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RESPONSES OF THREE TOMATO (*Lycopersicon esculentum* L.) VARIETIES TO DIFFERENT SALINITY LEVELS

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ABSTRACT

One of the abiotic stressors that have a substantial influence on agricultural productivity is salt stress. The effect of salinity was examined on tomato (*Lycopersicon esculentum* L.) plants; as germination indices, growth parameters and biochemical responses of three tomato ('Salimah', 'Yassamen', and 'Bushra'). The effect of salinity on germination indices has been studied in laboratory and pots trials, while growth parameters and biochemical traits of plants as well as seedling emergence were studied under greenhouse conditions. The results of this study showed that salinity at 12 ds.m-1 significantly lowered all assessed germination indices (germination percentage, speed of germination, mean germination time, mean daily germination, peak value of germination and germination value) in both laboratory and pot trials when compared to controls. The results showed that the growth parameters (plant height, leaf area index and fresh and dry weight of shoot and root) of plants treated with salinity at 6 and 12 ds m-1 for 45 days were reduced significantly compared to control, and the salinity effect was significant at 12 than 6 ds m-1 level. The results revealed that tested salinity at 12 ds m-1 reduced chlorophyll a and total chlorophyll significantly compared to other treatments, in contrast carotenoid, anthocyanin, proline, free amino acids, total soluble proteins, H2O2, MDA and membrane stability index (MSI) were significantly higher in tomato plants treated with salinity at 12 ds m-1 than other treatments. It's highly recommended to using tolerant variety 'Bushra' in salt affected area.

Keywords: Biochemical traits; germination; growth parameters; salt stress; tomato.

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is one of the most important, popular, nutritious, and tasty vegetables cultivated in Iraq, and it is one of the most popular, nutritious, and palatable plants in the Solanaceae family [1]. Tomatoes are regarded to be part of a healthy diet since they are low in fat and cholesterol-free, vitamin A, ascorbic acid and potassium are among the nutrients found in

substantial amounts in tomatoes, as well as non-nutritive phytochemicals like carotenoids and polyphenols [2]. Salinity (soil salinity or irrigation water) is one of the most serious issues affecting agriculture on a worldwide scale, particularly in arid and semi-arid areas (Munns and Tester, 2008, Abass [3]). Iraq is one of the top of Arab and Asian countries in terms of entire area damaged by salinity, which sapped the production capacity of 70% of Iraq's total irrigated territory, with up to 30% of it entirely out of production [4]. Tomato classified as moderately sensitive to salinity, where they tolerate a salinity level of up to 2 $ds.m^{-1}$ without loss of yield, however, increasing salt levels above that reduces agricultural productivity of most crops and has an impact on soil physicochemical qualities as well as the area's ecological balance. Reduction of agricultural production, poor economic returns, and soil degradation are all consequences of salt [5]. Seed germination, plant development, and water and nutrient uptake are disrupted by salinity, as a result of such interactions between morphological, physiological, and metabolic processes [6,7]. Zubair district, which is located west of Basrah governorate in the south of Iraq, is one of the main areas for the production of the tomato crop in Iraq. Agriculture in this region depends entirely on groundwater due to the lack of surface water resources and low rainfall, so well water is the main water resource for agriculture in this region [4]. The current study aims to assess the responses of three varieties of tomatoes ('Salimah', 'Yassamen', and 'Bushra'), which are prevalent varieties in Zubair region to several levels of salinity (2, 6 and 12 $ds.m^{-1}$) of irrigation water, the study includes the effect of salinity on germination indices and growth parameters, as well as the biochemical response.

MATERIALS AND METHODS

During the cultivation season of 2020-2021, the study was performed in the laboratories and greenhouse of plant protection department of Agriculture College, Basrah University. Three tomato varieties ('Salimah', 'Yassamen', and 'Bushra') were selected, and seeds were obtained from local markets. The seeds were soaked for 15 minutes in a 10% sodium hypochlorite solution (as a treatment to eliminate any fungal contamination that might be pathogenic to plants and interact with our treatment) before being rinsed three times with distilled water.

Design of Treatments

Three different levels of NaCl (in terms of EC) were employed throughout the experiment: 2 (as control), and 12 $ds.m^{-1}$. Distilled water was used to prepare irrigation water with the required NaCl-salinity. Based on a preliminary survey of the salinity levels of the irrigation waters and soils in different cultivation areas of tomato, the NaCl-salinity range was chosen for the evaluation salinity stress on tomato plants.

Laboratory Experiment

In the laboratory 10 sterilized seeds of each variety were put in each petri dish of 9 cm diameter on a filter paper moistened with 2 mL of respective salinity level treatment in triplicates. The petri dishes were covered to prevent the loss of moisture by evaporation. The petri dishes were incubating for 10 days at 25^{o} C temperature and 65% relative humidity. Every 24 hours, germination percentage and other traits were recorded daily. After 10 days of incubation, the final germination indices were measured. Each dish received about 20-25 mL of respective salinity level treatment throughout the trial period.

Pots Experiments

Pots trail was conducted at greenhouse conditions, examined tomato varieties were evaluated for their responses to in three levels of salinity (control, 6 and 12 ds m^{-1}). 5 seeds per variety to a pot containing 1 kg of soil, the characteristics of which are presented in Table (1). Each three pots were irrigated with individual salinity level up to field capacity. The pots grouped to three groups each group contain 27 of pots (three varieties x three levels of salinity x three replications). First group was irrigated for 10 days to determine germination indices as in laboratory experiment, second group was irrigated for 45 days to determine growth parameters and third group was irrigated for 60 days to evaluate the biochemical responses.

