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Alleviation methods to combat toxic impact of saline water irrigation for growing tomato (*Solanum lycopersicum*)

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Abstract

An appropriate experimental site was selected for the collection of soil after laboratory analysis. This experiment, comprised of 3 variable factors to be tested; first test factor was saline water of different qualities having EC (electrical conductivity) of 1, 2 and 3 dSm^{-1} {Water (W1), Water (W2) and Water (W3)}, which were applied at different rates {(Normal irrigation level (IL1) and 10% lesser irrigation level (IL2)} in order to save water as well as salt addition occurring from saline water. The third test factor was mulching (plastic or crop residues, M2 and M3 respectively) against no mulching (M1). The objective was to reduce evaporation resulting in lesser crop water requirements and decreased salt accumulation through decreased irrigation. All treatments were replicated thrice with completely randomized design (CRD) of statistics growing tomato crop. Saline waters of varying levels were prepared artificially and applied according to treatment proposal. Mulching was also applied to different pots according to treatment plan. Uniform dose of NPK fertilizers were used to meet nutrient requirements of plants. There was complete maintenance and protection of tomatoes from diseases and insects by appropriate measures. Irrigation with saline water started after two weeks of tomato transplanting to ensure the establishment of plants. At tomato maturity, plant sampling was taken from all pots for laboratory determinations. All the data were processed statistically using appropriate procedures. Data indicated that maximum plant height, fresh weight/yield, dry weight mass, plant diameter, number of tomato fruits/plant as well as highest amounts of N, P and K in tomato plants were noted when water having EC less than 1.0 dSm^{-1} was used at normal rate and coupled with crop residues mulching. Through these techniques farmers can grow vegetables, especially tomato using poor quality water without any salt hazards.

Keywords: Crop residue mulching, Irrigation, Plastic mulching, Saline water, Tomato

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Introduction

Usage of saline water irrigation is one of major limitation of crop growth in Pakistan. Addition of saline water is affecting normal crop physiology and imposes negative impact on soil water and plant relationships in the soil (Plaut et al., 2013; Iqbal & Qureshi, 2021)). Usage of salty irrigation water causes accumulation of high salts in roots area of growing plant (Kim et al., 2016). Hence, it causes reduction in crop yield and also impairs soil properties (Zaman & Qureshi, 2018; Murtaza et al., 2020). According to latest census, Pakistan is 5th biggest country of the world with population of about 235.8 million people. Through a rise in the existing ratio, the population index of the nation could surpass 403 million by 2050. Water supply is expected to considerably exceed demand due to population growth, which will further improve wastewater production and release into the environment (Natasha et al., 2020).

Water has a major key role for sustaining life, yet it faces both quantitative drawbacks and qualitative liability (Akram & Iqbal, 2019). By 2050, global water use is projected to rise by up to 55%, driven primarily by increased demands from domestic use, thermal electricity generation, and manufacturing (Connor, 2015). The greatest threat to all living things, particularly plants, is a lack of water. There has been 17% decline in the amount of water available to agriculture, which will significantly lower crop production. In order for plants to develop and stay alive, they need between 70-80 % of water for different important biochemical, photochemical, and physiological processes (Jiménez, 2006). Water is required for the enhancement of soil physicochemical properties, including soil porosity, aeration, texture, and structure, which are all important for the long-term production of agricultural crops (Zhang et al., 2019). Therefore, sufficient supply of water in the soil is essential for the efficient uptake of vital nutrients for optimal plant growth (Silva et al., 2016). It has also been projected that by the middle of the twenty-first century, the world's water consumption will rise by up to 55% (Chaoua et al., 2019).

Tomato is an herbaceous annual plant classified within the family Solanaceae, cultivated primarily for its consumable fruit (Liberato**,** 2018). The fruit of tomato is consumed in its raw form, including as pulp, in salads, and as juice. Additionally, it is utilized in various cooked preparations, such as soups, sauces, and ketchup (Rowles et al., 2018; Shah et al., 2019). The utilization of highly nutritional tomatoes offers several health benefits, including protection against many diseases such as cancer. As an important nutrient-rich crop, the global use and demand for tomatoes are raising (Parvin et al., 2015). Tomatoes are grown on 4.8 million hectares worldwide, with a total comprehensive output of 145.15 trillion kilograms (Khapte et al., 2019). Asia leads global tomato output with a 53.8% share, followed by America (17.9%), Europe (16%), Africa (11.9%), and Oceania (0.4%). Top ten tomato-producing countries are India, Egypt, Italy, Brazil, USA, Turkey, Spain, China, Iran, and Mexico (Sandoval-Ceballos et al., 2021). Despite being a brief-season crop, the average yield of tomatoes is insufficient to meet consumer requirement due to extreme water shortage experienced during growth (Chand et al., 2021). Due to importance of water, current research has been planned to evaluate impact of brackish water irrigation on development, produce and nutrients status of tomatoes growing from normal soil.

