MITIGATION OF DROUGHT STRESS IN TOMATO BY EXOGENOUS APPLICATION OF SALICYLIC ACID

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Dedicated to

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Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled ***"MITIGATION OF DROUGHT STRESS IN TOMATO BY EXOGENOUS APPLICATION OF SALICYLIC ACID"*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in HORTICULTURE,*** *embodies the results of a piece of bona fide research work carried out by* ***MD. REZWAN SARKER,*** *Registration. No.* ***09-03434*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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ABSTRACT

A pot experiment was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during October 2015 to April 2016.The seeds of BARI Tomato-14 were used as planting material. The two factors experiment was laid out in Randomized Complete Block Design with three replications. The total treatment combinations were 12 (3×4). The experiment consisted of two factors: Factor A: Three levels of moisture percentage such as, W_1: 100%, W_2: 75% and W_3: 50% evapotranspiration moisture and Factor B: Four concentrations of salicylic acid as mitigating agent of drought stress S_0: Control, S_1: 50 ppm, S_2: 75 ppm and S_3: 100 ppm respectively. The results of the experiment showed that, drought stress significantly influenced morphology, physiology, yield contributing characters and yield of tomato. The lowest plant height (96.7cm), SPAD value (35.2), and individual fruit weight (55.3 g) recorded at W_3; whereas the highest plant height (104.9 cm), SPAD value (43.6), and individual fruit weight (67.9 g) value recorded at W_1. The results also showed that, salicylic acid significantly increased the growth contributing characters as well as yield of tomato. The highest plant height (105.1 cm), highest SPAD value (43.8), and individual fruit weight (62.6 g) recorded at S_2 and lowest from S_3. For combined effect, the tallest plant (110.0 cm), highest weight of individual fruit (69.0g), highest number of fruits plant^{-1} (36.8), highest fruit yield plant^{-1} (2.3 kg) and highest fruit yield (97.9 t ha^{-1}) produced from W_1S_2; whereas the lowest from W_3S_0. This result suggests that, exogenous application of salicylic acid can effectively mitigate the deleterious effect of drought stress in tomato.

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LIST OF ACRONYMS

BARI	=	Bangladesh Agricultural Research Institute
CBR	=	Cost Benefit Ratio
CCC	=	Chlorocholine chloride
RCBD	=	Randomized Complete Block Design
DAS	=	Days after sowing
ET	=	Evapotranspiration
et al.	=	and others *(at elli)*
FAO	=	Food and Agriculture Organization of the United Nations
FRG	=	Fertilizer Recommendation Guide
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
POD	=	Peroxidase
ROS	=	Reactive Oxygen Species
SA	=	Salicylic Acid
SAW	=	Soil Available Water
SOD	=	Superoxide Dismutase
SPAD	=	Soil-Plant Analysis Development
T	=	Leaf Temperature
TSP	=	Triple Super Phosphate
TSS	=	Total Soluble Solids
WUE	=	Water Use Efficiency

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most popular vegetables in the world which is cultivated in almost all parts of Bangladesh. Tomato fruits are eaten raw or cooked and other dishes like as soups, juice, jam, jelly, ketchup, pickles, sauces, conserves, puree, paste, powder and other products. In terms of human health, tomato is a major component in the daily diet and constitutes an important source of minerals, vitamins and antioxidants. Lycopene in tomato is a vital anti-oxident that helps to fight against cancerous cell formation as well as other kind of health complications and diseases (Kumavat and Chaudhari, 2013). Nevertheless, it plays a vital role in providing a substantial quantity of vitamin C and A in human diet (Farooq *et al.*, 2005). At present, tomato ranks third, next to potato and sweet potato, in terms of world vegetable production (FAO, 2013). The leading top ten tomato producer country in the world are China, India, United States, Turkey, Egypt, Iran, Italy, Spain, Brazil and Mexico (FAO, 2012). The world dedicated 4.8 million hectares in 2012 for tomato cultivation and the total production was about 161.8 million tons. Bangladesh produces 251 thousand tones of tomato from 26300 hectares of land, the average yield being 9.54 t ha^{-1} (FAOSTAT, 2013) which is very low compare with the world average yield.

The productivity of crops is not increasing in parallel with the food demand due to changing environmental factors both biotic and abiotic. Various abiotic environmental stresses such as drought, high or low temperature, salinity, flooding, metal toxicity, etc. which pose serious threat to world agriculture. In Bangladesh congenial atmosphere remains for tomato production during low temperature winter season that is (November - April). But water deficit or drought stress occurs during this season especially in northwestern regions.

Drought stress is a major abiotic environmental cue impairing many physiological and metabolic processes in plants, which may lead to suppressing plant growth and development, reducing crop productivity or plant death. Drought reduces crop production on 25% of arable land throughout the world (Farooq *et al*., 2009a). Drought slows growth, induces stomatal closure, and therefore reduces photosynthesis (Nemeth *et al*., 2002). So the main consequence of drought stress is decreased growth and development caused by reduced photosynthesis, a process in which plants combine water, carbon dioxide and light to make carbohydrates for energy. Across plant species drought imposes various physiological and biochemical limitations and adverse effects (Chaves and Oliveira, 2004; Wang *et al.*, 2003). Drought stress elevates generation of reactive oxygen species (ROS), an effect common in plants exposed to most abiotic stresses (Foyer and Noctor, 2005). Increased the accumulation of such ROS may lead to many deleterious effects like protein degradation, lipid peroxidation and pigment bleaching in tomato plants.

The alleviation of oxidative damage and increase resistance to environmental stresses, at critical growth stages of plant, are often correlated with an efficient antioxidative system. Such systems may be induced or enhanced by the application of chemicals such as salicylic acid (SA) (He *et al*., 2005). SA plays an essential role in preventing oxidative damage in plants by detoxifying super oxide radicals, produced as a result of stress (Munns and Tester, 2008). Salicylic acid acts as a potential non-enzymatic antioxidant as well as an endogenous plant growth regulator of phenolic nature, naturally occurs in plants in very low amounts. Which plays an important role in regulating a number of plant physiological processes such as photosynthesis, stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Arfan *et al*., 2007). Increased concentration of intracellular proline and consequently enhanced plant drought tolerance can also be achieved by exogenous application of salicylic acid. Exogenous application of SA also has been reported to modulate activities of intracellular antioxidant enzymes superoxide dismutase (SOD), peroxidase (POD) and increase plant tolerance to environmental stresses (Sakhabutdinova *et al.*, 2004; Senaratna *et al.*, 2000). SA shows protective effects against drought stress (Senaratna *et al.*, 2000; Shakirova *et al.*, 2003; Singh and Usha, 2003) on plants. When Tomato plants treated with SA increased their drought tolerance (Senaratna *et al.*, 2000). In cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid (Larque-Saavedra and Martin-Mex, 2007). In recent years, some studies have indicated that salicylic acid can enhance the plant growth, yield and quality (Khodary, 2004). Therefore, this study was conducted to determine the application of salicylic acid on tomato plant under drought stress to improve growth, yield and production of tomato fruits.

With conceiving the above scheme in mind, the present research work was undertaken in order to fulfilling the following objectives:

i. To investigate the morpho-physiological and yield contributing characters and yield of tomato at different moisture lavels.
ii. To find out the effect of salicylic acid on morpho-physiological and yield contributing characters and yield of tomato.
iii. To determine the interaction of different moisture stress and salicylic acid on tomato.

CHAPTER II

REVIEW OF LITERATURE

Drought is a great problem in the northern region of Bangladesh, where a vast area remains fallow due to lack of proper supply of irrigation water. The situation is becoming worst because of drastically lowering the water table. Tomato is one of the important vegetable crops in Bangladesh and other countries of the world and it has drawn attention by the researchers for it various way of consumptions and nutritional value. It can be cultivated to a wide range of climates ranging from tropics to within a few degree of the artic circle. However, in spite of its broad cultivation area, production is hindered, facing in a varied biotic factor and abiotic stress conditions. Very limited research works have been conducted to adapt tomato crop in the drought prone area of Bangladesh. An attempt was made to find out the performance of tomato at different levels of moisture stress as well as to find out the possible mitigation ways by using salicylic acid in the drought stressed tomato plants. To facilitate the research works different literature have been reviewed in this chapter under the following sub headings.

2.1 Effect of drought stress

Drought stress during vegetative or early reproductive growth usually reduces yield by reducing the number of seeds, seed size and seed quality. To assess the effect of drought stress on seed yield, seed quality and growth of tomato, the experiment was conducted by Pervez *et al.* (2009) in green house in plastic pots at Pen-y-Fridd field station, University of Wales, Bangor, U.K. during 2003-2004. Tomato cv. ‘Moneymaker’ was used as a test crop. There were four treatments i.e. early stress (when first truss has set the fruits), middle stress (when fruits in first truss were fully matured and started changing their colour), late stress (when fruits on first truss were ripened fully), whereas in control no stress was imposed. Analysis of data regarding various attributes (fruit weight and shoot dry weight per plant, number of seeds per fruit, total number of seeds and seed weight per plant and vigour of seed) showed that drought stress had non-significant effect on vigour, quality and yield of tomato seed. Plant height, number of leaves and number of fruits per plant showed significant results toward drought stress signifying drought effects on growth of tomato.

An experiment was conducted by Nahar and Gretzmacher (2002) to evaluate the effect of water stress on nutrient uptake, yield and quality of tomato (*Lycopersicon esculentum* Mill.) under subtropical conditions with four tomato varieties (BR-1, Br-2, BR-4 and BR-5) in the net house of the Department of Soil Science, Dhaka University, during the period from November 1998 to March 1999. Results revealed that yield and dry matter production were adversely affected at 100 % and 40 % of the field capacity. The dry matter produced by the plants due to stress was dependent on variety. In dry matter production the highest dry matter was obtained by BR-1, followed by BR-5, BR-2 and BR-4. However BR-2, BR-4 and BR-5 did not show significant difference among themselves. The results also revealed that 70 % field capacity was the best treatment. However there was no significant difference between the two treatments, 70 % and 40 %, but the dry matter production was lower at 40 % compared to 70 % field capacity.

Giannakoula and Ilias (2013) conducted an experiment to evaluate the effect of water stress and salinity on growth and physiology of tomato (*Lycopersicon esculentum* mill.) and they observed that the application of moderate salt stress on tomato plants can enhance lycopene and potentially other antioxidant concentrations in fruits. The increase in lycopene in response to salt stress in the tomato fruits varied from 20% to 80%. Although the specific biological mechanisms involved in increasing fruit lycopene deposition has not been clearly elucidated, evidence suggests that increasing antioxidant concentrations is a primary physiological response of the plant to salt stress. Additionally drought stress during cultivation increased the antioxidant capacity of tomato fruit while maintaining the lycopene concentration. In addition, the effects of silicium were investigated, added to the nutrient solution either at low concentration or at an increased concentration. The present study clearly indicates that an enhanced silicium supply to tomato increases markedly the lycopene contents, irrespective of the salinity status in the tomato fruit.

Water is a vital substrate in the photosynthetic process. Crop production as well as plant growth is restricted by water scarcity. If deficit irrigation programs are in practice, throughout the growing season or during a particular growth period, plants are exposed to specific levels of water stress. This occurs where evapotranspiration demand or crop water requirements are significantly reduced. Close to optimum yields can be obtained under deficit irrigation, providing a specific amount of yield reduction of a given crop with a certain amount of water-saving. The saved water can be used in irrigating other areas or crops. This innovative concept has been given different name such as deficit irrigation, deficient evapotranspiration (ET) or irrigation and limited irrigation (English *et al*. 1990).

An experiment with nutrient solution was conducted in the glasshouse of the University of Applied and Life Science, Vienna, Austria to evaluate the effect of water stress on root and shoot development of seven tomato cultivars. The stress levels were 20, 25 and 30 minutes (withholding water) as low, medium and severe stress. The experiment revealed that the cultivars BR-4 and BR-5 showed comparatively tolerance to drought as their root length, root dry weight and root/shoot ratio were higher under water stress condition (Nahar, 2011).

A field experiment was conducted by Kirda and Kanver (1998). They stated that Crop quality may be increased with proper deficit irrigation practice. It has been observed that protein content and baking quality of wheat (*Triticum aestivum* L.) fiber length and strength of cotton (*Gossypium hirsutum* L.) and sugar concentration of sugar beet (*Beta vulgaris* L.) and grape (*Vitis vinifera* L.) increase under deficit irrigation.

A field experiment was conducted by Birhanu and Tilahun (2010) at Melkassa Agricultural Research Center, Ethiopia to study the effects of moisture stress on the yield and quality of two tomato cultivars. The two tomato cultivars were exposed to four irrigation water deficit levels expressed as percentages of potential evapotranspiration (ETc) as: 0% ETc, 25% ETc, 50% ETc, and 75%ETc deficit. The total plant biomass decreased with stress level while the fruit dry matter increased. As a result, the harvest index (fruit dry matter weight/plant dry matter weight) was increased with stress level. Both the number and size of tomato fruits were found to decrease with moisture stress. The incidence of sun-scald and blossom end rot was higher in the more stressed plants (75% ETc) deficit. The total soluble solids (TSS) content was significantly affected by irrigation treatments. The total soluble solids content was increased with stress level while the fruit water content was decreased.

An experiment was carried out by Nuruddin *et al.* (2003) at greenhouse in Canada in which two available soil water deficit thresholds, 65 and 80%, at which plants were irrigated to field capacity were factorially combined with five irrigation timing patterns: (l) no water stress; (2) stress throughout the entire growing season; (3) stress during first cluster flowering and fruit set; (4) stress during first clusters fruit growth; and (5) stress during first cluster fruit ripening. They observed that water stress throughout the growing season significantly reduced yield and fruit size, but plants stressed only during flowering showed fewer but bigger fruits than completely non-stressed plants.

The experiment was conducted by Aynur and Tari (2010) under ecological conditions typical of the Konya Plain, a semi-arid climate, in 2004 and 2005. Results of the field experiments showed that yield suitable for processing (68.7-72.7 t ha^{-1}) and paste output 5 (12.2-12.9 t ha^{-1}) were obtainable under conditions of II application ($p<0.01$). MFW, FD, PV, and TSS were significantly affected from treatments ($p<0.05$). High stress resulted in the highest soluble solids. The total irrigation water amount and water consumptive use of the mentioned application (I1) were determined as 426 and 525mm in

2004. In 2005, the total irrigation water amount and water consumptive use of the same treatment were 587 and 619mm, respectively.

Karim *et al*. (1996) carried out a field experiment to determine the optimum soil moisture regimes and water requirement for achieving the maximum yield potential of tomato on a clayey terrace in Bangladesh. A maximum yield of 37.0 8 t ha^{-1} was obtained when allowing 30% depletion of soil available water (SAW). The total water use and the WUE were found to be 193.6 mm and 1911 kg ha^{-1} cm^{-1}, respectively. They also concluded that at soil moisture depletions exceeding 40% of SAW, a severe water stress was placed on growing tomatoes, hence yield was significantly reduced.

Rahman *et al.* (1999) found that water stress decreased yield, flower number, fruit set percentage and dry matter production in all varieties tested. Photosynthetic rate (Pr), transpiration rate (T), leaf water potential (ψ) WUE were reduced and leaf temperature (T) and stomatal resistance (r) were increased by water stress in all cultivars.

Ubaidullah *et al.* (2002) revealed that different irrigation intervals showed significant effects on all the parameters except the number of days to flowering. Maximum number of fruit per plant and fruit weight per plant, plant height and total yield were recorded in treatments irrigated at 10 days intervals, while maximum number of flower of clusters per plant (13.47) was observed at 15 days intervals of irrigation.

Tomato being very sensitive to soil water regime it is necessary to maintain even moisture supply, over watering is harmful, so also insufficient irrigation for tomato. Flower development in tomato cv. Roma was arrested and flower at all stages dropped and fruit growth ceased when water was withheld for a few days (Bose *et al.,* 2000).

Younghah *et al*. (1999) found that total and marketable yields were increased by increasing soil water tension and by varying night temperature (14 ± 1°C to

10 ± 1°C). Fruit cracking decreased with increasing soil water tensions. They also found that total yield was positively correlated to soil water. Soluble solids content, total acidity and citric acid content were higher in cracked fruits than in normal fruits.

Rainfall is the main source of water for plant growth and unpredictable weather patterns and improper water use in agriculture are the main causes for drought (Smith, 2000). Drought impacts all stages of plant growth. During germination, drought stress delays the germination process and at extreme water deficit, germination ceases (Blum, 1996). At the vegetative stage, it reduces plant vigor and growth. In the early reproductive stage, drought affects fertilization, leading to reduction in seed set and at a later stage, it affects seed filling and hence, reduced yield (Boutraa and Sanders, 2001). Drought stress also reduces the quality and economic value of the crop.

Besides affecting plant growth and productivity, drought stress also causes secondary stresses like oxidative stress, which in turn leads to denaturation of functional and structural proteins (Wang *et al.*, 2003). Some plants like corn tend to produce toxic chemicals, such as nitrates under water deficiency, which are lethal to livestock (Livingston *et al.*, 1995).

Water movement through a plant is a passive process, where it is driven by water potential differences between the soil, plant and atmosphere and the hydraulic conductivities between each component (Lobet *et al.*, 2014). Water moves from high water potential to a lower potential. Plants absorb water from soil through roots and absorbed water moves to xylem vessels through radial water movement. After entering to xylem vessels, water moves from roots to leaves through the xylem and release to atmosphere as water vapor through stomata.

Plants prefer adequate water supply for functioning. However, under drought conditions, create high water pressure difference between soil and plant roots initially and it continues towards canopy with the progression of the stress.

This is not favorable to its normal functioning. Plants have different mechanisms to overcome drought stress and can involve either tolerance or avoidance. Tolerance describes those physiological and biochemical adaptations that allow plants to survive under drought stress. Avoidance is concerned with maintaining a favorable water status in the plant by adopting different physiological and biochemical processes (Malinowski and Belesky, 2000).

Different parts of a plant respond differently to water deficit. Leaves have different strategies when they are under drought stress. Leaf rolling, leaf shedding or low stomatal conductance is the main responses of the leaf to drought stress (Hu *et al*, 2006). Stomatal closure helps to minimize transpiration. Root growth increase with drought stress. Accumulation and translocation of assimilates, maintaining cell wall elasticity and osmotic adjustment are some of the other drought stress tolerance mechanisms exhibited by plants (Malinowski and Belesky, 2000).

Stomatal closure is the initial response from a plant to drought stress (Osakabe *et al*., 2014). Stomatal closure stimulated by the turger pressure change in guard cells due to low water supply. This is induced by the secretion of abscisic acid where it can activate different signaling molecules to trigger stress tolerance through activation of stress responsive genes in the system.

Smit and Singles (2006) studied how canopy development was affected by drought stress in sugarcane. Poor canopy development reduces light interception, and their photosynthesis. Furthermore, they showed that the drought stress increased leaf senescence and led to yield reduction. Bosabalidis and Kofidis (2002) proved that drought stress results in a decrease in size of both mesophyll and epidermal cells in olive, however, the cell density increased.

