The Effect of Salt Stress on Growth Performance and Fruit Yield of Tomato (*Lycopersicon esculentum* Mill.*)* Varieties

MSc. THESIS

ABAY TECHALU

FEBRUARY, 2023

HARAMAYA UNIVERSITY, ETHIOPIA

The Effect of Salt Stress on Growth Performance and Fruit Yield of Tomato (*Lycopersicon esculentum* Mill.*)* Varieties

A Thesis Submitted to the College of Natural and Computational Sciences,
School of Biological Sciences and Biotechnology, Postgraduate Program Directorate

Haramaya University

In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Biology

BY

Abay Techalu

February , 2023

HaramayaUniversityEthiopia,

APPROVAL SHEET

POST-GRADUATE PROGRAM DIRECTORATE

HARAMAYAUNIVERSITY

As Thesis Research advisors, we hereby certify that we have read and evaluated this thesis prepared under our guidance by AbayTechalu entitled "The Effect of Salt stress on Growth Performance and Fruit Yield of Tomato (*Lycopersicon esculentum* Mill.*)* Varieties.And we recommended that it be submitted as fulfilling the thesis requirements.

Meseret Chimdessa (PhD) _____________ _______________

Major Advisor Signature Date

Yohanes Petros (PhD.) _____________ _______________

Co-Advisor Signature Date

As a member of Board Examiner of the M.Sc. Thesis Open Defense Examination, we certify that we have read and evaluated the thesis prepared by Abay Techalu and Examined the candidate. We recommend that the Thesis be accepted as fulfilling the Thesis requirement for the degree of Masters of Science in Biology.

------------------------------- ______________ __________________

Chairman Signature Date

------------------------------- ______________ __________________

Internal Examiner Signature Date

------------------------------- ______________ _______________

External Examiner Signature Date

Final approval and acceptance of the thesis is contingent up on the submission of its final

Copy to the Council of postgraduate program Directorate

STATEMENT OF THE AUTHOR

By my signature below, I declare and affirm that this thesis is my work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis, and compilation of this thesis. Any scholarly matter that is included in the thesis has been given recognition through citation.

This thesis has been submitted in partial fulfillment of the requirements for the Master of Science in Biology at Haramaya University. The Thesis is deposited in the Haramaya University Library to be made available to borrowers under the rules of the library. I Solemnly declare That this thesis has not been submitted to any other institution anywhere for the award of Any academic degree, diploma or certificate.

Brief quotations from this Thesis may be made without special permission provided that accurate and complete acknowledgment of the source is made. Requests for permissions for extended quotations from or reproductions of this Thesis in whole or in part may be granted by the head of the school of Biological Sciences and Biotechnology when in his or her judgment the proposed use of the materials in the interest of scholarship. In all other instances, however, permission must be obtained from the author of the Thesis.

Name: Abay Techalu

Signature: ___________________

Date: ____________________

Place: Haramaya University

Date of Submission: February 2023

BIOGRAPHICALSKETCH

The author, Abay Techalu, was born in March 1988 in Laygainte Woreda, North Gondar, Amara National Regional State, Ethiopia. He attended his elementary education at Gobegobe Elementary School from 1993 to 1994 and secondary education at Nefas Mewecha Secondary School from 1995 to 1998 in Nefas Mewecha town. After completing Secondary School, he jigjiga University in 2012 to pursue studies leading to B.Sc. Degree in Biology, and graduated in July. Soon after graduation, he was employed by the Ministry of Education(Moe) as a biology teacher in the Somali Region dolo zone, Ware Dare Woreda,Wardare General Secondary School in Somali Regional State and served until he joined the Postgraduate Program Studies at Haramaya University in July 2006 to pursue his graduate studies in Master of Science in Biology

ACKNOWLEDGEMENTS

I would like to express my deepest and most sincere appreciation to my major advisor Dr. Meseret Chimdessa and my co-advisor Dr. Yohanes Petros for their guidance, sound advice, and their encouragement at all stages of my work. Their excellent teaching and constructive criticism and comments from the initial conception to the end of this work are highly appreciated. I would also like to take this opportunity to thank the School of Plant Science, Haramaya University, for allowing me to work in the greenhouse and the School of Biological Sciences and Biotechnology for hosting me as M.Sc. student.

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CSA	Central Statistical Agency
FAO	Food and Agricultural Organization
IBC	Institute of Biodiversity Conservation
LSD	Least Significance Difference
Masl	Meter above Sea Level
MoE	Ministry of Education
RCBD	Randomized Complete Block Design
SPSS	Statistical Package for Social Sciences
MAORD	Ministry Of Agriculture and Rural Development
FAOSTAT	Food and Agriculture Organiztion corporate Statistical data base

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

TABLE **PAGE**

Effect of Salt Stress on growth performance an fruit yield of Tomato Lycopersicon esculentum Mill.)varieties

ABSTRACT

Tomato (Lycopersicum esculentum mill.) is one of the most popular, important, and widely used vegetable crops as ranked number two vegetable in the world after potato. Tomato is an important cash-generating crop for smallholder farmers and employs in the production and processing industries in Ethiopia. The present study was conducted to assess germination, growth, physiological, and yield responses of 3 tomato varieties at Three different salinity levels. Evaluation of the varieties for salt tolerance was carried out in the laboratory and greenhouse in 2021. Each treatment was replicated three times and arranged in factorial arrangement. Germination percentage, germination Energy and Germination index, Relative Germination rate, Relative salt injury rate, plant height, fruit yield, shoot fresh weight, root fresh weight, root length, and shoot length were measured. All the traits showed a significant decrease (P<0.05).in 0.12,0.16,0.18 Nacl concentration The result revealed that the highest germination percentage (83%) was recorded from 0.12mM for the variety Melkashola while the lowest germination percentage (3%) was recorded from 0.18mM for the variety Miya. The highest shoot fresh weight (0.41g/plant) and the lowest root fresh weight was (0.31kg/ plant. The highest yield (0.2kg) was recorded at 0.12mM variety melkashola. Among the varieties, MelkaShola was found to be more salt tolerant.The results of laboratory and green house experiment showed that the variety melkashola produced the highest mean value in almost all of the traits considered at all level of salt concentrations,where as the remaining varities Fetan and Miya showed lower means almost in all of the traits considered.

Keywords: germination, salt concentration, seedling stage and varities

1. INTRODUCTION

Plants are sessile organisms that inevitably encounter a variety of abiotic stresses that are all together estimated to reduce crop yields by about 50% worldwide (Wang *et al.*, 2003). Salinity is one of the abiotic stresses that is widely distributed in both irrigated and non-irrigated areas of the world contaminating the soil, and directly affecting plant growth and development (Allakhverdiev *et al*., 2000). Worldwide, more than 45 million hectares of irrigated lands have been damaged by salt, and 1.5 million hectares are taken out of production each year as a result of high salinity levels in the soil (Munns and Tester, 2008). High salinity level affects plants in several ways: membrane disorganization, reduction of cell division and expansion of metabolic process, nutritional disorder, and genotoxicity **(**Hasagawa *et al.*, 2000; Munns, 2002; Zhu, 2007). Most crop species such as beans, onion, pepper, corn, sugarcane, cabbage, and tomato are sensitive to salinity, and salinity reduces their productivity by about 6-19%.The effect of salinity on plants' biochemical, physiological, and morphological characteristics has already been studied (Ashraf and Harris, 2004). A primary response in salt-stressed plants is decreased water use efficiency, leading to overall toxicity and yield reduction (Glenn and Brown, 1998). Tomato is a major horticultural crop with an estimated annual global production of over 146 million metric tons (FAOSTAT, 2012). It is one of the most widely produced and consumed vegetables in the world, both for the fresh fruit market and the processed food industries. Furthermore, tomato fruits or plants are occasionally used for decoration (ornamental value). In recent years, tomatoes have become an important source of lycopene, which is a powerful antioxidant that acts as an anti-cancer. Tomatoes are also providing vitamins and minerals. For example, one medium ripe tomato (~145 g) can provide up to 40 % of the recommended daily allowance of vitamin C and 20 % of vitamin A. They also contribute B vitamins, potassium, iron, and calcium to the diet (FAO, 2008).Tomato is an annual plant that can reach a height of over two meters (Naika et al., 2005). Height is among characters with high heritability (Veershetty, 2004, Mohanty, 2003, Singh et al., 2000). Apart from fruit characteristics, the plant habit of tomatoes separates them into two distinct groups, those that are determinate and indeterminate cultivars. Cultivars reach a height of 1.0 to 1.2 meters, at which stage the lead growth develops into a flower truss and similar things happen to all lateral branches. Indeterminate plants produce one or two stems, which grow until they are stopped by removing the growing point. Indeterminate types usually have smaller fruits and reach maturity later.

