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Original Paper

Evaluation of Tomato (*Solanum lycopersicum* L.) Varieties under Different Salt Stress Levels

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***Abstract*— Tomato is a crop of immense economic importance worldwide and salinity is one of the major abiotic factors limiting its production and productivity in Ethiopia. The study was conducted to assess growth, physiological activities and yield responses of two tomato varieties to six different salinity levels. Evaluation of the varieties for salt tolerance was carried out in greenhouse in 2018/19. Each treatment was replicated three times and arranged in Randomized Complete Block Design in factorial arrangement. Most of the traits showed significant decrease (P<0.0001) as salinity level increased from lower to higher concentration. The highest shoot fresh weight (163.13g/plant), shoot dry matter (32.8g/plant) and leaf area (26.93cm2) were recorded for the control treatment and the highest root fresh weight (12.27g/plant), root dry weight (5.53g/plant) and fruit yield (22.71 tone/ha) were recorded at 1dSm-1for variety Melka Shola, while the lowest shoot fresh weight (79.9g/plant), shoot dry matter (22.67g/plant), leaf area(17.63 cm2), root fresh weight (6.12g/plant) and root dry weight (3.8g/plant) were recorded at 5 dSm-1 for variety ARP tomato-d2. The lowest yield (16.73 tone/ha) was recorded at 5 dSm-1 for variety ARP tomato-d2. The highest and the lowest values of photosynthetic rate (0.82 µmolCo2m-2s-1 and (0.47 µmolCo2m-2s-1 respectively) were obtained from the control treatment and the highest salinity level for variety Melka Shola, whereas, corresponding values of (0.84µmolCo2m-2s-1 and 0.56 µmolCo2m-2s-1 were recorded for variety ARP tomato-d2. Results of laboratory analysis showed that, sodium and Na/K significantly increased with increased salinity level. However, potassium, Sulfur and phosphorus showed significant decrease with increasing salinity level. Melka Shola was found to be more salt tolerant as compared to ARP tomato-d2. 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.**

Keywords—Irrigation water salinity, Photosynthetic rate, Tomato yield.

I. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the *Solanaceae* family. It is a crop of immense economic importance worldwide [1]. Global production of tomato was estimated at over 164 million metric tons from 4.73 million ha of land [2]. The current tomato production in Ethiopia is estimated at 277, 74.538 tons from 5,235.19 hectare of land [3]. Its consumption has been linked to reduced risks of cancer especially prostate cancer and reduced occurrence of cardiovascular diseases [4] because it is rich in high amounts of antioxidants [5]. Tomato has high nutritional value and it is the second most important vegetable crop next to Potato [6].

Soil salinization has become a major concern for the past few years in the whole world since it is one of the consequences of climate change with the rise of the ocean's level. When there is not enough precipitation, the water rich in salts rises from the groundwater by capillarity, favoring the accumulation of salts in the upper layer of the soil, where they continually accumulate in the absence of precipitation. These natural events cause what is referred to as primary salinization, which is different from secondary salinization, determined, instead, by human intervention [7]. Due to its deleterious effects on crop growth and yield, salinity stress should have given particular attention [8].

Soil salinization could occur due to in appropriate irrigation methods, in areas with high rates of evapotranspiration, irrigation with saline water and inappropriate drainage conditions [9].

Salts have three effects on plants. First, they play a role in water uptake due to the osmotic effect. Salinity stress (soluble salts) lower the osmotic potential. This causes difficulty in water uptake by roots. In addition to osmotic effect, salinity stress could also result in toxic effect especially NaCl, due to the competition of Na+ with other cations such as Ca+. [10].

High uptake of Na and Cl ions also result in nutrient imbalance in plants [11]. Consequently, it affects plant growth and yield.

The reduced lumen size of xylem vessels of the plants conductive tissues is among the effects of salinity on plants at the morphological level [12]. Salt stress have an impact on lipids that constitute the cell membrane and can therefore compromise its composition and stability [13]. One of the responses of plants at the onset of salt stress is the production of antioxidant molecules, as well as enzymes scavenging ROS [14]. The chemical structure antioxidants allows hydrogen atom transfer mechanism to occur via pure H transfer [15].

Some plant species can be specifically adapted to grow on soils with high salinity conditions [16]. They develop tolerance mechanisms by producing antioxidants and osmo-protectants to bring about tolerance against oxidative stress and osmotic stress, respectively [17]. 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 [13]. Thus, it is essential to screen released tomato varieties under different salinity levels with the following specific objectives: to determine the effect of different salinity levels of irrigation water on growth and yield of released tomato varieties and to identify potential sources of salt tolerance for future breeding activities.

II. Materials And Methods

A. Study Area

The experiment was implemented at Teppi Agricultural Research Center during 2018/2019 main cropping seasons in the Greenhouse starting from August 2018. Teppi is located in South Western part of Ethiopia in SNNP Regional State at an elevation of 1200 meters above sea level and it is situated at 7o 10, 54.5, N Latitude and 35o 25, 04.3-28. 2, E Longitude. The average maximum and minimum monthly temperatures in the greenhouse were 22.5 and 28.6oC, whereas the maximum and minimum relative humidity were 41 and 72.3% respectively, for the experiment season.

