h	5.175 d
S_2M_3	6.000 g	5.325 cd
S_3M_0	3.825 l	4.875 ef
S_3M_1	4.675 k	4.625 g
S_3M_2	4.925 jk	4.600 g
S_3M_3	5.000 jk	4.700 fg
LSD value$_{(0.05)}$	0.3271	0.1759
CV %	7.08	4.80

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M_0 = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

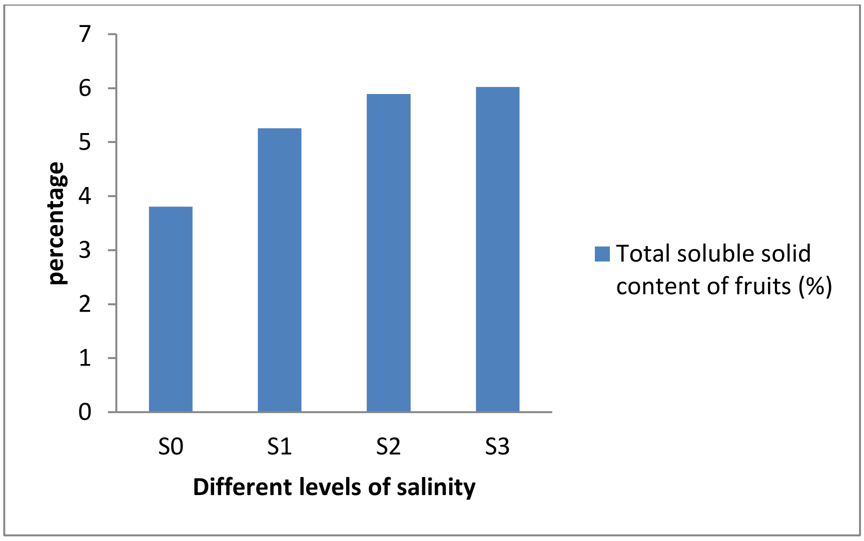
S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

14. Total soluble solid content

Total soluble solid content of tomato fruits varied significantly for different levels of salt stress (Appendix VII).. Figure.21 reveals that, total soluble solid content of tomato fruits was recorded highest (6.025) from S_3, which was statistically similar to S_2 (5.894); followed by S_1(5.256). On the contrary, the lowest value was observed from S_0 (3.806). Guiseppe (2006) reported the same.

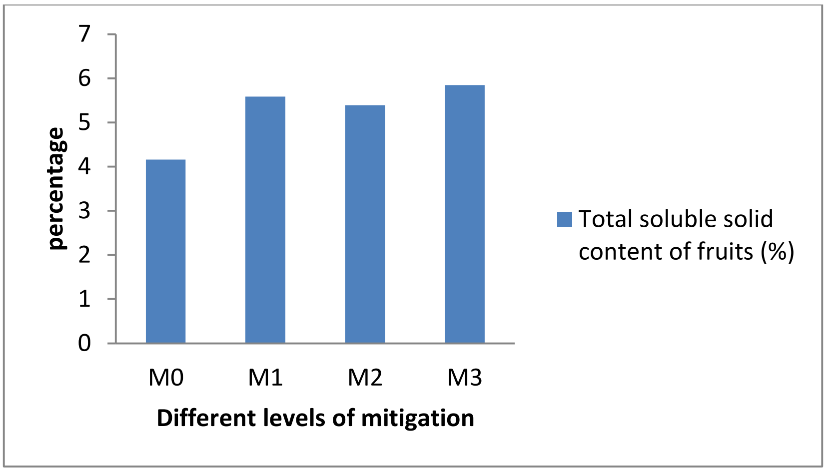
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on total soluble solid content of tomato fruits(Appendix VII).. Figure.22 reveals that, total soluble solid content of tomato fruits was recorded highest (5.844) from M_3; followed by M_1 (5.588) and M_2 (5.387). On the contrary, the lowest value was observed from M_0 (4.162).

Combined effect of salinity and mitigation agent showed different significant variation on total soluble solid content of tomato fruits (Appendix VII). Table 9 shows that highest result was recorded from S_3M_3 (6.600).Whereas the lowest value was observed from S_0M_0 (2.800),



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 21. Effect of salinity levels on total soluble solid content of fruits (%)



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

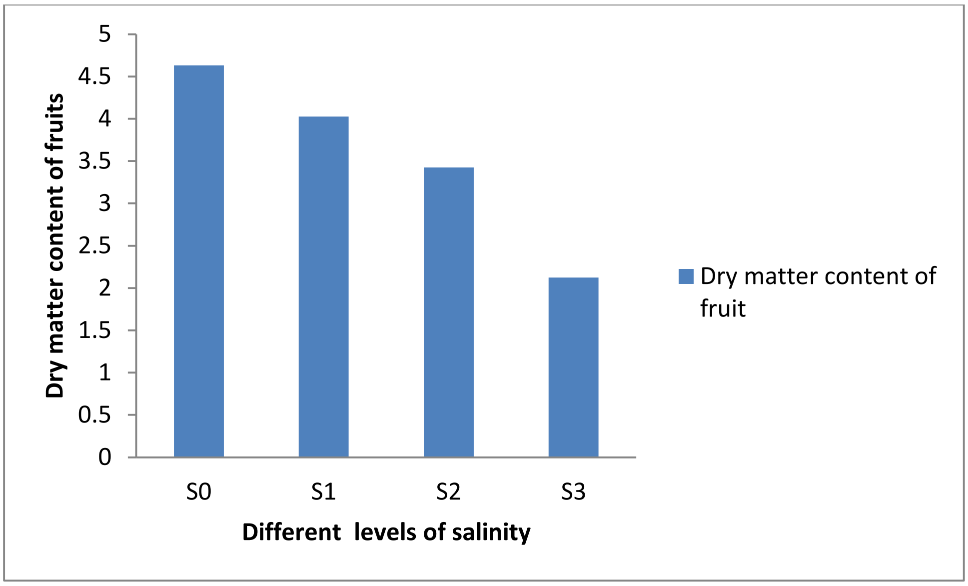
Fig no. 22. Effect of mitigation levels on total soluble solid content of fruits (%)

