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Germination Response of Released Tomato (*Solanum lycopersicum* L.) Varieties to Salt Stress

[1]*Shamil Alo,* [2]*Derbew Belew and* [3]*Edossa Etissa*

[1]Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia
Teppi Agricultural Research Center, P.O. Box: 34, Teppi, Ethiopia
[3]Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia
Melkassa Agricultural Research Center, P.O. Box: 436, Adama, Ethiopia
[2]Jimma University, College of Agriculture and Veterinary Medicine, P.O. Box: 307, Jimma, Ethiopia

Abstract: Tomato (*Solanum lycopersicum* L.) is one of the most important fruit vegetables that produced in vast areas in the world including Ethiopia. Many crop plants including tomatoes are susceptible to high salinity and it is considered as among the major abiotic factors limiting its production and productivity in Ethiopia. High salt level of irrigation water may induce a reduction and delay of germination and other germination parameters. The present study was conducted to assess germination responses of 14 tomato varieties to six different salinity levels. Evaluation of the varieties for salt tolerance was carried out in laboratory in 2018. Each treatment was replicated three times and arranged in Randomized Complete Block Design in factorial arrangement. Germination percentage, germination index, germination speed and seedling vigor were measured. All the traits showed significant decrease ($P<0.0001$) with increased salt concentration. The result clearly revealed that the highest germination percentage (95%) was recorded from the control treatment for variety ARP, while the lowest germination percentage (11.67%) was recorded from 5 dSm^{-1} for variety Eshet. The higher values of germination indices (107 and 101.8) were recorded in the 1dSm^{-1} for the Awash River and Gelilea varieties respectively and 100% were recorded in the control treatment for most of the varieties, while the highest salinity level (5 dSm^{-1} NaCl) resulted in the lowest germination index (14.3%) for variety Challi. Highest values of seedling vigor index, (1225.5, 1231.17 and 1211.58) were resulted from the control treatment for varieties Gelilea, ARP tomato d-2 and Melka Shola, respectively. In contrast, the highest salinity level (5 dSm^{-1} NaCl) resulted in the lowest seedling vigor index (61.5) for variety Melka Salsa. The result clearly revealed that highest number of speeds of germination (10 and 9.91) was recorded in the 1 dSm^{-1} and control treatments respectively for the variety ARP tomato d-2. On the other hand, highest salinity concentration (5 dSm^{-1}) NaCl resulted in the lowest speed of germination (0.29 and 0.22) for varieties Melka Salsa and Eshet respectively. The findings of the study revealed that, Melka Shola, ARP tomato d-2, Gelilea and Awash River were found to be more salt tolerant as compared to other varieties on the basis of studied traits. Since the present experiment was conducted for one season and under controlled condition, it deserves further evaluation and verification under field condition in salt affected areas and the effect of salinity on tomato quality also deserves further investigation.

Key words: Irrigation water salinity · Tomato germination

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is the major horticultural crop with an estimated global production of 164 million metric tons from 4.73 million ha of land [1]. In Ethiopia, current tomato production is estimated at 277,74.538 tons from 5,235.19 hectare of land for the *Meher* (main season) [2] and it is an important food ingredient in daily diet of people in almost all regions of the country. It is an important cash-generating crop to small-scale farmers and provides employment in the production and processing industries [3].

Corresponding Author: Shamil Alo, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

Despite its importance, still the national average yield of tomato for the *Meher* (Main season) in Ethiopia is 5.31 ton/ha [2], which is quite incomparable with the average yield of other countries such as China, USA, Turkey, India, Egypt, Italy and Spain with average yield of 22.67, 80.61, 35.81, 18.61, 40.00 and 76.35 ton/ha, respectively [4]. A number of constraints are contributing to lower yield and yield components of tomato under farmer's condition in developing countries like Ethiopia including lack of improved varieties that tolerate different stresses. Among them, salinity is the most contributing stress factors [5].