B. Varieties

For the Greenhouse experiment, two best varieties (ARP tomato-d2 and Melka Shola) that were selected from the laboratory observation in terms of salt tolerance were used and grown in pots. The experiment consisted of a total number of twelve treatments (six salt levels (tap water as control (0.15dSm-1), 1, 2, 3, 4 and 5dSm-1) and two varieties (ARP tomato d-2 and Melka Shola).

C. Experimental Design and Management

The experiment was laid out in a Randomized Complete Block Design (RCBD) in factorial arrangement with three replications and a total of 360 pots. Ten pots were used per plot and arranged by keeping 30cm and 1m spacing between plants and between rows, respectively. The size of each pot was 30 cm in diameter and 35 cm in height. The plot size was 3m2 (1.5m x 1.6m) and 7.5m x 30m was the total area occupied by the experiment in the greenhouse. The seeds of both varieties were sown on seedling trays and watered using non-saline water for 30 days. Growth media was prepared from forest soil and sand in 3:1 ratio, respectively, filled in pots one month prior to transplanting the seedlings and arranged in the greenhouse. Soil samples were taken from the prepared media. Then, saturated soil paste (soil samples saturated with distilled water) was prepared, the soil water was then extracted and EC and pH of the extract were measured using conductivity meter and pH meter, respectively, before application of the treatments.

After 30 days, seedlings were transplanted to the pots and irrigated uniformly for ten (10) days with non-saline water. Saline solutions were prepared in separate containers to get the desired electrical conductivity and the containers were labeled according to the treatment solution (control, 1,2,3,4 and 5dSm-1). Each container was filled with tap water and the treatment solutions were prepared by adding 0.64, 1.28, 1.92, 2.56 and 3.2 grams of NaCl salt per a liter of water for 1,2,3,4 and 5dSm-1 respectively. Then, application of saline water treatments started after the seedlings were watered with non-saline water for ten days according to the water requirement of the crop and 16% leaching requirement was applied.

Plant tissue analysis was done at Horticoop Ethiopia (Horticulture) PLC Soil and Plant Analysis Laboratory at Debre Zeit after harvesting the crop. The concentration of nutrients (Calcium, Potassium, Sodium, Magnesium, and Phosphorus, Sulfur and Na+ /K+ ratio in the tomato plant tissue) was analyzed after harvest. 1N hydrochloric acid (diluted 83.3ml concentrated HCl to 1L deionized H_2O) and 6N hydrochloric acid (diluted 50ml concentrated HCl to 100ml deionized H_2O) were used as reagents. The following procedures were followed for ashing of plant tissue to determine the concentration of Na, K, Mg, Ca, P and S in the plant tissue and overall processes: 1.25g plant tissue sample was weighted into "high form" porcelain crucible. Sample was placed in to furnace and the temperature were increased gradually until it reached 540^{o}C where samples were ashed for six hours. Samples were then wetted with small amount of deionized water, then 5-10ml of 6N HCL and brought to near dryness on hot plate. Ash was dissolved by adding 10 ml 1N HCl to crucible. Dissolved ash was transferred quantitatively into 100 ml volumetric flasks. Samples were washed down and diluted with deionized water and shake. Finally, aliquot was collected into ICP test tube and the concentration of each nutrient were measured using Mehlich III method.

D. Data Collection and Analysis

1) Growth parameter

The following growth parameters were measured in the greenhouse experiment:

- Number of leaves/plants: Five sample plants were selected per each plot at 36 days after the commencement of treatment application and number of leaves on each plant was counted and the average value was used for analysis.
- Leaf Area: Leaf area was measured using a Photoelectric Leaf Area Measure GDX-500. Nine leaves per plant were taken from different positions on the plant and the area of each leaf was measured at 36 and 65 days after the commencement of treatment application and the average value was used for analysis.

- Plant Height: Five plants were randomly selected from each plot at flowering stage and plant height was measured from the base to the tip of the stem by using pocket meter.
- Shoot fresh and dry weight per plant: After harvesting, all the shoots of five randomly selected plants were collected and fresh weight was recorded immediately. Then after, shoots were chopped into very thin pieces and were put into envelop and placed in an oven at 75 °C until a constant weight was obtained and dry mass was measured in gram by using digital balance and finally the average values were used for analysis.
- Root fresh and dry weight per plant: After harvesting, all the roots of five randomly selected plants were collected and fresh weight was recorded immediately. Then after, roots were chopped into very thin pieces and were put into envelop and placed in an oven at 75 °C until a constant weight was obtained. Root dry mass was measured in gram by using digital balance and finally the average values were used for analysis.
- Root to shoot ratio: Root to shoot ratio was calculated from the dry matter yield of shoots and roots.

2) Physiological data

Photosynthetic Rate: Photosynthetic rate was measured using Chlorophyll Fluorometer at flowering stage. Five green and fully expanded leaves were selected per plot and photosynthetic rate was measured during 10 AM to 5 AM time of the day.

3) Tomato fruit yield data

Fruit yield (ton/ha): Fruit yield was recorded on plant basis and then converted in to ha. 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 in both laboratory and Green house experiments.

III. Results And Discussion

A. Leaf Number

No significant difference was observed between salinity levels ($P<0.2313$), nor between varieties ($P<0.9085$) and their interaction ($P<0.8503$) for leaf number per plant. In general, leaf number decreased with increasing salinity level. The reason for lower number of leaves at higher salinity could be restriction in the movement of water from root to shoot, resulting in reduction in leaf growth.