When the plant is under drought stress, the root pushes deeper in search of water. It was found that the root length increases with drought stress (Turkan *et* *al*., 2005; Bahrami *et al*., 2012). Sharp and LeNoble (2002) observed an increase in the rate of root tip elongation with the increase in drought stress in maize. However, the root volume and the dry weight reduced significantly under the drought stress (Geetha *et al*., 2012; Hadi *et al*., 2014).

Drought stress also affects shoot length. Under water deficient, shoot length in sesame (*Sesamum indicum* L.) was reduced (Bahrami *et al*., 2012), but in some cases, it showed reduction at the initial stage and then an increase in shoot length. Further, some plants increased shoot length initially and then reduced (Turkan *et al*., 2005).

Plant vascular bundles have a major role in the transport of water and nutrients in tomatoes. It was found that the rate of flow of xylem fluids was reduced and hydraulic resistance at the pedicel and the peduncle increased with drought stress (Van Ieperen *et al*., 2003). Salleo *et al.* (2000) tested the effects of xylem cavitation on stomatal conductance in Laurel (*Laurus nobilis* L.). Cavitation was measured using ultrasound acoustic emissions (UAE) and when water potential was reduced, UAE level increased. Increased UAE level indicates, that the high loss of hydraulic conductance due to reduced rate of xylem fluid flow.

There is a significant reduction in plant growth under drought stress. Initially, turgor pressure is reduced and this results in reduction of cell elongation (Farooq *et al*., 2009b). Also, drought stress causes damage in mitosis which results in limited cell division. Both reduced cell elongation and limited cell division negatively impacts plant growth (Farooq *et al*., 2009b).

Plant water potential influences physiological functions of plants, including photosynthesis, transpiration, respiration, photorespiration, stomatal conductance (Chaves *et al*., 2002; Blanke and Cooke, 2004; Flexas *et al*., 2004).

Under drought stress, stomata close and this affects CO_2 flux. Stomatal closure is one of the first responses to drought stress (Hommel *et al.*, 2014; Xie *et al.*, 2014). Stomata close when plant water potential reduces or if the leaf turgor reduces. The response limits CO_2 exchange in leaves (Chaves *et al.*, 2002). Low CO_2 flux causes an increase in ROS. On the other hand, plant tissue water potential is reduced by drought. Low tissue water potential reduce the activities of ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco), phosphoenolpyruvate carboxylase (PEPCase), NADP- malic enzyme (NADP-ME), fructose-1,6-bisphosphatase (FBPase) and pyruvate orthophosphate dikinase (PPDK) enzymes. Both ROS production and reduced activity of enzymes lower the carboxylation. Further, drought causes a down-regulation of non-cyclic electron transport, which negatively affects ATP synthesis. As a result of low carboxylation and low ATP levels, photosynthesis drops under drought conditions (Farooq *et al*., 2009b).

Rizhsky *et al.* (2002) observed that respiration was reduced with drought stress. Bell *et al*. (1971) noted that the mitochondrial oxygen uptake declined with an increase in drought stress in maize. Furthermore, Burton *et al.* (1998) observed limited root respiration with drought in sugar maple. Ribas-Carbo *et al*. (2005) found that respiration rate was diminished with a rise in drought stress in soybean leaves. However, photorespiration was greater in drought stressed soybean than in non-stressed plants (Haupt-Herting *et al*., 2001).

As drought stress progresses, it reduces the leaf water potential and stomatal conductance (Smit and Singles, 2006). Blanke and Cooke (2004) found that the leaf water potential reduced under severe drought stress, but Miyashita *et al*. (2005) discovered that the leaf water potential stayed constant for a period after the onset of water and then reduced rapidly. Furthermore, the recovery after re-watering declined gradually when the drought stress progressed. Reduction of leaf water potential with stress also affected leaf relative water content. Leaf relative water content was reduced with drought (Turkan *et al*., 2005; Valentovic *et al*., 2006).

When a plant is subjected to drought, there is an increase in ABA biosynthesis, leading to elevated ABA levels in the tissues (Plant *et al*., 1991). The increase in the ABA concentration in leaves results in stomatal closure and minimal water loss from the plant. However, the stomatal closure reduces photosynthesis (Zegzouti *et al*., 1997). High ABA concentration in root tips was observed in plants subjected to drought stress (-1.6 MPa) (Sharp and LeNoble, 2002). Bray (1988) studied the role of ABA in drought, using an ABA deficient tomato. In optimal growth conditions, ABA concentration in this mutant was 50% of the wild type plant. When both the wild type and mutant were exposed to drought stress, there was a significant increase in the synthesis of ABA in the wild type but reduced in the mutant. It was recorded that the ABA concentration of the mutant under drought stress was 6% of its ABA concentration grown under optimal conditions.

2.2 Effect of salicylic acid

In order to study the effects of salicylic acid on yield quantity and quality of tomato, an experiment was carried out by Javaheri *et al.* (2012). The experiment was based on randomized complete blocks design with four replications at research center of Shirvan Agricultural Faculty in 2011. Foliar application of five concentrations of salicylic acid (0, 10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} M) were used. Results showed that application of salicylic acid affected tomato yield and quality characters of tomato fruits so that tomato plants treated with salicylic acid 10^{-6} M significantly had higher fruit yield (3059.5 g per bush) compared to non-treated plants (2220 g per bush) due to an increase in the number of bunch per bush. Results also indicated that application of salicylic acid significantly improved the fruit quality of tomato. Application of salicylic acid increased the amount of vitamin C, lycopene, diameter of fruit skin and also increased rate of pressure tolerance of fruits. Fruit of tomato plants treated with salicylic acid 10^{-2} M significantly had higher vitamin C (32.5 mg per 100 g of fruit fresh weight) compared to non treated plants (24 mg per 100g fruit fresh weight). Salicylic acid concentration 10^{-2} M also increased the diameter of fruit skin (0.54 mm) more than two fold compared to control (0.26 mm). Fruit Brix index of tomato plants treated with salicylic acid 10^{-2}M significantly increased (9.3) compared to non-treated plants (5.9). These results suggest that foliar application of salicylic acid may improve quantity and quality of tomato fruits.

Using salicylic acid (SA) is a relatively inexpensive and quick method for promoting growth and yield of crops under saline conditions. A pot experiment was conducted by Salehi *et al.* (2011) to evaluate the effect of SA on tomato growth under salt stress condition. The experiment was complete randomized block with 3 replications, 4 levels of irrigation water salinity (0, 4, 8 and 12 dS m^{-1}) and 4 levels of SA concentration (0, 10^{-6}, 10^{-4} and 10^{-2} M) which was foliar sprayed. There was highly significant reduction in shoot fresh and dry weights and number of flowers per plant with increasing salinity. There was no significant difference between shoot fresh and dry weighs and number of flowers per plant for SA treated plants and control. However, fresh weight of plants treated with 10^{-6} M SA was significantly higher than the other two concentrations. Within each salinity level, SA application did not have significant effects on the measured characteristics. Based on these results, under this experimental condition, SA acid did not improve the salt tolerance of tomato. However, lower concentrations of SA needs to be evaluated.

Excessive soil salinity is a major constraint limiting the distribution of plants in natural habitats, and is an increasingly severe agricultural problem in arid and semi-arid regions. Higher salinity levels caused significant reduction in growth parameters like leaf area, leaf length and root and shoot dry weight. Salicylic acid (SA), a plant phenolic is now considered as a hormone-like endogenous regulator, and its role in the defence mechanisms against biotic stressors has been well documented. In recent years its role has been widely investigated in abiotic stress (salinity, drought, water deficit and so on). An experiment was conducted by Ahmed *et al.* (2011) to study the effects of salicylic acid on growth and some physiological characters of salt stressed tomato plants. The presence of salicylic acid at low concentration (0.01 mM) in culture medium riched with NaCl 100 mM (6 $g \cdot L^{-1}$) improves the tolerance of tomato *cv.* Golden Sunrise to salinity. This amelioration results in stimulation of growth and development of plants. The applied of SA in saline medium induce, an increase in chlorophyll content, a better supply of essential elements in plant growth, such as K^+, a decrease in toxic ions such Na^+ and Cl^- in aerial organs and an additional synthesis of organic solutes and osmoprotectors like proline and proteins. All these results suggest that salicylic acid could be successfully used in alleviating depressive effects of salt, drought and water deficit on the productivity of the cultivated tomato.

An experiment was conducted by Majeed *et al.* (2016) to investigate the mitigation of drought stress by foliar application of salicylic acid and potassium in mung bean. Treatments comprised of three drought stress (control, drought stress at flowering stage and drought stress at flowering and pod formation stages) and foliar application salicylic acid (100 ppm) alone and in combination with potassium (1%). Irrigation missing at flowering stage, affected less the growth and yield as compared with irrigation missing at both flowering and pod formation stage. Exogenous application of salicylic acid and potassium could mitigate the adverse effects of drought stress significantly.

Mungbean (*Vigna radiata* L.) is an important legume crop of Asia and a major component of many cropping systems. The crop grown under non-irrigated condition, encounters drought stress at different growth stages. Plants produce proteins in response to abiotic and biotic stress and many of these proteins are induced by phytohormones such as salicylic acid. SA is synthesized by many plants and is accumulated in the plant tissues under the impact of unfavorable abiotic factors, contributing to the increase of plants resistance to drought stress. The field experiment was laid out by Nezhad *et al.* (2014) in randomized complete block design with split plot design with three replications. Drought stress in three levels (I_1: Regular watering 5 days, I_2: 10 days, I_3: 15 days) allocated to main plots and foliar application of salicylic acid in four levels (S_1:

0, S_2: 0.5, S_3:1, S_4:1.5 Mmol) was allocated to sub plots. Drought stress and salicylic acid on plant height, number of branch, number of pod and biological yield was significant.

Two field experiments were conducted by Mady (2009) to study the effect of foliar application with 50 and 100 ppm of salicylic acid (SA) and 100 and 200 ppm of vitamin E (VE) and their combination on some growth aspects, photosynthetic pigments, minerals, endogenous phytohormones, flowering, fruiting and fruit quality of tomato cv. Super strain B during 2006 and 2007 seasons. Plants were sprayed two times at 30 and 45 days after transplanting. Result indicated that, different applied treatments significantly increased all studied growth parameters as number of branches and leaves per plant, leaf area per plant and leaves dry weight as well. Besides, the two concentrations of each applied salicylic acid or vitamin E obviously increased photosynthetic pigments, NPK, Fe, Zn, Mn, total carbohydrates and crude protein concentrations in leaves of treated plants as compared with those of untreated ones. Also, all treatments increased gibberellins and cytokinins level in tomato shoots whereas Auxins and abscisic acid were decreased. Furthermore, the highest early and total yields were obtained with salicylic acid 50ppm + vitamin E 200ppm followed by SA 100 + VE 200ppm, respectively. In addition, chemical composition of minerals and some bioconstituents such as carbohydrates, vitamin C, total soluble solids in tomato fruits were also increased at the same treatments. Therefore, the study strongly admit the use of salicylic acid and vitamin E as foliar application not only increased early and total yields but also getting a good fruit quality as well.

The study was undertaken by Kowalska and Smolen (2013) to evaluate the effect of an increased salt concentration in a nutrient solution and foliar application of salicylic acid and $KMnO_4$ (the latter causing oxidative stress) on the yield, fruit quality and nutritional status of tomato plants. Salinity stress was stimulated by elevating the electrical conductivity (EC) of a nutrient solution by a proportional increase in the content of all macro- and micronutrients. In 2009- 2010, tomato plants were grown on rock wool, in a heated foil tunnel. The experiment included two sub-blocks with two EC levels (2.5 and 4.5 mS cm^{-1}). Within each sub-block, the following foliar application variants were distinguished: 1. control, without foliar application; 2. salicylic acid (SA); 3. SA/$KMnO_4$. In the SA/$KMnO_4$ combination, solutions of these compounds were applied alternately every 7 days. SA was applied in the concentration of 0.01%, while the concentration of $KMnO_4$ was 0.1%. Foliar treatments were conducted at 7-day intervals from the 3rd cluster flowering stage until ten days before the first harvesting of fruits. Irrespective of the EC of the nutrient solution, foliar application of SA as well as SA/$KMnO_4$ had no significant effect on the tomato yield, total acidity and dry matter or soluble sugar content in fruits. Neither did it affect significantly the mineral status of plants except for an increase in the Mn level induced by SA/$KMnO_4$. A significantly higher content of ascorbic acid together with a decreased content of phenolic compounds and free amino acids resulted from the foliar application of SA and SA/$KMnO_4$. Salicylic acid counteracted the oxidative stress caused by $KMnO_4$.

This experiment was conducted by Kazemi (2014) to study the effect of salicylic acid and methyl jasmonate as pre- harvest treatments on the tomato vegetative growth, yield and fruit quality. The experiment was completely randomized experimental design with four replications. These factors included salicylic acid (SA) in 2 levels (0.5 and 0.75 $mmolL^{-1}$) and methyl jasmonate (MJ) in 3 levels (0.25, 0.5 and 0.75 $mmolL^{-1}$) applied on tomato. The results showed that 0.25 $mmolL^{-1}$ MJ and 0.5 $mmolL^{-1}$ SA both caused a significant increase in vegetative and reproductive growth compared to other levels ($p \leq 0.05$). The interaction between MJ and SA (0.5 $mmolL^{-1}$ SA + 0.25 $mmolL^{-1}$ MJ) on vegetative and reproductive growth was significant, as well. The plant height increased to its maximum (105.11, 120.31 and 120.14 cm) with 25 $mmolL^{-1}$ MJ, 0.5 $mmolL^{-1}$ SA and 0.5 $mmolL^{-1}$ SA + 0.25 $mmolL^{-1}$ MJ application, respectively. The maximum number of fruits per plant (35.12) and number of flower per plant (7) was recorded with 0.5 mM MJ+0.5 mM SA application. Application of high MJ and SA concentration caused a significant decrease in chlorophyll index and dry weight while MJ +SA combination had no significant effect. The maximum chlorophyll content (23.1 and 25 SPAD) and dry weight (6.89 and 6.97 g) was recorded with 0.5 mM SA and 0.25 mM MJ application. The leaves-NK content was not affected by application of MJ alone or in combination, but low SA (0.5 mmolL^{-1}) concentrations alone significant increasing leaves -NK content and chlorophyll content. Interaction between factors was not significant in chlorophyll, dry weight and chemical contents. The results indicated that 0.25 mmolL^{-1} MJ and 0.5 mmolL^{-1} SA both caused a meaningful increase in fruit quality compared to other levels ($p \leq 0.05$). The interaction between MJ and SA (0.5 mmolL^{-1} SA+ 0.25 mmolL^{-1} MJ) on fruit quality was significant. On the other side, the interaction between MJ and SA on yield and fruit weight was significant. Highest means of yield (170.32 Mg. ha^{-1}) and fruit weight (95.14 g) were found in tomato treated with 0.5 mmolL^{-1} SA+ 0.25 mmolL^{-1} MJ, followed by 165.12(Mg. ha^{-1}) and 85.6 (g) with 0.5 mmolL-1 SA and 163.7 (Mg. ha^{-1}) and 89.12 (g) with 0.25 mmolL^{-1} MJ. The maximum TSS (6°Brix), TA (3.59 %) and vitamin C (15.14) were recorded with 0.5 mmolL^{-1} SA + 0.25 mmolL^{-1} MJ applications.

Fahraji *ei al.* (2014) reported that seed treatment or foliar application of chemicals like glycinebetaine, kinetin and salicylic acid may increase yield of different crops due to reduction in stress induced inhibition of plant growth. Salicylic acid (SA) is part of a signaling pathway that is induced by a number of biotic and abiotic stresses. It has been recognized as an endogenous regulatory signal in plants mediating plant defense against pathogens. It was shown that exogenous treatment of young maize plants with SA grown under optimal growth conditions provided protection against subsequent low-temperature stress. Besides the obvious visual symptoms this observation was confirmed by changes in chlorophyll fluorescence parameters and electrolyte leakage measurements. SA application inhibited Na accumulation in salinity condition. This main indicate that, seed pretreatment with SA induced a reduction sodium absorption and toxicity, which is further reflected in low membranes injury, high water content and dry matter production.

Salicylic acid (SA) acts as an important signaling molecule which modulates plant responses to environmental stresses. This experiment was conducted by Ahmad *et al.* (2014) to assess the effect of exogenous application of SA on plant growth, photosynthesis and compatible solute accumulation in economically important *Allium cepa* var. *Aggregatum* (shallot) under drought stress. Drought stress was imposed in the form of 5 days interval drought and SA (0.5 mM) was applied exogenously to both drought stressed and normal plants. Leaf samples were harvested on 30th, 45th, 60th and 75th day after planting. SA induced significantly plant growth in terms of dry weight, relative water content and photosynthetic pigments in both normal and drought stressed plants. The compatible solute accumulations were increased significantly under drought stress, but highly significant was found in presence of SA and drought stress. Therefore, the exogenous application of SA under drought stress, altered proline metabolism significantly, leading to the maintenance of the turgor by accumulating significant higher levels of proline content in shallot, supporting its protection from drought stress. Further, the addition of SA under drought stress increased glycine betaine, soluble sugars and free amino acid contents which acts as osmoticum and help plant in maintenance of water potential under extreme environmental conditions. Hence, help the plant to cope with the adverse effects of stress by retaining its water content.

A field experiment was conducted by Bakry *et al*. (2012) at the experimental farm of National Research Center, Nubaria, El-Behaira Governorate, Egypt, during two successive seasons. The aim of this work was to investigate drought stress mitigation by foliar application of salicylic acid (SA) at four levels (0, 25, 50 and 75 mg L^{-1}) on linseed two varieties (Olin and Amon, of oil purpose types) grown under newly reclaimed sandy soil. SA was applied twice as foliar spraying and skipping the irrigation at 45 and 60 days after sowing in two linseed varieties. Application of 25, 50 and 75 mg L^{-1} SA to flax two varieties. SA treatment improved morphological criteria of linseed varieties (shoot and root height, fresh and dry weights) compared to untreated plants when exposed to drought stress under newly reclaimed sandy soil. Application of SA increased photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments), total soluble sugars, polysaccharides, total carbohydrates, proline and free amino acids, indole acetic acid, phenol contents. Meanwhile, decreased lipid peroxidation as malonaldhyde contents as compared with untreated control. SA application increased yield and yield components as plant height, technical length, fruiting zone length, number of fruiting branches $plant^{-1}$, number of capsules $plant^{-1}$, also, biological yield $plant^{-1}$, seed yield $plant^{-1}$, seed yield fed^{-1}, straw yield, 1000 seeds weight when compared with the untreated controls. Data also show that, foliar spray of salicylic acid increased oil% and oil yield (kg fed^{-1}) as compared with controls. Also, qualitative and quantitative changes in fatty acid compositions were obtained in response to SA under drought stress. In conclusion, cultivation of two linseed varieties under drought stress in newly reclaimed sandy soil was more effective with foliar spraying with 75 mg L^{-1} of SA plant.