They bear fruits over a long period and are ideally suited to staking and pruning, both in open ground and in tunnels. They have much smaller pedicel scars than larger fruited sorts (Naika et al., 2005).Soil Salinity is one of the most devastating environmental stress caused by mismanagement of irrigation and aridity,results in major reductions in cultivated land size, crop productivity and quality all over the world (Shahbaz and Ashraf, 2013). In many areas of the world,salinity is one of the principal environmental causes of soil degradation, and consequently, asource of reduction in biomass (Amalet *a*l., 2014). To over come the effect of salt stress, plants produce antioxidants and osmo-protectants to bring about tolerance against oxidative sress and osmotic stress,respectively(Garridoet al., 2014).In line with this, great efforts have been devoted to understand the physiological aspects of tolerance to salinity in plants, as abasis for plant breeders to develop salt tolerant genotypes(Rashedet al., 2016). The Determinate types have a relatively concentrated fruit set that lasts only two or three weeks and the fruit ripens much faster than those from indeterminate types (Naika et al., 2005*)*. Tomato plays a major role in human nutrition as a vegetable; it constitutes an important component of the human diet, especially in developing countries (Stevens, 1974). It is the second most consumed vegetable in the world behind potatoes. Tomatoes are eaten fresh in salads or processed and can be stewed, fried, baked, used to produce soup, or used as juice. In addition to this versatility, tomatoes are also an important source of vitamins and minerals. They are an excellent source of phosphorus, iron, and vitamins A, B, and C. They also contain small amounts of the B complex vitamins; thiamin, niacin, and riboflavin (Cobley and Steele, 1976; Peirce, 1987; Purse glove, 1988; Varela et al., 2003Naika et al., 2005). Furthermore, tomato is the richest source of nutrients, dietary fibers, and antioxidants like lycopene and beta-carotene, the compounds that protect cells from cancer (Hobson, 1993).Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely grown vegetable crops in the world, second to potato. It originally came from the tropical area from Mexico to Peru (Maerere et al., 2006; FAO, 2005). In Ethiopia, there is no exact information as to when tomato was first introduced; however, the crop is cultivated in different major growing areas of the country. In the 2015 cropping calendar, tomato production in Ethiopia was about 22,788 tons from harvested area of 3,677 ha (CSA 2015). At the physiological level, salinity can cause nutrition (N, Ca, K, P, Fe, and Zn) deficiency and oxidative stress (Munns, 1993). The yields have been known to decrease as salinity increases with either surface irrigation water (Paliwal and Yadav, 1980;

Van Hoorn *et al*., 1993) or drip irrigation water (Singh *et al*., 1978; Levy, 1992). However, the severity of salt stress on crops depends on the cultivar (Zhang *et al*., 1993). Moreover, it has been suggested that more research is needed to identify the variety which will perform better at germination stage and give higher yield under high soil salinity condition(Kassayeet al.,2013). Though there are improved varieties of tomatoes from Melkasa Agricultural research center, no study has been conducted on their performance under high salinity levels. This experiment is, therefore, designed to test the salt tolerance level of three varieties of tomato released by Melkasa Agricultural research center In Ethiopia.

1.1. Obejective

1.2.1 General Objective:

- To screen tomato varieties for salinity tolerance

1.2 .2. Specific objectives

- Assess the effect of salt concentration on the growth performance of the different tomato varieties;
- Evaluate the effect of salt concentration on tomato germination, growth and yield.
- Identify the best salt tolerant Melkassa tomato variety.

2. LITERATURE REVIEW

2.1. Origin Botany and Domestication of Tomato

Tomato belongs to the genus *Lycopersicon,* especially *L. esculentum* which is grown for its edible fruit. The genus *Lycopersicon* of the family *Solanaceae* is believed to have originated in the coastal strip of western South America, from the equator to about 30° latitude south (Taylorlor, 1986; Papadopoulos, 1991). The European chroniclers made few references to it, and sometimes misinterpreted certain quotes that contain the word tomato as referencing the tomato, when they were referring to another species. This may have produced an overestimation of the real importance of the tomato in pre-Columbian times. The word tomato, introduced into the Spanish language in 1532 (Corominas, 1990), comes from the word tomato; which means in general to plants bearing spherical Tomatoes were domesticated in America; however, the original site of domestication and the early events of domestication are largely obscure (Peralta and Spooner, 2007). Two hypotheses have been advanced for the original place of tomato domestication, one Peruvian and the other Mexican. Although definite proof of the time and place of domestication is lacking, Mexico is presumed to be the most probable region of domestication, with Peru as the center of diversity for wild relatives (Larry and Joanne, 2007).

2.2. Major Cultivars of Tomato

There are two types of commonly grown tomatoes based on their growth habit. The most commercially grown varieties are determinate types. These are "bushy" types that have a defined period of flowering and fruit development. However, most heirloom garden varieties and greenhouse tomatoes are indeterminate, which means they produce flowers and fruit throughout the life of the plant (Lemma, 2001**).**

2.3. Nutritional Value of Tomato

Tomatoes can play an important role in the human diet. They are a valuable source of vitamins A and C, as well as several minerals, including calcium, iron, manganese, and particularly, potassium. It contains an average of 0.09 mg of vitamin A and 15 mg of vitamin C per 100 g of fruit, as well as 397 mg of potassium per 100 g of fruit. They also contain lycopene, which is a carotenoid (a pigment involved in photosynthesis) that gives the red color to tomatoes, pink grapefruit, and watermelons. Several population studies haveindicated that diets high in lycopene may offer protection against certain cancers.Depending on the purpose and varietal nature, tomatoes are produced for salad and processing purposes.salad tomatoes are ahaving quality good flavor, color, and texture that satisfies the consumer's preference as well as are suitable for post-harvest handling and marketing, even over long distances. Processing tomatoes have high juice contents, firmness of the fruit, and the recommended pH.In addition,processing tomatoes must have also the rheological characteristics required by the relevant food processing industry (Tilahun, 2002).

2.4. Economic Importance of Tomato in Ethiopia

Tomato (*Lycopersicon esculentum* Mill*)* is one of the most popular, important, and widely used vegetable crops as ranked number two vegetable in the world after potato. Tomato is an important cash-generating crop for smallholder farmers and employs in the production and processing industries in Ethiopia. It is also an important source of vitamins A and C as well as minerals. Currently, yellow-type tomatoes that are high in beta-carotene are also becoming important in the market for dietary preference. Farmers are interested in tomato production more than any other vegetable for its multiple, year-round harvest potential productions, which results in high profit per unit area Lemma *et al*. (2003). The fresh fruit is sliced and used as salad. It is also cooked for making local sauce. Processed products such as tomato paste, tomato juice, tomato ketchup, and whole peel tomato are produced for local market and export. Recently, tomatoes is recognized for treating various human diseases. Such diverse uses make the tomato an important vegetable in irrigated agriculture in the country and production is also rapidly increasing in many parts of the country (MOARD, 2009).