B. Leaf Area

Both salinity level and variety and their interaction ($p<0.0001$) significantly affected leaf area of tomato plants. The highest leaf area (26.93 cm2), was recorded for the control treatment with variety Melka Shola, whereas the lowest value (17.63 cm2) was recorded at 5dSm-1for the variety ARP tomato d-2. Variety Melka Shola showed higher leaf area values as compared to ARP for all the salinity treatments (Fig. 1).

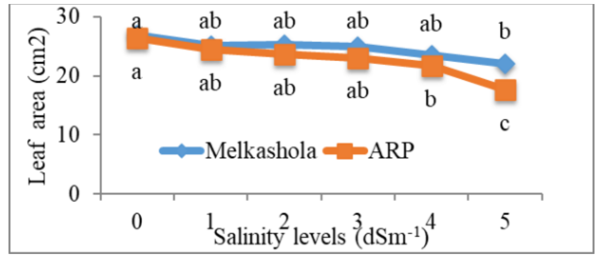

Fig. 1. Leaf area of tomato as affected by the interaction of salinity level and variety

C. Plant height

Plant height was significantly affected by main factors (salinity level and variety) and their interaction ($P<0.0001$). The tallest (127cm) and the shortest (93.33cm) tomato varieties were observed in the control treatment and at highest salinity levels, respectively, for variety Melka Shola, whereas, the corresponding values 151.11cm and 98.89cm were for variety ARP tomato d-2 (Fig. 2).

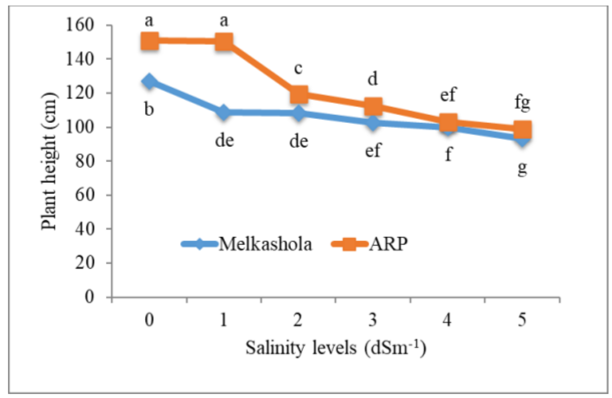

Fig. 2. Plant height of tomato as affected by the interaction of salinity and variety

D. Shoot fresh weight per plant

Significant difference was observed between salinity level, varieties and their interactions ($p<0.0001$) for shoot fresh weight. The highest shoot fresh weight was recorded for the control treatment and 1dSm-1 (163.13g/plant) and 162.33g/plant) respectively, for variety Melka Shola and at 1dSm-1 and 2dSm-1 with respective values of (153.07 g/plant and 159.67g/plant) for variety ARP tomato d-2 (Fig 3). The highest salinity concentration of 5dSm-1NaCl resulted in the lowest average shoot fresh weight (79.9g/plant) of variety ARP.

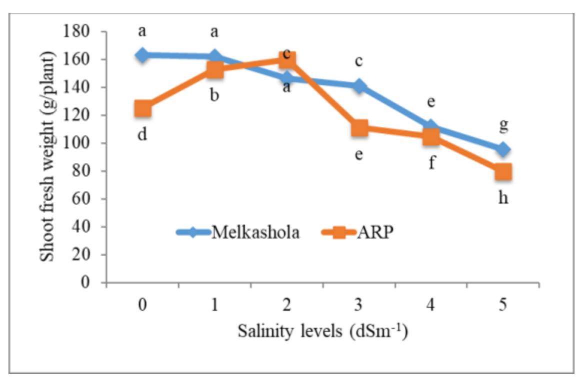

Fig. 3. Shoot fresh weight of tomato as affected by the interaction of salinity level and variety

E. *Shoot dry weight per plant*

Significant difference was observed due to the main factors (salinity level and variety) and their interaction (p<0.0001) for shoot dry matter yield. The highest average shoot dry matter yield (32.8 g/plant) was recorded for the control treatment with variety Melka Shola, whereas the lowest value (22.67 g/plant) was recorded for 5dSm-1 with variety ARP tomato d-2 (Fig. 4).

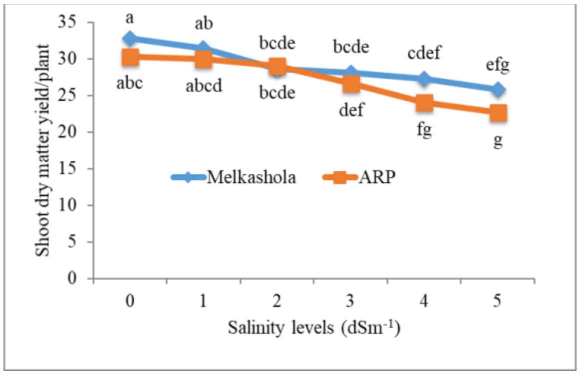

Fig. 4. Shoot dry matter of tomato as affected by the interaction of salinity level and variety

F. *Root fresh weight*

Significant difference was observed due to the main factors (salinity level and variety) and their interaction (p<0.0001) for root fresh weight. The highest average root fresh weight (12.27g/plant), was recorded for 1dSm-1with variety Melka Shola, whereas the lowest value (6.12g/plant) was recorded at 5dSm-1for variety ARP tomato d-2 (Fig. 5).