15. Dry matter content of fruits (%)

Dry matter content of tomato fruits varied significantly for different levels of salt stress (Appendix VII). Figure.23 reveals that, dry matter content of tomato fruits was recorded highest (4.631) from S_0, which was statistically similar to S_1 (4.025); followed by S_2 (3.42). On the contrary, the lowest value was observed from S_3 (2.125). similar result was found from Guiseppe (2006), Jamal *et al.*, (2014) and Jogendra *et al.* (2011)

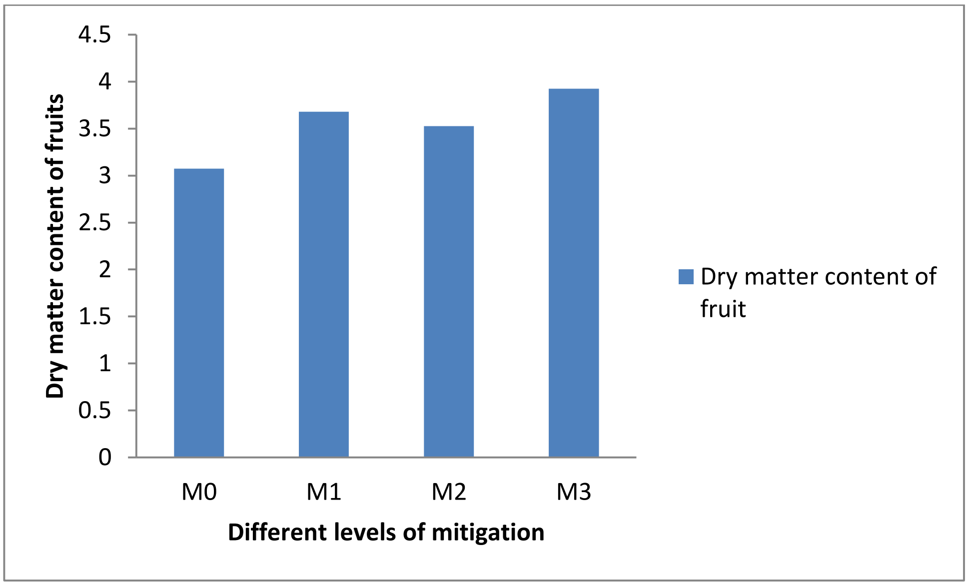
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on dry matter content of tomato fruits(Appendix VII). Figure.24 reveals that, dry matter content of tomato fruits was recorded highest (3.925) from M_3; followed by M_1 (3.681) and M_2 (3.525). On the contrary, the lowest value was observed from M_0 (3.075). Laila *et al.* (2011) states that SA increases dry matter content.

Combined effect of salinity and mitigation agent showed insignificant variation on dry matter content of tomato fruits (Appendix VII). Table 9 shows that highest result was recorded from S_0M_3 (5.000).Whereas the lowest value was observed from S_3M_0 (1.100),



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 23. Effect of salinity levels on Dry matter content of fruits (%)



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 24. Effect of mitigation levels on Dry matter content of fruits (%)

Table No.09. Combined effect of Salinity and SA with JA as mitigation agent on Total soluble solid content of fruits (%) and Dry matter content of fruit.

Treatment	Parameters	
	Total soluble solid content of fruits (%)	Dry matter content of fruit
S_0M_0	2.800 i	4.400 bcd
S_0M_1	4.000 h	4.625 b
S_0M_2	3.925 h	4.500 bc
S_0M_3	4.500 g	5.000 a
S_1M_0	3.900 h	3.800 fgh
S_1M_1	5.625 de	4.100 def
S_1M_2	5.500 e	4.000 efg
S_1M_3	6.000 cd	4.200 cde
S_2M_0	4.950 f	3.000 j
S_2M_1	6.225 abc	3.600 hi
S_2M_2	6.125 bc	3.400 i
S_2M_3	6.275 abc	3.700 ghi
S_3M_0	5.000 f	1.100 l
S_3M_1	6.500 ab	2.400 k
S_3M_2	6.000 cd	2.200 k
S_3M_3	6.600 a	2.800 j
LSD value$_{(0.05)}$	0.4390	0.3467
CV %	11.75	13.70

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

S_0 = 0 dSm^{-1}, M_0 = 0 (Control),

S_1 = 4 dSm^{-1}, M_1 = 1 mM of Salicylic Acid,

S_2 = 7 dSm^{-1}, M_2 = 10 µm of Jasmonic Acid,

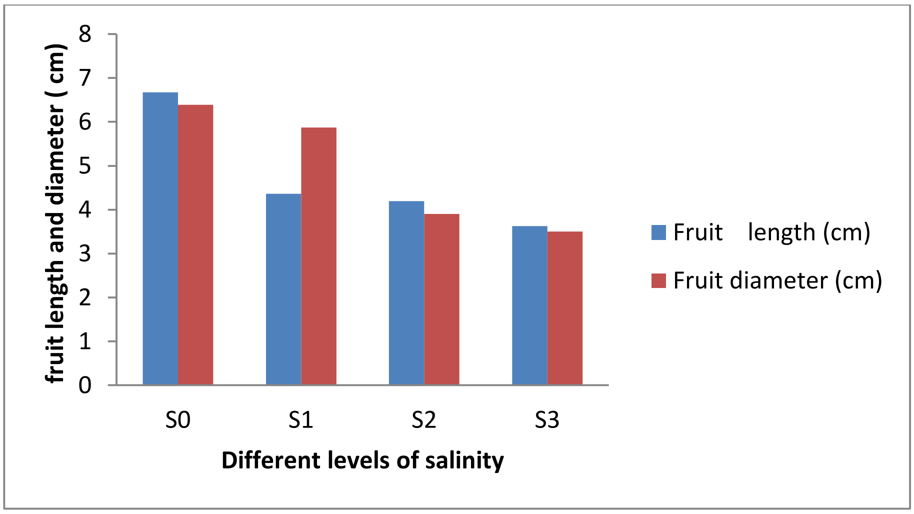
S_3 = 10 dSm^{-1} M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

16. Length of fruit

Length of tomato fruits varied significantly for different levels of salt stress. Figure.25 reveals that, length of tomato fruits was recorded highest (6.671 cm) from S_0; followed by S_1 (4.361 cm) and S_2 (4.196 cm) respectively. On the contrary, the lowest value was observed from S_3 (3.624 cm). Hala 2014 have reported the same.