Germination Indices

According to Ranal and De Santana [8], germination indices were measured on the 10th day of laboratory and pots trials as follow:

a- Germination percentage (%) by using equation:

$$Germination\ percentage\ (\%) = \frac{seeds\ germinated}{total\ seeds} * 100$$

b- Germination speed index by using equation

$$\text{Germination speed index} = \frac{n1}{d1} + \frac{n2}{d2} + \frac{n3}{d3} + \cdots \frac{n3}{d3}$$

Which n = number of germinated seeds and d= number of days.

c- Mean germination time by using equation

$$Mean\ germination\ time\ (seed\ /day) = n1 * d1 + n2 * d2 + n3 * d3 + \cdots . . n10 * d10$$

Which n = number of germinated seeds and d= number of days.

d- Mean daily germination by using equation

$$Mean\ daily\ equation = Total\ number\ of\ germinated\ seeds\ /\ total\ number\ of\ days$$

e- Peak germination value by using formula

$$Peak\ germination\ value = \frac{Highest\ seedgerminated}{Number\ of\ days}$$

f- Germination Value by using formula

$$Germination\ value = \frac{Peak\ germination\ value}{mean\ daily\ germination}$$

Table 1 presents the properties of the soil used in agriculture

Table 1. Some properties of soil used in culture

Properties	Value	Unit
pH	7.8	
Electric conductivity (EC)	5.3	$ds.m^{-1}$
Organic matter	1.66	%
Cation exchange capacity CEC	8.29	$cmole.kg^{-1}$
Sand	78.60	%
Clay	12.20	%
Silt	9.20	%
Soil texture	Sandy loam	

Growth Parameters

Plant height (cm) was measured using a metric ruler from the surface of the soil to the top of the plant, leaf area (cm^2) which the fourth leaf from the top of each replicate was placed on the scanner machine and then converted into images read by the computer with high resolution, and then leaf area was calculated using ImageJ program depending on the method described by Aboukarima et al. [9]. Fresh and dry weight of shoot and root system taken from the plants, separated into shoot and root. The fresh weights of the shoots and roots were recorded, following which they were dried for 72 hours at 70° C and the dry mass weights of the shoots and roots were determined using an electronic scale (TE 2148 Sartorius).

Biochemical Parameters

60 days after the tomato plants were exposed to salinity in the selected levels, the following biochemical parameters were measured:

Pigments Content

The extraction of pigments was performed following Arnon [10] methodology and concentrations of chlorophyll (a, b and total), carotenoids and anthocyanin were calculated by Asare-Boamah et al. [11] formulas after absorbance of supernatants was recorded at 645, 663, 534 and 470 nm:

$$Chlorophyll\ a = 12.7(OD663) - 2.69(OD645) * \left(\frac{V}{W}\right)$$

$$Chlorophyll\ b = 22.9(OD645) - 4.68(OD663) * (\frac{V}{W})$$

$$Totol\ Chlorophyll = 20.2(OD645) - 8.02(OD663) * (\frac{V}{W})$$

$$Anthocyanin = 0.0821 * (OD534) - 0.0439(OD634) - 0.002423(OD661)$$

$$Carotene = \left((OD470) - 17.1\right) * (chla + chlb) - (9.479 * anthocyanin)/119.26$$

Proline Content

The Proline content in leaf tissues was measured by interaction with ninhydrin chromatically at 520 nm [12].

Free Amino Acids (FAA)

Using the Ninhydrine reagent and a 570 nm optical density measurement, the method of Lee and Takahashi (1966) was used to quantify the free amino acids.

Total Soluble Protein

Total soluble protein extraction was carried out according to Bavei et al. [13], and then was determined by the Bradford [14] colorimetric method using Bradford reagent at 595 nm.

Hydrogen Peroxide (H_2O_2)

H_2O_2 concentration was measured calorimetrically at 390 nm, and H_2O_2 (38%, Evonik, Germany) was used to produce a reference curve according to Sergiev et al. [15].

Malondialdehyde (MDA)

MDA was utilized as a membrane lipid peroxidation marker. MDA was extracted 5% (w/v) using trichloroacetic acid (TCA), the absorbance at 532 and 600 nm were measured, and the MDA concentration was calculated using the extinction coefficient of 155 [16].

Membrane Stability Index (MSI)

MSI was estimated using the equation [17].

$$MDI = \left(1 - \frac{C1}{C2}\right) * 100$$

Where C1 and C2 are the electric conductivities measured at 40° C and 100° C, respectively.

Statistical Analysis

The trials used a completely randomized factorial design with three salinity levels (2, 6, and 12 ds.m-1 NaCl) and three tomato varieties ('Salimah', 'Yassamen', and 'Bushra'). All measures were done three times; data was analyzed using SPSS-22 software for two-way analysis of variance (SPSS In., Chicago, IL., USA). The least significant difference (LSD) was used to assess significant differences between means. Statistical significance was defined as a P value of less than 0.05.

RESULTS AND DISCUSSION

Effect of Salinity on Seed Germination Indices *In vitro* and Pots Trail

Seed germination indices of three tomato varieties were daily recorded after applied salinity treatments up to 10 days in both laboratory and pots experiments. Results of laboratory trial illustrated in Fig. 1 and Fig. 2 (a-f); the main effects of salinity; variety and the interaction effects between them were significant to all measured indices with an exception with main effect of variety and interaction on peak value of germination. Salinity at 12 ds m^{-1} reduced all indices significantly more than at 6 ds m^{-1}. Effect of salinity at 12 ds m^{-1} level reduced the germination percentage by 73.45%, speed of germination by 72.59%, mean germination time by 28.94%, mean daily germination by 49.47%, peak value of germination by 76.25% and germination value by 87.58% compared to control.