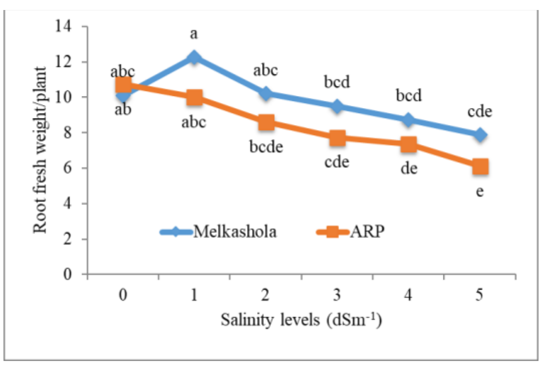

Fig. 5. Root fresh weight of tomato as affected by the interaction of salinity level and variety

G. *Root dry weight*

Significant difference was observed between salinity levels, varieties and their interaction (P<0.0001) for root dry weight. The highest average root dry weight (5.53 g/plant), was recorded at 1dSm-1for the variety Melka Shola, whereas the lowest root fresh weight (3.8 g/plant) was recorded at 5dSm-1 for variety ARP tomato d-2 (Fig. 6). Both varieties showed decreasing root dry matter along with increasing salinity concentrations. However, variety Melka Shola had better dry matter accumulation under higher salinity stress as compared to ARP tomato d-2.

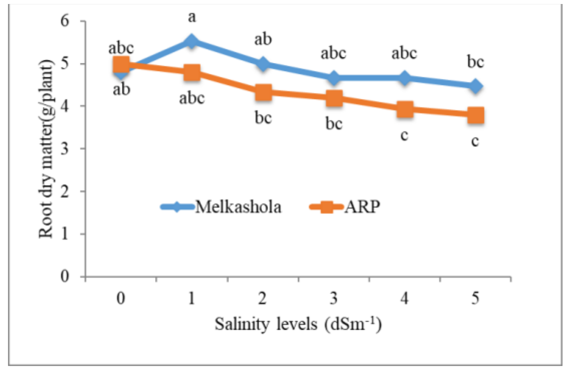

Fig. 6. Root dry weight of tomato as affected by the interaction of salinity level and variety

H. *Root to Shoot Ratio*

Root to shoot ratio was not affected by salinity (P<0.8032), variety (P<0.3049) and their interaction (P<0.5482). However, lower root to shoot ratio was recorded for the lowest salt concentration. It was observed that, root to shoot ratio increased with increasing salt concentrations, indicating that, tomato root was less affected by the salinity stress than did the shoot part, although there was no significant difference between the treatments (Table 1).

I. *Photosynthetic rate*

The effect of salinity levels, varieties and their interaction showed significant difference (P<0.0001) for the rate of photosynthesis. The highest and the lowest photosynthetic rates (0.82 µmolm-2s-1 and 0.47 µmolm-2s-1) of tomato leaves were recorded for the control treatment and highest salinity level respectively for variety Melka Shola, whereas the respective values of 0.84 µmolm-2s-1 and 0.56 µmolm-2s-1 were for variety ARP tomato d-2 (Fig. 7). It was observed that increasing salinity level from 1 to 5dSm-1NaCl significantly reduced photosynthetic rate of tomato compared with the control treatment for both varieties. Unlike for the other parameters, variety ARP exhibited higher photosynthetic rate as compared to Melka Shola.

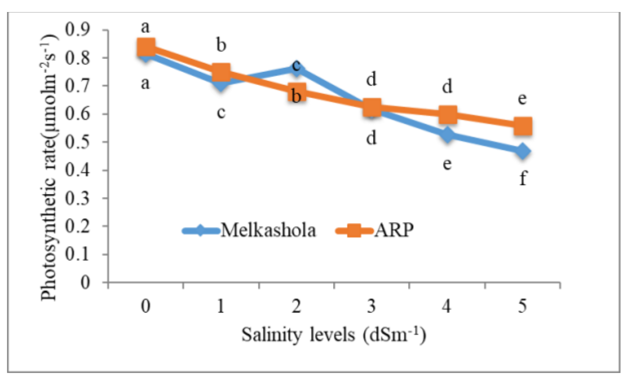

Fig. 7. Photosynthetic rate of tomato as affected by the interaction of salinity level and variety

J. *Fruit yield*

Difference between salinity level, variety and their interaction were significant (P<0.0001) for tomato yield. Highest yields of 214.8, 227.1 and 215.9 q/ha) were recorded for the control and at 1 and 2dSm-1 for variety Melka Shola with the corresponding yields of 213.4, 217.8 and 196.5 for variety ARP tomato d-2, respectively. The minimum yield (167.3 q/ha) was recorded at 5dSm-1 NaCl level for variety ARP tomato d-2 (Fig. 8). In general, it was observed that increased concentrations of NaCl significantly reduced tomato yield compared with the lower salt levels. The result indicated that the highest salinity concentration of NaCl highly affected yield of tomato for both varieties. However, variety Melka Shola showed better relative tolerance as compared to ARP tomato d-2.