Salt affected soils are becoming one of the main problems in Ethiopia [6]. The arid and semi-arid agro-ecologies, which account for nearly 50% of the country's land areas, are regarded as marginal environments for crop production mainly due to soil and water salinity [7]. Salinity has threatened the productivity of irrigated lands, which is producing more than 40% of the total food requirement of the country [8].

Low levels of annual rainfall and high daily temperatures have led to high water evaporation rates and consequently contributed to high concentrations of soluble salts in these lowland areas [9]. The soil salinity problem in Ethiopia also stems from use of poor-quality water coupled with intensive use of soils for irrigation, poor on-farm water management practices and lack of adequate drainage facilities [10]. Chloride and sulfate salts of sodium and calcium (mainly NaCl and $CaSO_4$) are assumed to be the major soluble salts contributing to the very high salinity level of these soils [11].

High levels of both Na^+ and Cl^- in plants are inhibitory to a number of metabolic and cellular processes [12]. Salt stress in soils causes physiological drought to plants, which result in the reduction of osmotic potential of the plant and excessive toxicity of Na and Cl ions to cells causing the disruption of cell organelles and their metabolism. High uptake of Na and Cl ions also result in nutrient imbalance in plants [13]. Consequently, it affects plant growth and yield. In addition to this, salinity stress causes reactive oxygen species (ROS) to be produced, inducing oxidative stress in crop plants [14].

To overcome the effects of salt stress, plants produce antioxidants and osmo-protectants to bring about tolerance against oxidative stress and osmotic stress, respectively [15]. In line with this, great efforts have been devoted to understand the physiological aspects of tolerance to salinity in plants, as a basis for plant breeders to develop salinity tolerant genotypes [16].

As correcting saline conditions in field and greenhouse would be expensive and temporary, selection and breeding for salt tolerance can be a wise solution to minimize salinity effects and improve production efficiency of crops. It has been suggested that great magnitude of genotypic variability in tomato cultivars (*Solanum lycopersicum* L.) was found for salt tolerance at the germination stage [17]. This shows that breeding for tolerant cultivars of tomato is possible under saline conditions. Most of the export crops such as cotton, sugarcane, citrus, banana and vegetables are being produced in the Rift valley of Ethiopia. However, development of large-scale irrigation projects in the Rift valley area in the absence of proper drainage systems for salinity control has resulted in increasing severity and rapid expansion of soil salinity and sodicity problems leading to complete loss of land for crop cultivation in these areas [7]. Nearly 20 tomato varieties have been released and registered by Ethiopian Agricultural Research System. However, the reaction of these varieties and genotypes to salt stress was not yet been assessed, except that very few varieties have been tested under low salt concentrations at germination and seedling stages (Personal Communication). Moreover, it has been suggested that more research is needed to identify the variety which will perform better at germination stage and give higher yield under high soil salinity condition [5]. Thus, it is essential to screen released tomato varieties under different salinity levels to determine the effect of different salinity levels of irrigation water on seed germination of released tomato varieties and to identify potential sources of salt tolerance for future breeding activities.

MATERIALS AND METHODS

Descriptions of the Study Areas: The study was conducted at Melkassa Agricultural Research Centers in 2018/19 in the laboratory starting from August 2018. Melkassa is located in the Central Rift Valley of Ethiopia at 8°24'N latitude, 39°21'E longitude and at an altitude of 1,550 meter above sea level.