2.5. Salt Stress and its Effect on Plants

Saline soils contain a high percentage of soluble salts, with one or more of these salt components being present in excess. Sodium chloride (NaCl) is the most commonly encountered source of salinity (Henry *et al*., 1987; Li *et al*., 2006). However, sulfate and bicarbonate anions and calcium and magnesium cations may contribute to salinity problems. Alkali soils are low in soluble salts but have high sodium content and are characterized by high pH (Henry *et al*., 1987). Salt stress arises from the excessive uptake of salts by plants (Luttge and Smith, 1984). There are at least three components of salt stress in plants, including osmotic effects, nutritional effects, and toxic effects (Leopold and Willing, 1984). The degree to which each one of these components of salinity stress influences growth is dependent upon many factors e.g., plant species, the ionic composition of the saline water, humidity, and stage of plant development. Levitt (1980) has drawn a line between ion stress and salt stress. He defined salt stress as a condition in which salt concentration is high enough to make the water potential not high enough to lower plant water potential. Ion imbalance specifically results from disturbed ionic ratios in the cells after an accumulation of ions present in the salt (Cheeseman, 1988). Exposure of plants to extreme conditions such as high salinity causes a diverse set of physiological, morphological, and developmental changes (Jensen *et al*., 1996). Much of the strain in salinity stress is related to water stress arising from the excessive uptake of salts by the plants and the resulting reduction in water potential. This stress reduces leaf expansion due to a reduction in leaf turgor, and can severely restrict crop yield (Addicott, 1983).

2.6. Salinity Tolerance

Plants have to fight against abiotic stresses from the environment, such as drought, extreme temperature, salt, and UV irradiation, for growth and crop production (Pell *et al*., 2009). Low-molecular-weight antioxidants and antioxidant enzymes play important roles in scavenging and controlling the production and accumulation of reactive oxygen species (ROS) when plants are exposed to environmental stresses (Chalker-Soolt *et al*., 1999). Therefore, various metabolic pathways using secondary metabolites have evolved in plants to help them adapt to changing environments (Bewley and Black, 1994). Flavonols, anthocyanins, and proanthocyanidins are secondary plant metabolites that are known collectively as flavonoids. Flavonoids are found to directly scavenge Q2- and ·OH through single electron transfer (Larsol and Kiemenc, 1997), and the total flavonoid level is found to be highly correlated to a plant's antioxidant capacity (Bahron *et al*., 2004). Anthocyanin is also linked to stronger abiotic stress resistance (Bahron *et al*., 2004). Phenols, including flavonoids (flavonols, flavones, anthocyanins, etc.) and several classes of non-flavonoids (phenolic acids, lignin's, stilbenes, terpenoids, etc.), have been found to determine the antioxidant activity biosynthetic pathways appear to be mostly regulated at the transcriptional level (Qualttocchio *et al*., 2006). There are several techniques to enhance the endogenous proline accumulation for salt defense mechanisms such as exogenous application (Santos *et al*., 1996; Hoque *et al*., 2007; Kaya *et al*., 2007), biosynthesis gene(s) (Zhu *et al*., 1998; Han and Hwang, 2003) and degradation gene(s) knock-out (Nanjo *et al*., 1999).

2.7. The Genetic and Physiological Basis of Salt Tolerance

Recently, it has been reported that the positive effect of rootstocks on salt tolerance of grafted cultivars is related to the capacity to maintain ionic homeostasis in leaves by reducing the accumulation of toxic ions and maintaining the acquisition of essential nutrients like K+ (Albacete et al., 2009). This capacity has been related to an enhanced production and root-to-shoot transport of cytokinins and their effects on sourcesink relations (Perez-Alfoceaet al., 2010). Cytokinins help to delay leaf senescence and to maintain shoot growth and fruit yield (Albaceteet al., 2009, 2010; Ghanemet al., 2011a). Root-targeted breeding and biotechnology are being considered as powerful strategies to improve salt tolerance in crop species (Asinset al., 2010; Perez-Alfocea et al., 2010; Ghanem et al., 2011b). Marker-assisted breeding is a viable approach for enhancing stress tolerance in tomato. To this end chromosomal regions bearing quantitative trait loci have been explored. Although much progress has been made in tomato genetic transformation, success in developing transgenic tomatoes withhigh salt tolerance has been limited (Foolad, 2007). The transgenic plants accumulated high concentration of Na+ and Cl− in their leaves (Apse et al., 1999). Overproduction of this vacuolar Na+ /H+ antiport protein 21 increased the ability of transgenic plants to accumulate the Na+ in their vacuoles and thus to reduce its toxic effects in cytosol. This was the first single-gene transformation with a highly positive result in obtaining salt-tolerant tomato plants. In another study, transgenic tomato plants expressing the antisense prosystemin gene performed better under saline conditions than the wild type (Orsiniet al., 2010). Prostystem in transgenic plants maintained high stomatal conductance under saline conditions while leaf abscisic acid and proline contents in these plants were low indicating that these transgenic plants experienced a less stressful environment. Similarly, plant biomass of transgenic plants was also higher. Furthermore, a comparative profile of gene expression showed that partial stomatal closure is not mediated by ABA or components of ABA signal transduction pathway (Orsini et al., 2010). A better understanding of the genetic, biochemical, and physiological basis of salt tolerance would increase the success in developing transgenic tomato lines with increased salt tolerance. The identification, cloning, and characterization of genes involved in tolerance may allow plants with multiple transgenes to be produced. Advanced molecular techniques make this goal achievable (Foolad, 2007). Using mutants, the function of specific genes can be studied easily.

For example, the TSS1 (tomato salt-hypersensitive) locus was discovered in tomato usingtss1mutant (Borsaniet al., 2001).

2.8 Variability among Tomato Genotypes for Salt Response

The plant's response to salinity stress is characterized by the adaptation potential involving morphological and physiological changes, in which many genes and pathways are involved. Plant early responses to salt stress are relatively well defined, and among others include the alteration of cytoplasmic free Ca2+ activation of Ca2+, production of secondary signaling molecules such as reactive oxygen species (ROS) and abscisic acid (ABA) for regulation and maintenance of ion homeostasis (Julkowska and Testerink, 2015). Tomato, the largest horticultural crop next to potato in the world, is a selfpollinating diploid species and a model for genetic studies (Lin et al., 2014). While most modern tomato cultivars are sensitive to moderate levels of salinity stress, natural variation in salinity tolerance has been found in wild tomato species, including S. cheesmaniae, S. chmielewskii, S. habrochaites, S. lycopersicoides, S. pennellii and S. pimpinellifolium (Li et al., 2011). It has been suggested that great magnitude of genotypic variability in cultivated tomato cultivars (Solanum lycopersicum L.) was also found for salt tolerance at 22 the germination stage (Jogendra et al., 2011). Research into genes responsible for these QTLs have led to the identification of few tomato genes involved in improvement of tomato tolerance to salinity stress, including two tomato HKT1 (High-affinity Potassium Transporter) genes on chromosome 7 (Asinset al., 2013). HKT1-like transporters are involved in Na+ xylem unloading (Plettet al., 2010; Almeida et al., 2014). The two tomato HKT transporters, HKT1;1 and HKT1;2, are Na+ selective transporters, preventing Na+ accumulation in aerial parts and indirectly improving K+ homeostasis. Different studies showed that only HKT1;2 has a significant role in Na+ homeostasis and salinity tolerance in tomato (Jaime-Perez et al., 2017).