The main effects of salinity and variety were significant to all assessed germination indices in the pots experiment, whereas the interaction effect between salinity and variety was significant only to the mean daily germination, peak value of germination, and germination value indices, as shown in Fig. 3 (a-f). Also as in laboratory experiment, salinity at 12 ds.m^{-1} reduced all indices significantly more than other treatments and compared to control, thus was evident by a significant reduction of germination percentage by 42.56%, speed of germination by 54.94%, mean germination time by 50.28%, mean daily germination by 35.71%, peak value of germination by 33.33 and germination value by 50.00%. In both experiments, In terms of germination indices, the 'Salimah' variety was more sensitive to all salinity levels tested, but the 'Yassamen' variety was more tolerant to salinity, especially under greenhouse conditions. However, under laboratory conditions, there was no significant difference between 'Yassamen' and 'Bushra' types in all germination indices except the mean germination time index, wherein 'Yassamen' variety had a greater value.

Findings of present study indicated the negative effect of salinity, particularly at high levels on germination indices whether under laboratory or pots conditions, that might be explained by the presence of NaCl salt in the medium lowering the osmotic potential to the point where it delays or prevents the intake of water required for nutrient mobilization required for germination. Additionally, absorption of excess Na^+ and Cl ions from the medium causes toxicity, which contributes to biochemical process disruption [18, 19]. During germination, salinity disrupts nutritional and hormone balances, particularly gibberellin (GA)/abscisic acid (ABA). As a result, germination is delayed due to excessive saline levels [20]. The results of this study agreed with those of Amir et al. [21]; Singh et al. [22]; Al-Daej [23], which reported that tomato seed germination indices were negatively affected by an increased dose of NaCl.

Effect of Salinity in Growth Parameters

Growth parameters which includes plant height, leaf area, fresh and dry weight of shoot and root were recorded after 45 days of exposing three varieties of tomato to different salinity levels. Salinity negatively affected all of the growth parameters measured (Fig. 3), the variability analysis indicated that salinity at 12 ds m^{-1} significantly reduced all growth parameters compared to other treatments, with an exception of the fresh and dry weight of the shoot, which

wasn't differ significantly with salinity at 6 ds m^{-1}. Growth parameters in control treatment were: plant height 11.27 cm, leaf area 5.99 cm^2, shoot fresh weight 363.33 mg, shoot dry weight 33.55 mg, root fresh weight 27.11 mg and root dry weight 4.87 mg, salinity treatment with 12 ds.m^{-1} reduced to 6.53 (Fig. 4,b), 3.32 (Fig. 5,b), 114.33 (Fig. 6,b), 13.11 (Fig. 7,b), 6.81 (Fig. 8, b) and 1.26 (Fig. 9,b), for above-mentioned parameters, respectively. While the studied varieties did not differ significantly in their response to salinity in all measured growth parameters except in dry weight of shoot and root. Also the variance analysis showed the interaction effect of examined factors was significant.

Plants suffer from nutritional ion imbalances, decreased stomatal conductance, poor photosynthetic activity, and morphological changes such as reduced leaf number, plant size and root length, as a result of salinity produced by NaCl. (Munns and Tester, 2008; Petretto et al. [24]). Growth suppression the early reaction of the plant to salt exposure, which occurs between minutes to days, induces stomatal closure and cell expansion inhibition, mostly in the shoot [25]. Plants, on the other hand, absorb salts that affect their turgor, photosynthesis, and the activity of certain enzymes [26]. Due to a reduction in shoot and root development under enhanced salt-stressed circumstances, the plant loses a significant amount of dry biomass accumulation [27]. Additionally, a drop in shoot dry weight might be linked to a slower rate of leaf formation, resulting in fewer leaves, which leads to less photosynthesis and dry matter accumulation, as shown in our results [28]. The results of this study are in consistent with the results of many studies, such as study of Najla et al . [29]; Singh et al. [22]; Zhang et al. [30]; Al-Daej [23]; Tanveer et al. [31], which found that the increasing of NaCl doses reduced tomato plants growth.

Effect of Salinity on Photosynthetic Pigments

The data presented in Table 2 showed that salinity caused a reduction in Chlorophyll a and total Chlorophyll content significantly, on contrast, carotenoids and anthocyanin content increased significantly in salt stressed plants. However, Chlorophyll b content did not differ significantly either between salinity levels or between varieties, as well as interaction effect of salinity and varieties. The results also revealed that according to a cumulative mean of salinity level, salinity at 12 ds m-^{1} reduced Chlorophyll a content up to 24.02% and total Chlorophyll up to 18.38% compared to control ones. Chlorophyll a and total chlorophyll content significantly were found to be high in 'Bushra' variety than others with 3.42 and 4.35 mg g^{-1}, respectively. Although the highest rate of reduction was observed in 'Bushra' variety in content of Chlorophyll a and total Chlorophyll than other varieties which were 32.71 and 22.22% respectively. Carotenoids content showed a significantly higher level of increment over the control under salt stress at 12 ds m^{-1} and the level were increased from 1.96 to 2.17 mg g^{-1}. 'Bushra' variety had significantly higher content of carotene than other varieties with 2.19 mg.g^{-1}.