Experimental Materials

Treatments and Experimental Design: The study consisted of six levels of salt concentrations (Awash river water as control (0.15), 1, 2, 3, 4 and 5 dSm^{-1}) and fourteen released tomato varieties (Melka Salsa, Melka Shola, Gelilema, Chali, Cochoro, Eshet, Fetan, Metadel, Bishola,

Table 1: List of released tomato varieties by MARC and Hybrid cultivars used for the study

No.	Variety	Year of Release (E.C.)	Productivity (ton/ha) Research field	Farmer field	Days to Maturity	Responsible/Source Organization/company
1	Melka-salsa	1990	45.0	-	100-110	MARC
2	Melka-shola	1990	43.0	-	100-120	MARC
3	Gelilema	2007	50.0	-	80-92	MARC
4	Chali	1999	43.0	-	80-90	MARC
5	Cochoro	1999	46.3	-	70-80	MARC
6	Eshet	1997	39.4	-	130-140	MARC
7	Fetan	1997	45.4	-	110-120	MARC
8	Metadel	1997	34.5	-	90-140	MARC
9	Bishola	1997	34.0	-	140-150	MARC
10	Miya	1999	47.1	-	75-80	MARC
11	ARP tomato d2	2004	43.5	-	80-90	MARC
12	Galilea	2003	66.6	65.9	70-75	Green Life Plc
13	Awash River	2007	50-75	40-70	75	Mekamba Plc
14	Venis	2007	75	55	75	Markos Plc

Source: MoA (1998-2014)

Miya, ARP tomato d2, Galilea, Awash River and Venis). The total number of treatment combinations was 84 (six different salinity levels in combination with fourteen tomato varieties). Thus, the experiment consisted of a total of 252 experimental units. A Randomized Complete Block Design in factorial arrangement was used and the treatments were replicated three times.

Experimental Procedures: For the laboratory experiment, 11 tomato varieties (Melka Salsa, Melka Shola, Gelilema, Challi, Bishola, Cochoro, Fetan, Eshet, Metadel, ARP tomato-d2 and Miya) were obtained from Melkassa Agricultural Research Center and three hybrid lines (Gelilea, Venis and Awash River) were obtained from different seed companies (Green Life Plc, Markos Plc and Mekamba Plc). The varieties were screened for salt tolerance using six levels of salinity treatments at germination stage on Petri dishes in the laboratory at Melkassa Agricultural Research Center. The electrical conductivity (EC) and total dissolved salts (TDS) of the Awash river water were tested by using the conductivity meter 4310 JENWAY and pocket TDS scan 20 respectively.

Then, the levels of salt solutions were prepared using NaCl salt (pure 99.5% assay) to get the desired electrical conductivity of the solution (treatment) in separate containers. The amount of NaCl salt added per unit of irrigation water was calculated using formula indicating relationship between the electrical conductivity (dSm^{-1}) and TDS (mg/L) of the solutions as TDS (g/L) = 0.64g x EC, where EC is the desired electrical conductivity of solution [18]. Accordingly, 0.64 gram of NaCl was used per a liter of water to get the electrical conductivity of 1 dSm^{-1} and calculated for all treatments following the same formula.

Tomato seeds were sterilized by soaking in a 5% alcohol solution for 5 minutes. After the treatment, the seeds were washed several times with distilled water to remove the alcohol from the seed surface. Petri dishes were also sterilized with alcohol and thoroughly washed before use with clean water. Petri dishes were layered with filter papers (9 cm diameter) and 40 seeds were put in each Petri dish on the filter paper moistened with the respective treatment solutions in three replications. Five ml of saline treatments were added to each Petri dish containing seeds as described in the previous works [17]. The Petri dishes were covered to prevent the loss of moisture by evaporation and put in the laboratory for 14 days. Seeds that produced full radicle were considered as germinated seeds. The initial germination counts were started at 4th day and final germination counts were made at 14th day after treatment application and the result was expressed as percentage.