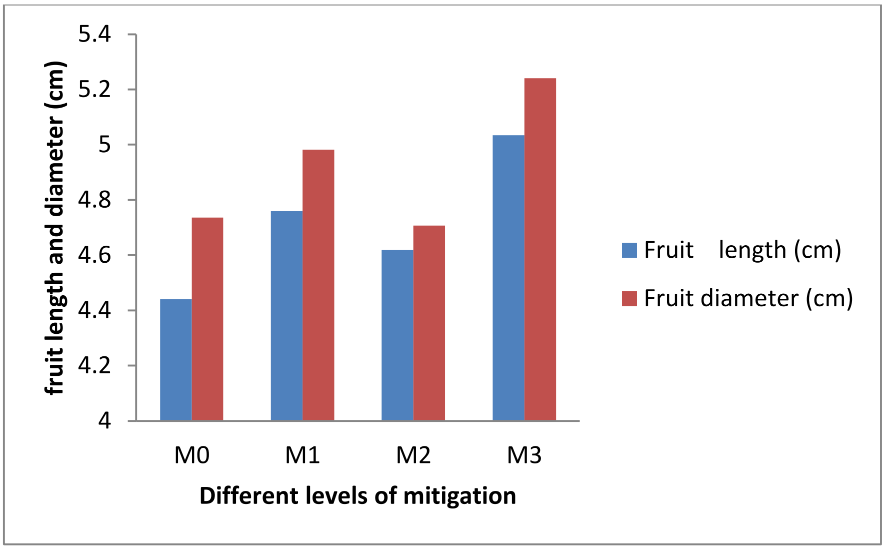
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on length of tomato fruits. Figure.26 reveals that, length of tomato fruits was recorded highest (5.034 cm) from M_3; M_1 (4.759 cm) and M_2 (4.619 cm), where both were significantly similar to each other. On the contrary, the lowest value was observed from M_0 (4.440 cm). Laila *et al.* (2011) reported that SA improves yield related characters in plant. Kazan *et al.* (2015) states JA significantly enhances yield related characters.

Combined effect of salinity and mitigation agent showed different significant variation on length content of tomato fruits. Table 10 shows that highest result was recorded from S_0M_3 (7.150 cm).Whereas the lowest value was observed from S_3M_0 (3.332 cm).



$S_0 = 0$ dSm^{-1}, $S_1 = 4$ dSm^{-1}, $S_2 = 7$ dSm^{-1}, $S_3 = 10$ dSm^{-1}

Fig no. 25. Effect of salinity levels on Fruit length (cm) and Fruit diameter (cm)



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 26. Effect of mitigation levels on Fruit length (cm) and Fruit diameter (cm)

17. Diameter of fruit

Diameter of tomato fruits varied significantly for different levels of salt stress. Figure.25 reveals that, diameter of tomato fruits was recorded highest (6.389 cm) from S_0; followed by S_1 (5.872 cm) and S_2 (3.902 cm) respectively. On the contrary, the lowest value was observed from S_3 (3.503 cm). Similar result was found from Hala 2014.

Salicylic acid and Jasmonic acid as mitigation agent had significant effect on diameter of tomato fruits. Figure.26 reveals that, diameter of tomato fruits was recorded highest (5.240 cm) from M_3; M_1 (4.982 cm) and M_0 (4.736 cm),. On the contrary, the lowest value was observed from M_2 (4.707 cm). Laila *et al.* (2011) reported that SA improves yield related characters in plant. Kazan *et al.* (2015) states JA significantly enhances yield related characters.

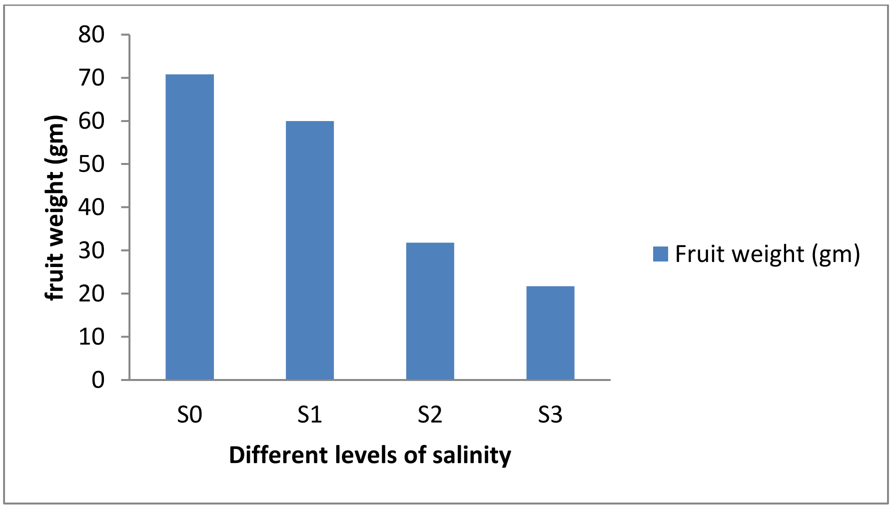
Combined effect of salinity and mitigation agent showed different significant variation on diameter content of tomato fruits. Table 10 shows that highest result was recorded from S_0M_3 (6.680 cm).Whereas the lowest value was observed from S_3M_0 (3.300 cm).