In terms of anthocyanin content, it increased from 0.069 mg g^{-1} in control plants to 0.125 mg.g^{-1} in plants treated with salinity at 12 ds m^{-1}, that's up by 44.80%. 'Bushra' variety recorded a higher accumulation of anthocyanin than other varieties with 0.115 mg.g^{-1}. It is noteworthy that all the varieties studied had the same tendency in their response to salinity on plant pigments, either increasing or decreasing. Chlorophyll content under saline conditions is a commonly reported phenomenon and typical symptom of oxidative stress [32], this might be owing to the negative effect of salt stress, which induces early leaf maturation and reduced chlorophyll pigments [33], also might be related to an imbalance in ion, in particular Mg^{+2} ion deficiency (as an integral part of chlorophyll) and/or chlorophyll oxidation in salinity stressed conditions [34]. Santos [35] stated that abiotic stress including salt stress activate chlorophyllase enzyme that degrades chlorophyll. Chlorophyll content decreases as a response to slow synthesis or rapid degradation [36]. Carotenoids and anthocyanin, as well as other antioxidants, have the ability to protect stressed plants from the effects of reactive oxygen species, according to Verma and Mishra [37]. As a stress by-product, reactive oxygen species (ROS) are produced, consequently, plants must counteract the damage by synthesizing antioxidant molecules such as carotenoids and anthocyanin as

a non-enzymatic plant mechanism for ROS detoxification. Anthocyanin accumulation in leaves appears to be an osmoprotective response to high salt concentration-induced water stress [38].

Effect of Salinity in Biochemical Responses

A two-way ANOVA revealed a significant effect of salinity level and varieties in the proline content of plant leaves (Table 3), also, the salinity vs variety interactions were significant, reflecting that all varieties responded similarly to the different NaCl concentrations. Proline content increased from 0.20 µg g^{-1} FW in control to 0.27 and 0.60 µg g^{-1} FW, respectively at 6 and 12 ds m^{-1} salinity levels. 'Salimah' variety recorded significantly higher proline content with 0.46 µg g^{-1} FW. Proline is the most prevalent endogenous osmolyte accumulated in response to numerous abiotic stresses, including salinity, and it may operate as a signaling/regulatory molecule capable of activating several adaptive processes [39]. According to Armengaud et al. [40] salt stress induces the activation of genes involved in proline biosynthesis, resulting in a buildup of proline. Also, according to Marco et al. [41], proline buildup in stressed plants is mediated by either stimulation of proline biosynthesis genes (P5CS, P5CR) or inhibition of genes involved in its breakdown pathway (PDH silencing).

The highest significant content of free amino acids (FAA) was 2.47 mg g^{-1} FW which recorded in main effect of salinity levels (12 ds m^{-1}) and varieties ('Bushra' variety). Interaction between the examined factors was also significant. The lowest significant content of FAA was found at control (1.77 mg g^{-1} FW), while the lowest FAA content (1.72 mg g^{-1} FW) was found in 'Salimah' among the varieties. Free amino acid accumulation in salt-stressed plants might be associated to protein breakdown or synthesis inhibition. [42]. According to Bray et al. [43], certain amino acids work as compatible cytoplasmic solutes, and their increased accumulation acts as a mechanism of intracellular osmotic adjustment in order to sustain cytoplasmic osmotic potentials under salinity stress. Total soluble protein increased significantly from 5.52 mg g^{-1} FW in control plants to 5.68 and 6.11 mg g^{-1} FW, at 6 and 12 ds m^{-1}, respectively. The overall mean of total soluble protein for the 'Yassamen' variety was 6.11 mg g^{-1} FW, which was significantly higher than the other varieties. Also, results showed a significant difference of interaction between salinity levels and varieties (Table 3). Plants under stress tend to accumulate proteins with small molecular mass that employed as a source of nitrogen storage and mobilized after the stress is relieved or removed. Furthermore, these proteins may play a function in osmotic regulation [44,45].

Results of (Table 3) indicated that plants treated with salinity at 12 ds.m^{-1} showed significantly higher H_2O_2 concentration, i.e., 0.94 µM.g^{-1} FW compared to that treated with salinity at 6 ds.m^{-1} (0.71 µM g^{-1} FW) and control plants (0.60 µM g^{-1} FW). Regarding varieties, higher significant H_2O_2 concentration recorded to 'Yassamen' variety and it was 0.92 µM g^{-1} FW. A significant interaction between factors was observed. MDA content increased significantly under salinity stress at 12 ds.m^{-1} from 1.00 in control plants to 2.20 nmole g^{-1} and this represents an increase of 36.17%. Overall mean MDA content of 'Yassamen' variety (1.56 nmole g^{-1}) was significantly higher compared with other varieties. A significant interaction between the two factors was observed in MDA content. Membrane stability index (MSI) was affected by salinity treatment, which is significantly lower in salt-stressed plants. Indeed, the reduction was 24.26% and 40.08% in salinity at 6 and 12 ds.m^{-1}, respectively compared to control plants. The differences between three varieties were significant. 'Bushra' variety has a lower MSI with 60.25% while a higher value recorded for 'Yassamen' variety with 71.81%. Significant interaction effect was observed between study factors. As a result of abnormalities in the electron transport chain and buildup of photoreducing power, the amount of ROS in plant tissues rises during salt stress, leading in ROS formation, including H_2O_2, and membrane damage, as evidenced in high MDA levels and a reduction in MSI [46,47,48,49].