2.9. Biotic Approaches for Improving Salt Stress

Development of crop plants tolerant to salt stress is very important to meet the growing food demand. It has been suggested to exploit naturally occurring inter-and intra-specific genetic variability by hybridization of selected salt tolerant genotypes with high yielding genotypes adapted with target environment (Munnset al., 2006). Among various strategies, biotic approach could be adopted to cope with salinity stress. This is because the uptake and assimilation of mineral nutrients including Na+ and Cl− are genetically controlled and can be manipulated (Flowers, 2004; Munns, 2005; Munnset al., 2006) and some plants have ability to grow under high saline conditions (Ashraf, 2004; Flowers, 2004). It is largely believed that the adverse effects of salt stress on plant growth are mainly due to its toxic and osmotic effects, therefore major focus is on selective ion accumulation or exclusion, control of sodium uptake and its distribution within the plant, compartmentation of ions at cellular or at whole plant level (Munns, 2005 and Tester, 2008). Because of the complex nature of salinity tolerance, as well as the difficulties in maintaining long-term growth experiments, trait-based selection criteria have been recommended for screening techniques. Specific traits are less subject to environmental influence than growth rates.

2.10 . Tomato root and shoot Shoot

Shoot was affected drastically in plants grown under salt stress than in control environment (Amir et al., 2011; Hamed et al., 2011; Jogendra et al., 2011).Kamrani et al. (2013), Osakabe et al. (2014) and Xu et al. (2010) reported that salt stress brings about osmotic stress and subsequently ionic toxicity and oxidative stress. Salt stress limits water available to plants, hence, causes osmotic stress, which leads to loss in turgor pressure of the plant especially in the leaves due to decreased water potential, resulting in wilting that affects plant morphology and biomass production. Edris et al. (2012) has also reported similar result in that tomato plant shoot fresh weight was highly reduced with increasing NaCl concentration.Salinity reduced fresh and dry weight of plants (Kassaye et al.,2013; Dheeba et al., 2015). Deficiency in dry and fresh biomass at higher concentration might be due to poor absorption of water from the growth medium due to physiological drought (Ramezani et al., 2011). Root senses the effect of soil salinity and influences root-to-shoot signaling to control shoot growth and physiology via hormonal signals, such as cytokines, ABA and auxin IAA, thus coordinating assimilate production and usage in competing sinks (Perez-Alfocea et al., 2010). Salt stress leads to changes in growth, morphology and physiology of the roots that will, in turn, change water and ion uptake and the production of signals (hormones) that can transfer information to the shoot, affecting the whole plant when the roots are growing in a salty medium (Smolik et al., 2011).In spite of the negative effects of salt on roots, the root growth in tomato appears to be less affected whereas, shoot was affected drastically, so that the dry weight ratio was higher in plant grown under salt stress than in control environment. Root/shoot dry weight ratio was increased under higher salt 26 concentration (Jogendra et al., 2011). The rise in root/shoot dry weight in tomato under salt stress must be accompanied by changes in the allocation of assimilates between root and shoot meaning that, greater proportion of assimilates for root compared with shoot (Amir et al., 2011; Hamed et al., 2011; Chookhampaeng et al.,2007). According to Danait (2018) root dry weight is positively correlated to salinity but, shoot dry weight is negatively correlated to salinity.

2.11.Tomato Physiology

High salt concentration in the root zone hinders plants growth and development. To overcome this problem, plants have developed the mechanisms of physiological adaptation, such as development of the root system to acquire water or accumulation of osmoprotectants. Proline is one of well-known osmoprotectants and its accumulation is widely observed in various organisms under salt stress. The amino acid may play a role in protecting membranes and proteins against adverse effects of higher concentrations of inorganic ions and temperature extremes. In tomatoes, proline accounts for only a small fraction of the total concentration of osmotically active solutes (Trovatoet al., 2008; Szabados and Savoure, 2009). The mechanism of salt tolerance depends on the capacity for osmotic adjustment, which allows growth to continue under saline conditions. Salt stress leads to changes in growth, morphology and physiology of the roots that will in turn change water and ion uptake and the production of signals (hormones) that can transfer information to the shoot. Then the whole plant is affected when the roots are growing in a salty medium (Smoliket al., 2011). Stomata conductance and photosynthetic rate play important role in growth and development of any plants. The increasing salinity level decreased the stomata conductance and the reduction is greater at the highest level. The irrigation water with excessive salinity has negative effects on the chlorophyll content of tomato (Zhaiet al., 2015). Tomato is moderately tolerant to saline environment. Salt stress also down regulates the physiological and biochemical processes going on in tomato (Riveroet al., 2014; AlHarbiet al. 2015; Manan et al., 2016). Reduced water contents lead to the stomatal closure to safeguard further loss of water by transpiration (Manan et al., 2016). In addition to reduced transpiration and stomatal closure, net photosynthesis also reduced under salt stress by the production of ROS, not proper functioning and decrease in chlorophyll contents and rubisco (Zhang et al., 2009; Zribiet al., 2009). Physiological 27 efficiency of tomato is also adversely affected by saline conditions. High salt concentration also causes an ionic imbalance and osmotic shock to tomato plants (Ciobanu and Sumalan, 2009). As in most mesophytes the amount of Na^+ and Cl^- increased, while that of Ca^{2+} and K^+ decreased in the tomato plants under saline conditions (Turhanet al., 2009). K^+ /Na^+ ratio also decreased both in roots and shoots (Li, 2009). Both the accumulation of specific toxic ions including Na^+ and changes in leaf hormone relations contribute to leaf senescence and hence limit tomato productivity under saline conditions (Ghanemet al., 2008). In leaves showing premature senescence due to salinity, ABA increased while IAA strongly decreased with salinization time. Salinity affects photosynthesis by decreasing CO_2 availability because of diffusion limitations (Flexaset al., 2007) and a reduction of the contents of photosynthetic pigments (Ashraf et al.,2013).

2.12 .Tomato yield

As soil salinity increase fruit yield decrease. The fruit yield and increasing salinity have strong negative correlation (Danait, 2018). Soil salinity causes prominent losses of yield in all crops, therefore causing to reduction in crop production (Ashraf, 2009; Cha-um. et al., 2011). Increasing salt stress restricts plant growth and yield around the world (Ali et al., 2014; Mittelstet et al., 2015). Tomato yield negatively affected by the increasing salinity (Shao et al., 2012; Shao et al., 2013; Hou et al., 2014). As reported by (Mestre et al., 2012) blossom end rot is related to high salinity and environmental factors. Irrigation with saline water has been shown to enhance the occurrence of blossom-end rot in tomato, pepper fruits, and eggplants, a nutritional disorder related to Ca^{2+} deficiency. The reduction of stomatal conductance under salt stress conditions result to the lower photosynthetic rate that in turn leads to lower total yield of the crop (Kassaye et al., 2013). Tomato is considered by some authors to be sensitive to moderately sensitive to salt stress (Foolad, 2007; Ciobanu and Sumalan, 2009) and 50% yield loss occurs at moderate salinity level ($5 dSm^{-1}$) (Ciobanu and Sumalan, 2009). Salinity stress has been reported to cause alteration in a variety of morphological attributes and to decrease almost all growth parameters, including shoot and root fresh and dry weights, plant height, total leaf area and yield, and some yield quality attributes (Li, 2009; Tantawy et al., 2009). It has also been reported that both vegetative and fruit growth of tomato decrease markedly under saline conditions (Campos et al., 2006). 28 Salt stress also causes changes in a range of metabolic processes. For example, protein contents and activities of ascorbate peroxidase and catalase decreased, proline contents increased, and superoxide dismutase activity remained unchanged under saline conditions (Chookhampaeng et al., 2008). In mature tomato fruit, the amount of sucrose and the activity of sucrose phosphate synthase increased while fruit yield decreased under saline conditions (Chookhampaeng et al., 2008). Carbon partitioning and sucrose metabolism in both sink and source organs have been studied in salt-tolerant and salt-sensitive tomato genotypes (Balibrea et al., 2000). Dry weight was reduced to a greater extent in sensitive than in tolerant cultivars. Physiological efficiency of tomato is also adversely affected by saline conditions. For example, leaf water and osmotic potentials decreased in tomato plants while endogenous ABA concentrations increased under saline conditions (Maggio et al., 2007). Furthermore, considerable decrease in stomatal conductance and evapotranspiration was observed in tomato plants subjected to saline medium (Katerji et al., 2003). The activity of the nitrate reductase decreased under saline conditions and this reduction was ascribed mainly to lower uptake of NO3 and higher uptake of Cl– (Flores et al., 2002). Increase in proline content, ascorbic acid, and hydrogen peroxide was reported in tomato under saline regimes by Li (2009). The activities of other antioxidant enzymes such as catalase, peroxidase, superoxide dismutase, and ascorbate peroxidase were also reported to be increased under saline conditions (Li, 2009). High salt concentration also causes an ionic imbalance and osmotic shock to tomato plants (Ciobanu and Sumalan, 2009). As in most mesophytes the amount of Na+ and Cl− increased, while that of Ca2+ and K+ decreased in the tomato plants under saline conditions (Maggio et al., 2007; Li, 2009; Turhan et al., 2009). K+ /Na+ ratio also decreased both in roots and shoots (Li, 2009). Both the accumulation of specific toxic ions including Na+ and changes in leaf hormone relations contribute to leaf senescence and hence limit tomato productivity under saline conditions (Ghanem et al., 2008).