An experiment was conducted by Waseem *et al*. (2006) to assess whether exogenously applied SA through the rooting medium could mitigate the adverse effects of water stress on plant growth, photosynthesis and nutrient status of two wheat genotypes. For this purpose, salicylic acid @ 0, 5, and 10 mg L^{-1} was applied through the rooting medium to plants of two wheat lines growing in plastic beakers (250 mL) filled with Hoagland's nutrient solution containing 0 or 19% PEG_{8000} to represent two water regimes of control (0 MPa) and -0.6 MPa respectively. Different levels of SA applied through the rooting medium increased photosynthetic rate in both cultivars under non-stress conditions but only in S-24 under water stress conditions. Exogenous application of 5 or 10 mg L^{-1} SA caused an increase in stomatal conductance, transpiration rate, and sub-stomatal of water stressed plants of cv. S-24 whereas it was true for drought plants of MH-97 only when 5 mg L^{-1} SA applied. Cultivar S-24 was generally higher in N and P contents of shoot and root than that in genotype MH-97 under both normal and water stress conditions. A decrease in shoot and root N contents of both genotypes and shoot and root P contents of genotype S-24 only was observed in stressed plants when 5 mg L^{-1} of SA was applied through the rooting medium, whereas the same was true for root P and shoot Ca^{2+} contents in the non-stressed plants of both cultivars. Application of salicylic acid through the rooting medium significantly reduced the root K^+ of two cultivars under both normal and water deficit conditions. Although, exogenously applied SA through the rooting medium had growth promoting effects under non-stress conditions, it did not mitigate the adverse effects of drought stress on growth of both cultivars, though genotype MH-97 showed some recovery under water stress conditions.

An experiment was carried out by Aghdam *et al.* (2012) to evaluate the effect of postharvest salicylic acid treatment on reducing chilling injury in tomato fruit. Tomato fruits at mature green stage were treated after harvest with salicylic acid (0, 1 and 2 mM), and then stored under chilling temperature (1ºC) for 21 days. The chilling injury (CI) symptoms, electrolyte leakage and malondialdehyde content were significantly reduced and proline content was significantly increased by salicylic acid treatments. Salicylic acid application had no significant effect on total phenolics content but phenylalanine ammonia-lyase (PAL) activity was significantly reduced in treated fruits. Overall, the results obtained from the present experiment suggest that salicylic acid has potential postharvest applications in alleviating the chilling injury symptom in tomato fruit.

Growth and productivity of banana is seriously restricted by water deficit. Salicylic acid (SA) induces biotic and abiotic stress tolerance in crops. Bidabadi *et al.* (2012) conducted an experiment to study the ameliorative effects of SA on water stress in banana (*Musa acuminata* cv. ‘Berangan’, AAA). Shoot tip explants with 8 mm in size were treated with varying SA concentrations (0, 1, 2 and 3 mM) and incubated on MS media containing different levels (0, 1, 2 and 3 %) of PEG *in vitro*. After 2 months, proliferation rate, fresh weight increase, relative water content, chlorophyll level, proline accumulation, malondialdehyde (MDA) and H_2O_2 contents were measured and analyzed. The results indicated that with increasing levels of PEG, proliferation rate, fresh weight increase, relative water content and chlorophyll concentrations were significantly decreased. The SA concentrations improved shoot tips performance by increasing proliferation rate, fresh weight increase and relative water content. Although non SA-treated shoot tips were not significantly responsive to increasing levels of PEG in terms of elevated proline content, they responded positively to supply of SA by showing significant increase in proline and chlorophyll contents under water stressed conditions. SA treatments also enhanced plant tolerance against oxidative stress. This was observed through significant reduction in H_2O_2 and MDA contents of SA-treated shoot tip under water stress conditions. The results revealed that exogenous application of SA helped to reduce the harmful effects of water deficit on banana regenerate *in vitro*.

Increased plant tolerance to stress may be chemically induced with applications of salicylic acid (SA). The aim of this study was to determine the change in the SA leaf concentration over time in response to the SA spraying in leaves of greenhouse grown tomato. In sprayed leaves the SA concentration showed changes over time similar to the reported responses to environmental stress. Two days after the first application, the SA foliar concentration reached the maximum of 8 $\mu g.g^{-1}$, equivalent to twice the amount observed in the control plants. SA decreased until it reached the level of control plants eight days later. A second application showed actually the same response, but with a faster decline of SA in two days. According to the results of this assay, SA applications on tomato should be performed within a minimum interval of eight days in order to maintain the SA concentration related with the increase in plant tolerance to environmental stress (Guzmán-téllez *et al*., 2014).

To study the effect of salicylic acid on photosynthetic pigments (chlorophyll *a*, *b*, total chlorophyll, and carotenoids), polyphenol compounds, anthocyanin, flavonoids, phenylalanine ammonia-lyase activity, malondialdehyde, lipoxygenase activity, electrolyte leakage, relative water content, soluble sugar contents, and protein content of black cumin (*Nigella sativa*) under drought stress in hydroponic culture, an experiment was conducted by Kabiri *et al.* (2014) as a completely randomised design in a factorial arrangement with three replicates. Experimental treatments included salicylic acid at three levels (0, 5, and 10µM) and drought stress (induced by polyethylene glycol 6000) at four levels (0, –0.2, –0.4, and –0.6 MPa). Results showed that salicylic acid application through the root medium increased drought tolerance of black cumin seedlings. Plants pre-treated with salicylic acid exhibited slight injury symptoms whereas those not pre-treated with salicylic acid had moderate damage and lost considerable portions of their foliage. In conclusion, salicylic acid could protect the *Nigella* plant against drought stress through increasing of all the mentioned traits, and 10µM salicylic acid was the most effective level under both conditions.

Salicylic acid (SA) plays a critical role in plant development and defense responses to biotic and a biotic stresses. In other to study the effects of salicylic acid on some quality characters of tomato different concentration of salicylic acid (10^{-2}, 10^{-4}, 10^{-6}, 10^{-8} molar and control) was done in seedling stage as foliar replication. Measured characters was including (number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter). This study showed that salicylic acid significantly affected number of panicle in a bush, yield, fruit number in panicle, fruit number in bush, fruit weight and fruit diameter. Among foliar application, the highest rate of tomato yield with mean of 3059.5 g obtained in SA_3 (SA at 10^{-6} M), highest numbers of panicle in tomato bushes with mean of 31.25 measured in SA1 (SA at 10^{-2} M). Highest fruit number in panicle and highest fruit number in bush obtained by mean of 3.5 and 66.75 in SA_1 (SA at 10^{-2} M), respectively and minimum amount of all this characters was recorded in control treatment and the highest amount of fruit weight and also fruit diameter was measured in control treatment with mean of 61.50 g and 51.75 mm, respectively (Javaheri *et al.*, 2014).

Tomato plants grown in nutrient solutions with different K^+ levels were used to study the effect of salicylic acid and Potassium status on Na^+ uptake and Na^+ accumulation in the shoot and root. Changes in the nutrient K^+ levels induced evident differences in internal K^+ content. When low and normal – K^+ plants treated with SA were exposed in saline condition (50 mM Nacl) during experiment, Na^+ uptake in low- K^+ plants was greater than in normal – K^+ plants. At the presence of SA, Na+ uptake in low- K+ plants was lower than low- K+ plants alone. Normal – K^+ plants plus SA showed lowest amount of Na uptake and accumulation. In addition, K^+ starvation favored the Na^+ uptake and the Na^+ accumulation both in the root and in the shoot. When the plants were exposed to heat stress by a sharp increase of the temperature to 32^0C during the same period of time, the stimulating effect of K^+ starvation on the water uptake was even greater. The high temperature increased Na^+ uptake in both types of plants, but the Na^+ accumulation in the shoot was only favored in low K^+ plants (Abdi *et al*., 2011).

Several studies have demonstrated that exogenous SA application enhances plant growth and development. Fariduddin *et al.* (2003) showed that mustard plants sprayed with low concentrations of SA produced larger amounts of dry matter and had higher photosynthetic rate in comparison with control plants. SA application to corn and soybean promoted leaf area and dry weight of plants (Khan *et al.* 2003). In another study Hussein *et al.* (2007) revealed that growth traits of wheat plants were improved as a result of SA spraying on the plants. In addition, Hayat *et al.* (2010) reported that soaking of wheat grains in low concentrations of SA significantly promoted growth of wheat seedlings.

Salicylic acid has been reported to induce flowering in a number of plants. In cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid (Larque-Saavedra and Martin-Mex, 2007). It was reported that the foliar application of salicylic acid to soybean also enhanced the flowering and pod formation (Hayat, 2010). Flowering is another important parameter that is directly related to yield and productivity of plants. Salicylic acid has been reported to induce flowering in a number of plants. In cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid (Larque-Saavedra and Martin-Mex 2007). It was reported that the foliar application of salicylic acid to soybean also enhanced the flowering and pod formation (Hayat *et al*., 2010).

2.3 Use of growth substances for mitigation of drought stress in plant

Many plant growth regulators (PGRs) are known to alleviate the negative effects of drought stress in plants. However, limited research has been conducted to investigate the potential benefits of exogenous application of PGRs in wheat plants grown under drought stress. The present study was under taken by Anosheh *et al*. (2012) to evaluate the effects of salicylic acid (SA) and chlormequat chloride (CCC) on drought-stress induced changes in morpho-physiological and biochemical characteristics of two commonly grown wheat cultivars in Iran were assessed. Plants were field grown under three water regimes, non-stress (normal irrigation), moderate drought stress (water withheld from flowering stage to season end), and severe drought stress (water withheld from double ridges stage to season end), and two foliar applications of PGRs, SA (0.7 mM) and CCC (2.5 g L^{-1}). Drought stress increased canopy temperature and decreased leaf area index and plant height in both cultivars, however, exogenous applications of PGRs reduced these harmful effects considerably. Drought stress also significantly increased the levels of total soluble proteins and free proline, the activities of antioxidant enzymes superoxide dismutase, peroxidase and catalase, and decreased the contents of chlorophyll *a* and chlorophyll *b*. Application of CCC significantly increased all measured parameters except total soluble proteins and application of SA increased total soluble proteins, chlorophylls *a* and *b*, and peroxidase activity. These observations indicated that both SA and CCC were effective in alleviating adverse effects of drought stress in wheat, though the responses of the two wheat cultivars were not always the same. The beneficial effects of SA and CCC in reducing the adverse effects of drought stress may be due to improving stomatal regulation, maintaining leaf chlorophyll content, increasing water use efficiency, and stimulating root growth.

Salt stress is amajor environmental constraint most limiting plant productivity. Seeking salt-tolerant crops requires an examination of the behavior of the plant development including seed germination stage. The effects of NaCl stress (100 mM) combined or not with different solutions of phytohormones ABA (0.005 mM), GA_3 (0.005 mM) and SA (0.5 mM) on germination of two processing tomato cultivars named Rio Grande (Rg) and Imperial (Ip) were investigated. Seeds were subjected to salt stress, combined or not with hormones, at two stages of development (48 and 96 hours). The results showed that the germination rate and germinate value of the two processing cultivars of tomato were influenced by the different treatments. On the other hand, salicylic acid as GA_3 attenuates the effect of NaCl. Instead, the middle enriched with ABA inhibits seed germination. Moreover, the tested stress conditions had shown a significant variability in the germination and handling between the two germination stages. Nevertheless, the effect of GA_3 and SA on the germination of two processing tomato varieties to improve the inhibitory effect of ABA and salinity was discussed (Arbaoui *et al.*, 2015).

The present investigation was carried out by Jaiswal *et al*. (2014) to elucidate the mechanism of salinity tolerance by exogenous supply of salicylic acid at two concentrations viz. 100 and 200 ppm under created salinity stress of 50 mM and 100 mM NaCl in the soil. To check the efficacy of salicylic acid under salinity at 45, 60 and 75 days after sowing, foliar spray was done to study on biochemical parameters which lead to significant increase in chlorophyll content as well as sugar and starch content at the level of 100 ppm salicylic acid. Proline, one of the stress induced amino acid at concentration of 200 ppm also showed increased level indicating its potential role in combating salinity stress. Similar results were obtained for antioxidative enzymes like SOD and CAT at the level of salicylic acid at 200 ppm. Thus, it can be concluded that application of salicylic acid at varying concentrations of 100 and 200 ppm can lead to overcome salinity situations up to a certain extent.

Drought is an important factor-limiting yield in maize. Cytokinins are well reported for reducing the perilous effects of drought stress in maize (*Zea mays* L.). A net house study was planned by Ali *et al.* (2011) to compare the efficacy of synthetic cytokinins, benzyl amino purine (BAP) with a natural source of cytokinins i.e., leaf extract of *Moringa olifera* as foliar application on maize seedlings subjected to different levels of drought (75% and 50% of field capacity). On weekly basis, the plants were sprayed with BAP (50 mg L^{-1}) and moringa leaf extracts (MLE) (30 times diluted with water) @ 25 mL $plant^{-1}$. The Plants applied with normal irrigation (100% field capacity) and water sprays were taken as control. The crop was analyzed for seedling vigor, growth, water relations, physiological attributes and enzymatic antioxidants. The results showed that drought stress significantly affected the leaf area, plant height; rooting density, root fresh and dry weights, shoot fresh and dry weights, cell membrane thermostability (CMT), leaf temperature, osmotic and turgor potentials, peroxidase (POD) activity and chlorophyll *a* contents. Foliar applications significantly improved the leaf area, plant height, root fresh and dry weights, CMT and chlorophyll *a*, *b* contents. BAP alleviated the drought stress better than other treatments as it increased the root fresh and dry weights, CMT, chlorophyll *a* and *b* contents significantly. MLE increased leaf area, plant height, chlorophyll *a* and *b* contents under severe drought stress (i.e., 50% field capacity) and root fresh and dry weights under mild stress. Under normal and mild drought stress levels, MLE found as a best stimulus for plant growth.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November 2015 to April 2016 to study the mitigation of drought stress in tomato by using exogenous salicylic acid. The materials and methods that were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate condition of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Location of the experimental site

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24.09^0N latitude and 90.26^0E longitudes. The altitude of the location was 8 m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka.

3.2 Characteristics of soil that used in pot

Experimental site belongs to the Modhupur Tract (UNDP, 1988) under AEZ No. 28 and 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. The nutrient status of soil under the experimental pot were collected and analyzed in the Soil Resource Development Institute, Dhaka and results have been presented in Appendix I.

3.3 Climatic condition of the experimental site

Experimental area is situated in the sub-tropical climate zone, which is characterized by heavy rainfall during the months of April to September and scanty rainfall during the rest period of the year. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.4 Planting materials

Seedlings of 30 days of BARI Tomato-14 were used as planting material. The seedlings of tomato were grown at the nursery of Horticulture Farm of Sher-e-Bangla Agricultural University. BARI Tomato-14, a high yielding variety of Tomato was developed by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.5 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Different levels of moisture

i. W_1 = 100% evapotranspiration moisture
ii. W_2= 75% evapotranspiration moisture
iii. W_3= 50% evapotranspiration moisture

Factor B: Different levels of salicylic acid

i. S_0 = Control (Foliar spray of water without salicylic acid)
ii. S_1 = Foliar spray with 50 ppm salicylic acid
iii. S_2 = Foliar spray with 75 ppm salicylic acid
iv. S_3 = Foliar spray with 100 ppm salicylic acid

There were 12 (3 × 4) treatments combination such as:

W_1S_0, W_1S_1, W_1S_2, W_1S_3, W_2S_0, W_2S_1, W_2S_2, W_2S_3, W_3s_0, W_3S_1, W_3S_2 and W_3S_3.

3.6 Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experiment area was divided into three equal blocks. Each block contained by 48 pots where 12 treatments combination were allotted at random. Four plants were placed under each treatment. There were 144 unit pot altogether in the experiment. Each pot was 35 cm (14 inches) in diameter and 30 cm (12 inches) in height.

3.7 Raising of seedlings

A common procedure was followed in raising of seedlings in the seedbed. 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. All weeds and stubbles were removed and 5 kg well rotten cowdung was applied during seedbed preparation. The seeds were sown in the seedbed at 16 November, 2015 to get 30 days old seedlings. Germination was visible 3 days after sowing of seeds. After sowing, seeds were covered with light soil to a depth of about 0.6 cm. Heptachlor 40 WP was applied @ 4 kg ha^{-1} around each seedbed as precautionary measure against ants and worm. Necessary shading by banana leaves was provided over the seedbed to protect the young seedlings from scorching sun. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in this seedbed.

3.8 preparation of pot

A ratio of 1:3 well rotten cow dung and soil were mixed and pots were filled 15 days before transplanting. Silty Loam soils were used for pot preparation. All 144 pots were filled on 30 November, 2015. Weeds and stubbles were completely removed from the soil.

3.9 Uprooting and transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seedbed and were transplanted in the experimental pots in the afternoon of 16 December, 2015 maintaining two seedlings in each pot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to roots with ensuring maximum retention of roots. The seedlings were watered after transplanting. Shading was provided using banana leaf sheath for three days to protect the seedlings from the hot sunlight and removed after seedlings were established.

3.10 Application of manure and fertilizers

The collected soil was measured as a cubic meter by applying length (m) × width (m) × high (m). For field crops, a depth of soil is considered 15 centimeter (0.15m). So, one decimal land is ($40.5\text{m}^2 \times 0.15$ m) = 6.075 m^3 (approximate) which has considered as a root zone soil. Total volume of collected soil was calculated which has found 14.65 m^3 considering Length 3.5 m × width 3.1 m × height 1.35 m. Recommended fertilizer dose for tomato for very low status soil: organic matter, urea (Total nitrogen: minimum 46%), MP (as Muriate of potash: 60% K_2O), TSP (as Triple Super Phosphate: 48% P_2O_5) and gypsum (as $CaSO_4.2H_2O$ containing 19% S) for one decimal land is 50 kg, 1.6 kg, 0.68 kg, 0.5 kg, and 0.43 kg which has considered for 6.075 m^3 of root zone soil, respectively (FRG 2012). Total soil volume was 14.65 m^3 and one decimal is equal to 6.075 $\text{m}^{3.}$ So, a comparison was made to estimate the exact amounts of organic matter, MP, TSP and Gypsum has found $\text{organic matter (OM)} = \frac{50\times14.65}{6.075} = 120.6\text{ kg},\ MP{:}= \frac{0.68\times14.65}{6.075} = 1.64\text{ kg},\ TSP = \frac{0.5\times14.65}{6.075} = 1.20\text{ kg},\ \text{Gypsum} = \frac{0.43\times14.65}{6.075} = 1.04$ respectively. Finally, the calculated amount of organic matter, half of MP and all required TSP and Gypsum were applied prior filling the pot with soil. One decimal land can be accommodating 162 plants considering spacing row to row and plant to plant 50 cm × 50 cm. Our total plants under experimentation were 144 which needed 1422 g of urea for three time of application. Each time @ 3.30 g urea per plant was applied at 15, 30 and 45 days after transplanting as a ring method. Rest half of MP was applied in two split dose at 30 and 45 days after transplanting at the time of 2nd and 3rd dose of urea application. Each time @ 3.42 g MP was applied per plant.