Table 2. Effect of salinity levels (ds.m^{-1}) in photosynthetic pigments of three tomato varieties

Variety	Salinity level ds.m^{-1}	Chla (mg.g^{-1})	Chlb (mg.g^{-1})	Total Chl (mg.g^{-1})	Carotenoids (mg.g^{-1})	Anthocyanin (mg.g^{-1})
'Salimah'	Control	3.05	0.96	4.08	1.94	0.068
	6	2.73	0.98	3.72	2.08	0.082
	12	2.42	1.03	3.38	2.12	0.121
'Yassamen'	Control	3.38	0.77	4.27	1.87	0.050
	6	2.97	0.8	3.78	1.98	0.060
	12	2.85	0.89	3.62	2.12	0.103
'Bushra'	Control	4.31	1.02	5.04	2.09	0.089
	6	3.04	1.03	4.08	2.21	0.102
	12	2.9	0.73	3.92	2.28	0.153
LSD of interaction effect at 0.05		0.51	NS	0.32	NS	NS
Overall mean of variety effect						
'Salimah'		2.73c	0.99a	3.73c	2.04b	0.090b
'Yassamen'		3.07b	0.82a	3.89b	1.99b	0.071c
'Bushra'		3.42a	0.93a	4.35a	2.19a	0.115a
Overall salinity level effect						
Control		3.58a	0.91a	4.46a	1.96c	0.069c
6		2.91b	0.94a	3.86b	2.09b	0.081b
12		2.72b	0.88a	3.64c	2.17a	0.125a

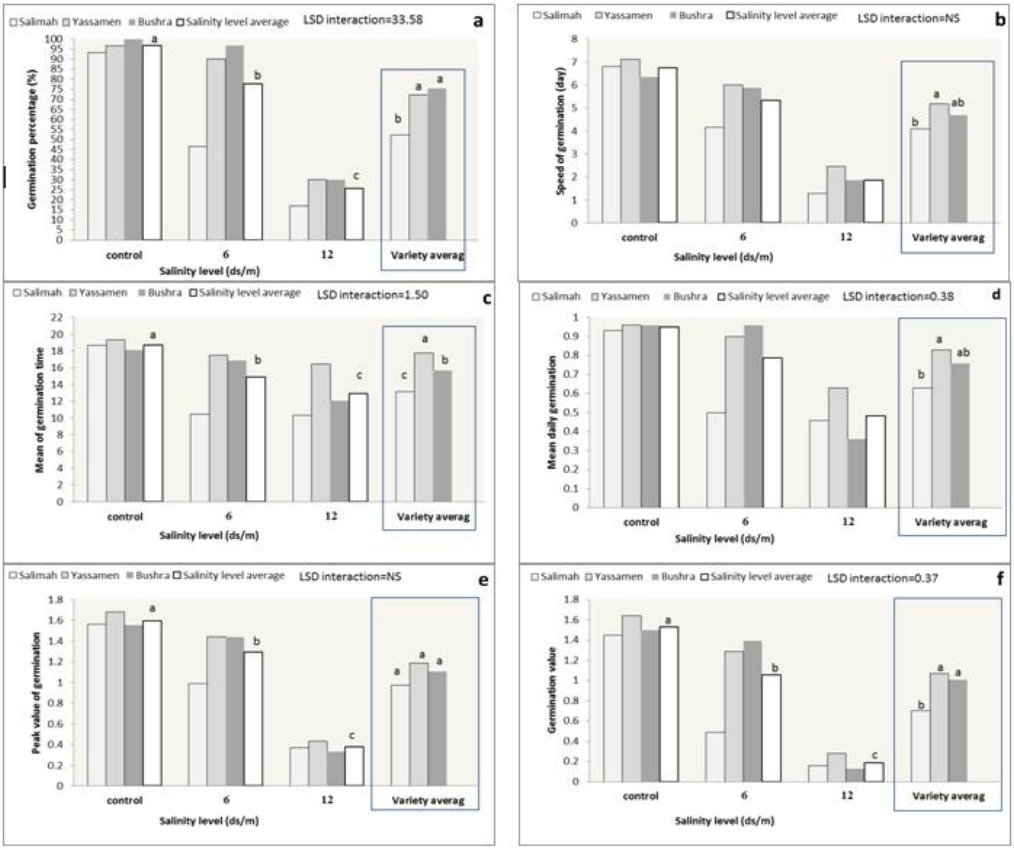

Fig. 1. Effect of different salinity level in germination indices of three cultivars of tomato under laboratory condition

a: germination percentage; b: Speed of germination; c: Mean germination time; d: Mean daily germination; e: Peak value of germination; f: Germination value