Data Collection: In the laboratory experiment germination process was recorded using the procedures described by [19, 20]. Three parameters of germination were recorded:

1. Standard germination percentage: Standard germination count was made at 14th day after treatment application and expressed in percentage using the following equation [19, 20].

$$SG = \frac{\text{Number of normal seedlings}}{\text{Number of total seeds sown}} \times 100$$

Germination Index (GI): GI was calculated according to the following equation [21]:

$$GI = \frac{Germination\ Percentage\ in\ eacht\ reatment}{Germination\ Percentage\ in\ control\ treatment} \times 100$$

Seedling Vigor Index (SVI): SVI was calculated according to the following equation as described by [22]:

SVI = [(Root length (cm) + shoot length(cm) x Germination %]

Speed of Germination (SG): Speed of germination was measured by the following formula [19]:

$$SG = \frac{No.\ of\ germinated\ seeds}{Days\ to\ first\ count} + ... + \frac{No.\ of\ germinated\ seeds}{Days\ to\ final\ count}$$

Statistical Analysis: Data was subjected to Analysis of variance (ANOVA) and simple correlation analysis was performed using SAS PROC CORR (SAS Institute, 2008) version 9.0. Treatment means were separated by using Duncan's Multiple Range Test at 5% probability level for all the parameters recorded.

RESULTS AND DISCUSSION

Standard Germination Percentage: The effects of salt concentrations, varieties and their interactions on standard germination percentage showed significant difference ($P<0.0001$). The result revealed that the highest germination percentage (95%) was recorded for the control treatment for variety ARP tomato d-2. On the other hand, the highest salinity level (5 dSm^{-1} NaCl) resulted in the lowest germination percentage (11.67%) for variety Eshet (Table 2). Increasing salinity levels from 1 to 5 dSm^{-1} NaCl significantly reduced the standard germination percentages compared with the control treatment. At the final germination count, the applied moisture (treatment solution) was totally absorbed by the seeds of all varieties in the control plot.

In contrast, the moisture remained unabsorbed in the treatments with the higher salt concentrations, except for few varieties (ARP tomato-d2, Melka Shola and Gelilea) that showed better water uptake and germination percentage. This indicates that, in the higher salt concentrations the seed could not absorb water due to higher osmotic pressure of the solution or the lower water potential of the solution, while there was high water absorption by seeds in the control and lower salt concentrations. Since seed germination is a function of hydrolysis that helps the breakdown of starch to simple sugars and oxidizing of resulting sugar to energy, salt may have effect on hydrolysis (i.e. synthesis of enzyme amylase) and metabolic impairment. The reason why seeds of some varieties absorbed more water and showed higher germination percentage in concentrated salt solution may due to the ability of osmotic adjustment and tolerance to salinity stress. This result was in agreement with the findings of [23, 24] who reported the effect of external salinity on seed germination may be partially osmotic or ion toxicity, which can alter physiological processes such as enzyme activities.

Among the different varieties treated with different NaCl concentration, ARP tomato-d2, Melka Shola and Gelilea gave higher standard germination percentage (Table 2). Varieties Eshet, Challi, Metadel and Melka Salsa, on the other hand, gave lower standard germination percentage. For any seed to germinate there should be uptake of water by the process of imbibition then a general activation of seed metabolism follows. The water imbibition is followed by the diffusion of GA to the cytoplasm that is responsible for the production of amylase enzyme used for the breakdown of starch to simple sugars that facilitate germination. But, under higher salt conditions the process was delayed due to osmotic pressure. This result was in line with the findings of [17] who reported that germination of tomato seeds drastically

Table 2: Standard germination percentage as affected by the interaction of salinity level and variety