18. **Weight of individual fruit**

Weight of individual tomato fruits varied significantly for different levels of salt stress. Figure.27 reveals that, weight of individual tomato fruits was recorded highest (70.82 gm) from S_0; followed by S_1 (59.93 gm) and S_2 (31.77 gm) respectively. On the contrary, the lowest value was observed from S_3 (21.71 gm). The result was consistent with Humayun *et al.* (2010) and Jamal *et al.* (2014)

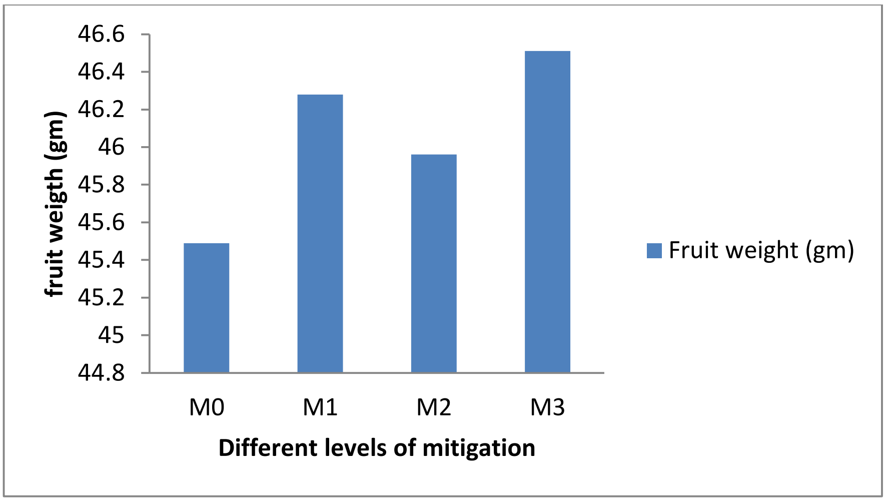
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on weight of individual tomato fruits. Figure.28 reveals that, weight of individual tomato fruits was recorded highest (46.51 gm) from M_3; M_1 (46.28 gm) and M_2 (45.96 gm). On the contrary, the lowest value was observed from M_0 (45.49 gm). Wasternack *et al.*(2002) repored that JA improves fruit characters. Similarly Humayun *et al.*(2010) states that SA enhances growth and yield elated characters.

Combined effect of salinity and mitigation agent showed different significant variation on weight of individual tomato fruits. Table 10 shows that highest result was recorded from S_0M_3 (71.25 gm).Whereas the lowest value was observed from S_3M_0 (20.83 gm).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 27. Effect of salinity levels on individual fruit weight (gm) per plant



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

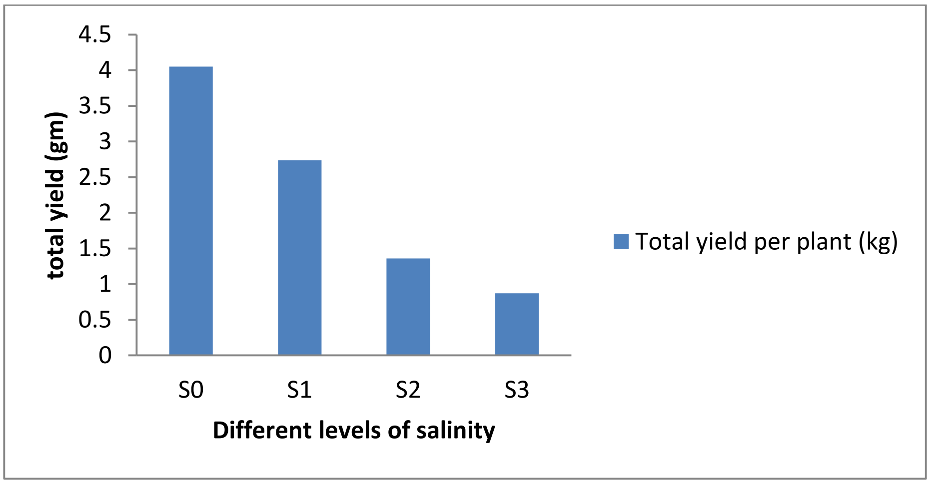
Fig no. 28. Effect of mitigation levels on individual Fruit weight (gm)

19. **Total Fruit Weight per plant (kg)**

Total fruit weight per tomato plant varied significantly for different levels of salt stress. Figure.29 reveals that, total fruit weight per tomato plant was recorded highest (4.052 kg) from S_0; followed by S_1 (2.736 kg) and S_2 (1.360 kg) respectively. On the contrary, the lowest value was observed from S_3 (0.870 kg). similar results was found from Humayun *et al.* (2010) and Siddiky *et al.* (2012)

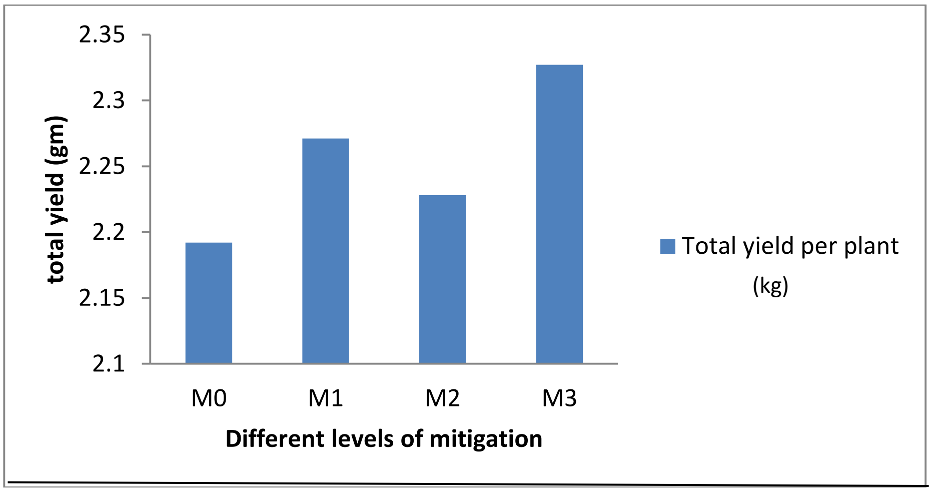
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on total fruit weight per tomato plant. Figure.30 reveals that, total fruit weight per tomato plant was recorded highest (2.327 kg) from M_3; followed by M_1 (2.271 kg) and M_2 (2.228 kg) respectively. On the contrary, the lowest value was observed from M_0 (2.192). Sibgha *et al.*(2008) concluded that SA have ample effect on fruit related characters, similarly Sheteawi (2007) revealed that JA also improves yield and yield related characters.