3.11 Application of the treatments

3.11.1 Salicylic acid

Tomato plants were treated with 50ppm, 75ppm and 100ppm salicylic acid which were prepared by adding 50, 75 and 100 mg salicylic acid per litre of water respectively. Those doses were applied as a foliar spray at 15, 30, 45 and 60 days after transplanting (DAT).

3.11.2 Moisture levels

Gravimetric method was used to find out proper strategy to irrigate pot plants. In this method, plastic pot with soil was weighed using weighing balance and all the plastic pots was made in equal weight including soil which was 10 kg where only empty plastic pots was 0.8 kg. Water was added in each pot to make it well saturated condition. The difference between two weights is the evaporation rate. Pot with soil was allowed for two days tying with polythene sheet. After two days, the plastic pot with wet soil was weighted. The loss of water = weight of pot soil in saturated water – weight of pot soil after allowing two days. The amount of water loss during the two days was recovered completely by irrigation, for control pots only. Other pots received 75% and 50% of the water added to the control plants.

3.12 Intercultural operations

3.12.1Gap filling

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

3.12.2 Weeding

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

3.12.3 Staking

When the plants were well established, staking was given to each plant by bamboo sticks for support to keep them erect.

3.12.4 Plant protection measures

Melathion 57 EC was applied @2 ml L^{-1} of water against the insect pests like cutworm, leaf hopper, fruit borer and others. The insecticide application was made fortnightly after transplanting and was stopped before two week of first harvest. Furadan 10G was also applied during pot preparation as soil insecticide. During foggy weather precautionary measure against disease attack of tomato was taken by spraying Diathane M-45 fortnightly @2 g L^{-1} of water at the early vegetative stage. Ridomil gold was also applied @ 2 g L^{-1} of water against blight disease of tomato.

3.13 Harvesting

Fruits were harvested at 3 days interval during early ripe stage when they developed slightly red color. This indeterminate type of fruit harvesting was started from last week of February and was continued up to first week of April, 2016.

3.14 Data collection

Experimental data were recorded from 30 days after transplanting and continued until harvest. The following data were recorded during the experimental period.

A. Morphological characteristics

3.14.1 Plant height (cm)

Plant height was measured from plant of each unit pot from the ground level to the tip of the longest stem and mean value was calculated. Plant height was recorded at 10 days interval starting from 30 days to 70 DAT.

3.14.2 Number of branches per plant

The total number of branches per plant was counted from plant of each unit pot. Data was recorded at 10 days interval starting from 30 days to 70 DAT.

3.14.3 Number of leaves per plant

The total number of leaves per plant was counted from plant of each unit pot. Data was recorded at 10 days interval starting from 30 days to 70 DAT.

3.14.4 Leaf area (cm^2)

Leaf area (LA) was determined from middle portion of plant by measuring length and breadth of leaf using scale at flowering stage and 30 days after flowering.

B. Physiological characteristics

3.14.5 SPAD value

The SPAD meter is a hand-held device that is widely used for the rapid, accurate and non-destructive measurement of leaf chlorophyll concentrations. Chlorophyll content of leaf was determined from plant samples by using an automatic SPAD meter. SPAD was recorded at first flowering stage and 30 days after flowering.

3.14.6 Dry matter content of leaves (%)

After harvesting, randomly selected 100 g leaf sample sliced into very thin pieces were put into envelop and placed in oven maintained at 60°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. The dry matter contents of leaf were computed by the following formula:

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

C. Yield and yield contributing characteristics

3.14.7 Number of flower cluster plant^{-1}

The number of flower cluster was counted from plant of each unit pot and the numbers of flower clusters produced per plant were recorded.

3.14.8 Number of flowers cluster^{-1}

The number of flower was counted from plant of each unit pot and number of flower produced per cluster was recorded on the basis of flower cluster per plant.

3.14.9 Number of flowers plant^{-1}

The number of flower per plant was counted from plant of each unit pot and the average number of flowers per plant was recorded.

1.14.10 Number of fruits cluster^{-1}

The number of fruits per cluster was counted from plant of each unit pot and average the number of fruits per clusters was recorded.

3.14.11 Number of fruits plant^{-1}

The number of fruit per plant was counted from plant of each unit pot and the average number of fruits per plant was recorded.

3.14.12 Length of fruit (cm)

The length of fruit was measured with a slide calipers from the neck of the fruit to the bottom of 5 selected fruits from each pot and there average was taken and expressed in cm.

3.14.13 Diameter of fruit (cm)

Diameter of fruit was measured at the middle portion of 5 selected fruit from each pot with a slide calipers and there average was taken and expressed in cm.

3.14.14 Weight of individual fruit (g)

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

$$\text{Weight of individual fruit } (g) = \frac{Total\ weight\ of\ fruit\ per\ plant}{Total\ number\ of\ fruit\ per\ plant}$$

3.14.15 Yield plant^{-1} (kg)

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

3.14.16 Yield (t ha^{-1})

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

3.15 Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

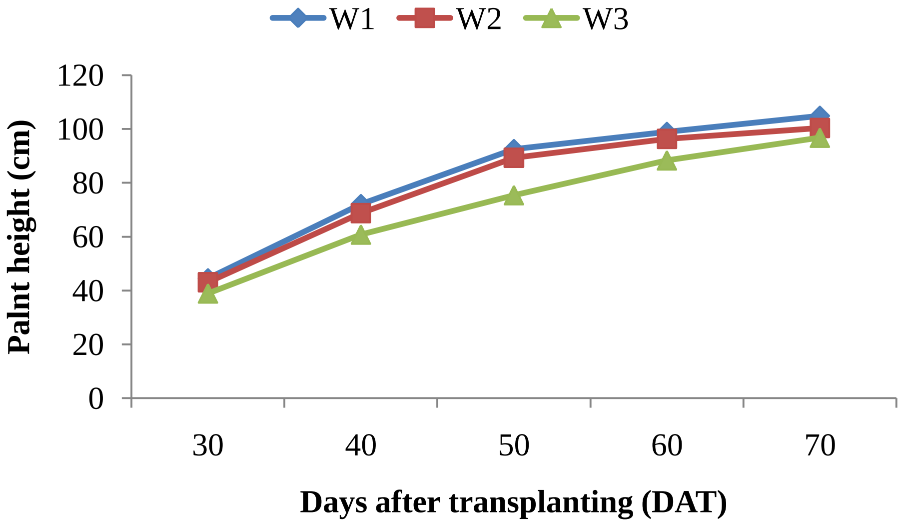
The experiment was conducted to study the mitigation of drought stress in tomato by exogenous application of salicylic acid. Data on different growth and yield parameter were recorded. The analyses of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendix III-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following sub headings:

4.1 Plant height (cm)

Plant height of tomato varied significantly (Appendix III) for different levels of moisture at 30, 40, 50, 60 and 70 days after transplanting (DAT) under the present trial (Appendix III) at 30, 40, 50, 60 and 70 DAT. The tallest plant (44.50, 72.09, 82.54, 98.91 and 104.90 cm, respectively) was recorded from W_1 which was statistically similar with W_2 except at 40 DAT, whereas the shortest plant (38.92, 60.79, 75.42, 88.35 and 96.77 cm, respectively) was recorded from W_3 which was statistically similar with W_2 at 70 DAT (Figure 1). Data revealed that the drought stress reduced the morphological parameters such as plant height of tomato. Pervez *et al.* (2009) found that significant results toward drought stress signifying drought effects were registered on plant height of tomato plant. Ubaidullah *et al.* (2002) also found the similar result.

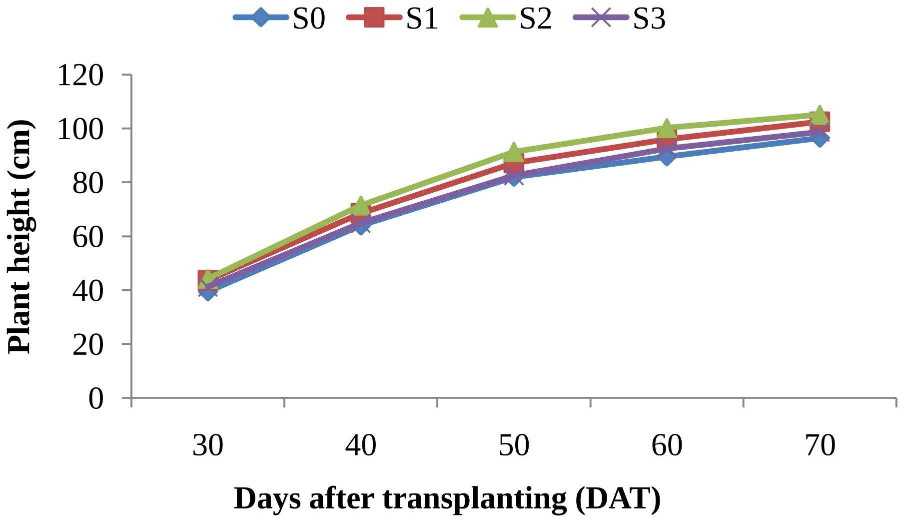
Significant variation was recorded for different levels of salicylic acid on plant height of tomato at 30, 40, 50, 60 and 70 DAT (Appendix III). Data revealed that at 30, 40, 50, 60 and 70 DAT, the tallest plant (44.29, 71.50, 91.37, 100.20 and 105.10 cm, respectively) was found from S_2 which was statistically similar with S_1, while the shortest plant (39.49, 63.94, 81.97, 89.57 and 96.48 cm, respectively) was recorded from S_0 which was statistically similar with S_3 (Figure 2). This is similar to the findings of Kazemi (2014) and Bakry *et al.*

(2012) who found that application of salicylic acid increased plant height of tomato under drought stress.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 1. Effect of moisture stress on plant height (at different days after transplanting, $LSD_{0.05}$ = 1.96, 3.19, 4.33, 4.72 and 5.13 for 30 DAT, 40 DAT, 50 DAT, 60 DAT and 70 DAT, respectively) of tomato



S_0: Control i.e. Foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Figure 2. Effect of salicylic acid on plant height (at different days after transplanting, $LSD_{0.05}$ = 2.26, 3.69, 5.00, 5.45 and 5.93 for 30 DAT, 40 DAT, 50 DAT, 60 DAT and 70 DAT, respectively) of tomato

Combined effect of different levels of moisture and salicylic acid showed significant differences on plant height of tomato at 30, 40, 50, 60 and 70 DAT (Appendix III). At 30, 40, 50, 60 and 70 DAT, the tallest plant (46.21, 75.41, 98.87, 104.40 and 110.0 cm, respectively) was found from W_1S_2 treatment combination which was statistically similar with W_1S_0, W_1S_1, W_1S_3, W_2S_1 and W_2S_2 at 30 and 40 DAT; W_1S_1, W_2S_1 and W_2S_2 at 50 DAT; W_1S_1, W_1S_3, W_2S_1 and W_2S_2 at 60 DAT; W_1S_0, W_1S_1, W_1S_3, W_2S_1, W_2S_2, W_3S_1 and W_3S_1 at 70 DAT; while the shortest plant (35.27, 57.05, 72.97, 83.15 and 92.08 cm, respectively) was found from W_3S_0 treatment combination which was statistically similar with W_3S_3 at 30 DAT; W_3S_1 and W_3S_3 at 40 DAT; W_3S_1, W_3S_2 and W_3S_3 at 50 DAT; W_2S_0, W_3S_1 and W_3S_3 at 60 DAT; W_3S_3, W_2S_0, W_2S_1, W_2S_3, W_3S_1, W_3S_2 and W_3S_3 at 70 DAT (Table 1). This is similar to the findings of Nezhad *et al.* (2014) who found that drought stress and salicylic acid on plant height was significant.

Table 1. Combined effect of different levels of moisture and salicylic acid on plant height of tomato at different days after transplanting (DAT)

Treatment	Plant height (cm) of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1S_0	42.65 abcd	70.20 abc	89.39 bcd	93.98 bcde	100.40 abcd
W_1S_1	45.16 abc	73.16 a	94.46 abc	100.40 abc	105.70 ab
W_1S_2	46.21 a	75.41 a	98.87 a	104.40 a	110.00 a
W_1S_3	43.96 abcd	69.60 abc	87.45 bcde	96.89 abcd	103.50 abc
W_2S_0	40.55 de	64.57 cd	83.55 def	91.59 cdef	96.96 bcd
W_2S_1	44.26 abcd	71.41 ab	91.96 abcd	97.62 abcd	102.00 abcd
W_2S_2	45.29 ab	73.41 a	95.77 ab	101.60 ab	104.80 abc
W_2S_3	42.11 bcd	65.47 bcd	86.06 cde	94.55 bcde	97.68 bcd
W_3S_0	35.27 f	57.05 e	72.97 g	83.15 f	92.08 d
W_3S_1	41.44 bcde	60.98 de	75.18 fg	89.79 def	99.79 abcd
W_3S_2	41.37 cde	65.67 bcd	79.46 efg	94.61 bcde	100.40 abcd
W_3S_3	37.61 ef	59.44 de	74.08 g	85.86 ef	94.77 cd
LSD $_{(0.05)}$	3.91	6.39	8.66	9.43	10.26
CV (%)	5.48	5.61	5.96	5.89	6.02

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

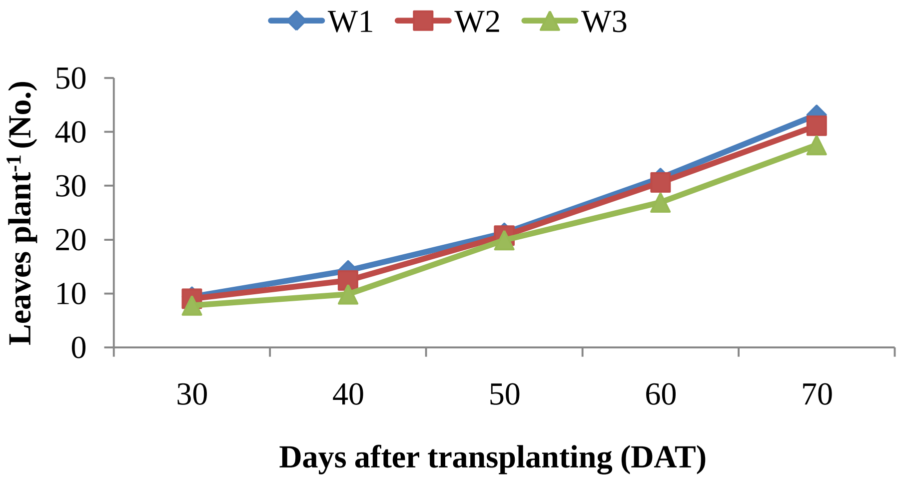
S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

4.2 Number of leaves plant^{-1}

Statistically significant variation was recorded for number of leaves plant^{-1} of tomato due to different levels of moisture at 30, 40, 50, 60 and 70 DAT under the present trial (Appendix IV). At 30, 40, 50, 60 and 70 DAT the maximum number of leaves plant^{-1} (9.38, 14.27, 21.24, 31.42 and 43.16, respectively) was observed from W_1 which was statistically similar with W_2 at 30, 50 and 60

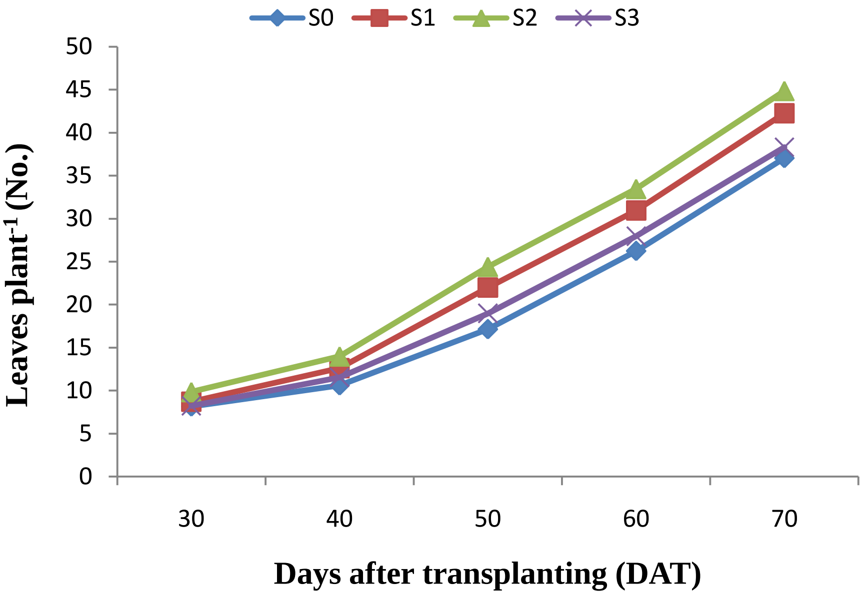
DAT, while the minimum number of leaves plant^{-1} (7.78, 9.84, 19.90, 26.89 and 37.54, respectively) was found from W_3 which was statistically similar with W_2 at 50 DAT (Figure 3). Leaves have different strategies when they are under drought stress. Leaf rolling, leaf shedding or low stomatal conductance were the main responses of the leaf to drought stress (Hu *et al*, 2006). Pervez *et al.* (2009) found that significant results toward drought stress signifying drought effects were registered on the number of leaves of tomato plant.

Different levels of salicylic acid varied significantly on number of leaves plant^{-1} of tomato at 30, 40, 50, 60 and 70 DAT (Appendix IV). Data revealed that at 30, 40, 50, 60 and 70 DAT, the maximum number of leaves plant^{-1} (9.85, 13.99, 24.41, 33.46 and 44.85, respectively) was obtained from S_2, whereas the minimum number of leaves plant^{-1} (8.15, 10.60, 17.13, 26.23 and 37.03, respectively) was found from S_0 which was statistically similar with S_3 at 30 and 70 DAT (Figure 4). This is similar to the findings of Mady (2009) who found that salicylic acid varied significantly on number of leaves plant^{-1} of tomato.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 3. Effect of moisture stress on number of leaves plant^{-1} (at different days after transplanting, $LSD_{0.05}$ = 0.40, 0.69, 1.25, 1.24 and 1.43 for 30 DAT, 40 DAT, 50 DAT, 60 DAT and 70 DAT, respectively) of tomato



S_0: Control i.e. foliar spray water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Figure 4. Effect of salicylic acid on number of leaves plant^{-1} (at different days after transplanting, $LSD_{0.05}$ = 0.47, 0.79, 1.45, 1.43 and 1.65 for 30 DAT, 40 DAT, 50 DAT, 60 DAT and 70 DAT, respectively) of tomato

Number of leaves plant^{-1} of tomato showed significant differences due to combined effect of different levels of moisture and salicylic acid at 30, 40, 50, 60 and 70 DAT (Appendix IV). At 30, 40, 50, 60 and 70 DAT, the maximum number of leaves plant^{-1} (10.83, 16.28, 25.58, 35.83 and 47.46, respectively) was found from W_1S_2 treatment combination which was statistically similar with W_2S_2 except at 40 DAT. The minimum number of leaves plant^{-1} (7.26, 8.74, 24.47 and 34.64 at 30, 40, 60 and 70 DAT, respectively) was found from W_3S_0 treatment combination which was statistically similar with W_3S_1 and W_3S_3 at 30 and 40 DAT; W_2S_0 and W_3S_3 at 60 DAT; W_2S_0, W_2S_3 and W_3S_3 at 70 DAT. At 50 DAT, the minimum number of leaves plant^{-1} (16.35) was found from W_2S_0 treatment combination which was statistically similar with W_1S_0, W_3S_0 and W_3S_3 (Table 2).