3. MATERIALS AND METHODS

3.1. Description of the study area

A laboratory experiment was conducted in the botanical science Laboratory, Department of biology Haramayaya University Ethiopia. The greenhouse experiment was conducted at Haramaya University Research Station at Rarre. The station at Rarre is 1980 m.a. s.l and located at 9^o 26 N and 42^o 3 E is situated in the tropical belt of eastern Ethiopia and is characterized by a sub-humid type of climate by an average annual rainfall of about 790mm. The annual mean temperature of the area is 17^o C with mean minimum and maximum temperatures of 3.8 and 25^o C, respectively (Tekalign and Hammes, 2005).

3.2 Plant materials

Seeds of three available tomato varieties (Melkashola, Fetan, and Miya) were obtained from Melkasa Agricultural Research center.

3.3 Study design

The design of the study involved laboratory as well as greenhouse experiments. The laboratory study was based on bioassay to assess salt tolerance in terms of seed germination percentage, seed germination energy, seed germination index, seed relative germination rate, and seed relative salt injury rate. The greenhouse experiment was focused on morphological variations based on yield-related traits under salt stress conditions in tomato varieties. The experimental design was a randomized complete block design (RCBD) in factorial combination and three replications for each treatment and control.

3.4 Laboratory Screening

To evaluate the response of three tomato varieties to NaCl salinity, the seeds of the three tomato varieties were first sterilized in 0.01%HgCl2 solution for 3 minutes and then rinsed with distilled water. The germination experiment was conducted in a laboratory, at room temperature using the procedures followed by Mamo et al. (1996). Glass Petri-dishes with a diameter of 10cm were lined with what man no 3 filter paper arranged in factorial combination with three replications. Germination tests were carried out at four NaCl concentrations (0.12, 0.16, and 0.18 (milli mole) following Muhammad et al. (2011). The solution was prepared by dissolving 0.00702gm, 0.00936gm, and 0.01053gm of pure NaCl in one liter of distilled water respectively. Salt solutions of equal volume (5ml) were added to the Petri dishes that are lined with filter paper until the filter paper gets completely wet. Thereafter, seeds (10) of each variety were placed on wetted filter paper. The control received no salt solution but distilled water of equal volume as the salt treatment groups. To keep the filter paper moist the same amount of salt solution and distilled water were applied every other day to salt-treated and control groups, respectively. The seeds were checked for germination every other day and the germination count was continued for 15 days. Germination tests were recorded daily and a seed was considered germinated when both plumule and radicle had emerged > 0.5 cm (Abdul et Al., 2006).

3.5 Green House Experiment

Varieties were surface sterilized in $HgCl_2$ (0.01%) solution for five minutes and washed with distilled water. After surface sterilization, seeds (10) of the three tomato varieties were sown in pots (with a surface area of $380cm^2$) filled with agricultural soil collected from the research farm of Haramaya University. After germination and right after the emergence of the third leaf, seedlings were randomly assigned to three level salinity treatments (0.12mM, 0.16mMand0.18mM) and control one received distilled water in three replications.

3.6 Data Collection

Data collected on germination percentage (GP), germination energy (GE), Germination index (GI), Relative germination rate (RGR), Relative salt injury rate (RSIR), Seedling shoot length (SSL), Seedling root length (SRL), Seedling shoot fresh weight (SFW), Seedling root fresh weight (SRW), were obtained from a laboratory experiment. Whereas plant height (PH), Day of flowering (DF), and fruit yield (FY), were obtained from the greenhouse experiment.

3.7 Germination and seedling-related traits

The germination percentage was calculated by the following formula (Li, 2008).

Germination percentage $= \frac{Total\ germinated\ seeds\ in\ the\ treatment}{total\ number\ of\ seeds\ sown} \times 100$

Germination energy: Germination energy was calculated by the following formula (Li, 2008)

Germination energy$= \frac{Germinated\ seeds\ total\ in\ the\ treatment\ in\ seven\ days}{Total\ number\ of\ seeds\ sown}$

Germination index; Germination index was calculated by the following formula (Li, 2008)

Germination index$= \frac{Sum\ germinated\ seeds\ in\ t\ days}{The\ number\ of\ corresponding\ germination\ days}$

Relative germination rate; Relative germination rate was calculated by the following formula (Li-, 2008)

Relative germination rate=$\frac{Germination\ percentage\ Nacl\ solution}{Germination\ percentage\ of\ the\ control}$

Seedling Root length (SRL) (cm): fifteen days after germination in the Petri-dish, five randomly selected plants per Petri-dish were measured for their Root length (the distance from crown to root tip) in centimeters and the average was recorded.

Seedling shoot length (SSL) (cm): fifteen days after germination in the Petri-dish, five randomly selected plants per Petri-dish were measured for their shoot length (the distance from crown to leaf tip) in centimeters and the average was recorded.

Seedling root fresh weight (SRFW)(g): fifteen days after germination in the petri-dish, SRFW was measured by taking five randomly selected plants from each petri-dish using sensitive balance and the average was recorded in g

Seedling shoot fresh weight (SSDW) (g): fifteen days after germination in the petri dish, SSDW was measured by taking five randomly selected plants from each petri-dish using sensitive balance and the average was recorded in g.

Plant height(cm): Plant Height was measured from the ground level to the shoot tip.

Flowering date: Number of days from sowing to the opening of first flower for all varities and treatments was recorded.

Fruit yield(kg): The matured fruits were harvested per plant.

3.8 Data Analysis

Data obtained from laboratory and greenhouse experiments were analyzed statistically by using the statistical package SPSS for windows 20.0 (SPSS: Chicago, IL, USA). Data were first checked for normality of distribution and one-way analysis of variance (one-way ANOVA) was employed to analyze data. The differences between means were considered to be statically significant at $p<0.05$

4. RESULTS AND DISCUSSION

4.1. Effect of salinity on germination percentage of tomato varieties

Seed germination significantly ($p<0.05$) varied between the different salt concentrations as well as between varieties under salt treatments. (Table 1). Compared to the control (distilled water-treated seeds) in which germination was 100% for all varieties, seed germination progressively decreased with increasing salinity (Table 1). Although no difference was seen between the three varieties in percent germination under control treatment, the Variety Melkashola had significantly ($p<0.05$) higher germination followed by Fetan and Miya varieties (Table 1),

At the final germination count, the applied moisture (treatment solution) was absorbed by the seeds of all varieties in the control plot. In contrast, the moisture remained unabsorbed in the treatments with the highest salt concentrations, except for the variety Melkashola which showed better water uptake and germination percentage. This indicates that in the higher salt concentration the seeds could not absorb water due to the higher osmotic pressure of the solution or the lower water potential of the solution. Since seed germination is a function of hydrolysis that helps the breakdown of starch to simple sugars and oxidizing of resulting sugar to energy, salt may affect hydrolysis (i.e. synthesis of enzyme amylase) and metabolic impairment. The reason why seeds of some varieties absorbed more water and showed higher germination percentages in concentrated salt solution may be due to the ability of osmotic adjustment and tolerance to salinity stress. Among the different varieties treated with different NaCl concentrations, MelkaShola gave a higher standard germination percentage Than Fetan and Miya varities.