Materials and Methods

During winter season of 2024, current research activities were conducted within the vicinity of study zone of University of Sargodha, Pakistan. Field soil was collected from a representative area after prior analysis to assess its suitability for the experiment. The collected soil was sieved using 2 mm sieve for getting unchanging particle size. The sieved soil was then air-dried for 24 hours. The air-dried and sieved soil was utilized for analyzing many physico-chemical parameters comprising EC (1.92 dSm^{-1}), pH (8.20), content of organic matter (0.77%), available phosphorus (7.9 ppm) and potassium (120.5 ppm) as well as soil textural class (Sandy Clay Loam). The sieved and characterized soil collected from the same field site was used to fill pots with 10 kg for each pot. Tomato seedlings were obtained from the Ayub Agricultural Research Institute, Faisalabad. One tomato seedling was planted per pot. A predetermined fertilizer dose of 1-gram urea per pot was applied to promote optimal plant growth and development. Urea served as the nitrogen source, while single superphosphate (SSP) and muriate of potash (MOP) provided phosphorus and potassium, respectively. Completely randomized design (CRD) with 3 factors was employed to statistically analyze the experiment.

Treatments

Factor A: Irrigation water qualities (W): Three different types of water were used for irrigation like W1 = Having EC < than 1.0 Deci siemens per meter (control treatment), W2 = Having EC 2.0 Deci siemens per meter and W3 = Having EC 3.0 Deci siemens per meter

Factor B: Irrigation levels (IL): Two levels of irrigation were used like **IL_1.** Normal irrigation and **IL_2.** Ten % lesser water per irrigation

Factor C: Mulching (M): Two types of mulching were used with zero mulching like **M_1.** No mulching, **M_2.** Plastic mulching and **M_3.** Crop residues mulching

Soil and plant analysis

Soil and plant analysis was conducted prior to tomato plants sowing and plant analysis after harvesting tomato crop. Established laboratory methods from U.S. Salinity Laboratory Staff (1969) were employed for all analyses, with any deviations explicitly referenced. Method 54a of USDA Handbook 60 was used to get digestion of all tomato plants. After digestion of plant samples, contents of nitrogen, phosphorus and potassium were determined from each treatment samples.

Estimation of organic matter contents

Contents of organic matter in soil were determined through titration method using ferrous sulphate and potassium dichromate indicator (Walkley & Black, 1934).

Estimation of phosphorus contents

Available phosphorus from soil was analyzed through Watnabe & Olsen (1965) method.

Observations and data recording

Plant growth parameters were assessed at harvest (160 days after sowing) following the established protocols. Specific details of the measured parameters include plant height, stem diameter, fresh and dry weight and number of tomato fruits on each plant.

Statistical analysis

Each set of data was statistically examined, and ANOVA was made by means of Statistix 8.1. Tukey's (LSD) test was applied to study significance of treatment means at 5% probability level (Steel et al., 1997).

Results and Discussion

Significant differences between treatment effects were identified using the LSD test at a 1% probability level, and these differences will be marked by various letters (a, b, c, etc.).

Means sharing similar letters in a column are not significantly different at P>0.01

Plant height

Data indicated that plant height of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected height of tomato plants. These differences in plant height of tomato were noted noteworthy statistically (Table 1). Usage of water having EC less than 1.0 proved superior to other waters having EC = 2.0 and 3.0 Deci siemens per meter in producing plant height of tomatoes. Maximum height of 35.50 cm followed by 34.15 cm was noted with usage of W1 (control). However, minimum plant height of 22.30 cm was observed with the irrigation of water having EC = 3.0 dS m^{-1} (Table 1). Differences among all values of plant height showed statistically significant differences. Implication of mulching techniques also proved beneficial and significant in enhancing height of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to plant height of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 1). Results of previous researchers favored these findings. According to Nzediegwu et al. (2019), tomato plant growth under wastewater irrigation was not only enhanced, but nutritional concentrations was also positively boosted. Nonetheless, the treatment of wastewater had significantly improved the tomato plant's growth characteristics, including the fruit's potassium content and root fresh-dry weight. Alam et al. (2020) study shows similar findings, regarding wastewater reuse that shows prospects for economic gain. They claimed that the NPK, organic matter, and humic acid levels in wastewater was enough. In this study, the growth of tomato plants using wastewater resulted in improvements in plant height, leaf count, stem diameter, and shoot length.