Table 2. Combined effect of different levels of moisture and salicylic acid on the number of leaves plant^{-1} of tomato at different days after transplanting (DAT)

Treatment	Number of leaves plant^{-1} of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1S_0	8.41 cdef	12.52 cde	17.50 ef	27.45 efg	39.48 de
W_1S_1	9.41 b	14.72 b	22.76 bc	33.15 bc	44.32 b
W_1S_2	10.83 a	16.28 a	25.58 a	35.83 a	47.46 a
W_1S_3	8.88 bcd	13.56 bc	19.10 de	29.26 e	41.39 cd
W_2S_0	8.77 bcd	10.53 fgh	16.35 f	26.77 fgh	36.97 efg
W_2S_1	8.98 bc	12.97 cd	22.50 c	31.85 cd	43.72 bc
W_2S_2	10.22 a	14.54 b	25.05 ab	34.89 ab	46.54 ab
W_2S_3	8.12 def	11.59 def	18.99 de	28.91 ef	37.19 efg
W_3S_0	7.26 g	8.740 i	17.53 ef	24.47 h	34.64 g
W_3S_1	7.71 efg	10.07 ghi	20.64 cd	27.76 efg	38.65 def
W_3S_2	8.49 cde	11.14 efg	22.61 bc	29.67 de	40.56 d
W_3S_3	7.64 fg	9.403 hi	18.81 def	25.67 gh	36.30 fg
LSD $_{(0.05)}$	0.81	1.38	2.51	2.48	2.86
CV (%)	5.46	6.68	7.18	4.94	4.16

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

4.3 Number of branches plant^{-1}

Different levels of moisture varied significantly in terms of number of branches plant^{-1} of tomato for at 30, 40, 50, 60 and 70 days after transplanting (DAT) under the present trial (Appendix V). At 30, 40, 50, 60 and 70 DAT the maximum number of branches plant^{-1} (3.96, 7.03, 12.50, 18.31 and 20.03, respectively) was recorded from W_1 which was statistically similar with W_2 at

70 DAT, whereas the minimum number of branches plant^{-1} (3.20, 6.26, 10.00, 15.01 and 17.31, respectively) was recorded from W_3 which was statistically similar with W_2 at 40 DAT (Table 3). Pervez *et al.* (2009) found that drought stress caused severe depression on the production of number of branches of tomato.

Table 3. Effect of different levels of moisture on the number of branches plant^{-1} of tomato at different days after transplanting (DAT)

Treatment	Number of branches plant^{-1} of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1	3.96 a	7.04 a	12.50 a	18.31 a	20.03 a
W_2	3.73 b	6.48 b	11.71 b	17.08 b	19.28 a
W_3	3.21 c	6.26 b	10.00 c	15.01 c	17.31 b
LSD $_{(0.05)}$	0.20	0.29	0.54	1.06	0.93
CV (%)	6.64	5.28	5.60	7.43	5.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

Number of branches plant^{-1} of tomato showed significant differences due to different levels of salicylic acid at 30, 40, 50, 60 and 70 DAT (Appendix V). Data revealed that at 30, 40, 50, 60 and 70 DAT, the maximum number of branches plant^{-1} (3.93, 7.77, 13.24, 18.89 and 21.15, respectively) was found from S_2, whereas the minimum number of branches plant^{-1} (3.38, 5.71, 10.11, 15.22 and 17.19, respectively) was found from S_0 which was statistically similar with S_3 (Table 4). Bakry *et al*. (2012) and Mady (2009) also found the similar results.

Table 4. Effect of different levels of salicylic acid on the number of branches plant^{-1} of tomato at different days after transplanting

Treatment	Number of branches plant^{-1} of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
S_0	3.39 c	5.71 c	10.11 c	15.22 c	17.19 c
S_1	3.65 b	6.89 b	12.02 b	17.34 b	19.34 b
S_2	3.93 a	7.77 a	13.24 a	18.89 a	21.15 a
S_3	3.57 bc	5.99 c	10.25 c	15.74 c	17.80 c
LSD $_{(0.05)}$	0.24	0.34	0.62	1.22	1.07
CV (%)	6.64	5.28	5.60	7.43	5.80

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: Control i.e. foliar spray of water without salicylic Acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Different levels of moisture and salicylic acid showed significant differences due to their combined effect on number of branches plant^{-1} of tomato at 30, 40, 50, 60 and 70 DAT (Appendix V). At 30, 40, 50, 60 and 70 DAT, the maximum number of branches plant^{-1} (4.20, 8.42, 14.90, 20.79 and 22.54, respectively) was recorded from W_1S_2 treatment combination which was statistically similar with W_1S_1, W_1S_3 and W_2S_2 at 30 and 60 DAT; W_2S_2 at 70 DAT. The minimum number of branches plant^{-1} (2.90, 5.52, 13.82 and 15.59 at 30, 40, 60 and 70 DAT, respectively) was found from W_3S_0 treatment combination which was statistically similar with W_3S_1 and W_3S_3 at 30 DAT; W_1S_0, W_1S_3, W_2S_0, W_2S_3 and W_3S_3 at 40 DAT; W_2S_0, W_3S_1 and W_3S_3 at 60 DAT; W_2S_0, W_3S_3 at 70 DAT. At 50 DAT, the minimum number of branches plant^{-1} (9.02) was found from W_3S_3 treatment combination which was statistically similar with W_2S_0, W_3S_0 and W_3S_1 (Table 5). Nezhad *et al.* (2014) found that moisture and salicylic acid showed significant differences due to their combined effect on number of branches plant^{-1} of tomato.

Table 5. Combined effect of different levels of moisture and salicylic acid on the number of branches plant^{-1} of tomato at different days after transplanting (DAT)

Treatment	Number of branches plant^{-1} of tomato at different days after transplanting				
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
W_1S_0	3.75 bcde	6.02 fg	10.63 def	16.60 de	18.44 cde
W_1S_1	3.99 abc	7.59 bc	13.48 bc	18.85 abc	20.16 bc
W_1S_2	4.21 a	8.43 a	14.90 a	20.79 a	22.54 a
W_1S_3	3.91 abcd	6.11 efg	11.01 de	17.00 cde	18.97 cde
W_2S_0	3.50 def	5.59 g	10.04 efg	15.24 efg	17.55 ef
W_2S_1	3.68 cde	6.65 de	12.49 c	17.58 bcd	19.75 cd
W_2S_2	4.13 ab	7.81 b	13.60 b	19.35 ab	21.77 ab
W_2S_3	3.60 cdef	5.87 fg	10.73 def	16.13 def	18.06 def
W_3S_0	2.91 g	5.52 g	9.67 fg	13.82 g	15.59 g
W_3S_1	3.27 fg	6.45 ef	10.10 efg	15.59 defg	18.11 def
W_3S_2	3.46 ef	7.08 cd	11.22 d	16.54 de	19.14 cde
W_3S_3	3.20 fg	5.98 fg	9.02 g	14.08 fg	16.38 fg
LSD $_{(0.05)}$	0.41	0.59	1.08	2.11	1.85
CV (%)	6.64	5.28	5.6	7.43	5.8

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

4.4 Leaf area (cm^2)

Statistically significant variation was recorded for leaf area due to different levels of moisture at flowering stage and 30 days after flowering (Appendix VI). At flowering stage and 30 days after flowering, the maximum leaf area (198.8 and 185.6 cm^2, respectively) was recorded from W_1 which was statistically similar with W_2 at 30 days after flowering, while the minimum leaf area (176.5 and 174.8 cm^2, respectively) was found from W_3 which was statistically similar with W_1 at 30 days after flowering (Table 6).

Table 6. Effect of different levels of moisture on leaf area (cm^2) of tomato at flowering stage and 30 days after flowering (DAF)

Treatment	Leaf area (cm^2) at first flowering	Leaf area (cm^2) at 30 DAF
W_1	198.8 a	185.6 a
W_2	187.3 b	182.5 ab
W_3	176.5 c	174.8 b
LSD $_{(0.05)}$	9.11	8.43
CV (%)	5.74	5.5

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

Different levels of salicylic acid varied significantly on leaf area of tomato at flowering stage and 30 days after flowering (Appendix VI). At flowering stage and 30 days after flowering, the maximum leaf area (193.9 and 189.7 cm^2, respectively) was obtained from S_2 which was statistically similar with S_1, whereas the minimum leaf area (181.7 and 174.2 cm^2, respectively) was found from S_0 which was statistically similar with S_1 and S_3 (Table 7). This is similar to the findings of Ahmed *et al.* (2011) and Khan *et al.* (2003).

Table 7. Effect of different levels of salicylic acid on leaf area (cm^2) of tomato at flowering stage and 30 days after flowering (DAF)

Treatment	Leaf area (cm^2) at first flowering	Leaf area (cm^2) at 30 DAF
S_0	181.7 b	174.2 b
S_1	189.1 ab	183.5 ab
S_2	193.9 a	189.7 a
S_3	185.4 ab	176.5 b
LSD $_{(0.05)}$	10.52	9.74
CV (%)	5.74	5.5

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Leaf area of tomato showed significant differences due to combined effect of different levels of moisture and salicylic acid at flowering stage and 30 days after flowering (Appendix VI). At flowering stage and 30 days after flowering, the maximum leaf area (205.3 and 193.2 cm^2, respectively) was attained from W_1S_2 treatment combination which was statistically similar with W_1S_1, W_1S_3, W_2S_2 and W_1S_0 at flowering stage; W_1S_1, W_2S_1, W_3S_2, W_1S_3, W_1S_0, W_2S_3, at 30 days after flowering, whereas the minimum leaf area (170.9 and 165.9 cm^2, respectively) was attained from W_3S_0 treatment combination which was statistically similar with W_3S_1, W_3S_1 and W_3S_2 at flowering stage; W_3S_3, W_2S_0 at 30 days after flowering (Table 10).

4.5 SPAD values

Significant variation was observed for SPAD values of tomato plant due to different levels of moisture at flowering stage and 30 days after flowering (Appendix VI). At flowering stage and 30 days after flowering, the highest SPAD values (47.41 and 43.62, respectively) was obtained from W_1, whereas the lowest SPAD values (38.11 and 35.26, respectively) was found from W_3, respectively (Table 8).

Table 8. Effect of different levels of moisture on SPAD value of tomato at flowering stage and 30 days after flowering (DAF)

Treatment	SPAD value at first flowering	SPAD value at 30 DAF
W_1	47.41 a	43.62 a
W_2	40.88 b	37.53 b
W_3	38.11 c	35.26 c
LSD $_{(0.05)}$	1.88	2.20
CV (%)	5.27	6.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

SPAD values of tomato at flowering stage and 30 days after flowering varied significantly due to different levels of salicylic acid (Appendix VI). At flowering stage and 30 days after flowering, the highest SPAD value (43.82 and 40.35, respectively) was found from S_2 which was statistically similar with S_1, while the lowest SPAD value (40.47 and 37.32, respectively) was recorded from S_0 which was statistically similar with S_3 (Table 9).

Table 9. Effect of different levels of salicylic acid on SPAD value of tomato at flowering stage and 30 days after flowering (DAF)

Treatment	SPAD value at first flowering	SPAD value at 30 DAF
S_0	40.47 c	37.32 b
S_1	42.75 ab	38.80 ab
S_2	43.82 a	40.35 a
S_3	41.47 bc	38.75 ab
LSD $_{(0.05)}$	2.17	2.54
CV (%)	5.27	6.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Combined effect of different levels of moisture and salicylic acid showed significant differences in terms of SPAD values of tomato at flowering stage and 30 days after flowering (Appendix VI). At flowering stage and 30 days after flowering, the highest SPAD value (49.73 and 45.66, respectively) was observed from W_1S_2 treatment combination which was statistically similar with W_1S_1 and W_1S_3 at flowering stage; W_1S_1, W_1S_3 and W_1S_0 at 30 days after flowering. The lowest SPAD value (37.13 at flowering stage) was observed from W_3S_0 treatment combination which was statistically similar with W_3S_3, and W_3S_1; (34.34 at 30 days after flowering) was observed from W_3S_0 treatment combination which was statistically similar with W_2S_1, W_3S_2, W_2S_0, and W_3S_3 (Table 10).

Table 10. Combined effect of different levels of moisture and salicylic acid on leaf area and SPAD value of tomato at flowering stage and 30 days after flowering (DAF)

Treatment	Leaf area and SPAD value of tomato at flowering stage and 30 days after flowering			
	Leaf area at first flowering	Leaf area 30 at DAF	SPAD value at first flowering	SPAD value at 30 DAF
W_1S_0	191.2 abcde	180.6 abcd	45.00 bc	41.95 abc
W_1S_1	201.0 ab	186.3 ab	47.97 ab	44.07 a
W_1S_2	205.3 a	193.2 a	49.73 a	45.66 a
W_1S_3	197.8 abc	182.3 abcd	46.93 ab	42.79 ab
W_2S_0	183.0 bcdef	176.0 bcd	39.28 def	35.66 de
W_2S_1	186.9 bcdef	183.6 abc	41.40 cde	37.13 de
W_2S_2	194.3 abcd	1917 ab	42.73 cd	39.08 bcd
W_2S_3	184.8 bcdef	178.9 abcd	40.08 def	38.25 cde
W_3S_0	170.9 f	165.9 d	37.13 f	34.34 e
W_3S_1	179.3 def	180.6 abcd	38.88 ef	35.20 de
W_3S_2	182.2 cdef	184.3 abc	39.00 def	36.29 de
W_3S_3	173.5 ef	168.3 cd	37.41 f	35.21 de
LSD $_{(0.05)}$	18.23	16.87	3.76	4.41
CV (%)	5.74	5.5	5.27	6.71

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

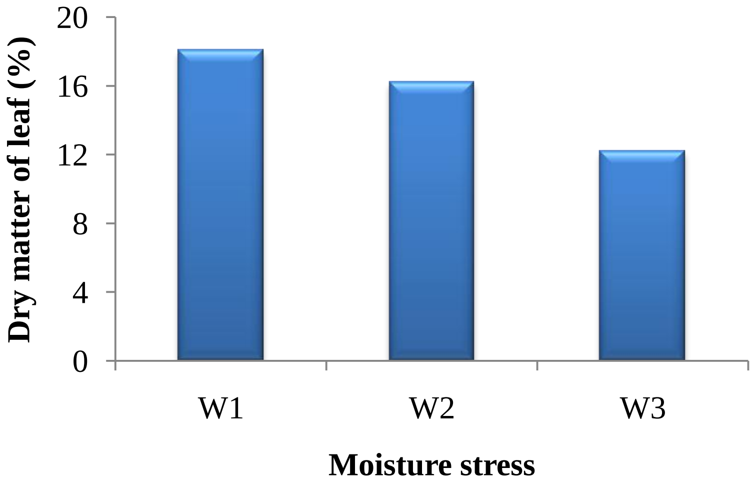
W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

4.6 Dry matter of leaf (%)

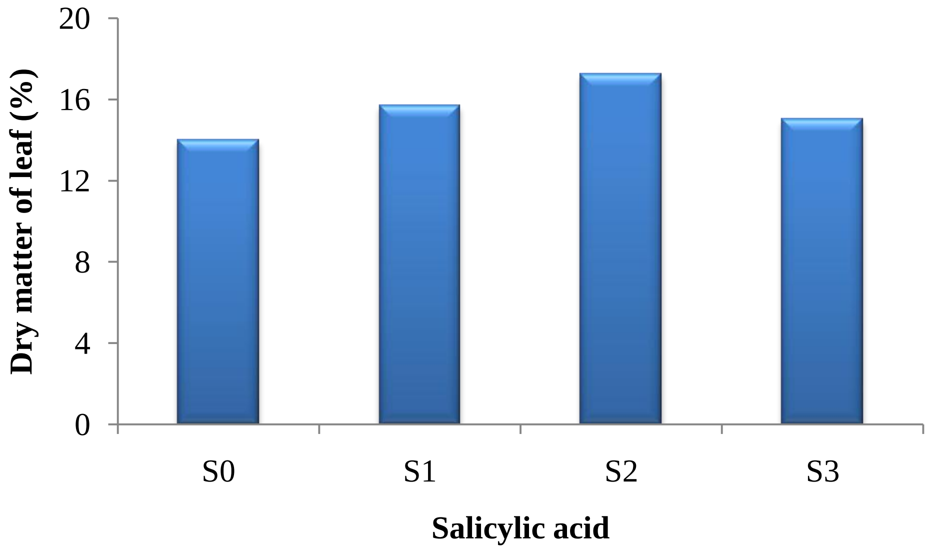
Dry matter content of leaf in plant of tomato varied significantly for different levels of moisture under the present trial (Appendix VII). The highest dry matter content of leaf in plant (18.07%) was found from W_1, whereas the lowest (12.22%) was observed from W_3 (Figure 5). Birhanu and Tilahun (2010), Pervez *et al.* (2009) and Nahar and Gretzmacher (2002) similarly found that the dry weight reduced significantly under the drought stress.

Different levels of salicylic acid showed significant differences on dry matter content of leaf in plant of tomato (Appendix VII). The highest dry matter content of leaf in plant (17.26%) was recorded from S_2, while the lowest (13.99%) was found from S_0 (Figure 6). Fahraji *et al.* (2014) indicated that seed pretreatment with salicylic acid induced a reduction sodium absorption and toxicity, which is further reflected in low membranes injury, high water content and dry matter production.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 5. Effect of moisture stress on dry matter of leaf of tomato ($LSD_{0.05}$= 0.64)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

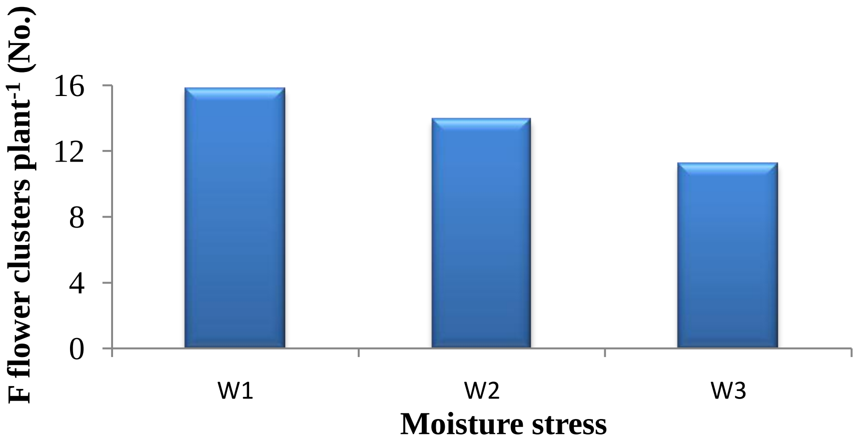
Figure 6. Effect of salicylic acid on dry matter of leaf of tomato ($LSD_{0.05}$ = 0.74)

Combined effect of different levels of moisture and salicylic acid showed significant differences on dry matter content of leaf in plant (Appendix VII). The highest dry matter content of leaf in plant (19.57%) was observed from W_1S_2 treatment combination, while the lowest (10.40%) was recorded from W_3S_0 treatment combination which was statistically similar with W_3S_3 (Table 11).