	Varieties													
Salt (dSm^{-1})	Bishola	Fetan	Eshet	Challi	Metad-el	Melka Salsa	Melka Shola	ARP	Gelile-ma	Venis-e	Gelil-ea	Awash River	Cocho-ro	Miya
RW (0.15)	65^{n-q}	85^{b-h}	65^{n-q}	86.67^{a-h}	59.17^{qr}	73.33^{i-n}	94.17^{ab}	95^{a}	69.17^{l-p}	90.83^{a-d}	91.67^{a-c}	73.33^{i-n}	85.83^{a-h}	72.50^{i-n}
1	71.67^{j-o}	72.50^{i-n}	19.17^{za-d}	62.50^{o-r}	28.33^{w-y}	35^{vw}	90^{a-e}	90.83^{a-d}	55^{rs}	79.17^{f-k}	93.33a-^{c}	78.33^{g-l}	78.33^{g-l}	70.83^{l-o}
2	50^{st}	66.67^{m-q}	23.33^{yzab}	17.50^{a-d}	25^{x-za}	25^{x-za}	88.33^{a-f}	87.5^{a-g}	39.17^{uv}	75^{i-m}	87.5^{a-g}	71.67^{j-o}	60^{qr}	47.50^{stu}
3	31.67^{v-y}	45^{tu}	16.67^{a-d}	19.17^{za-d}	22.5^{yza-c}	18.33^{a-d}	87.5^{a-g}	84.17^{c-h}	19.17^{za-d}	73.33^{i-n}	80.83^{e-j}	$64.17^{n-q'}$	45.83^{tu}	45^{tu}
4	23.33^{yzab}	33.33^{v-x}	11.67^{d}	15^{a-d}	15.83^{a-d}	13.33^{cd}	80.83^{e-j}	81.67^{d-i}	15.83^{a-d}	72.5^{i-n}	77.5^{h-k}	$61.67^{p-r'}$	40^{uv}	30^{w-y}
5	27.5^{w-z}	31.67^{v-y}	11.67^{d}	12.5^{d}	15.83^{a-d}	10.83^{d}	67.5^{m-q}	78.33^{g-l}	16.67^{a-d}	39.17^{uv}	70^{l-p}	35.83^{vw}	33.33^{v-x}	29.17^{w-y}
CR							9.98							
CV							8.89							

Means with the same letters with columns and rows are not significantly different at 5% probability level, CV = Coefficient of Variation, CR =Critical range, RW= river water used as control

Table 3: Germination index (%) as affected by the interaction of salinity level and variety

	Varieties													
Salt (dSm^{-1})	Bisho-la	Fetan	Eshet	Challi	Metadel	Melka Salsa	Melka Shola	ARP	Gelil-ema	Veni-se	Gelil-ea	Awash River	Coch-oro	Miy-a
RW (0.15)	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}	100^{a-c}
1	96.8^{a-e}	85.2^{d-I}	29.5^{v-zabc}	72.2^{k-m}	48^{p-t}	47.9^{p-t}	95.6^{a-e}	95.5^{a-e}	79.9^{h-k}	87.2^{c-I}	101.8^{ab}	107^{a}	91.6^{b-h}	97.7^{a-d}
2	77.2^{i-l}	78.5^{i-k}	36.8^{s-z}	$20.3^{bcd'}$	42.6^{q-u}	$34.2^{u-zab'}$	93.7^{b-f}	92^{b-h}	56.7^{n-p}	82.6^{f-k}	95.6^{a-e}	97.8^{a-d}	70.3^{k-m}	65.8^{l-n}
3	48.5^{p-t}	53^{o-r}	$25.8^{yza-d'}$	$22^{bcd'}$	37.8^{s-y}	$24.9^{za-d'}$	92.9^{b-f}	88.7^{c-i}	$27.8^{x-zabc'}$	80.9^{g-k}	88.3^{c-i}	87.8^{c-i}	53.7^{o-q}	62.2^{m-o}
4	$36.1^{t-za'}$	39.4^{s-v}	$18.1^{cd'}$	$17.2^{cd'}$	$26.8^{x-zabcd'}$	$18.3^{cd'}$	85.8^{d-i}	86^{d-i}	$22.8^{bcd'}$	79.9^{h-k}	84.8^{e-i}	84.4^{e-j}	46.9^{p-t}	41.3^{r-v}
5	42.4^{q-u}	37.2^{s-y}	$18.4^{cd'}$	$14.3^{d'}$	$26.6^{x-zabcd'}$	$14.9^{d'}$	71.7^{k-m}	82.4^{f-k}	24.2^{za-d}	42.9^{q-u}	76.4^{i-l}	49.3^{p-s}	38.8^{s-x}	40.1^{s-v}
CR							13.41							
CV							9.69							