Table 1 Effect of saline water irrigation on tomato plant height (cm)

Saline water treatments	M₁ (No mulching)		M₂ (Plastic mulching)		M₃ (Crop residues mulching)		Mean
	IL_1	IL_2	IL_1	IL_2 10 %	IL_1	IL_2	
W1	31.30^a	29.30^a	33.20^a	30.60^a	35.50^a	34.15^a	32.34^A
W2	28.40^b	26.70^b	30.70^b	27.20^b	32.00^b	30.25^b	29.21^B
W3	25.50^c	22.30^c	26.50^c	24.30^c	28.80^c	27.15^c	25.76^C
Mean	28.40^C	26.10^E	30.13^B	27.37^D	32.10^A	30.52^B	29.10

W1 = Having EC < than 1.0 Deci siemens per meter (control treatment); W2 = Having EC 2.0 Deci siemens per meter; W3 = Having EC 3.0 Deci siemens per meter; IL_1 = Normal irrigation; IL_2 = 10 % less water per irrigation

Fresh weight/yield of tomato fruit

Fresh weight or yield of tomatoes is the goal of tomato cultivation and hence, it is the most important parameter. Data indicated that fresh weight/yield of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected fresh weight of tomato plants. These differences in fresh weight of tomato were significant statistically (Table 2). Water having EC < 1.0 Deci siemens per meter proved superior to waters of EC 2.0 and 3.0 Deci siemens per meter in producing fresh weight of tomatoes. Maximum fresh weight of 62.18 g followed by 60.33 g was noted W1. However, minimum fresh weight of 50.03 g was observed with irrigation of water having EC = 3.0 dS m^{-1} (Table 2). Differences among all values of fresh weight showed statistically significant differences. Fresh weight or yield of tomato continued to decline with the increasing level of salts in irrigation water in systematic manner. Implication of mulching techniques also proved beneficial and significant in enhancing fresh weight of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all 03 types of waters regarding fresh weight of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 2). Results from previous researchers favoured the following findings. The application of raw wastewater from the food industry improves soil fertility and tomato and cucumber performance, according to the Qaryouti et al. (2015) study's findings. However, tomato plant's development parameters, such as the potassium content of the fruit and the fresh-dry weight of the roots, had improved greatly as a result of the wastewater treatment.

Table 2 Fresh weight /yield of tomato affected by salty water

Saline water treatments	M₁ (No mulching)		M₂ (Plastic mulching)		M₃ (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	57.44 a	54.12 a	59.67 a	56.27 a	62.18 a	60.33 a	58.34 A
W2	55.24 ab	52.34 ab	57.45 b	54.76 a	59.66 b	57.21 b	56.11 B
W3	53.71 b	50.03 b	55.63 b	51.74 b	56.82 c	54.48 c	53.74 C
Mean	55.46 C	52.16 D	57.58 B	54.26 C	59.55 A	57.34 B	56.06

Dry weight of tomato fruit

Dry weight of tomatoes is an important yield parameter. Data indicated that dry weight of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected dry weight of tomato plants. The dry weight of tomato plants differed significant statistically (Table 3). Usage of W1 proved superior to W2 and W3 in producing dry weight of tomatoes. Maximum dry weight of 12.45 g followed by 11.16 g was noted for W1. However, minimum dry weight of 4.71 g was observed with the irrigation of water having EC = 3.0 dS m^{-1}. Differences among all values of dry weight showed statistically significant differences. Dry weight or yield of tomato continued to decline with the increasing level of salts in irrigation water in systematic manner. The implication of mulching techniques also proved beneficial and significant in enhancing dry weight of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to dry weight of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 3). Results from the previous researchers favoured the given information's. Zeeshan et al. (2020) designed a pot experiment; they irrigated the tomato plants with wastewater. Nevertheless, the tomato plant's development features, such as the fruit's potassium content and the plant dry weight, had improved dramatically as a result of the wastewater treatment.