4.7 Number of flowers cluster plant^{-1}

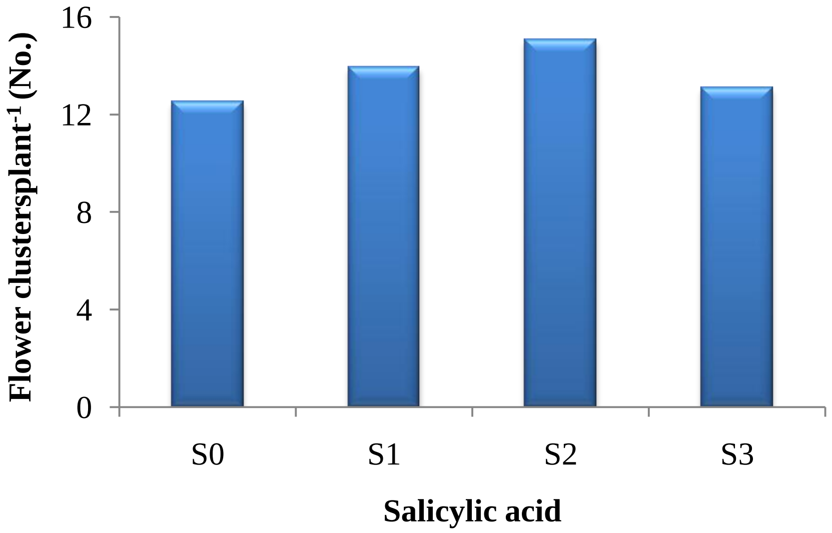
Different levels of moisture varied significantly in terms of number of flower cluster plant^{-1} of tomato (Appendix VII). Data revealed that the highest number of flower cluster plant^{-1} (15.81) was found from W_1, while the lowest number (11.25) was recorded from W_3 (Figure 7). This is similar to the findings of Ubaidullah *et al.* (2002).

Different levels of salicylic acid showed significant differences on number of flower cluster plant^{-1} of tomato (Appendix VII). The highest number of flower cluster plant^{-1} (15.09) was recorded from S_2, whereas the lowest number (12.52) was found from S_0 which was statistically similar with S_3 (Figure 8).



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 7. Effect of moisture stress on flower clusters plant^{-1} of tomato ($LSD_{0.05}$ = 0.64)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

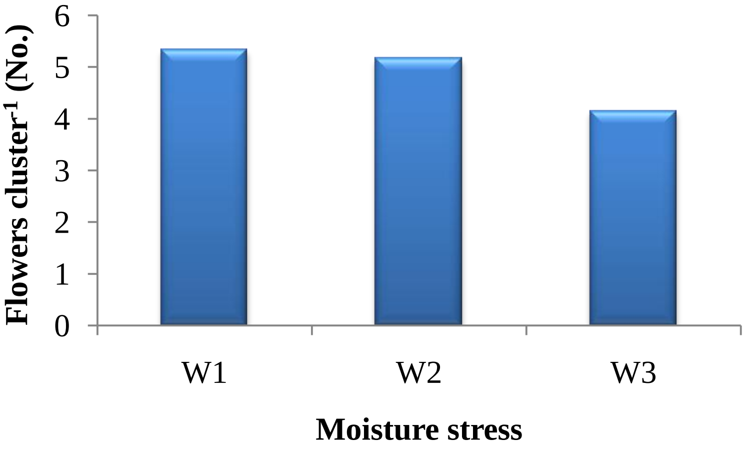
Figure 8. Effect of salicylic acid on flower clusters plant^{-1} of tomato ($LSD_{0.05}$ = 0.74)

Combined effect of different levels of moisture and salicylic acid showed significant differences on number of flower cluster plant^{-1} (Appendix VII). The highest number of flower cluster plant^{-1} (17.43) was observed from W_1S_2 treatment combination which was statistically similar with W_1S_1, while the lowest number (10.50) was attained from W_3S_0 treatment combination which was statistically similar with W_3S_1 and W_3S_3 (Table 12).

4.8 Number of flowers cluster^{-1}

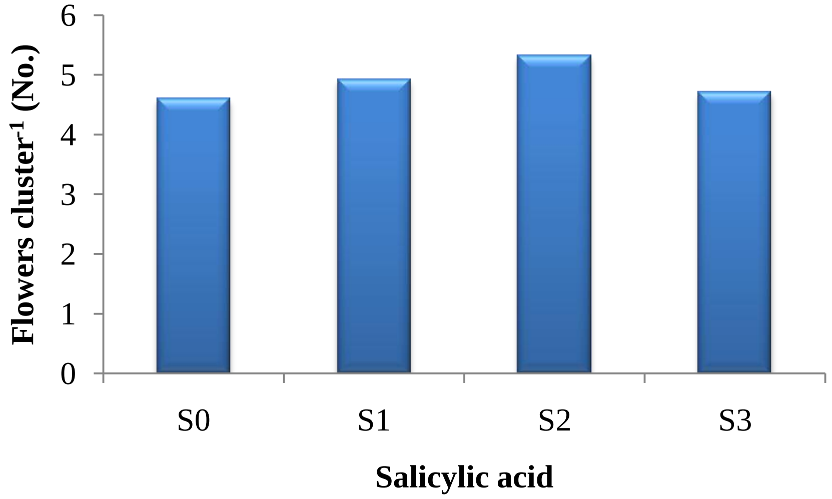
Different levels of moisture varied significantly in terms of number of flowers cluster^{-1} of tomato (Appendix VII). The highest number of flowers cluster^{-1} (5.34) was recorded from W_1 which was statistically similar with W_2. On the other hand, the lowest number (4.16) was recorded from W_3 (Figure 9). This is similar to the findings of Ubaidullah *et al.* (2002).

Number of flowers cluster^{-1} of tomato showed significant differences for different levels of salicylic acid (Appendix VII). The highest number of flowers cluster^{-1} (5.32) was found from S_2, while the lowest number (4.60) was recorded from S_0 which was statistically similar with S_3 (Figure 10).



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 9. Effect of moisture stress on flowers cluster^{-1} of tomato ($LSD_{0.05}$ = 0.23)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

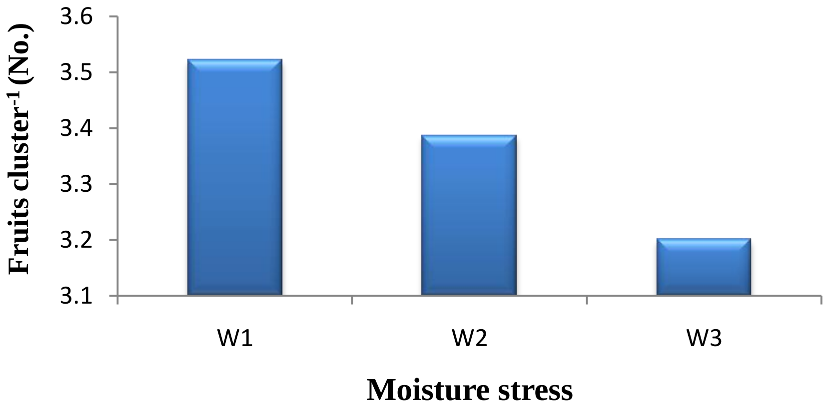
Figure 10. Effect of salicylic acid on flowers cluster^{-1} of tomato ($LSD_{0.05}$ = 0.26)

Statistically significant variation was recorded for the combined effect of different levels of moisture and salicylic acid on number of flowers cluster^{-1} (Appendix VII). The highest number of flowers cluster^{-1} (5.90) was recorded from W_1S_2 treatment combination which was statistically similar with W_2S_2, while the lowest number (3.93) was found from W_3S_0 treatment combination which was statistically similar with W_3S_1 and W_3S_3 (Table 11).

4.9 Number of fruits cluster^{-1}

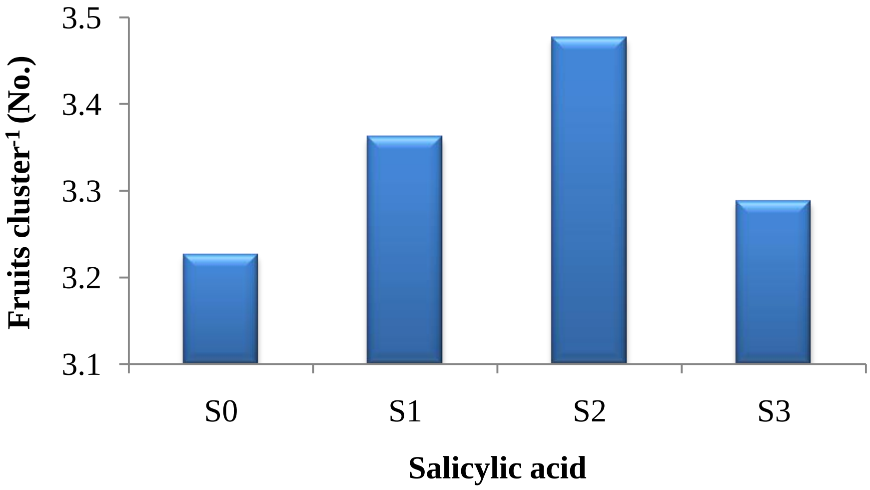
Number of fruits cluster^{-1} of tomato varied significantly for different levels of moisture under the present trial (Appendix VII). The highest number of fruits cluster^{-1} (3.52) was recorded from W_1 which was statistically similar with W_2. On the other hand, the lowest number (3.11) was recorded from W_3 (Figure 11). This is similar to the findings of Nuruddin *et al.* (2003).

Different levels of salicylic acid showed significant differences on number of fruit cluster^{-1} of tomato (Appendix VII). The highest number of fruits cluster^{-1} (3.48) was found from S_2 which was statistically similar with S_1, whereas the lowest number (3.23) was found from S_0 which was statistically similar with S_3 (Figure 12).



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 11. Effect of moisture stress on fruits cluster^{-1} of tomato ($LSD_{0.05}$ = 0.15)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Figure 12. Effect of salicylic acid on fruits cluster^{-1} of tomato ($LSD_{0.05}$ = 0.18)

Combined effect of different levels of moisture and salicylic acid showed significant differences on number of fruits cluster^{-1} (Appendix VII). The highest number of fruits cluster^{-1} (3.66) was attained from W_1S_2 treatment combination which was statistically similar with W_1S_1, W_1S_3, W_2S_1 and W_2S_2

while the lowest number (2.98) was recorded from W_3S_0 treatment combination which was statistically similar with W_1S_0, W_3S_1, W_3S_2 and W_3S_3 (Table 11).

Table 11. **Combined effect of different levels of moisture and salicylic acid on dry matter content of leaf, number of flower cluster plant^{-1}, number of flowers cluster^{-1} and number of fruits cluster^{-1}**

Treatment	Dry matter of leaf (%)	Flowers cluster plant^{-1} (No.)	Flowers cluster^{-1} (No.)	Fruits cluster^{-1} (No.)
W_1S_0	16.91 cde	14.20 cde	4.98 cd	3.43 abc
W_1S_1	18.20 b	16.24 ab	5.40 bc	3.50 ab
W_1S_2	19.57 a	17.43 a	5.90 a	3.65 a
W_1S_3	17.61 bcd	15.35 bcd	5.08 cd	3.49 ab
W_2S_0	14.65 fg	12.85 fg	4.89 de	3.26 bcde
W_2S_1	16.37 de	14.09 def	5.18 bcd	3.44 ab
W_2S_2	17.97 bc	15.47 bc	5.56 ab	3.53 ab
W_2S_3	15.79 ef	13.35 efg	5.05 cd	3.30 bcd
W_3S_0	10.40 i	10.50 i	3.93 g	2.98 e
W_3S_1	12.56 h	11.50 hi	4.19 fg	3.13 cde
W_3S_2	14.25 g	12.37 gh	4.52 ef	3.24 bcde
W_3S_3	11.67 hi	10.62 i	3.99 g	3.07 de
LSD $_{(0.05)}$	1.29	1.28	0.45	0.31
CV (%)	4.91	5.51	5.46	5.44

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

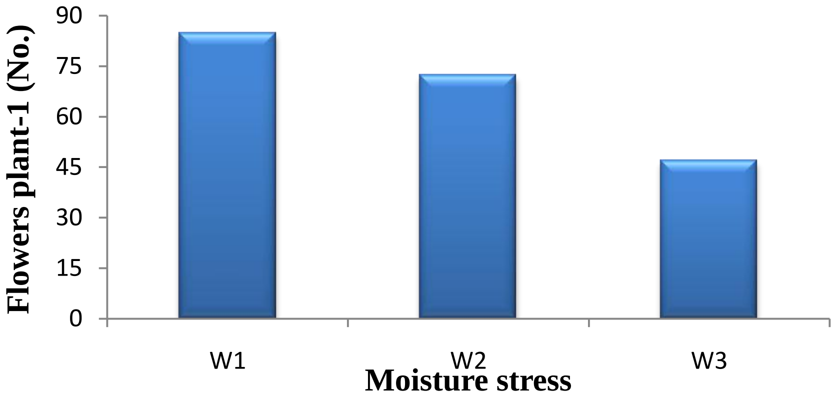
W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

4.10 Number of flowers plant^{-1}

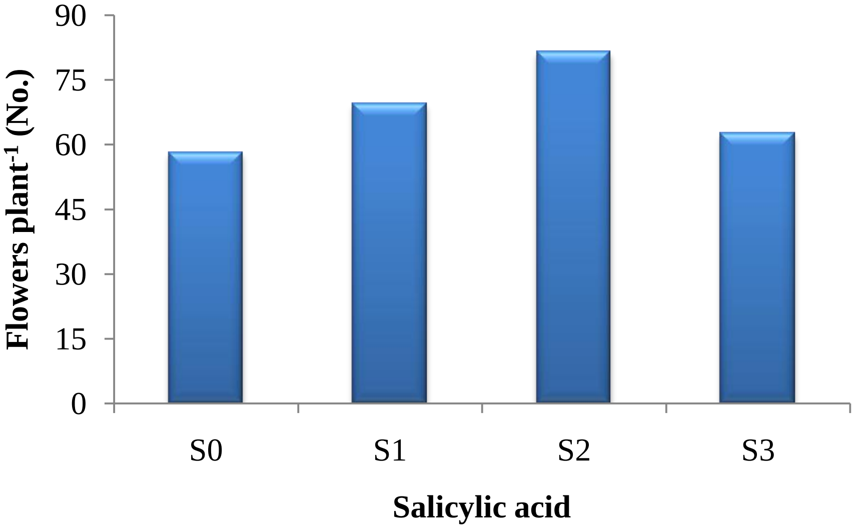
Number of flowers plant^{-1} of tomato varied significantly due to different levels of moisture under the present trial (Appendix VIII). The highest number of flowers plant^{-1} (84.84) was found from W_1, while the lowest number (46.88) was observed from W_3 (Figure 15). This is similar to the findings of Rahman *et al.* (1999) who found that water stress decreased flower number of tomato plant. Photosynthetic rate (Pr), transpiration rate (T) and leaf water potential (ψ) and WUE were reduced, and leaf temperature (T_{IC}) and stomatal resistance (r) were increased by water stress in all cultivars.

Significant variation was recorded for different levels of salicylic acid on number of flowers plant^{-1} of tomato (Appendix VIII). The highest number of flowers plant^{-1} (81.46) was recorded from S_2, while the lowest number (58.28) was observed from S_0 (Figure 16). Flowering is another important parameter that is directly related to yield and productivity of plants. Salehi *et al.* (2011) and Hayat (2010) also found the similar result. Salicylic acid has been reported to induce flowering in a number of plants.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 13. Effect of moisture stress on flowers plant^{-1} of tomato ($LSD_{0.05}$ = 3.02)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

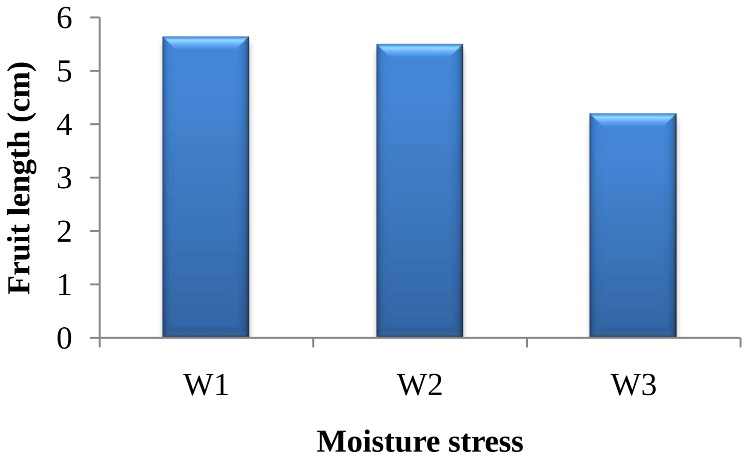
Figure14. Effect of salicylic acid on flowers plant^{-1} of tomato ($LSD_{0.05}$ = 3.45)

Different levels of moisture and salicylic acid showed significant differences on number of flowers plant^{-1} due to combined effect (Appendix VIII). The highest number of flowers plant^{-1} (102.8) was found from W_1S_2 treatment combination and the lowest number (41.24) was observed from W_3S_0 treatment combination which was statistically similar with W_3S_3 (Table 15).

4.11 Length of fruit (cm)

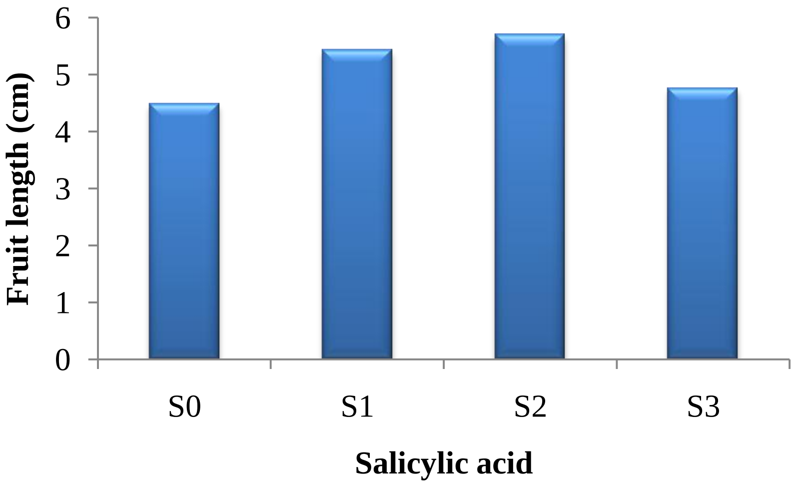
Length of fruit of tomato varied significantly for different levels of moisture under the present trial (Appendix VIII). The highest length of fruit (5.62 cm) was recorded from W_1 which was statistically similar with W_2. On the other hand, the lowest length (4.19 cm) was recorded from W_3 (Figure 15)

Different levels of salicylic acid showed significant differences on length of fruit of tomato (Appendix VIII). The highest length of fruit (5.70 cm) was attained from S_2, whereas the lowest length (4.49 cm) was recorded from S_0 (Figure 16).