Table 1. seed germination percentage of the three tomato varieties under different salt concentrations

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	100	83	53	20
Fetan	100	60	33	6
Miya	100	40	13	3

4.2 Effect of salinity on germination energy of tomato varieties

Germination energy showed significantly variation between the different salt concentrations and Tomato varieties as indicated in table (Table 2). Compared to the control (distilled water-treated seeds) in which germination was better for all varieties, Germination energy progressively decreased with increasing salinity (Table 2). Although no difference was seen between the three varieties in Germination energy under control treatment, Variety Melkashola had significantly ($p<0.05$) higher germination energy than both Fetan and Miya varieties (Table 2), This suggests that seeds germination time for varieties Miya and Fetan was elongated under salt stress. This result was in agreement with that of Xue et al. (2004) who found that a high level of salinity can significantly inhibit seed germination. Salt-induced inhibition of seed germination could be attributed to osmotic stress or specific ion toxicity (Huang and Redmann, 1995). Several authors have reported that salinity stress affected seed germination either by decreasing the rate of water uptake (osmotic effect) and/or by facilitating the intake of ions which may change certain enzymatic or hormonal activities inside the seed (ion toxicity) (Huang and Redmann, 1995).

Table 2. Germination energy of tomato the three tomato varieties under different salt concentrations

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	0.15	0.13	0.1	0.07
Fetan	0.15	0.01	0.08	0.06
Miya	0.15	0.07	0.06	0.03

4.3 Effect of salinity on germination index of tomato varieties

The germination index significantly ($p<0.05$) varied between the different salt concentrations as well as between varieties (Table 3). Compared to the control (distilled water-treated seeds) in which the germination index was better for all varieties, the Germination index progressively decreased with increasing salinity (Table 3). Although no difference was seen between the three varieties in the Germination index under control treatment, the Variety Melkashola had a significantly ($p<0.05$) higher germination index followed by Fetan and Miya varieties (Table 3).Generally, the germination index decreased as the salinity level increased from the control to the highest level. This could probably be due to the toxic effect of salt ions on the seed. This result was in line with the findings of Khayatnezhad and Gholamin (2011) who reported that an increased germination index is indicative of decreased phytotoxicity and thus of more mature germinated seeds. The result showed that of the three varieties, Miya and Fetan are the most affected by salinity when compared with Melkashola.

Table 3. germination index of the three tomato varieties under different salt concentrations

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	4.2	3.11	2.85	1
Fetan	4.2	1	0.6	0.5
Miya	4.2	0.7	0.5	0.3

4.4 Effect of salinity on the relative germination rate of tomato verities

Relative germination rate significantly varied between the different salt concentrations as well as between varieties under salt treatments (Table 4). Compared to the control (distilled water-treated seeds) in which the relative germination rate was better for all varieties, values progressively decreased with increasing salinity (Table 4). Although no difference was seen between the three varieties under control treatment, the Variety Melkashola had a significantly ($p<0.05$) higher relative germination rate followed by Fetan and Miya varieties when treated with different salt concentration (Table 4). The result of this study agrees with that of Akhtar and Hussan (2008) and Kaydan and Yagmur (2008) who worked on different plant species.

Table 4. relative germination rate of the three tomato varieties under different salt concentrations

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	93.3	0.82	0.75	0.53
Fetan	93.3	0.75	0.71	0.46
Miya	93.3	0.7	0.66	0.4

4.5 Effect of salinity on a seedling shoot and root length of tomato verities

Shoot length significantly ($p<0.05$) varied between the different salt concentrations as well as between varieties under salt treatments (Table 5). Compared to the control (distilled water-treated seeds) in which shoot growth was better for all varieties, values progressively decreased with increasing salinity (Table 5). Although no difference was seen between the three varieties under control treatment, the Variety Melkashola had significantly ($p<0.05$) higher shoot growth followed by Fetan and Miya varieties (Table 5). Decrement in shoot growth with increasing salinity level may be attributed to physiological dysfunction. Inhibition of long-distance transport of nutrient ions by salinity has been proposed to explain the reduced nutrient content in the shoot due to displacement of K+ and Ca^{2+} by Na on the membranes, hence reduced shoot growth due to reduced rates of cell division and elongation (Zade and Naeini, 2007). It is also possible that the reduction in shoot length with increasing salinity is related to the inhibitory effect of salinity on water uptake by the root. This finding is in agreement with Yani-bing et al. (2010) who found a decrease in plumule and radicle lengths as the concentration of NaCl increases. Xiong and Zhu (2002) explained that salt stress inhibited the efficiency of translocation and assimilation of stored materials and might have caused a reduction in shoot growth. Papedo and Redman (2007) also reported the growth inhibitory effect of salinity on different bean cultivars.

Table 5. Mean seedling shoot lengths (cm) of the three tomato varieties under different salt Concentration

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	15	10	8	6.6
Fetan	15	9	6.6	4.3
Miya	15	7.3	5	3.3

4.6 Effect of salinity on seedling root length of tomato verities

Root length significantly ($p<0.05$) varied between the different salt concentrations as well as between varieties under salt treatments (Table 6). Compared to the control (distilled water-treated seeds) in which root growth was better for all varieties, values progressively decreased with increasing salinity (Table 6). Although no difference was seen between the three varieties under control treatment, the Variety Melkashola had significantly ($p<0.05$) higher root growth followed by Fetan and Miya varieties (Table 6). Salt stress causes low intra-cellular water potential and water scarcity around the root zone due to which roots fail to absorb sufficient water and nutrients for adequate plant growth (Mohammed, 2007; Sunil et al., 2012). A decrease in root and shoot growth under a saline environment causes reduced total plant growth. The result of this study is in agreement with Sehrawat et al. (2013b; 2013c). The reduction in root and shoot development may be due to the toxic effects of NaCl as well as unbalanced nutrient uptake by the seedlings. It may be also due to the ability of the root system to control the entry of ions to the shoot, which is crucial to plant survival in the presence of NaCl (Hajibagheri et al., 1989).

Table 6. Mean seedling root length (cm) of tomato varieties under the different salt concentration

	Salt Concentration (mM)			
Varieties	0	0.12	0.16	0.18
Melkashola	10	7	5	3.6
Fetan	10	6	3.6	1.3
Miya	10	4.3	2	0.03

4.7 Effect of salinity on a seedling shoot and root fresh weight of tomato varieties

Shoot fresh weight significantly ($p<0.05$) varied between the different salt concentrations as well as between varieties under salt treatments (Table 7). Compared to the control (distilled water treated seeds) in which shoot fresh weight was better for all varieties, values progressively decreased with increasing salinity (Table 7). A slight difference was also seen between the three varieties under the control treatment. However, the Variety Melkashola had a relatively higher shoot fresh weight followed by Fetan and Miya varieties (Table 7). Overall, shoot fresh weight significantly decreased as the salinity level increased from the control to the highest. The result also indicated that tomato varieties responded differently to different salt levels, where variety Melka Shola had higher shoot fresh weight as compared to Fetan and Miya. This could be probably due to the better potential of Melka Shola to selective ion accumulation or exclusion and ion compartmentalization.

Table7. Mean seedling shoot fresh weight of the tested tomato varieties under different salt concentrations.