Combined effect of salinity and mitigation agent showed different significant variation on total fruit weight per tomato plant. Table 10 shows that highest result was recorded from S_0M_3 (4.166 kg).Whereas the lowest value was observed from S_3M_0 (0.8228 kg). yield and yield related characters were improved when exposed to combination of SA and JA, states eman et al., (2018), Kazemi *et al.* (2014).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

Fig no. 29. Effect of salinity levels on total yield per plant



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 30. Effect of mitigation levels on total yield per plant

Table No. 10. Combined effect of Salinity and SA with JA as mitigation agent on Fruit weight (gm), Fruit diameter (cm), Fruit length (cm) and Total yield per plant.

Treatment	Parameters			
	Fruit length (cm)	Fruit diameter (cm)	Individual Fruit weight (gm)	Total yield per plant (kg)
S_0M_0	6.42 c	6.30 b	70.62 b	4.00 c
S_0M_1	6.62 b	6.35 b	70.75 b	4.04 b
S_0M_2	6.48 bc	6.21 b	70.68 b	3.99 c
S_0M_3	7.15 a	6.68 a	71.25 a	4.16 a
S_1M_0	4.13 f	5.52 d	59.67 d	2.66 g
S_1M_1	4.43 e	5.92 c	60.22 c	2.76 e
S_1M_2	4.20 f	5.63 d	59.65 d	2.71 f
S_1M_3	4.66 d	6.40 b	60.17 c	2.80 d
S_2M_0	3.86 g	3.81 fg	30.83 g	1.28 k
S_2M_1	4.25 f	3.97 ef	32.20 ef	1.38 i
S_2M_2	4.19 f	3.67 g	31.75 f	1.35 j
S_2M_3	4.47 e	4.15 e	32.30 e	1.41 h
S_3M_0	3.33 i	3.30 h	20.83 j	0.82 n
S_3M_1	3.72 gh	3.67 g	21.95 hi	0.89 m
S_3M_2	3.59 h	3.30 h	21.75 i	0.84 n
S_3M_3	3.85 g	3.73 fg	22.30 h	0.92 l
LSD value$_{(0.05)}$	0.16	0.25	0.4609	0.02
CV %	4.92	7.23	1.41	1.48

In a column having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability analyzed by LSD.

$S_0 = 0\ dSm^{-1}$, $M_0 = 0$ (Control),

$S_1 = 4\ dSm^{-1}$, $M_1 = 1$ mM of Salicylic Acid,

$S_2 = 7\ dSm^{-1}$, $M_2 = 10$ µm of Jasmonic Acid,

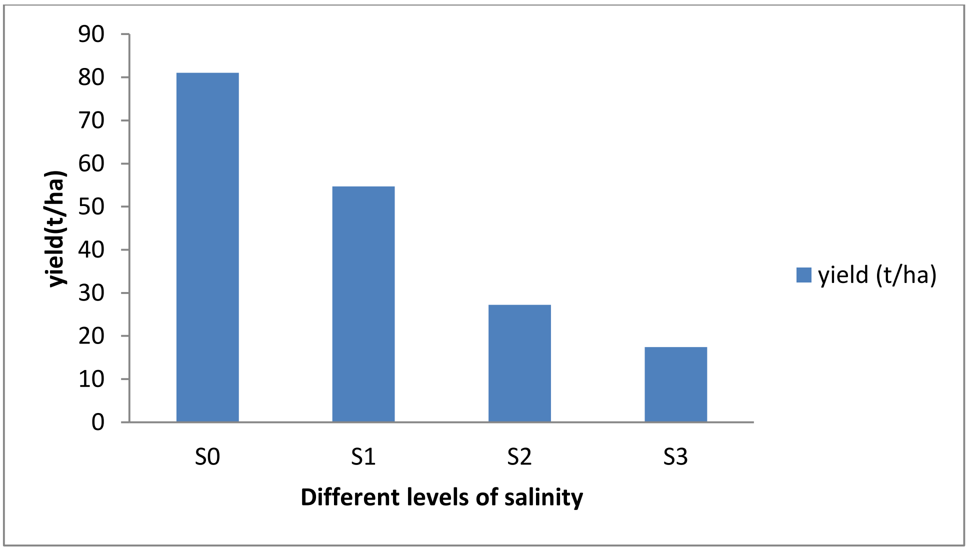
$S_3 = 10\ dSm^{-1}$ $M_3 = 1$ mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

20. **Yield (t/ha)**

Total yield (t/ha) varied significantly for different levels of salt stress. Figure.31 reveals that, total yield (t/ha) was recorded highest (81.04 t/ha) from S_0; followed by S_1 (54.71 t/ha) and S_2 (27.21 t/ha) respectively. On the contrary, the lowest value was observed from S_3 (17.40 t/ha).The yield of tomato is significantly reduced due to salinity, reported by Gorai *et al.*(2010), Jampeetong and Brix (2009) , Humayun *et al.*,(2010) and Siddiky *et al.* (2012).