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 15. Effect of moisture stress on fruit length of tomato ($LSD_{0.05}$ = 0.19)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

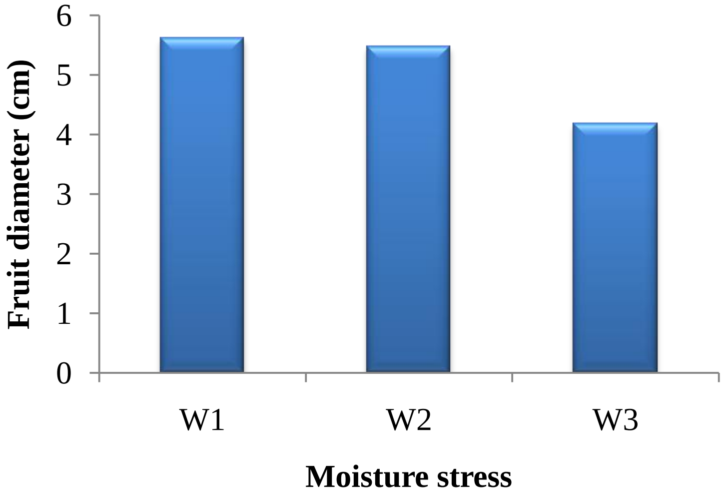
Figure 16. Effect of salicylic acid on fruit length of tomato ($LSD_{0.05}$ = 0.22)

Combined effect of different levels of moisture and salicylic acid showed significant differences on length of fruit (Appendix VIII). The highest length of fruit (6.33 cm) was recorded from W_1S_2 treatment combination which was statistically similar with W_2S_2, again the lowest length (3.48 cm) was observed from W_3S_0 treatment combination (Table 12).

4.12 Diameter of fruit (cm)

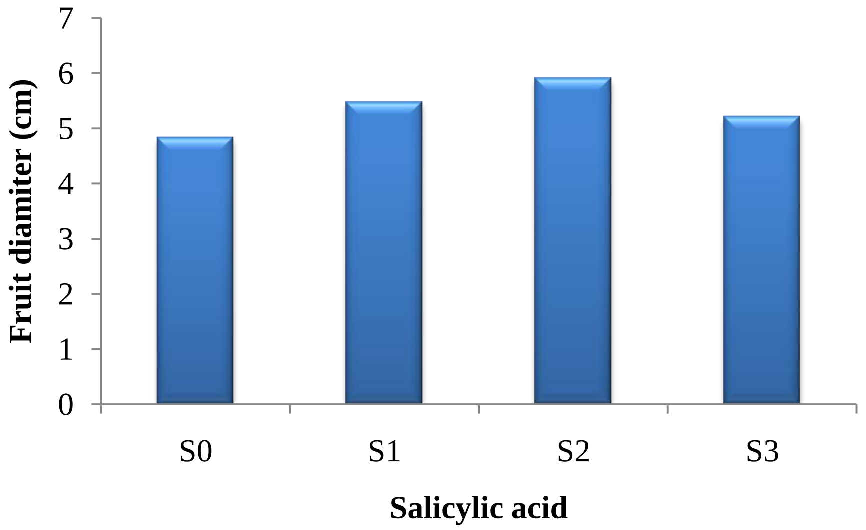
Different levels of moisture varied significantly for diameter of fruit of tomato (Appendix IX). The highest diameter of fruit (5.97 cm) was recorded from W_1, while the lowest diameter (4.43 cm) was found from W_3 (Figure 17).

Significant variation was recorded due to different levels of salicylic acid on diameter of fruit of tomato (Appendix VIII). Data revealed that the highest diameter of fruit (5.91 cm) was recorded from S_2, whereas the lowest diameter (4.82 cm) was found from S_0 (Figure 18). This is similar to the findings of Javaheri *et al*. (2014) who found that salicylic acid significantly influence diameter of fruit of tomato.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 17. Effect of moisture stress on fruit diameter of tomato ($LSD_{0.05}$ = 0.24)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Figure 18. Effect of salicylic acid on fruit diameter of tomato ($LSD_{0.05}$ = 0.27)

Diameter of fruit showed significant differences due to combined effect of different levels of moisture and salicylic acid (Appendix IX). The highest diameter of fruit (6.60 cm) was observed from W_1S_2 treatment combination which was statistically similar with W_2S_2 and W_2S_1; whereas the lowest diameter (3.77 cm) was recorded from W_3S_0 treatment combination (Table 12).

Table 12. **Combined effect of different levels of moisture and salicylic acid on, number of flowers plant^{-1}, length of fruit and Diameter of fruit**

Treatment	Flowers plant^{-1} (No.)	Length of fruit (cm)	Diameter of fruit (cm)
W_1S_0	70.94 d	4.94 cd	5.22 bc
W_1S_1	87.64 b	5.80 b	5.44 b
W_1S_2	102.8 a	6.33 a	6.60 a
W_1S_3	78.00 c	5.06 c	5.63 b
W_2S_0	62.65 e	5.05 c	5.46 b
W_2S_1	72.96 cd	5.91 b	6.29 a
W_2S_2	85.73 b	6.11 ab	6.32 a
W_2S_3	67.41 de	5.19 c	5.54 b
W_3S_0	41.24 h	3.48 f	3.77 e
W_3S_1	48.01 g	4.58 d	4.70 d
W_3S_2	55.86 f	4.66 d	4.81 cd
W_3S_3	42.41 gh	4.04 e	4.43 d
LSD $_{(0.05)}$	6.04	0.38	0.48
CV (%)	5.25	4.45	5.26

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

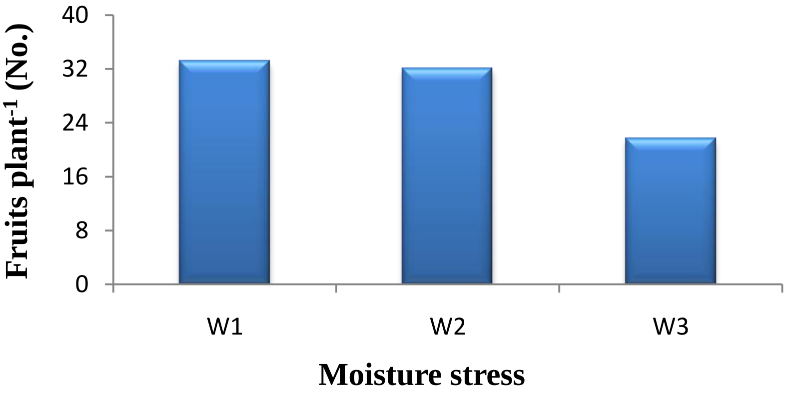
W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

4.13 Number of fruits plant^{-1}

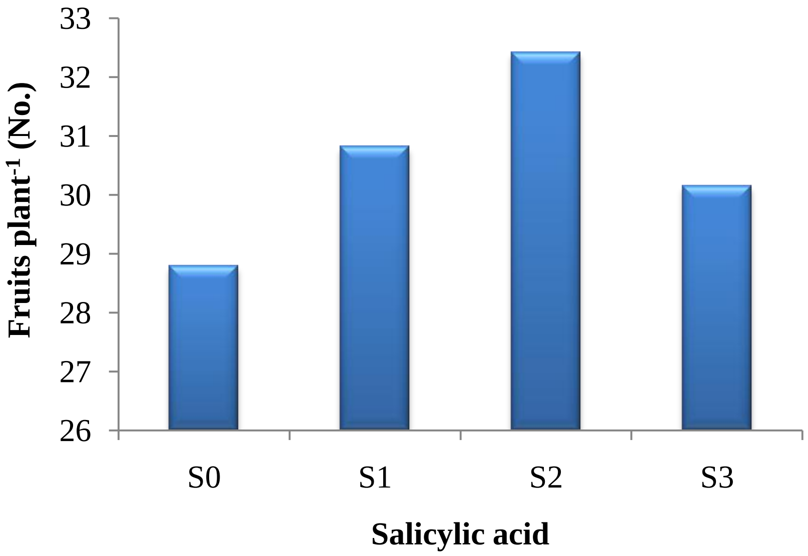
Significant variation was recorded in terms of number of fruits plant^{-1} of tomato due to different levels of moisture under the present trial (Appendix IX). The highest number of fruits plant^{-1} (34.96) was recorded from W_1 which was statistically similar with W_2, again the lowest number (23.93) was found from W_3 (Figure 19). Pervez *et al.* (2009) and Ubaidullah *et al.* (2002) also found the similar results and they showed significant results toward drought stress signifying drought effects on the number of fruits plant^{-1} of tomato.

Number of fruit plant^{-1} of tomato showed significant difference due to different levels of salicylic acid (Appendix IX). The highest number of fruits plant^{-1} (32.42) was recorded from S_2 and the lowest number (28.79) was recorded from S_0 (Figure 20). This is similar to the findings of Javaheri *et al*. (2014) who found that salicylic acid significantly influenced the number of fruits plant^{-1} of tomato.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 19. Effect of moisture stress on fruits plant^{-1} of tomato ($LSD_{0.05}$ = 1.08)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

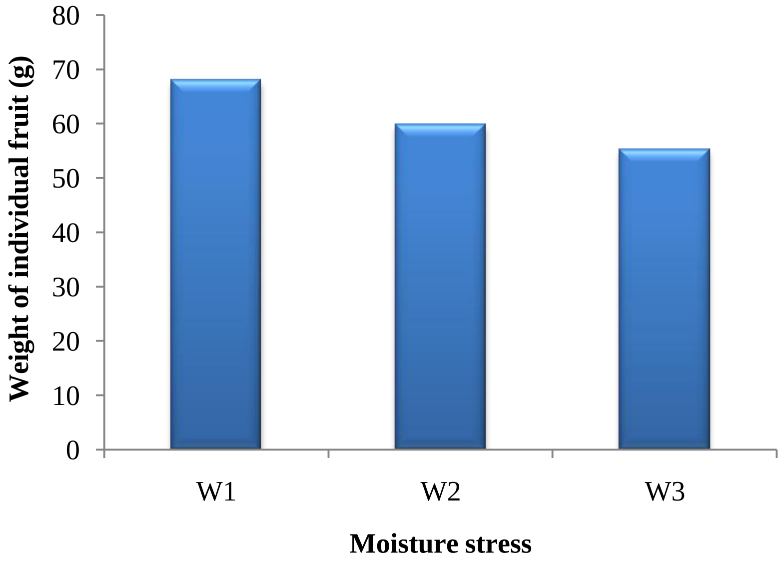
Figure 20. Effect of salicylic acid on fruits plant^{-1} of tomato ($LSD_{0.05}$ = 1.25)

Combined effect of different levels of moisture and salicylic acid showed significant differences on number of fruits plant^{-1} (Appendix IX). The highest number of fruits plant^{-1} (36.85) was observed from W_1S_2 treatment combination which was statistically similar with W_2S_2, whereas the lowest number (21.85) was attained from W_3S_0 treatment combination which was statistically similar with W_3S_3 (Table 13).

4.14 Weight of Individual Fruit (g)

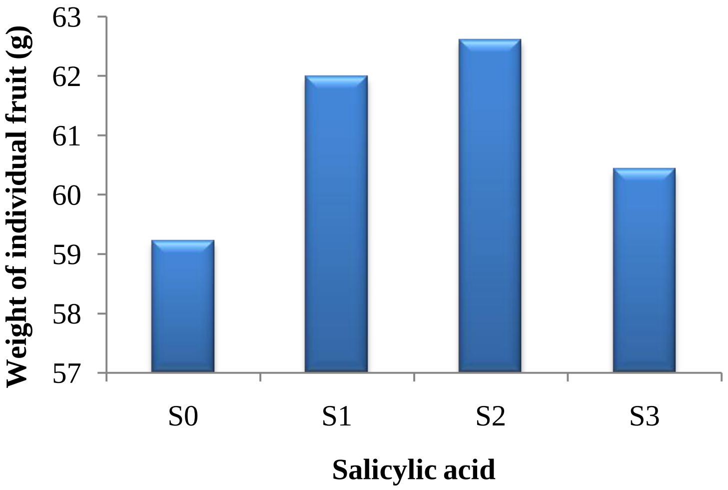
Weight of individual fruit of tomato varied significantly due to effects of different levels of moisture under the present trial (Appendix IX). The highest weight of individual fruit (67.95 g) was found from W_1. On the other hand, the lowest (55.30 g) was observed from W_3 (Figure 21). Pervez *et al.* (2009) and Ubaidullah *et al.* (2002) also found the similar results and they showed significant results toward drought stress signifying drought effects on the fruit weight of tomato.

Significant variation was recorded for different levels of salicylic acid on weight of individual fruit of tomato (Appendix IX). The highest weight of individual fruit (62.61 g) was recorded from S_2 which was statistically similar with S_1 and S_3, whereas the lowest weight (59.22 g) was attained from S_0 which was statistically similar with S_3 (Figure 22). This is similar to the findings of Javaheri *et al*. (2014) who found that salicylic acid significantly influence weight of fruit of tomato.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 21. Effect of moisture stress on weight of individual fruit of tomato ($LSD_{0.05}$ = 2.33)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

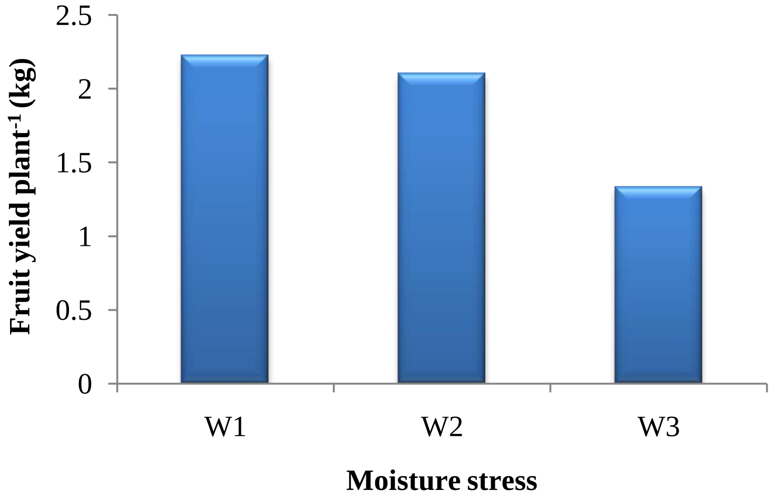
Figure 22. Effect of salicylic acid on weight of individual fruit of tomato ($LSD_{0.05}$ = 2.69)

Combined effect of different levels of moisture and salicylic acid showed significant differences on weight of individual fruit (Appendix IX). The highest weight of individual fruit (69.06 g) was observed from W_1S_2 treatment combination which was statistically similar with W_1S_0, W_1S_1 and W_1S_3 while the lowest (52.55 g) was recorded from W_3S_0 treatment combination which was statistically similar with W_3S_3 (Table 13).

4.15 Yield plant^{-1} (kg)

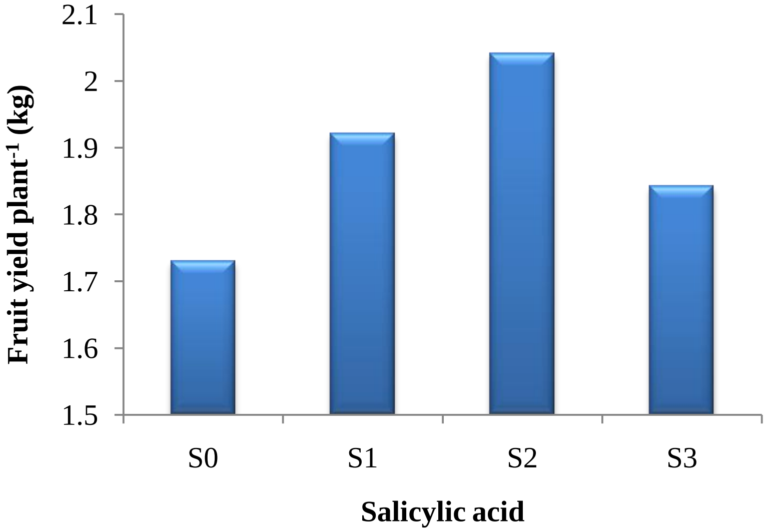
Different levels of moisture varied significantly in terms of yield plant^{-1} of tomato under the present trial (Appendix IX). The highest yield plant^{-1} (2.23 kg) was recorded from W_1, while the lowest yield (1.33 kg) was found from W_3 (Figure 23). This is similar to the findings of Pervez *et al.* (2009), Nuruddin *et al.* (2003), Ubaidullah *et al.* (2002) and Karim *et al.* (1996). They observed that water stress throughout the growing season significantly reduced yield and fruit size.

Different levels of salicylic acid showed significant differences on yield plant^{-1} of tomato (Appendix IX). The highest yield plant^{-1} (2.04 kg) was recorded from S_2, whereas the lowest yield (1.73 kg) was obtained from S_0 (Figure 24). This is similar to the findings of Kazemi (2014) who found that application of salicylic acid increased yield plant^{-1} of tomato under drought stress.



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 23. Effect of moisture stress on fruit yield of tomato ($LSD_{0.05}$ = 0.05)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

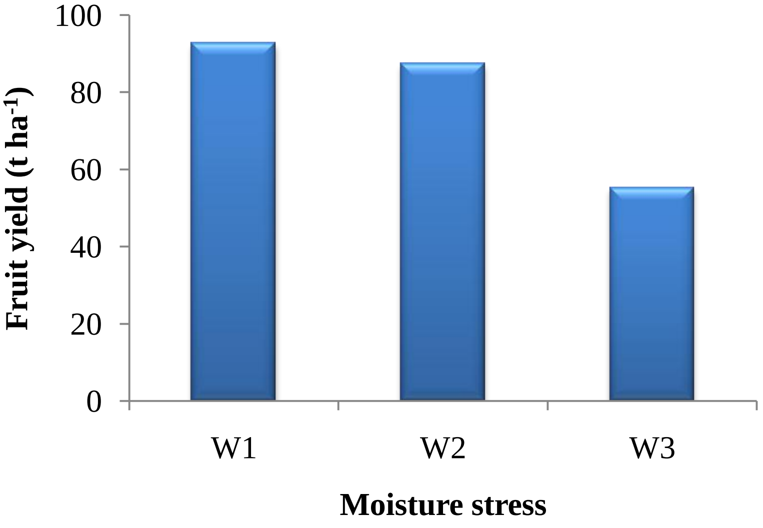
Figure 24. Effect of salicylic acid on fruit yield of tomato ($LSD_{0.05}$ = 0.06)

Yield plant^{-1} varied significantly due to the combined effect of different levels of moisture and salicylic acid (Appendix IX). The highest yield plant^{-1} (2.35 kg) was recorded from W_1S_2 treatment combination which was statistically similar with W_2S_2 and the lowest yield (1.15 kg) was observed from W_3S_0 treatment combination which was statistically similar with W_3S_3 (Table 13).