Table 3 Dry weight of tomato plants affected by salty water

Saline water treatments	M_1 (No mulching)		M_2 (Plastic mulching)		M_3 (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	09.92 a	08.21 a	10.88 a	09.41 a	12.45 a	11.16 a	10.34 A
W2	07.82 b	06.28 b	08.59 b	07.78 b	10.51 b	09.31 b	8.38 B
W3	05.91 b	04.71 c	06.87 c	05.06 c	08.78 c	06.43 c	6.29 C
Mean	7.88 C	6.40 D	8.78 B	7.42 C	10.58 A	08.97 B	8.34

Diameter of tomato fruit

Diameter of tomatoes is an important yield parameter. Data indicated that diameter of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected diameter of tomato plants. These differences in diameter of tomato showed statistically significant differences (Table 4). Usage of W1 proved superior to other W2 and W3 in producing diameter of tomatoes. Maximum diameter of 3.96 cm followed by 3.32 cm with W1. However, minimum diameter of 2.06 cm was observed with the irrigation of water having EC = 3.0 dS m^{-1}. Differences among all values of diameter remained significant statistically. Diameter of tomato continued to decline with the increasing level of salts in irrigation water in systematic manner. Implication of mulching techniques also proved beneficial and significant in enhancing diameter of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to diameter of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 4). Information from the previous researchers favored the following results. Becerra-Castro et al. (2015) conducted experiment that showed wastewater irrigation greatly boosts the output while reducing the expense of fertilizer because it is a possible source of nutrients and organic materials. As observed in rice, sugar beet, and sugarcane, high nitrogen uptake can also lengthen the vegetative development phase and delay the production and ripening of fruit.

Table 4 Diameter of tomato fruit affected by salty water

Saline water treatments	M_1 (No mulching)		M_2 (Plastic mulching)		M_3 (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	2.87 a	2.29 a	3.17 a	2.76 a	3.96 a	3.32 a	3.06 A
W2	2.61 ab	2.18 ab	2.98 b	2.64 ab	3.29 b	3.07 b	2.79 B
W3	2.36 b	2.06 b	2.57 c	2.49 b	3.06 c	2.83 c	2.56 C
Mean	2.61 D	2.18 E	2.91 C	2.62 D	3.44 A	3.07 B	2.80

Number of tomato fruit/plant

The number of tomato fruits/plant is an important yield parameter. Data indicated that number of tomato fruits/plant varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected number of tomato fruits/plant. These differences in number of tomato fruits/plant were significant statistically (Table 5). Usage of W1 proved superior to other W2 and W3 in producing number of tomato fruits/plant. Maximum number of tomato fruits/plant of 5 followed by 4 was noted for W1. However, minimum number of tomato fruits/plant of 3 was observed with the irrigation of water having EC = 3.0 dS m^{-1}. Differences among all values of number of tomato fruits/plant showed statistically significant differences. Number of tomato fruits/plant continued to decline with the increasing level of salts in irrigation water in systematic manner. Implication of mulching techniques also proved beneficial and significant in enhancing number of tomato fruits/plant. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to number of tomato fruits/plant. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 5). Results from the previous researchers favoured the following information. Almeelbi et al. (2014) conducting experiment that showed increased levels of metal contamination in the wastewater-irrigated site posed a serious risk to public health. The findings showed that eating fruits and vegetables that have been irrigated with wastewater carries some risk; even though the fruits appear healthy and are growing well, their concentrations of heavy metals far surpass the upper limits that are deemed safe for ingestion.

Table 5 Effect of saline water irrigation on number of tomato fruit per plant

Saline water treatments	M_1 (No mulching)		M_2 (Plastic mulching)		M_3 (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	4 a	3 a	5 a	4 a	5 a	4 a	4.17 A
W2	3 a	3 a	4 a	3 a	4 a	4 a	3.50 B
W3	3 a	3 a	4 a	3 a	4 a	3 a	3.33 B
Mean	3.33 B	3.00 B	4.33 A	3.33 B	4.33 A	3.67 AB	3.67