Means with the same letters with columns and rows are not significantly different at 5% probability level, CV = Coefficient of Variation, CR =Critical range, RW= river water used as control

Table 4: Seedling vigor index as affected by the interaction of salinity level and variety

	Varieties													
Salt (dSm^{-1})	Bisho-la	Fetan	Eshet	Challi	Metadel	Melka Salsa	Melka Shola	ARP	Gelil-ema	Venise	Gelilea	Awash River	Cochoro	Miya
RW (0.15)	751.25^{m-o}	975.5^{e-h}	637.1^{pq}	948.7^{f-i}	547.75^{q-s}	724.3^{n-p}	1211.58^{ab}	1231.17^{a}	792.92^{k-n}	1141.67^{abc}	1225.5^{a}	863.83^{h-m}	1000.75^{efg}	846^{i-m}
1	789.83^{k-n}	769.58^{l-n}	164.92^{za-h}	613.92^{p-r}	247.5^{x-z}	320.83^{u-x}	1074.67^{c-e}	1110.08^{bcd}	573^{qr}	912^{f-j}	1178.17^{abc}	816.83^{j-n}	856^{i-m}	752.58^{m-o}
2	579.83^{qr}	758.42^{l-o}	248^{x-z}	192.92^{yza-g}	229.67^{x-zabc}	248.5^{x-z}	897.5^{g-k}	924.83^{f-j}	462.75^{st}	931.83^{f-i}	1019.42^{def}	841.42^{i-m}	754.5^{m-o}	514.83^{r-t}
3	306.67^{xy}	412.5^{t-v}	120.33^{b-h}	161.25^{za-h}	172.67^{za-h}	117.83^{c-h}	871.58^{h-l}	888.5^{h-k}	166.33^{za-h}	707.92^{n-p}	901.5^{g-k}	551.92^{q-s}	428^{tu}	413.67^{t-v}
4	209.17^{x-za-e}	276^{x-z}	75.42h	108.83^{d-h}	114^{c-h}	82^{f-h}	638.33^{pq}	766.5^{l-o}	126.5^{b-h}	656^{o-q}	814.75^{j-n}	515.58^{r-t}	321.25^{u-x}	243.33^{x-za}
5	195.83^{yza-f}	234.83^{x-zab}	67.67^{h}	77.17^{gh}	101.58^{e-h}	61.5^{h}	418.25^{t-v}	619.17^{p-r}	129.17^{a-h}	314.67^{v-x}	622.17^{p-r}	255.33^{x-z}	248^{x-z}	218.08^{x-za-d}
CR						124.1								
CV						10.71								

Means with the same letters with columns and rows are not significantly different at 5% probability level, CV = Coefficient of Variation, CR =Critical range, RW= river water used as control

reduced with increasing salinity level. The genotypes which are least affected may be potential source of salinity tolerance for tomato breeding [25, 26]. Seed germination is usually the most critical stage in seedling establishment, determining successful crop and seed quality [27].

Germination Index (GI): Significant difference was observed between salinity level, varieties and their interactions ($p<0.0001$) with respect to germination index. The highest germination index was recorded for the control treatment. The highest salinity concentration of 5 dSm^{-1} NaCl resulted in the lowest average germination index (Table 3). Hence, germination index decreased as the salinity level increases from the control to the highest level. This could be probably due to toxic effect of salt ions on seed. This result was in line with the findings of [18] who reported that, an increased germination index is indicative of decreased phytotoxicity and thus of a more mature germinated seed.