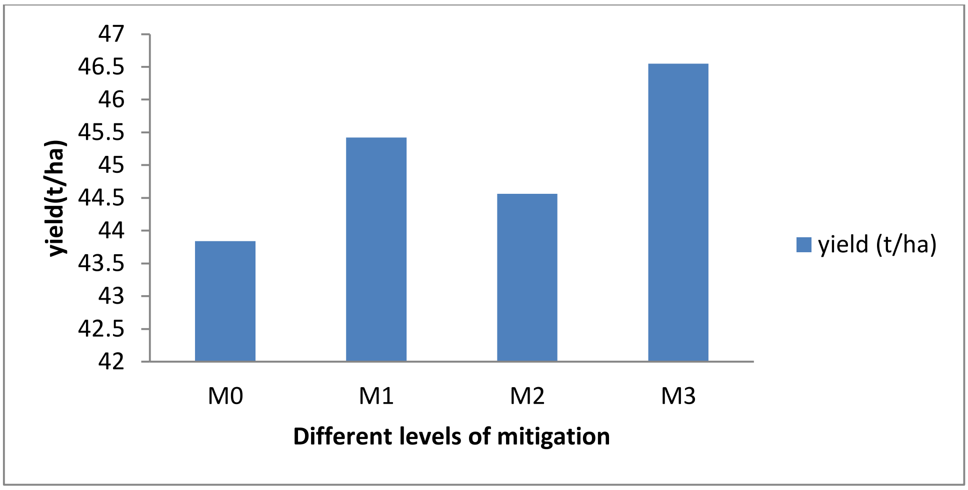
Salicylic acid and Jasmonic acid as mitigation agent had significant effect on per tomato plant. Figure.32 reveals that, yield per tomato plant was recorded highest (46.55 t/ha) from M_3; followed by M_1 (45.42 t/ha) and M_2 (44.56 t/ha) respectively. On the contrary, the lowest value was observed from M_0 (43.84 t/ha). similar results were found from eman *et al.* (2018), Kazemi *et al.* (2014) and Alireza Pazoki. (2015).

Combined effect of salinity and mitigation agent showed different significant variation on total yield (t/ha) per tomato plant. Table 10 shows that highest result was recorded from S_0M_3 (83.32 t/ha).Whereas the lowest value was observed from S_3M_0 (16.45 t/ha), When exogenous SA was applied yield increases significantly.



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}

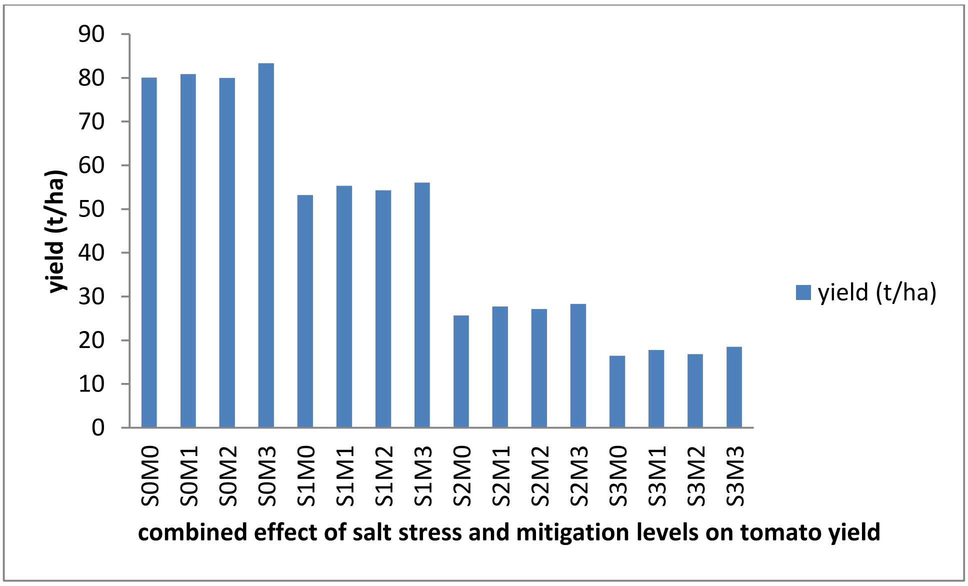
Fig no. 31. Effect of salinity levels on yields (t/ha)



M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid,
M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 32. Effect of mitigation levels on yields (t/ha)

Combined effect of salinity and mitigation agent showed different significant variation on yield per tomato plant. Figure 33 shows that highest result was recorded from S_0M_3 (83.32 t).Whereas the lowest value was observed from S_3M_0 (16.45 t).



S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1}
M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid, M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination)

Fig no. 33. Interaction of salt stress and mitigation levels on yields (t/ha)

CHAPTER V

SUMMARY AND CONCLUSION

This experiment was conducted to observe the effect of salt stress and salicylic acid and Jasmonic acid as mitigation agent in tomato. This study was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2016 to February 2017. The experiment consisted of two factors: Factor A (salinity level):S_0 = 0 dSm^{-1}, S_1 = 4 dSm^{-1}, S_2 = 7 dSm^{-1}, S_3 = 10 dSm^{-1} ; Factor B (mitigation level): M_0 = 0 (Control), M_1 = 1 mM of Salicylic Acid, M_2 = 10 µm of Jasmonic Acid, M_3 = 1 mM of Salicylic Acid and 10 µm of Jasmonic acid (combination). The experiment was laid out in Randomized Complete Block Design with 4 replications. Various morphological, physiological and yield contributing characters varies due to increasing salinity, and application of salicylic acid and Jasmonic acid singly or in combination have significantly mitigate this effect. Data on Plant height, number of branches and leaves, leaf area, chlorophyll content, dry weight of fruits, flowering date, number of cluster per plant, number of flower per cluster, fruit length and diameter, individual fruit weight as well as total yield per plant was recorded and highest was recorded in $S_0M_{3,}$,while lowest was in S_3M_0 combination.