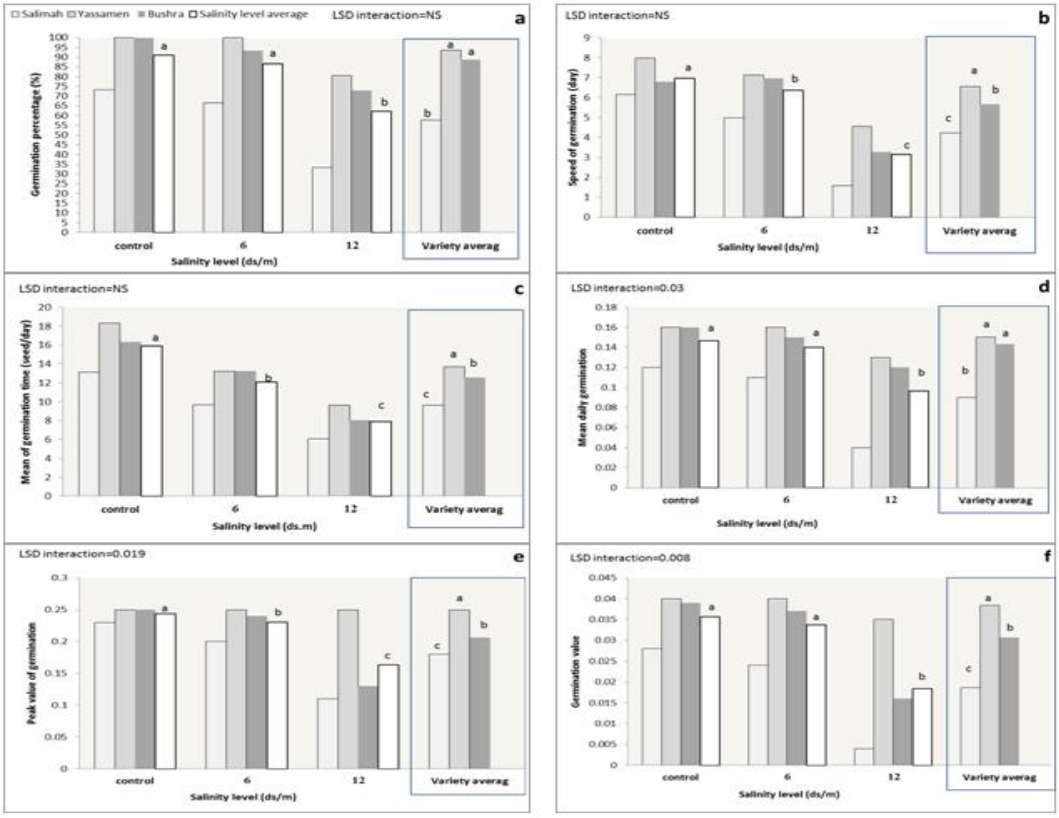

Fig. 2. Effect of different salinity level in germination indices of three cultivars of tomato under greenhouse condition

a: germination percentage; b: speed of germination; c: Mean germination time; d: Mean daily germination; e: Peak value of germination; f: germination value

Table 3. Biochemical response of three tomato varieties to salinity levels (ds.m^{-1})

Variety	Salinity level ds.m^{-1}	Proline (µg.g^{-1} FW)	FAA (mg.g^{-1} FW)	Total soluble protein (mg.g^{-1} FW)	H_2O_2 (µM.g^{-1} FW)	MDA (nmole.g^{-1})	MSI (%)
'Salimah'	**Control**	0.24	1.50	5.28	0.42	0.94	85.49
	6	0.34	1.65	5.63	0.50	0.99	60.30
	12	0.80	2.01	6.03	0.93	1.99	55.71
'Yassamen'	**Control**	0.14	1.80	5.91	0.78	1.16	87.83
	6	0.17	1.93	6.00	0.92	1.20	77.65
	12	0.62	2.45	6.43	1.05	2.34	50.41
'Bushra'	**Control**	0.21	2.02	5.39	0.60	0.90	81.11
	6	0.30	2.43	5.41	0.72	1.02	54.42
	12	0.39	2.95	5.88	0.85	2.28	46.05
LSD of interaction effect at 0.05		0.08	0.16	0.28	0.11	0.10	6.39
Overall mean of variety effect							
'Salimah'		0.46a	1.72c	5.65b	0.61c	1.31c	67.16b
'Yassamen'		0.31b	2.06b	6.11a	0.92a	1.56a	71.81a
'Bushra'		0.30b	2.47a	5.56b	0.72b	1.40b	60.25c
Overall salinity level effect							
Control		0.20c	1.77c	5.52c	0.60c	1.00c	84.66a
6		0.27b	2.00b	5.68b	0.71b	1.07b	64.12b
12		0.60a	2.47a	6.11a	0.94a	2.20a	50.72c

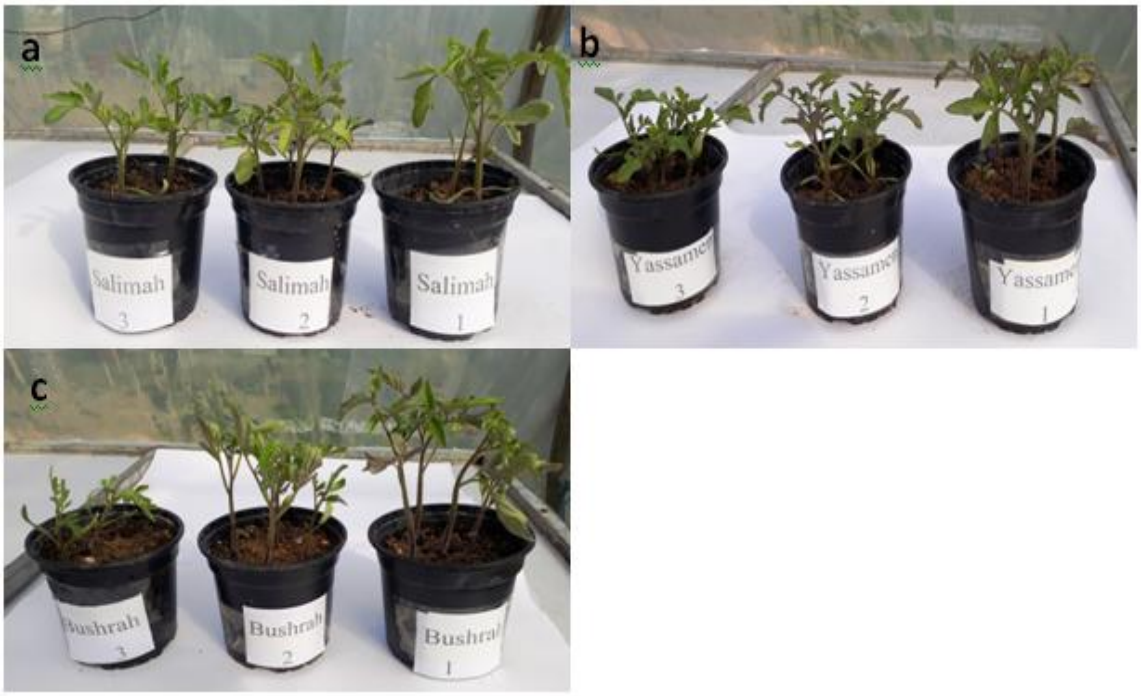

Fig. 3. Effect of salinity at different levels in growth of three cultivars of tomato

a: Salimah; b: Yassamen; c: Bushra; 1: control; 2: 6 $ds.m^{-1}$; 3: 12 $ds.m^{-1}$