4.16 Fruit yield (t ha^{-1})

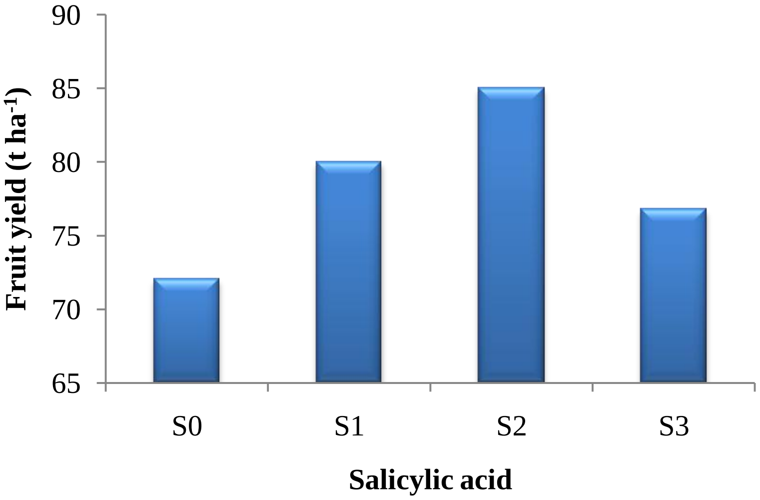
Different levels of moisture varied significantly in terms of fruit yield of tomato under the present trial (Appendix IX). The highest fruit yield (92.70 t ha^{-1}) was recorded from W_1, while the lowest fruit yield (55.31 t ha^{-1}) was found from W_3 (Figure 25).

Different levels of salicylic acid showed significant differences on fruit yield of tomato (Appendix IX). The highest fruit yield (85.04 t ha^{-1}) was recorded from S_2, whereas the lowest fruit yield (72.05 t ha^{-1}) was observed from S_0 (Figure 26).



W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture

Figure 25. Effect of moisture stress on fruit yield of tomato ($LSD_{0.05}$ = 2.39)



S_0: Control i.e. foliar spray of water without salicylic acid, S_1: Foliar spray with 50 ppm salicylic acid, S_2: Foliar spray with 75 ppm salicylic acid and S_3: Foliar spray with 100 ppm salicylic acid

Figure 26. Effect of salicylic acid on fruit yield of tomato ($LSD_{0.05}$ = 2.76)

Fruit yield varied significantly due to the combined effect of different levels of moisture and salicylic acid (Appendix IX). The highest fruit yield (97.95 t ha^{-1}) was recorded from W_1S_2 treatment combination which was statistically similar with W_2S_2 and the lowest fruit yield (47.87 t ha^{-1}) was observed from W_3S_0 treatment combination which was statistically similar with W_3S_3 (Table 13).

Table 13. Combined effect of different levels of moisture and salicylic acid on number of fruits plant^{-1}, weight of individual fruit, yield plant^{-1} and fruit yield

Treatment	Number of fruits Plant^{-1}	Weight of individual fruit (g)	Yield plant^{-1} (kg)	Fruit yield (t ha^{-1})
W_1S_0	32.10 c	67.26 a	2.18 bc	90.88 bc
W_1S_1	35.84 ab	68.83 a	2.21 bc	91.87 bc
W_1S_2	36.85 a	69.06 a	2.35 a	97.95 a
W_1S_3	35.05 ab	66.67 a	2.16 bc	90.08 bc
W_2S_0	32.42 c	57.85 bc	1.86 d	77.40 d
W_2S_1	32.03 c	60.07 b	2.15 bc	89.73 bc
W_2S_2	35.44 ab	61.06 b	2.25 ab	93.78 ab
W_2S_3	32.44 c	60.77 b	2.13 c	88.72 c
W_3S_0	21.85 f	52.55 d	1.15 g	47.87 g
W_3S_1	24.57 de	57.08 b-d	1.40 f	58.47 f
W_3S_2	26.35 d	57.71 bc	1.52 e	63.39 e
W_3S_3	22.95 ef	53.85 cd	1.24 g	51.52 g
LSD $_{(0.05)}$	2.16	4.66	0.11	4.78
CV (%)	4.18	4.50	3.56	3.60

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

W_1: 100% evapotranspiration moisture,
W_2: 75% evapotranspiration moisture and
W_3: 50% evapotranspiration moisture

S_0: Control i.e. foliar spray of water without salicylic acid,
S_1: Foliar spray with 50 ppm salicylic acid,
S_2: Foliar spray with 75 ppm salicylic acid and
S_3: Foliar spray with 100 ppm salicylic acid

CHAPTER V

SUMMARY AND CONCLUSIONS

The experiment was conducted at the Horticulture Research Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during October 2015 to April 2016 to study the mitigation of drought stress in tomato by exogenous application of salicylic acid. Seedlings of 30 days of BARI Tomato-14 were used as test crop. The experiment consisted of two factors: Factor A: moisture percentage (three levels) as W_1: 100% evapotranspiration moisture, W_2: 75% evapotranspiration moisture and W_3: 50% evapotranspiration moisture; Factor B: salicylic acid (four levels) as S_0: Control i.e. Foliar spray without salicylic acid, S_1: foliar spray with 50 ppm salicylic acid, S_2: foliar spray with 75 ppm salicylic acid and S_3: foliar spray with 100 ppm salicylic acid. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth and yield parameter were recorded and significant variations were found for different levels of moisture, salicylic acid and their combined effects.

At 30, 40, 50, 60 and 70 DAT, the tallest plant (44.50, 72.09, 82.54, 98.91 and 104.90 cm, respectively), maximum number of leaves plant^{-1} (9.38, 14.27, 21.24, 31.42 and 43.16, respectively) and maximum number of branches plant^{-1} (3.96, 7.03, 12.50, 18.31 and 20.03, respectively) was recorded from W_1, whereas the shortest plant (38.92, 60.79, 75.42, 88.35 and 96.77 cm, respectively), minimum number of leaves plant^{-1} (7.78, 9.84, 19.90, 26.89 and 37.54, respectively) and minimum number of branches plant^{-1} (3.20, 6.26, 10.00, 15.01 and 17.31, respectively) was observed from W_3. At flowering stage and 30 days after flowering, the maximum leaf area (198.8 and 185.6 cm^2, respectively) and the highest SPAD values (47.41 and 43.62, respectively) was recorded from W_1, while the minimum leaf area (176.5 and 174.8 cm^2, respectively) was found from W_3 and the lowest SPAD values (38.11 and 35.26, respectively) was found from W_3. The highest dry matter content of leaf in plant (18.07%), highest number of flower cluster plant^{-1} (15.81), highest number of flowers cluster^{-1} (5.34), highest number of fruits cluster^{-1} (3.52), highest number of flowers plant^{-1} (84.84), highest number of fruits plant^{-1} (34.96), highest length of fruit (5.62 cm), highest diameter of fruit (5.97 cm), highest weight of individual fruit (67.95 g), highest yield plant^{-1} (2.23 kg) and highest fruit yield (92.70 t ha^{-1}) was obtained from W_1; whereas lowest dry matter content of leaf in plant (12.22%), lowest number of flower cluster plant^{-1} (11.25), lowest number of flowers cluster^{-1} (4.16), lowest number of fruits cluster^{-1} (3.11), lowest number of flowers plant^{-1} (46.88), lowest length of fruit (4.19 cm), lowest diameter of fruit (4.43 cm), lowest number of fruits plant^{-1} (23.93), lowest weight of individual fruit (55.30 g), lowest yield plant^{-1} (1.33 kg) and lowest fruit yield (55.31 t ha^{-1}) was observed from W_3.

At 30, 40, 50, 60 and 70 DAT, the tallest plant (44.29, 71.50, 91.37, 100.20 and 105.10 cm, respectively), maximum number of leaves plant^{-1} (9.85, 13.99, 24.41, 33.46 and 44.85, respectively) and maximum number of branches plant^{-1} (3.93, 7.77, 13.24, 18.89 and 21.15, respectively) was found from S_2, while the shortest plant (39.49, 63.94, 81.97, 89.57 and 96.48 cm, respectively), minimum number of leaves plant^{-1} (8.15, 10.60, 17.13, 26.23 and 37.03, respectively) and minimum number of branches plant^{-1} (3.38, 5.71, 10.11, 15.22 and 17.19, respectively) was recorded from S_0. At flowering stage and 30 days after flowering, the maximum leaf area (193.9 and 189.7 cm^2, respectively) and the highest SPAD value (43.82 and 40.35, respectively) was obtained from S_2, whereas the minimum leaf area (181.7 and 174.2 cm^2, respectively) and the lowest SPAD value (40.47 and 37.32, respectively) was found from S_0. The highest dry matter content of leaf in plant (17.26%), highest number of flower cluster plant^{-1} (15.09), highest number of flowers cluster^{-1} (5.32), highest number of fruits cluster^{-1} (3.48), highest number of flowers plant^{-1} (81.46), highest length of fruit (5.70 cm), highest diameter of fruit (5.91 cm), highest number of fruits plant^{-1} (32.42), highest weight of individual fruit (62.61 g), highest yield plant^{-1} (2.04 kg) and highest fruit yield (85.04 t ha^{-1}) was recorded from S_2; while the lowest dry matter content of leaf in plant (13.99%), lowest number of flower cluster plant^{-1} (12.52), lowest number of flowers cluster^{-1} (4.60), lowest number of fruits cluster^{-1} (3.23), lowest number of dropped flowers plant^{-1} (17.65), lowest number of flowers plant^{-1} (58.28), lowest number of fruits sets plant^{-1} (40.64), lowest length of fruit (4.49 cm), lowest diameter of fruit (4.82 cm), lowest number of fruits plant^{-1} (28.79), lowest weight of individual fruit (59.22 g), lowest yield plant^{-1} (1.73 kg) and lowest fruit yield (72.05 t ha^{-1}) was found from S_0.

At 30, 40, 50, 60 and 70 DAT, the tallest plant (46.21, 75.41, 98.87, 104.40 and 110.0 cm, respectively), maximum number of leaves plant^{-1} (10.83, 16.28, 25.58, 35.83 and 47.46, respectively) and maximum number of branches plant^{-1} (4.20, 8.42, 14.90, 20.79 and 22.54, respectively) was found from W_1S_2 treatment combination. At 30, 40, 50, 60 and 70 DAT, the shortest plant (35.27, 57.05, 72.97, 83.15 and 92.08 cm, respectively) was found from W_3S_0. The minimum number of leaves plant^{-1} (7.26, 8.74, 24.47 and 34.64 at 30, 40, 60 and 70 DAT, respectively) was found from W_3S_0 and (16.35 at 50 DAT) was found from W_2S_0 treatment combination. The minimum number of branches plant^{-1} (2.90, 5.52, 13.82 and 15.59 at 30, 40, 60 and 70 DAT, respectively) was found from W_3S_0 and (9.02 at 50 DAT) was found from W_3S_3 treatment combination. At flowering stage and 30 days after flowering, the maximum leaf area (205.3 and 193.2 cm^2, respectively) and the highest SPAD value (49.73 and 45.66, respectively) was attained from W_1S_2 treatment combination, whereas the minimum leaf area (170.9 and 165.9 cm^2, respectively) and the lowest SPAD value (37.13 and 34.34, respectively) was measured from W_3S_0 treatment combination. The highest dry matter content of leaf in plant (19.57%), highest number of flower cluster plant^{-1} (17.43), highest number of flowers cluster^{-1} (5.90), highest number of fruits cluster^{-1} (3.66), highest number of flowers plant^{-1} (102.8), highest number of fruits plant^{-1} (36.85), highest length of fruit (6.33 cm), highest diameter of fruit (6.60 cm), highest weight of individual fruit (69.06 g), highest yield plant^{-1} (2.35 kg) and highest fruit yield (97.95 t ha^{-1}) was obtained from W_1S_2 treatment combination; lowest number of flower cluster plant^{-1} (10.50), lowest dry matter content of leaf in plant (10.40%), lowest number of flowers cluster^{-1} (3.93), lowest number of fruits cluster^{-1} (2.98), lowest number of flowers plant^{-1} (41.24), lowest length of fruit (3.48 cm), lowest diameter of fruit (3.77 cm), lowest number of fruits plant^{-1} (21.85), lowest weight of individual fruit (52.55 g), lowest yield plant^{-1} (1.15 kg) and lowest fruit yield (47.87 t ha^{-1}) was recorded from W_3S_0 treatment combination.

Above findings revealed that the combination of W_1S_2 was more suitable in consideration of yield contributing characters and yield. The yield of tomato was gradually decreased by the increase of drought stress and this reduction rate was decreased by exogenous supply of salicylic acid. Among the salicylic acid levels, S_2 (75 ppm) treatment showed the highest result in growth, physiology and yield parameters as compared to others.

However, to reach a specific conclusion and recommendation, more research work should be done on tomato cultivation under drought stress with various level of salicylic acid.

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APPENDICES

Appendix I. Soil characteristics of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field , SAU, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	27
Silt	43
Clay	30
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix II. Monthly meteorological information during October, 2015 to April, 2016

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr)
		Maximum	Minimum			
2015	October	29.50	19.40	81.10	22	6.9
	November	28.50	17.90	78.50	00	6.8
	December	27.60	15.20	74.60	00	6.3
2016	January	24.60	13.50	68.50	00	5.7
	February	28.90	18.00	67.00	30	6.7
	March	33.60	29.50	54.70	11	8.2
	April	33.50	25.90	64.50	119	8.2

Source: Meteorological centre, Agargaon, Dhaka (Climate Division)

Appendix III. Analysis of variance of the data on plant height (cm) of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	Df	Mean square of plant height (cm) at different days after transplanting				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Replication	2	18.41	9.74	42.86	22.04	49.33
Moisture stress (A)	2	100.41*	404.05*	994.01*	363.89*	198.20*
Salicylic acid levels (B)	3	44.06*	109.24*	175.05*	189.04*	132.79*
Moisture stress (A) X Salicylic acid levels (B)	6	2.04*	4.70*	10.67*	0.47*	2.61*
Error	22	5.34	14.22	26.14	31.04	36.74

*Significant at 5% level of probability

^{NS} Non significant

Appendix IV. Analysis of variance of the data on number of leaves plant^{-1} of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	Df	Mean square of leaf no. plant^{-1} at different days after transplanting				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Replication	2	1.59	1.05	1.13	1.61	5.56
Moisture stress (A)	2	8.51*	59.44*	5.46*	69.98*	97.14*
Salicylic acid levels (B)	3	5.57*	19.15*	93.43*	92.26*	116.37*
Moisture stress (A) X Salicylic acid levels (B)	6	0.42*	0.44*	2.49*	1.96*	4.59*
Error	22	0.23	0.66	2.20	2.15	2.86

*Significant at 5% level of probability

^{NS} Non significant

Appendix V. Analysis of variance of the data on number of branch plant^{-1} of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	Df	Mean square of branch no. plant^{-1} at different days after transplanting				
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
Replication	2	0.07	0.54	1.70	0.79	3.44
Moisture stress (A)	2	1.80*	1.93*	19.57*	33.50*	23.71*
Salicylic acid levels (B)	3	0.46*	7.89*	20.22*	24.90*	28.14*
Moisture stress (A) X Salicylic acid levels (B)	6	0.02*	0.27*	1.35*	0.41*	0.29*
Error	22	0.06	0.12	0.41	1.56	1.20

*Significant at 5% level of probability

^{NS} Non significant

Appendix VI. Analysis of variance of the data on leaf area index (cm^2) and SPAD value (%) of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	df	Mean square of leaf area index and SPAD value at different days after transplanting			
		Leaf area at first flowering	Leaf area at 30 DAF	SPAD value at first flowering	SPAD value at 30 DAF
Replication	2	2.52	128.42	9.88	0.37
Moisture stress (A)	2	1498.29*	373.00*	273.88*	224.10*
Salicylic acid levels (B)	3	244.83*	446.26*	19.30*	13.79*
Moisture stress (A) X Salicylic acid levels (B)	6	7.17*	16.23*	1.09*	1.29*
Error	22	115.84	99.24	4.93	6.77

*Significant at 5% level of probability

^{NS} Non significant

Appendix VII. Analysis of variance of the data on dry matter of leaf (%), number of flowers cluster plant^{-1}, number of flowers cluster^{-1} and number of fruits cluster^{-1} of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	df	Mean square values of			
		Dry matter of leaf (%)	Flowers cluster plant^{-1} (No.)	Flowers cluster^{-1} (No.)	Fruits cluster^{-1} (No.)
Replication	2	1.37	2.29	0.17	0.02
Moisture stress (A)	2	107.02*	62.93*	4.90*	0.54*
Salicylic acid levels (B)	3	17.02*	11.20*	0.92*	0.11*
Moisture stress (A) X Salicylic acid levels (B)	6	0.20*	0.29*	0.02*	0.003*
Error	22	0.58	0.57	0.07	0.03

*Significant at 5% level of probability

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on number of flowers plant^{-1} and length of fruit (cm) of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	df	Mean square values of	
		Flowers plant^{-1} (No.)	Length of fruit (cm)
Replication	2	124.76	0.030
Moisture stress (A)	2	4482.02*	7.47*
Salicylic acid levels (B)	3	921.03*	2.86*
Moisture stress (A) X Salicylic acid levels (B)	6	39.95*	0.05*
Error	22	12.74	0.05

*Significant at 5% level of probability

^{NS} Non significant

Appendix IX. Analysis of variance of the data diameter of fruit (cm), number of fruits plant^{-1}, weight of individual fruit (g), yield plant^{-1} (kg) and fruit yield (t ha^{-1}) of tomato as influenced by combined effect of moisture stress and different levels of salicylic acid

Source of variation	df	Mean square values of				
		Diameter of fruit (cm)	Fruits plant^{-1} (No.)	Weight of individual fruit (g)	Yield plant^{-1} (kg)	Fruit yield (t ha^{-1})
Replication	2	0.12	0.23	2.04	0.01	64.74
Moisture stress (A)	2	7.99*	486.06*	570.28*	4.16*	7131.52*
Salicylic acid levels (B)	3	1.92*	116.80*	33.31*	0.77*	1351.63*
Moisture stress (A) X Salicylic acid levels (B)	6	0.18*	4.88*	5.55*	0.04*	74.53*
Error	22	0.08	3.89	14.06	0.02	17.76

*Significant at 5% level of probability

^{NS} Non significant