At 35, 55 and 75 DAT, the height of tomato plant was recorded highest (50.41 cm, 63.19 cm, 67.63 cm) from S_0 as control, while The lowest value was observed from S_3 (34.53 cm, 48.03 cm, 56.94 cm). At 35, 55 and 75 DAT, the total Number of branches of tomato plant was recorded highest (5.000 cm, 6.125 cm, 8.125 cm) from S_0 as control, while the lowest value was observed from S_3 (1.938 cm, 2.375 cm, 3.313 cm). the total number of leaves per tomato plant was recorded highest (20.25 cm, 24.44 cm, 29.19 cm) from S_0 as control at 35, 55 and 75 DAT, while the lowest value was observed from S_3 (10.79 cm, 16.50 cm, 20.94 cm) . Data of leaf area of tomato was recorded at 55 DAT and observed highest (87.36 cm^2) from S_0 (no salt), while the lowest value was observed from S_3 (42.49). Data of Leaf chlorophyll content at 55

DAT was recorded highest (55.77 SPAD units) from S_0 (no salt), while the lowest value was observed from S_3 (46.70 SPAD units). The maximum date required to flowering was recorded (29.94) from S_3 as control, while the lowest value was observed from S_0 (23.88). Similarly, total number of flower clusters per tomato plant and total number of flowers per cluster per tomato plant was recorded highest (72.59 and 6.564) respectively from S_0, while the lowest value was observed from S_3 (51.81 and 4.963) respectively. Total Number of fruits per tomato plant was recorded highest (57.21) from S_0, while the lowest value was observed from S_3 (40.06). Volume of fruits was recorded highest (47.18) from S_0, while the lowest value was observed from S_3 (22.52). Vit-C content of fruits was recorded highest (8.650) from S_0, while the lowest value was observed from S_3 (4.606). P^H of tomato fruits was recorded highest (5.581) from S_0, while, the lowest value was observed from S_3 (4.700). Dry matter content of tomato fruits was recorded highest (4.631) from S_0, while the lowest value was observed from S_3 (2.125). But shelf life of fruits was recorded highest (12.56 days) from S_3 , while the lowest value was observed from S_0 (7.188 days). Similarly Total soluble solid content of tomato fruits was recorded highest (6.025) from S_3, while the lowest value was observed from S_0 (3.806). Length of tomato fruits was recorded highest (6.671 cm) from S_0, while the lowest value was observed from S_3 (3.624 cm). Diameter of tomato fruits was recorded highest (6.389 cm) from S_0, while the lowest value was observed from S_3 (3.503 cm). Weight of individual tomato fruits was recorded highest (70.82 gm) from S_0 while the lowest value was observed from S_3 (21.71 gm). Total Fruit Weight per tomato plant was recorded highest (4.052 kg) from S_0 while the lowest value was observed from S_3 (0.870 kg). , Total yield (tons/ha) was recorded highest (81.04 tons/ha) from S_0, while the lowest value was observed from S_3 (17.40 tons/ha).

Salicylic acid and Jasmonic acid singly or in combination can mitigate the effect of salinity.

Combined effect of salinity with salicylic acid and Jasmonic acid had significant effect on tomato. At 35, 55 and 75 DAT the plant height was recorded highest from S_0M_3 (52.75 cm, 71.00 cm, 71.50 cm) Whereas the lowest value was observed from S_3M_0 (30.98 cm, 44.88 cm, 51.28 cm). Total Number of branches of tomato plant was recorded highest from S_0M_3 (5.750 cm, 6.750 cm, 8.750 cm) Whereas the lowest value was observed from S_3M_0 (1.250 cm, 1.500 cm, 2.250 cm) at 35, 55 and 75. The total number of leaves per tomato plant at 35, 55 and 75 was recorded highest from S_0M_3 (22.25 cm, 28.00 cm, 30.75 cm) Whereas the lowest value was observed from S_3M_0 (8.675 cm, 14.00 cm, 19.50 cm). leaf area of tomato was recorded highest from S_0M_3 (100.3 cm^2) at 55 DAT. Whereas the lowest value was observed from S_3M_0 (35.91 cm^2). leaf chlorophyll content was recorded highest from S_0M_3 (57.38 SPAD units) at 55 DAT whereas the lowest value was observed from S_3M_0 (45.10 SPAD units). Days required from transplanting to 1^{st} flowering of tomato plant was recorded highest from S_3M_3 (30.50), whereas the lowest value was observed from S_0M_0 (18.75). Total number of flower clusters per tomato plant was recorded highest from S_0M_3 (74.07) Whereas the lowest value was observed from S_3M_0 (50.88). total number of flowers per cluster per tomato plant was recorded highest from S_0M_3 (7.008), Whereas the lowest value was observed from S_3M_0 (4.57), Total Number of fruits per tomato plant was recorded highest from S_0M_3 (58.47), Whereas the lowest value was observed from S_3M_0 (84.00), Volume of fruits was recorded highest from S_0M_3 (51.35), Whereas the lowest value was observed from S_3M_0 (20.00). Vit-C content of tomato fruits was recorded highest from S_0M_3 (9.200), Whereas the lowest value was observed from S_3M_0 (3.825). P^H of tomato fruits was recorded highest from S_0M_3 (5.850), Whereas the lowest value was observed from S_2M_0(4.550), Dry matter content of tomato fruits was recorded highest from S_0M_3 (5.000).Whereas the lowest value was observed from S_3M_0 (1.100), fruit quality i.e. shelf life and total soluble solid content shows different significant results from others. Shelf life of tomato fruits was recorded highest from S_3M_3 (14.25 days),Whereas the lowest value was observed from S_0M_0 (6 days) . similarly Total soluble solid content of tomato fruits was recorded highest from S_3M_3 (6.600).Whereas the lowest value was observed from S_0M_0 (2.800), Length content of tomato fruits was recorded highest from S_0M_3 (7.150 cm), Whereas the lowest value was observed from S_3M_0 (3.332 cm). Diameter content of tomato fruits recorded from highest was S_0M_3 (6.680 cm).Whereas the lowest value was observed from S_3M_0 (3.300 cm), Weight of individual tomato fruits was recorded highest from S_0M_3 (71.25 gm).Whereas the lowest value was observed from S_3M_0 (20.83 gm). Total Fruit Weight per tomato plant was recorded highest from S_0M_3 (4.166 kg).Whereas the lowest value was observed from S_3M_0 (0.8228 kg), the highest yield per hectare (83.32 t) was recorded from S_0M_3, whereas the lowest yield (16.45 t) was recorded from S_3M_0.

From the above discussion, it is revealed that combined application with salicylic acid and Jasmonic acid under control condition (no salt) was best for mitigating salt stress in tomato. Considering the discussions, we can be concluded that:

i. More experiment can be carried out with various levels of salt stress.
ii. Various levels of salicylic acid and Jasmonic acid can be used as mitigation agent for further study.
iii. Different combination of salicylic acid, Jasmonic acid, salt and their interaction can be used for further study.