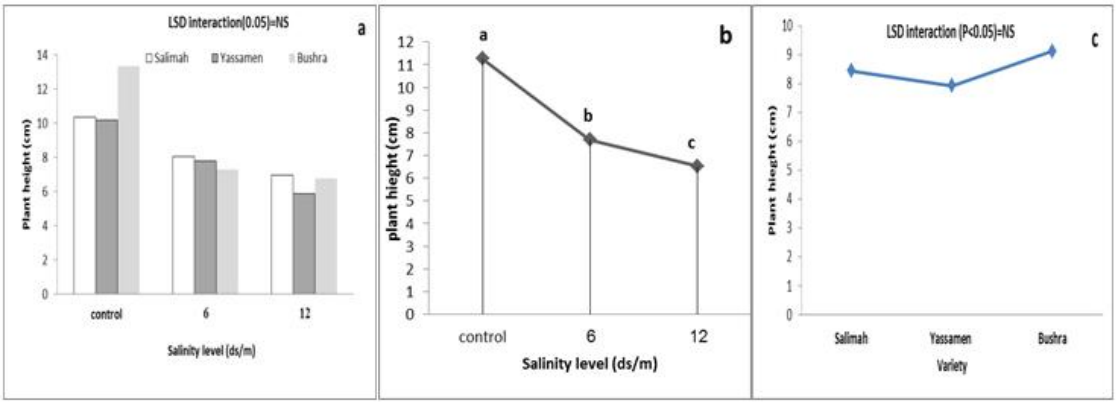

Fig. 4. Effect of salinity at different levels in plant height of three cultivars of tomato

a: interaction effect of study factors (salinity level and cultivar); b: overall mean of salinity levels; c: overall.

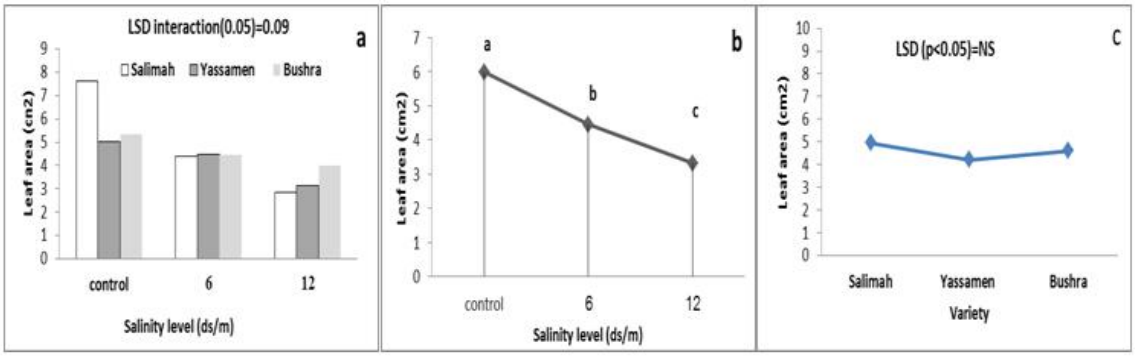

Fig. 5. Effect of salinity at different levels in leaf area (cm^2) of three varieties of tomato

a: interaction effect of study factors (salinity level and cultivar); b: overall mean of salinity levels; c: overall mean of varieties.

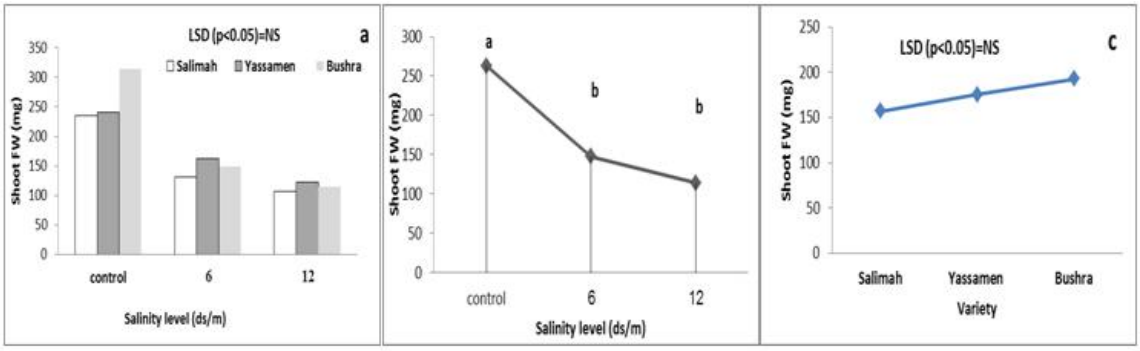

Fig. 6. Effect of salinity at different levels in shoot fresh weight (mg) of three varieties of tomato

a: interaction effect of study factors (salinity level and cultivar); b: overall mean of salinity levels; c: overall mean of varieties.