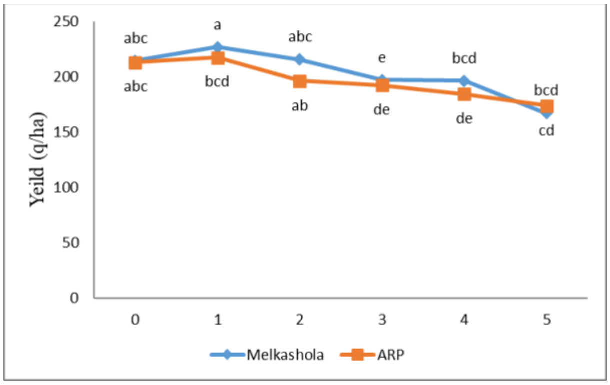

Fig. 8. Yield of tomato as affected by the interaction of salinity level and variety

K. Effect of salinity levels on concentrations of plant nutrients

Significant difference was observed for the interaction of variety with salinity level for (P<0.0001) for Na+/K+ ratio, Potassium, sodium and sulfur concentrations in tomato plant tissue. However, there was no significant difference between the treatments for Ca (P<0.4381), Mg (P<0.7475) and P (P<0.9225) concentrations. This indicates that Ca, Mg and phosphorus were not affected by NaCl concentrations. This could be probably due to the reason that these nutrients were sufficiently up taken by the varieties without being replaced by Na+. Though there was no significant difference for these nutrients, they showed a decreasing trend as salinity level increased.

The concentration K^+ in tomato plant tissue showed significant decrease at 5dSm-1 salinity level for variety ARP. In contrast, K concentration was not significantly affected by increasing salt level for variety Melka Shola (Fig. 9). However, the decreasing trend in concentration of potassium (K) at higher salinity level was observed for both varieties.

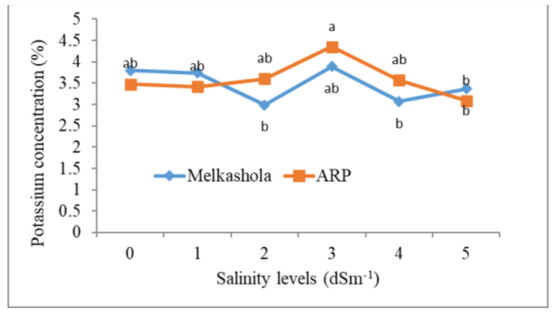

Fig. 9. Potassium concentration as affected by the interaction of salinity level and variety

TABLE I. THE MAIN EFFECTS OF SALINITY AND VARIETY ON PLANT TISSUE CONCENTRATION OF CALCIUM, MAGNESIUM AND PHOSPHORUS ON LEAF NUMBER AND ROOT TO SHOOT RATIO OF TOMATO

Salt level (dSm-1)	Leaf number per plant	Root to shoot ratio	Calcium	Magnesium	Phosphorus
Control	10.17	0.16	3.30	0.77	0.20
1	11.23	0.17	3.43	0.79	0.17
2	10.34	0.16	3.36	0.83	0.17
3	9.87	0.16	3.43	0.77	0.20
4	9.57	0.17	3.48	0.75	0.17
5	9.47	0.17	3.69	0.81	0.18
Mean	10.10	0.16	3.44	0.78	0.18
CV	12.76	11.22	11.20	10.29	19.80
CR	NS	NS	NS	NS	NS
Variety					
Melka Shola	10.13	0.17	3.58a	0.79	0.19
ARP tomato	10.08	0.16	3.31b	0.78	0.17
Mean	10.10	0.16	3.44	0.78	0.18
CV	12.65	10.80	10.87	9.95	18.80
CR	NS	NS	0.25	NS	NS

CV= Co efficient of variation, CR =Critical range, NS =Non-significant

Increasing irrigation water salinity level resulted in a significant increase of Na concentration of tomato plant tissue and the increase reached the highest (0.56%) value at 5 dSm^{-1} compared with the control (0.16%) specifically for variety ARP (Fig. 10). In the present study, both tomato varieties showed an increase in Na^+ while decreased tissue K^+ contents. However, variety Melka Shola exhibited the minimum concentration of Na^+. On the other hand, ARP tomato-2 showed elevated Na^+ contents as compared to Melka Shola.

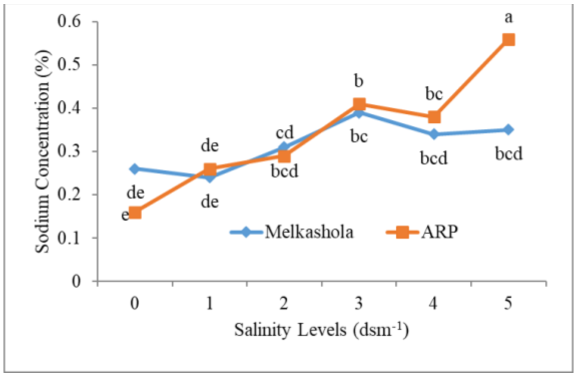

Fig. 10. Sodium concentrations as affected by the interaction of salinity level and variety

Maximum reduction of sulfur content in tomato plant tissue was noted at 5 dSm-1 salinity level. On the other hand, maximum values were recorded for the lower salinity level as shown in (Fig. 11). The results showed that salinity had significant effect on concentration of sulfur in the tomato plant tissue. Increased salinity concentrations significantly affected the uptake of K, S and Na/K ratio.