The higher values of germination indices (107 and 101.8) were recorded in the 1 dSm^{-1} for the Awash River and Gelilea varieties respectively and 100% were recorded in the control treatment for most of the varieties. In contrast, the highest salinity level (5 dSm^{-1} NaCl) resulted in the lowest germination index (14.3%) for variety Challi. Among the different varieties treated with different NaCl levels, ARP tomato-d2, Melka Shola, Gelilea and Awash River gave highest germination index Varieties Eshet, Challi and Melka Salsa on the other hand, had lower germination index. This indicated that Eshet, Challi and Melka Salsa were the most affected varieties due to the toxic effects of salinity as compared to the other varieties.

Seedling Vigor Index: Significant difference was observed between salinity level, varieties and their interactions ($p<0.0001$) for seedling vigor index. The highest seedling vigor index was recorded in the control treatment, while the highest salinity level (5 dSm^{-1} NaCl) resulted in the lowest value (Table 4). Hence, seedling vigor index decreased as the salinity level increased from the control to the highest. This could be probably due to osmotic and toxic effect of salt ions on seedling growth. This result was in line with the findings of [29], indicating that seedling vigor index decreased with increasing NaCl level. Increased seedling vigor index is an indicative of increased uniformity and good performance of the seedlings. Highest values of seedling vigor index, 1225.5, 1231.17 and 1211.58 were resulted from the control treatment for varieties Gelilea, ARP tomato d-2 and Melka Shola, respectively.

In contrast, the highest salinity level (5 dSm^{-1} NaCl) resulted in the lowest seedling vigor index (61.5) for variety Melka Salsa (Table 4). Similarly, varieties Eshet, Challi, Melka Salsa and Metadel showed lower values of seedling vigor index. This indicated that varieties Eshet, Challi, Melka Salsa and Metadel were the more affected due to higher salinity level as compared to the other varieties [30] also reported that plant vigor is one of the

Table 5: Speed of germination as affected by the interaction of salinity level and variety

	Varieties													
Salt (dSm^{-1})	Bisho-la	Fetan	Eshet	Challi	Metadel	Melka Salsa	Melka Shola	ARP	Gelil-ema	Venise	Gelilea	Awash River	Cochoro	Miya
RW (0.15)	4.56^{i-v}	6.71^{d-j}	4.47^{k-v}	4.84^{h-t}	4.80^{h-t}	5.54^{f-q}	9.64^{ab}	9.91^{a}	5.26^{g-r}	6.38^{e-k}	9.48^{ab}	6.71^{d-j}	7.57^{b-f}	5.6^{f-p}
1	4.49^{i-v}	5.77^{f-o}	$0.66^{b-e'}$	6.74^{d-i}	$2.59^{u-zabcd'}$	$2.62^{u-zabcd}$	8.60^{a-d}	10^{a}	3.35^{q-y}	$2.88^{s-zab'}$	8.53^{a-e}	7.10^{c-g}	6.60^{d-j}	6.56^{d-k}
2	3.46^{q-w}	6.19^{f-m}	$1.03^{za-e'}$	$0.55^{c-e'}$	1.25^{yza-e}	1.25^{yza-e}	6.81^{d-h}	8.53^{a-e}	$2.90^{s-zab'}$	6.68^{d-j}	5.28^{g-r}	6.83^{d-h}	5.49^{f-q}	$2.64^{t-zabcd'}$
3	$1.52^{xyza-e'}$	3.98^{m-v}	$0.46^{c-e'}$	0.85^{za-e}	1.03^{za-e}	$0.57^{c-e'}$	7.62^{b-f}	5.52^{f-q}	$0.75^{a-e'}$	2.71^{t-zabc}	6.09^{f-n}	3.87^{o-w}	3.93^{n-w}	3.65^{o-w}
4	$1.28^{yza-e'}$	$2.40^{w-zabcde'}$	$0.38^{de'}$	$0.58^{c-e'}$	$0.48^{c-e'}$	$0.37^{de'}$	6.59^{d-k}	6.28^{f-l}	$0.42^{c-e'}$	$3.02^{s-za'}$	9.16^{abc}	4.13^{l-v}	$1.93^{xyza-e'}$	$1.31^{yza-e'}$
5	$1.40^{yza-e'}$	$2.10^{w-zabcde'}$	$0.22^{e'}$	$0.68^{b-e'}$	$0.67^{b-e'}$	$0.29^{de'}$	5.045^{g-s}	3.19^{r-z}	$0.61^{c-e'}$	$0.98^{za-e'}$	4.37^{k-v}	$2.06^{w-za-e'}$	$1.57^{xyza-e'}$	$1.28^{yza-e'}$
CR							2.33							
CV							28							