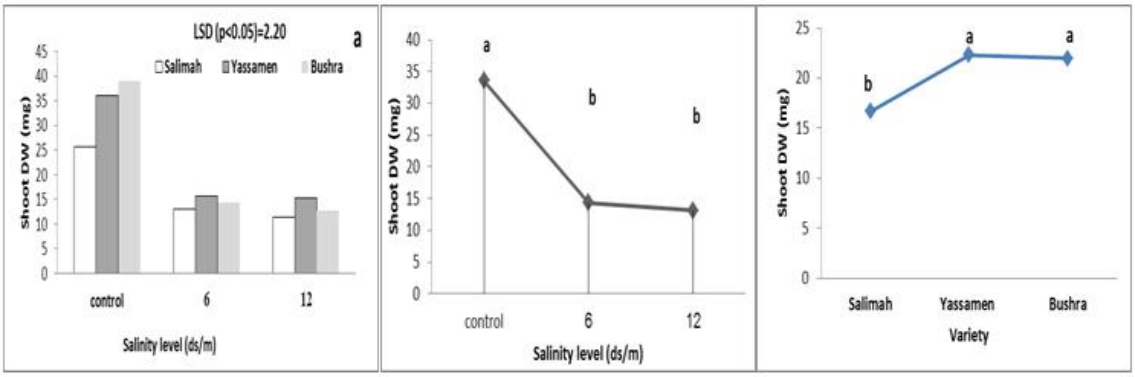

Fig. 7. Effect of salinity at different levels in shoot dry weight (mg) of three varieties of tomato

a: interaction effect of study factors (salinity level and cultivar); b: overall mean of salinity levels; c: overall mean of varieties.

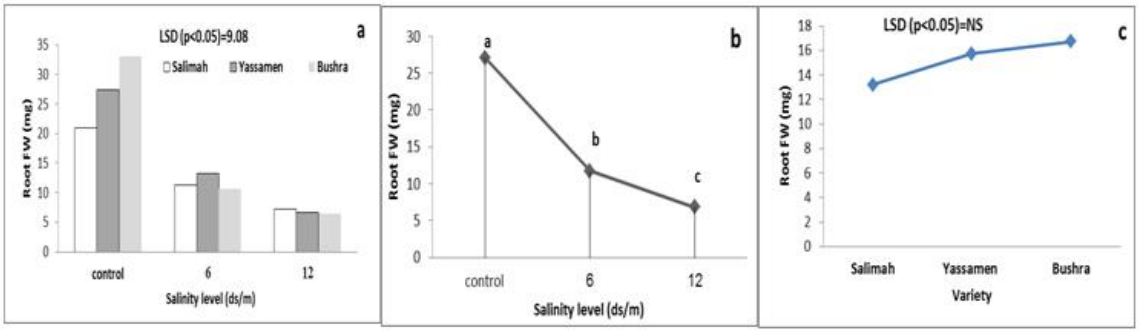

Fig. 8. Effect of salinity at different levels in root fresh weight (mg) of three varieties of tomato

a: interaction effect of study factors (salinity level and cultivar); b: overall mean of salinity levels; c: overall mean of varieties.

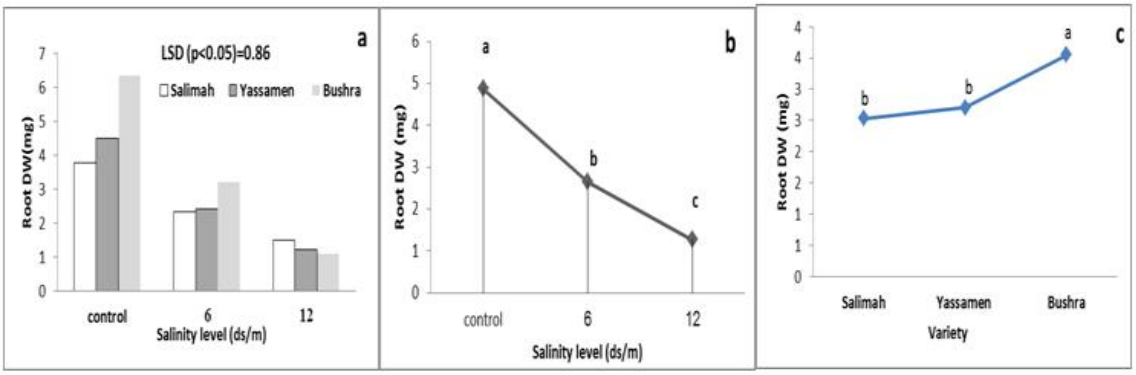

Fig. 9. Effect of salinity at different levels in root dry weight (mg) of three varieties of tomato

a: interaction effect of study factors (salinity level and cultivar); b: overall mean of salinity levels; c: overall mean of varieties.

CONCLUSION

According to the findings of this study, increased salinity can reduce tomato seed germination, and Salimah variety seeds are more sensitive to salinity at the germination stage than Yassemen and Bushra varieties. Increased salinity inhibited all the studied growth parameters of the tomato plant after 45 days of germination. Indeed, we found that the responses of three tomato cultivars to salt stress were similar in terms of growth parameters, with the exception of dry weight for root and shoot. Based on the results, Salinity had a significant effect on photosynthetic pigments other than Chl b. Salinity decreases the content of Chl a and total chlorophyll in the leaves while increasing the content of carotene and anthocyanin. When compared to the other varieties tested, the Salimah variety had the lowest content of photosynthetic pigments. Tomato plants increased proline, free amino acids, and total soluble protein in response to salinity stress biochemically, but there was no consistent pattern of response among varieties. Salinity has a negative effect on oxidative indicators, resulted in an increase in MDA content and a decrease in membrane stability index. Despite the fact that the Yassemen variety accumulated significantly more MDA than the other varieties, the Bushra variety had the lowest membrane stability index. In general, salinity has a negative impact on tomato plants at all stages of their lives; however, among the varieties, the Salimah variety is more sensitive to salinity, and the findings of this study recommend cultivating the Bushra variety in saline-affected areas, particularly in the study region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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