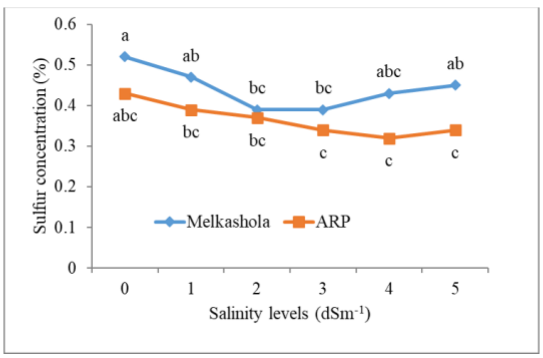

Fig. 11. Sulfur concentrations as affected by the interaction of salinity level and variety

The highest average Na^+/K^+ ratio in tomato plant tissue was recorded for the highest salt concentration of variety ARP tomato d-2. The control treatment exhibited the lowest average Na^+/K^+ ratio in tomato plant tissue. It was observed that increasing salinity level significantly increased Na^+/K^+ ratio in the plant tissue as compared with the control treatment (Figure 12). Hence, the highest Na^+/K^+ ratio (0.184) was recorded for 5dSm -1 while the lowest value (0.047) was for the control treatment.

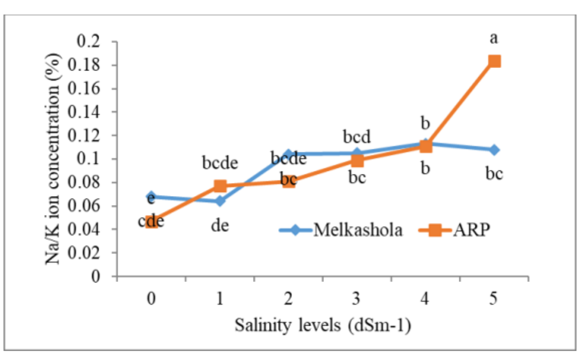

Fig. 12. Sodium/Potassium ratio concentrations as affected by the interaction of salinity level and variety

From the experiment, different visual symptoms such as wilting, yellowing of leaves, chlorosis of green parts, leaf tip burning, and necrosis of leaves, and scorching of the oldest leaves were observed after being treated with the salinized irrigation water and the symptoms were higher at higher salinity concentrations as compared to the control. Similar result has been reported by [18], indicating that salinity stress leads to an ion imbalance causing necrosis and premature death of older leaves. The reason in leaf area reduction under salinity stress could be as a result of physiological dryness and due to other growth parameters related to photosynthetic products. In line with this, [19] reported that the reduction in tomato leaf area under salt stress could be probably due to the reduction of growth parameters contributing to photosynthetic products. [20] Reported that reduction in the rate of leaf surface expansion followed by a cessation of expansion as the stress intensifies is among the earliest response to salt stress.

In the present study, plant height showed significant reduction for all varieties. [21] Reported similar result indicating that tomato plant height was highly reduced with increasing NaCl concentration. Shoot fresh weight significantly decreased as the salinity level increased from the control to the highest. This is due to the exosmosis of water and plasmolysis of plant cells as a result of hypertonic solution of the treatments. In addition to this, plants under take stomatal closer under high salt concentration due to water stress to safeguard the loss of water through transpiration. This may result in the reduction of photosynthetic rate and assimilate production. In another way, high salt concentration may result in the lower hydrolysis of enzymes responsible for different metabolic activities of the plant.

The result also indicated that tomato varieties responded differently to different salt levels, where variety Melka Shola had higher shoot fresh weight as compared to ARP tomato d-2. This could be probably due to the better potential of Melka Shola to selective ion accumulation or exclusion and ion compartmentalization. Similarly, [22] reported that the adverse effects of salt stress on plant growth are mainly due to its toxic and osmotic effects. [23], [24] and [25], reported that shoot was affected drastically in plants grown under salt stress than in control environment. The decrease in shoot fresh weight with increase in salt concentration was in line with the results reported by [26] and [27] indicating that salt stress brings about osmotic stress and subsequently ionic toxicity and oxidative stress. Salt stress causes osmosis stress by limiting the availability of water to plants. As a result, it leads to loss in turgor pressure of the plant due to decreased water potential that result in wilting that affect plant morphology and biomass production. [21] reported similar result in that tomato plant shoot fresh weight was highly reduced with increasing NaCl concentration. The similar results reported by [28] who showed that salinity reduced fresh and dry weight of plants. The lower dry and fresh biomass at increased salinity level mainly be due to poor absorption of water from the growth medium due to osmotic effect salinity or physiological drought [29].

The reduction in shoot dry matter yield under higher salinity level could probably be due to physiological dryness of the plants as a result of exosmosis and decline in plant water potential. The reduction in shoot dry matter with increasing salinity levels could also be due to reduced number of branches and leaves, leaf size and stem diameter of tomato plants. It was observed that, variety Melka Shola was better than ARP tomato-d2 in salt tolerance in terms of shoot dry matter production and, thus, salinity threshold level. [13] found that shoot fresh and dry weight decreased as salinity level increases from control to the highest concentration.