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	0.50	0.41	0.34	0.26
Fetan	0.49	0.38	0.32	0.24
Miya	0.32	0.24	0.12	0.03

4.8 Effect of salinity on seedling root fresh weight of tomato varieties

Likewise, root fresh weight was significantly ($p<0.05$) varied between the different salt concentrations as well as between varieties under salt treatments (Table 8). Compared to the control (distilled water-treated seeds) in which root fresh weight was better for all varieties, values progressively decreased with increasing salinity (Table 8). There was a significant difference between varieties under control treatment too whereby variety Melkashola had greater root fresh weight than the other varieties (Table 8). Since plant roots play a great role in plant growth and development, restriction in root growth may affect the whole processes when the plant grows under stress conditions. Perez-Alfocea et al. (2010) also reported the importance of root in the hormonal regulation of source-sink relations during the osmotic phase of salinity stress in tomatoes. They also reported that root senses the effect of soil salinity and influences root-to-shoot signaling to control shoot growth and physiology via hormonal signals, such as cytokines, ABA, and auxin (IAA), thus coordinating assimilate production and usage in competing sinks. Smolik et al. (2011) also found that salt stress leads to changes in the growth, morphology, and physiology of the roots that will, in turn, change the water and ion uptake and the production of signals (hormones) that can transfer information to the shoot, affecting the whole plant when the roots are growing in a salty medium.

Table 8. Mean seedling root fresh weight (gm) of the tested tomato verities under different salt concentrations

Varieties	Salt Concentrations (mM)			
	0	0.12	0.16	0.18
Melkashola	0.40	0.31	0.24	0.16
Fetan	0.39	0.28	0.22	0.14
Miya	0.22	0.14	0.2	0.1

4.9 Effect of salinity on yield and yield-related traits

4.9.1 Effect of salinity on the height of the tested tomato verities

Analyses of variance showed that plant height was significantly ($p<0.05$) affected by salt concentration and variety compared to the control treatment, the height of the tested tomato varieties progressively decreased with increasing salinity levels (Table 8). Comparison between varieties showed that Melkashola had the highest shoot growth measurement followed by Fetan and Miya varieties (Table 9). Salinity may result in a significant decrease in photosynthesis and an increase in transpiration rate leading to a shortage of assimilation to the developing organs, thus slowing down growth or stopping it entirely (El-Hendaway et al., 2005)

Table 9. Effect of salinity on the height (cm) of the tested tomato verities subjected to different concentrations of salt under greenhouse

Varieties	Salt Concentrations (mM)			
	0	0.12	0.16	0.18
Melkashola	55.66	43.33	31.33	18.66
Fetan	48.00	37.66	29.33	14.33
Miya	39.66	31.00	21.00	10.00

4.9.2 Effect of salinity on flowering dates of the tested tomato varieties

The mean flowering date significantly ($p<0.05$) varied due to salinity treatment and between varieties (Table 9). All varieties flowered early under control treatment compared to salt-treated ones and the time required to flower increased with salinity concentration. The Greenhouse result also showed that the variety Melkashola took a shorter time to complete flowering compared to Fetan and Miya varieties at all treatment levels (Table 9).

Table 10: Effect of salinity on flowering number of days to the flower of the tested tomato verities subjected to different concentrations of salt under greenhouse condition

Varieties	Salt Concentrations (mM)			
	0	0.12	0.16	0.18
Melkashola	43.33	55.00	66.0	74.0
Fetan	50.6	63.0	74.0	83.0
Miya	61.33	71.33	83.66	90.33

4.9.3 Effect of Salinity on the Number of Flowers of Each Tomato variety

The number of flowers per plant showed a significant difference due to variety as well as salt concentration. Compared to the control, the number of flowers decreased progressively with increasing salt concentration (Table 10). Comparison between varieties revealed that variety Melkashola had the highest number of flowers per plant followed by variety Fetan and Miya (Table 10). This finding agrees with that of Khan and Ungar et al. (2000) who reported a reduction in the number of flowers per plant under salinity. They also reasoned that salt stress may disrupt physiological processes in plants.

Table11. Effect of salinity on the number of flowers of the tested tomato varieties subjected to different concentrations of salt under greenhouse condition

Varieties	Salt Concentrations (mM)			
	0	0.12	0.16	0.18
Melkashola	18.6	11.00	7.33	5.00
Fetan	18.33	10.66	6.66	3.00
Miya	16.33	8.33	4.33	2.00

4.9.4 Fruit Yield

A significant difference ($p<0.05$) was observed in tomato fruit yield due to salinity level and variety difference. Compared to the control, fruit yield decreased under salinity in a concentration manner (Table 11). Variety Melkashola had the highest fruit yield followed by Fetan and Miya (Table 11).

Table12.Effect of salinity on the fruit yield (kg) of the tomato varieties subjected to different concentrations under greenhouse condition

Varieties	Salt Concentration (mM)			
	0	0.12	0.16	0.18
Melkashola	1.0	0.2	0.1	0.01
Fetan	1.0	0.1	0.01	0.0
Miya	1.0	0.02	0.001	0.0

5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Summary and conclusions

The research was carried out to evaluate salt stress tolerance at germination and yield-related traits of Tomato varieties through laboratory and greenhouse experiments. To achieve this objective three released Tomato varieties were taken for the pot experiment at *Rarre* greenhouse station at Haramaya University. The experiments were arranged in a completely randomized block design in factorial combination with three replications. For the experiment, four different levels of salinity 0, 12, 0.16, and 0.18 mM of NaCl was used to evaluate the relative tolerance of tomato varieties to salinity concerning various morphological, yields, and yield-related trait. The results of laboratory and greenhouses experiments showed that the variety Melkashola produced the highest mean value in almost all of the traits considered at all levels of salt concentrations, whereas the remaining varieties Fetan and Miya showed lower means almost in all of the traits considered. In conclusion, the result showed that varieties which are tolerant to salinity at the earlier stage are also tolerant at the later growth stage. Moreover, from this results point of view variety, Melkashola has shown better performance almost in all yield and yield-related traits. Therefore, this variety can tolerate up to 0.18 mM salinity level provided that other environmental factors are managed to this experimental conditions.

5.2. Recommendations

- ✓ This study mainly focused on morphological characters. Thus, I recommend that further investigation be undertaken through molecular markers to identify the genes that are responsible for salt tolerance.
- ✓ This study was carried out in the greenhouse, so further investigation in the field is recommended
- ✓ Out of the three varieties, Melkashola appeared to be better tolerant to salinity. Therefore, this tolerant Tomato variety should be screened for salinity tolerance in breeding programs

6. REFERENCES

Addicott, F. 1983. *Abscisi Acid*. Praeger Publishers, PP. 607. New York.

Albacete, A., Martınez-Andujar, C., Ghanem, M. E., Acosta, M., Sanchez Bravo, J., Asins, M. J., Cuartero, J., Lutts, S., Dodd, I. C., and Perez-Alfocea, F. 2009. Rootstock-mediated changes in xylem ionic and hormonal status are correlated with delayed leaf senescence and increased leafarea and crop productivity in salinised tomato. Plant Cell Environment.32: 928–938.

Allakhverdiev, S.I., Sakamoto, A., Nishiyama, Y., Inaba, M. and Murata, N. 2000. Ionic andosmotic effects of NaCl-induced inactivation of photosystem I and II in *Synechococcus* Species. *Plant Physiology*, 123: 1047-105

Apse, M. P., Aharon, G. S, Snedden, W. A., and Blumwald, E. 1999. Salt tolerance conferred by overexpression of a vaculolar Na/H antiport in Arabidopsis. Science285: 1256–1258.

Bewle J.D, Black, M. 1994.*Seeds Physiology of development and germination*, 2nd Edition. Plenum Press, New York. Cheeseman, J.M. 1988.Mechanisms of salinity tolerance in plants. *Plant Physiology*, 87: 547-550.

Borsani, O., Cuartero, J., Fernandez, J. A., Valpuesta, V., and Botella, M. A. 2001. Identification of two loci in tomato reveals distinct mechanisms for salt tolerance. Plant Cell1. 3: 873–887.