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APPENDICES

Appendix I. Characteristics of Horticulture Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

Morphological features	Characteristics
Location	Horticulture Garden ,SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly level
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fallow – Kohlrabi

Appendix II. Monthly average record of air temperature, rainfall, relative humidity and Sunshine of the experimental site during the period from October 2016 to April 2017.

Month	Air temperature (ºc)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
October, 2016	31.6	23.8	78	172.3	5.2
November, 2016	29.6	19.2	77	34.4	5.7
December, 2016	26.4	14.1	69	12.8	5.5
January, 2017	25.4	12.7	68	7.7	5.6
February, 2017	28.1	15.5	68	28.9	5.5
March, 2017	32.5	20.4	64	65.8	5.2
April, 2017	33.7	23.6	69	165.3	4.9

Source: Bangladesh Meteorological Department (Climate & Weather Agargoan, Dhaka - 1212Division)

Appendix III. Analysis of variance of the data on plant height of tomato under different Salinity and mitigation levels.

Source of variation	Degrees of freedom	Mean square Plant height (cm) at		
		30 DAT	50 DAT	70 DAT
Replication	3	0.313	3.888	1.010
Salinity (A)	3	706.507*	673.861 *	349.617*
Mitigation (B)	3	60.968*	103.041 *	100.338 *
Interaction (A×B)	9	14.489*	29.240 *	7.504 *
Error	45	0.431	3.460	0.608

*Significant at 5% level of probability

Appendix IV. Analysis of variance of the data on number of branches of tomato under different Salinity and mitigation levels.

Source of variation	Degrees of freedom	Mean square Number of branches at		
		30 DAT	50 DAT	70 DAT
Replication	3	0.391	1.016	1.521
Salinity (A)	3	27.682*	40.516*	64.854 *
Mitigation (B)	3	7.224 *	6.016 *	8.854*
Interaction (A×B)	9	0.155*	0.127*	0.146*
Error	45	0.635	0.571	0.732

*Significant at 5% level of probability

Appendix V. Analysis of variance of the data on number of leaves of tomato under different Salinity and mitigation levels.

Source of variation	Degrees of freedom	Mean square Number of leaves at		
		30 DAT	50 DAT	70 DAT
Replication	3	18.433	1.063	0.141
Salinity (A)	3	275.199*	186.104*	246.766*
Mitigation (B)	3	27.358*	61.396 *	28.016 *
Interaction (A×B)	9	4.451*	3.104 *	3.613 *
Error	45	8.129	1.029	1.263

*Significant at 5% level of probability

Appendix VI. Analysis of variance of the data of leaf area, SPAD value, volume and total soluble solid content of tomato under different Salinity and mitigation levels.

Source of variation	Degrees of freedom	Mean square			
		Leaf area (cm^2)	SPAD value	Volume of fruits	Shelf life of fruit
Replication	3	1.825	0.864	0.403	6.625
Salinity (A)	3	5902.263 *	233.937*	1663.908*	87.167*
Mitigation (B)	3	535.484 *	12.751 *	194.097 *	23.875*
Interaction (A×B)	9	61.766 *	1.417*	6.258*	0.236*
Error	45	0.530	0.604	0.453	0.458

*Significant at 5% level of probability

Appendix VII. Analysis of variance of the data on shelf life, Vit-C content, p^H of tomato under different Salinity and mitigation levels.

Source of variation	Degrees of freedom	Mean square			
		Vit-C content	P^H of fruit	Dry matter content of fruit %	Total soluble solid %
Replication	3	0.956	0.024	1.270	3.168
Salinity (A)	3	50.844 *	2.321*	18.280*	16.530*
Mitigation (B)	3	3.168*	0.620*	2.040*	8.896*
Interaction (A×B)	9	0.118 *	0.158*	0.284NS	0.119*
Error	45	0.211	0.061	0.238	0.380

*Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data on Days to 1st flowering, Flower cluster per plant, Number of flower per cluster, Days to 1st fruiting, Total number of fruit per plant and Days to 1st harvesting of tomato under different Salinity and mitigation levels.

Source of variation	Degree of freedom	Mean square			
		Days to 1st flowering	Flower cluster per plant	Number of flower per cluster	Total number of fruit per plant
Replication	3	1.307	0.664	1.529	0.348
Salinity (A)	3	100.141*	1369.531*	7.802*	909.396*
Mitigation (B)	3	62.224*	14.885*	3.613*	13.024*
Interaction (A×B)	9	7.071*	0.684NS	0.161NS	0.878*
Error	45	1.418	0.362	0.134	0.222

*Significant at 5% level of probability

Appendix IX. Analysis of variance of the data on Length of fruit (cm), Diameter of fruit (cm), Dry matter content in fruit (%),Weight of individual fruit (g) and Fruit weight per plant(g) of tomato under different Salinity and mitigation levels.

Source of variation	Degrees of freedom	Mean square				
		Length of fruit (cm)	Diameter of fruit (cm)	Weight of individual fruit (g)	Total Fruit weight per plant (g)	Yield (tons\ha)
Replication	3	0.233	0.060	0.620	0.001	0.501
Salinity (A)	3	28.860*	32.575*	8549.333*	32.955*	13182.254*
Mitigation (B)	3	1.004*	0.987*	3.136*	0.054*	21.730*
Interaction (A×B)	9	0.035*	0.057*	0.328*	0.002*	0.980*
Error	45	0.054	0.126	0.419	0.001	0.446

*Significant at 5% level of probability

Plate no. 1. Pictorial representation of the experimental field

Plate no.2.a. Seedbed of the experiment Plate no.2.b. Seedlings after transplanting

Plate no.3.a: Data collection

Plate no.3.b: Tomato fruits

Plate no.3.c: Brix meter

Plate no.3.d. p^H meter

Plate no.3.e: Estimating p^H of fruit juice

Plate no.3.f : Data collection