The restriction in root growth may affect the whole processes when the plant grows under stress condition. [30] Reported that root is very important in hormonal regulation of source–sink relations during the osmotic phase of salinity stress in tomato. They also reported that root senses the effect of soil salinity and influences root-to-shoot signaling to control shoot growth and physiology via hormonal signals, such as cytokines, ABA and auxin IAA, thus coordinating assimilate production and usage in competing sinks. [31] Found that salt stress leads to changes in growth, morphology and physiology of the roots that will, in turn, change water and ion uptake and the production of signals (hormones) that can transfer information to the shoot, affecting the whole plant when the roots are growing in a salty medium.

The reduction in root dry and fresh weights under higher salinity levels could be probably due to the adverse effects of salinity on tomato root development like root length, number and diameter as result of exosmosis and lower water potential in the roots. [13] found that root fresh and dry weight decreased as salinity level increases from control to the highest. Furthermore, they reported that tomato plant root was more affected as compared to the shoot part. However, less reduction in root growth as compared to the shoot part in the present study mainly be due to higher salt concentration which reduces water potential of the plant which results in the preferential allocation of biomass to roots.

Root to shoot ratio increased with increasing salt concentrations, indicating that, tomato root was less affected by the salinity stress than did the shoot part. This is due to the preferential allocation of assimilates to root due to osmotic stress. This result was in line with the findings of [24] who reported the root growth in tomato appears to be less affected, whereas, shoot was affected drastically, so that, the dry weight ratio was higher in plant grown under salt stress than in control environment. According to [32] and [23], the root/shoot dry weight ratio in tomato increased under higher salt concentration. This could be due to changes in allocation of assimilates between root and shoot. In such cases the greater proportion of assimilates allocated for root as compared with shoot. [33] reported that, root dry weight is positively correlated but, shoot dry weight is negatively correlated to salinity. In contrast, [34] reported that the phenomenon of photosynthesis proceeds normally in salt tolerant genotypes. Because such genotypes transport very small amount of toxic ions (Na^+) to the upper areas like leaf, they store them in their roots. That is an adaptation mechanisms of tolerant plant species to withstand the adverse conditions that sensitive species substantially lack.

The increasing salinity concentration causes the decrease in photosynthetic rate due to stomatal closure of the plant in response to salt stress and due to its effects on leaf gas exchange, particularly CO2. This result was in agreement with the findings of [13], who reported that stomatal conductance determines photosynthetic rate, which plays important role in growth and development of any plant, and increasing salinity level decreased stomatal conductance and the reduction was greater at the highest level. Such reduction of stomatal conductance under salt stress conditions may result in lower photosynthetic rate that, in turn, leads to lower total yield of the crop. In line with this [35] reported that irrigation water with excessive salinity has negative effects on the chlorophyll content of tomato, which directly influence photosynthetic rate of the plant. Photosynthetic rate was positively significantly ($p<0.001$) correlated with shoot fresh weight, shoot dry matter, plant height, and leaf area. However, it was negatively highly correlated to Na ion concentration in plant tissue.

Salt stress also negatively affects the physiological and biochemical processes going on in tomato [36] and [37]. Reduced plant water contents or water potential due to salt stress lead to stomatal closure to safeguard further loss of water by transpiration [38]. In addition to reduced transpiration due to stomatal closure, net photosynthesis also reduced under salt stress by the production of ROS and decrease in chlorophyll contents and rubisco activity [39] and [40]. ROS decrease net photosynthesis, chlorophyll content and rubisco activity by increasing the osmotic stress causing, oxidative damage due to lack of dissipation of excessive excitation of energy resulting in loss of chlorophyll leading to decreased rubisco activity that finally cause reduction in photosynthesis. Physiological efficiency of tomato is also adversely affected by saline conditions, as salinity affects photosynthesis by decreasing CO2 availability because of diffusion limitations [41] and a reduction in the contents of photosynthetic pigments [42].

At the salinity level of 5dSm-1 yield of tomato varieties decreased by almost 50% as compared to the control treatments. This could be probably attributed to reduced fruit number, fruit size and reduced dry matter accumulation in the fruits, which have direct contribution to lower fruit yields. This result was in agreement with the report of [43] that 50% tomato yield loss was occurred at moderate salinity level (5dSm−1). Due to the harmful impact of salt stress on the tomato growth, lowering of plant water potential, disturbance in mineral uptake and enhancement of plant respiration; result in the reduction of tomato yield. This result was in line with the findings of [33] who reported that fruit yield and increasing salinity have strong negative correlations. [44] and [45] reported that tomato yield was negatively affected by increasing salinity levels, as increasing irrigation water salinity levels resulted in a significant reduction in fruit yield.

Furthermore, it has been reported that high saline soil decreased the number of fruits/plants [46]. [47] Found that, NaCl stress resulted in decreased rate of fruit growth. The reduction of stomatal conductance under salt stress conditions may result in lower photosynthetic rate that, in turn, leads to lower total yield of the crop and the effects of reactive oxygen species under higher salinity may also the reason for reduced yield. In line with this [35] reported that irrigation water with excessive salinity has negative effects on the chlorophyll content of tomato, which directly influence photosynthetic rate of the plant.

High salt concentration in the irrigation water affect the physiological and biochemical process in tomato such as enzymatic activities, reduced water potential and oxidative damage due to increased ROS. In line with this, [36-38] reported that salt stress also down regulates the physiological and biochemical processes going on in tomato and reduced plant water contents or water potential due to salt stress lead to stomatal closure to safeguard further loss of water by transpiration. [39] and [40] reported that in addition to reduced transpiration due to stomatal closure, net photosynthesis reduced under salt stress by the production of ROS and decrease in chlorophyll contents and rubisco activity. ROS decrease net photosynthesis, chlorophyll content and rubisco activity by increasing the osmotic stress causing, oxidative damage due to lack of dissipation of excessive excitation of energy resulting in loss of chlorophyll leading to decreased rubisco activity that finally cause reduction in photosynthesis.