Corominas, J. 1990. Breve Diccionario Etimológico de la Lengua Castellana. Ed. Gredos, Madri

CSA (Central Statistical Agency) (2015). Crop Production Sample Survey, 2013/14. Report on Area and Production for MajorCrops (for Private Peasant Holdings ‘Meher’ season). Addis Ababa, Ethiopia.FAO, 2008..

Danait. H. 2018. Impact of surface and ground water salinity on soil and plant productivity in the central rift valley region around Lake Ziway. Academia Journal of Environmental Science. 6(3): 067-084.

FAOSTAT (Food and Agriculture Organization of the United Nations). 2012. Food and Agricultural commoditie production. URL: “http://faostat.fao.org/site/567/default.aspx”. Page last accessed: 29/06/1

Garrido Y, Tudela, A Marin, T Master, V Martinez and MI Gil,. 2014. Physiological, phytochemical and structural changes of multi-leaf lettuce caused by salt stress. *journal of the science of food and Agriculture*. 94: 1592-1599

Glenn, E.P. and Brown, J.J. 1998. Effects of soil salt levels on the growth and water use efficiency of Atriplex canescens (Chenopodiaceae) varieties in drying soil. *American Journal of Botany*, 85: 10-16.

Hasegawa, P.M., Bressan, R.A., Zhu, J.K., and Bohnert, H.J. 2000. Plant cellular and molecular responses to high salinity. Annu. Rev. *Plant Physiology*, 51: 463-499

Henry, L., Harron, B. and Flaten, D. 1987. The nature and management of salt affected land in Saskatchewan. *Soils and Crops Branch*, Saskatchewan Agriculture, Saskatoon, PP. 23.

Jensen, A.B., Busk, P.K., Figueras, M., Albà, M.M., Peracchia, G., Messeguer, R., Goday, A. and Pagès, M. 1996. Drought signal transduction in plants. *Plant Growth Regulation*, 20: 105-110

Joshi, A., A. Vikram, and M.C. Thakur. 2004. Studies on genetic variability, correlationand path analysis for yield and physico-chemical traits in tomato. Prog. Hort.,36(1): 51-58.

Julkowska, M.M. and Testerink, C. 2015. Tuning plant signaling and growth to survive salt. Trends Plant Science. 20(9): 586–594.

Larry R, Joanne L. 2007.Genetic resources of tomato. In: Razdan MK, Mattoo AK, eds. Genetic Improvement of solanaceous crops. Vol. 2.Tomato. Enfield, NH: Science Publishers

Lemma D., 2001. .Introduction. In: Abera Deressa and Solomon Degnachew (compilers), Training manual on horticultural crops production technologies (volume II: vegetables), Ethiopian Agricultural Research Organization, Melkasa Agricultural Research Center and World Vision Ethiopia. Melkasa, Ethiopia

Levitt, J. 1980. The nature of stress injury and resistance. In: *Responses of Plants to Environmental Stresses*. PP. 697. Academic Press, New York

Li, J., Liu, L., Bai, Y., Zhang, P., Finkers, R., Du, Y., Visser, R.G.F. and van Heusden, A.W. 2011. Seedling salt tolerance in tomato. Euphytica.178 (3): 403–414.

Luttge, U. and Smith, A. 1984. Structural, biophysical and biochemical aspects of the role of leaves in plant adaptation to salinity and water stress. PP. 125-150. In Staples, R.C., and Toenniessen, G.H. (ed.), *Salinity Tolerance in Plants*. John Wiley and Sons, Inc., New York.

Mittelstet AR, DE Storm and AL Stoecker. 2015. Using SWAT and empirical relationship to simulate crop yields and salinity levels in the North Fork River Basin. International Journal of Agricultural and Biological Engineering. 8: 1-15.

Munns, R. 1993. Physiological processes limiting plant growth in saline soils: some dogmas and hypotheses. *Plant Cell and its Environment*, 16: 15-24.

Munns, R. 2002. Comparative Physiology of Salt and Water Stress. *Plant Cell Environment*, 25: 239-250

Maerere A, Sibuga KP, Mwajombe KK (2006). Baseline survey oftomatoproduction in Mvomerodistrict-Morogororegion, Tanzania, Sokoine University of Agriculture Facultyof Agriculture, Morogoro, pp. 1-31.

MoARD 2009. Rural Capacity Building project.Course for Training of trainers on improved horticultural crop technologies. pp. 5-19. Horticultural workshop ofEthiopia, 1992. Addis Ababa, Ethiopia

Naika, S., J.van Lidt de Jeude., M, de Goffau., M. Hilmi and B.van Dam.2005. Cultivation of Tomato: production, processing and marketing. CTA. Series no 17

Nanjo, T., Kobayashi, T., Yoshiba, Y., Kakubari, Y. and Yamaguchi, S.K. 1999. Antisense suppression of proline degradation improves tolerance to freezing and salinity in Arabidopsis thaliana. FEBS Lett, 461: 205-210.

Papadopoulos, A.P. 1991. Growing Greenhouse Tomatoes in Soil and in Soilless Media. Agriculture Canada Publication 186/E, Communications Branch, Agriculture, Canada, Ottawa, Canada, pp 85-95.

Peralta, I.E Pell, A.K., Blank, M. and Das, A.B. 2009. Salt tolerance and salinity effects on plants: a review. Ecotoxicol. *Environal Safety*, 60: 324-349

Qualttocchio, R., Mutlu, F. Bozcuk, S. 2006. Mechanisms of high salinity tolerance in plants. *Methods of Enzymology*, 428: 419-38

Rashed MRU, MR. Roy, paul and MM. Haque.2016.*invitro* screening of salt Tolerant Genotypes in Tomato(*Solanum lycopersicum L.) Journal of Horticulture*. 3:186.

Santos, M.A., Camara, T., Rodriguez, P., Claparols, I. and Torné, J.M. 1996. Influence of exogenous proline on embryogenic and organogenic maize callus subjected to salt stress. *Plant Cell Tissue*. Org. Cult, 47: 59-65

Shao X, M. Hou and J. Chen. 2013. Effects of EM-calcium spray on Ca uptake, blossomend rot incidence and yield of greenhouse tomatoes (Lycopersicon esculentum L.). Research on Crops. 14: 1159–1166.

Singh, S.D., Gupta, J.P., Singh, P. 1978. Water economy and saline water use by drip irrigation. Agronomy, 70(6): 948-951. Cobley, L.S. and W.M Steele. 1976. An Introduction to the Botany of Tropical Crops

Stevens, M.A. 1974. Varietal influence on nutritional value. P. 87 – 110. In P.L. Whiteand N.SELVEY (eds.) Nutritional qualities of fresh fruits and vegetables. FuturaPubl. Co., Mt. Kisco, N.Y.

Taylor, I.B. 1986. Biosystematics of the tomatoIn: J.G. Atherton and J. Rudich (Eds.), *The Tomato Crop: A Scientific Basis for Improvement.* Chapman & Hall, New York. , pp. 1–34.

Tilahun, S., 2002. The improvement of the shelf life of vegetables through pre and postharvest Treatment. Ph.D. Thesis Presented to the University of Free State. South Africa. 27. Op.

Van Hoorn, J.W., Ugart, M.L. and van Alphen, J.G. 1993. Salinity control. In: H.P. Ritzema (Ed.), Drainage Principles and Applications, Publication: *International Institute for Land Reclamation and Improvement* (ILRI), Wageningen, Netherlands, 16: 533-600

Wang, W.R., Wang, Y., Yuan, N.D. and Guo, W. 2003. Effects of salt and water stress on plant biomass and photosynthetic characteristics of Tamarisk (Tamarix chinensis Lour.) seedlings. *African Journal of Biotechnology*, 10(78): 17981-89.

Zhu, B., Su, J., Chang, M., Verma, D.P.S., Fan, Y.L. and Wu, R. 1998. Overexpression of a 1pyrroline-5-carboxylate synthetase gene and analysis of tolerance to water- and salt-stress in transgenic rice. *Plant Science*, 139: 41-48.