Means with the same letters with columns and rows are not significantly different at 5% probability level, CV = Coefficient of Variation, CR =Critical range, RW= river water used as control

major determinants of salt tolerance in plants. Similar report by [31] also showed that growth vigor is such a mechanism which can avoid the toxic effects of salinity and vigor is an avoidance mechanism rather than tolerance mechanism which works as far as the productivity is concerned.

Speed of Germination: Significant difference was observed between salinity level, varieties and their interactions ($p<0.0001$) with respect to speed of germination. The result clearly revealed that highest number of speeds of germination (10 and 9.91) was recorded in the 1 dSm^{-1} and control treatments respectively for the variety ARP tomato d-2. On the other hand, highest salinity concentration (5 dSm^{-1}) NaCl resulted in the lowest speed of germination (0.29 and 0.22) for varieties Melka Salsa and Eshet respectively (Table 5). The highest salinity concentration of 5 dSm^{-1} NaCl recorded the lowest averages of this trait. This result concluded that, increasing salinity levels from 1 to 5 dSm^{-1} NaCl significantly reduced speed of germination compared with the control treatment. The result also indicated that, salinity highly affected speed of germination of different tomato varieties and lengthened the time needed to complete germination. The speed of germination was reduced, meaning that it took more days to complete the germination under salinity as compared with the control treatment for all of the evaluated tomato varieties. This result is in agreement with the result that reported by [25].

The seedlings that were grown under high salinity level (5 dSm^{-1}) showed lower speed of germination compared to others. Since higher salinity limited water absorption, it prevents the activation and early completion of germination process, as a result, speed of germination declined with increased salinity concentration. This result accords with the results reported by [32, 33] that the stimulation of germination and days required for its completion depend upon Gibbrelic Acid content in seed. A low level of GA in seed in saline medium was unable to break the mechanical resistance of endosperm against imbibitions of water by seed and this leads to the reduction in speed of germination. Since the higher salt concentration limited the water absorption, it slows down the germination speed. Delayed germination causes increased irrigation cost, irregular and weak seedling growth in the establishment of crops [25, 26, 34] also reported that genotypes that germinate earlier at higher salinity concentrations are supposed to be more vigorous and might be used as parents or potential donors in salinity tolerance crop breeding programs.

CONCLUSION AND RECOMMENDATION

Salinity is one of the major abiotic factors limiting production and productivity of tomato in Ethiopia. An experiment was conducted to assess germination responses of tomato varieties to different salinity levels under laboratory condition. Salinity induced in the form of NaCl solution had a pronounced effect on tomato varieties resulting in a considerable decrease in germination percentage, germination speed, germination index and seedling vigor index.

With increase in salt concentration, all the germination parameters were significantly reduced and the reductions were higher at 5 dSm^{-1}. In conclusion, variety Melka Shola and ARP tomato d-2 showed better tolerance as compared to others. Therefore, Melka Shola could be recommended for salt affected areas for farmers and other tomato producers in salinity affected areas for production and should be considered as potential planting material that is useful to breeders of salt tolerant cultivars. However, since the experiment was conducted under laboratory condition at early stage, the effect of salinity on tomato plants at the later growth stages should be done in order to draw sound conclusions and recommendation.

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