[49] Reported that both vegetative and fruit growth of tomato decrease markedly under saline conditions. That may be due to changes in a range of metabolic processes caused by salt stress. Protein contents and activities of ascorbate peroxidase and catalase decreased under saline conditions [32] and it also causes an ionic imbalance and osmotic shock to tomato plants [43]. The accumulation of Na^+ ions and changes in leaf hormone relations contribute to leaf senescence. This in turn results in limiting tomato productivity under saline conditions [50]. [41]. Reported that saline conditions adversely affected physiological efficiency of tomato due to effects of salinity on photosynthesis by decreasing CO2 availability because of diffusion limitations. Similarly, [51], reported that physiological efficiency of tomato is adversely affected by saline conditions. For example, leaf water and osmotic potentials decreased in tomato plants while endogenous ABA concentrations increased under saline conditions. Simple correlation coefficients revealed that tomato yield exhibited significant positive correlation with growth characters such as leaf number, root fresh weight, shoot dry matter, root dry matter, photosynthetic rate and shoot fresh weight ($P<0.0226$, $P<0.0070$, $P<0.0023$, $P<0.0278$, $P<0.0024$, $P<0.0022$), respectively). The positive and significant correlation coefficients (r- values) between yield and growth parameters indicate that yield was greatly influenced by these growth parameters under salt stress conditions. However, yield was negatively highly associated with Na ion, indicating that tomato yield significantly decreased with increasing salinity stress. Most of the growth parameters were positively correlated to each other. Root to shoot ratio was negatively correlated with most of the studied traits. However, leaf number, root fresh weight and root dry matter were showed positive correlation.

Disorder in translocation and distribution of minerals specially K^+ could be probably the reason for the decreased uptake of K^+ at the highest salinity level due to substitution of K with Na at its usual binding sites. The difference between varieties for K concentration imply, difference in osmotic adjustment and thus, can be used as selection criteria for salt stress tolerance. In line with this, [52], has reported that increase in K^+ concentration in nutrient solution could ameliorate negative effects of salt condition and potassium can alleviate the negative effects of NaCl on vegetative growth and yield. [53] Reported that the phenomenon of photosynthesis proceeds normally in salt tolerant genotypes. Because such genotypes transport very small amount of toxic ions (Na^+) to the upper areas like leaf, they store them in their roots. That is an adaptation mechanisms of tolerant plant species to withstand the adverse conditions that sensitive species substantially lack. In addition to this, [51] found similar observations in tomato. The correlation analysis showed that, K^+ indicated significant negative association with Na^+. This result was in agreement with the findings of [54] who reported that increased concentration of sodium affects the entry of K^+ ions. [53] Reported that sodium concentration increases in plants under salt stress and suppresses the potassium concentration.

The difference between the varieties for sodium and potassium content may be due to their genetic difference in ion uptake for osmotic adjustment. In line with this, [57] and [58] reported that salt tolerance is genetically controlled and the ability of plants to overcome the effects of salt depends on selective ion accumulation or exclusion or osmotic adjustment. [34] Stated that salt tolerant genotypes transport very small amount of toxic ions (Na^+) to the upper areas like leaf. Variety Melka Shola exhibited such potential and better accumulation of K as compared to the variety ARP tomato-d2. [34] Reported that sodium concentration increases in plants under salt stress and suppresses the concentration of potassium. [54] Reported that, at cellular level salinity brings about ionic toxicity by elevated Na^+ and Cl- levels. According to results of [55] increased Na^+ level was found in plants grown under higher salinity concentration. This indicates that Na^+ affected the proper uptake of S and P nutrients. This result was in agreement with that of [56] who reported that salinity has an antagonistic impact on the uptake of nutrients. In addition, [55] illustrated that Na and K suppressed or reduced the uptake and transportation of Ca and Mg cations under salt stress conditions. In the present study, it was observed that sulfur had significant negative association with Na^+. Better nutrient uptake under saline condition may help the plant to counteract the nutrient imbalance occurring under saline environment. This finding was in line with the result of [25], who reported that the lower value of Na^+/K^+ ratio, indicated more uptake of K^+ from soil/medium by plants and such types of plants are similar to non-salinized plant, i.e. salt tolerant.

IV. Conclusions

The comparison within varieties indicated that Melka Shola was tolerant as compared to ARP tomato-d2. It can be concluded that the main effects of salt on tomato varieties were due to the osmotic effect, ion toxicity (specifically Na^+) and nutrient imbalance due to increased uptake of Na^+ that resulted in reduction of Sulfur and Phosphorus uptake by plants. Potassium also indicated significant reduction with the increased salinity level. However, both varieties showed sufficient K^+ uptake under salinity stress. Variety Melka Shola showed better tolerance as compared to ARP tomato d-2. 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 for one year and under controlled conditions, on farm verification of the varieties in salt affected areas should be done in order to draw sound conclusions and recommendation and the effect of salinity on tomato quality also deserves further study.

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