Nitrogen contents in tomato plants

Nitrogen is essential nutrient required by all plants for their vegetative growth. It plays significant role in plants development, fruit yield and general growth. Nitrogen has important role in plant metabolism due to its integrity with chlorophyll, photosynthesis, enzymes and many vitamins. It affects root growth and make plants tolerant for high temperature stress. Data indicated that nitrogen contents of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected nitrogen contents of tomato plants. These differences in nitrogen contents of tomato showed statistically significant differences (Table 6). Usage of W1 proved superior to other W2 as well as W3 in building nitrogen contents of tomatoes. Maximum nitrogen contents of 7.98 % followed by 7.73 % was noted with W1. However, minimum nitrogen contents of 6.62 % were observed with irrigation of water having EC = 3.0 dS m^{-1}. Differences among all values of nitrogen contents remained significant statistically. Nitrogen contents of tomato continued to decline with the increasing level of salts in irrigation water in systematic manner. Implication of mulching techniques also proved beneficial and significant in enhancing nitrogen contents of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to nitrogen contents of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 6). Results of previous researchers favoured these findings. According to Chaoua et al. (2019) industrial wastewater significantly enhanced the development and output of tomato crops. Because wastewater contains a lot of plant nutrients, including micronutrients and organic matter (N, P, and K), amount of fertilizer needed is often reduced. Alghobar & Suresha (2016) reported similar outcomes. They asserted that wastewater's high nutritional value could promote better plant growth. As a matter of fact, data obtained indicated that tomato plants irrigated with wastewater significantly outperformed other plants irrigated with canal water.

Table 6 Effect of saline water irrigation on nitrogen (%) in tomato plants

Saline water treatments	M_1 (No mulching)		M_2 (Plastic mulching)		M_3 (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	7.27 a	7.05 a	7.42 a	7.29 a	7.98 a	7.73 a	7.46 A
W2	7.05 b	6.89 a	7.24 b	7.04 ab	7.65 b	7.48 b	7.23 B
W3	6.82 c	6.62 b	7.08 c	6.84 b	7.23 c	7.04 c	6.94 C
Mean	7.05 CD	6.85 D	7.25 BC	7.06 CD	7.62 A	7.42 AB	7.21

Phosphorus contents in tomato plants

Phosphorus is an important essential element for tomato plants. It has its prime role in uptake of water and nutrient, root growth, yield and plant health. Phosphorus is mandatory for photosynthesis process, maturity of fruits and creating disease resistance. It is also essential for maintenance of fruit quality. Data indicated that phosphorus contents of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected phosphorus contents of tomato plants. These differences in phosphorus contents of tomato were noted significant statistically (Table 7). Usage of W1 proved superior to W2 and W3 in building phosphorus contents of tomatoes. Maximum phosphorus contents of 1.56 % followed by 1.36 % was noted for W1. However, minimum phosphorus contents of 1.01 % were observed with irrigation of water having EC = 3.0 dS m^{-1}. Differences among all values of phosphorus contents showed statistically significant differences. Phosphorus contents of tomato continued to decline with the increasing level of salts in irrigation water in systematic manner. Implication of mulching techniques also proved beneficial and significant in enhancing phosphorus contents of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to phosphorus contents of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 7). Results of previous researchers favoured these findings. Meena et al. (2016) conducted a field trial in which they irrigated pearl millet using municipal wastewater. Findings indicated that applying municipal wastewater reduced the salinity of soil and increased the concentration of potassium, phosphorus, and microbial activity in the pearl millet crop. Cristina et al. (2020) found similar outcomes when they applied wastewater to soil, which raised amount of organic matter, potassium, and phosphorus in the soil and caused tomato plants to grow explosively.

Table 7 Effect of saline water irrigation on phosphorus (%) in tomato plants

Saline water treatments	M_1 (No mulching)		M_2 (Plastic mulching)		M_3 (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	1.39 a	1.26 a	1.42 a	1.28 a	1.56 a	1.36 a	1.38 A
W2	1.25 ab	1.14 b	1.29 b	1.13 b	1.37 b	1.21 b	1.23 B
W3	1.09 b	1.01 c	1.17 c	1.07 c	1.26 b	1.12 b	1.12 C
Mean	1.24 BC	1.14 D	1.29 B	1.16 CD	1.40 A	1.23 BCD	1.24

Potassium contents in tomato plants

In tomato plants potassium has significant role. It is involved in photosynthesis, translocation of nutrients and ripening of fruits. It is important in the maintenance of water balance in plants. It improves tolerance against drought in plants and improve flavor and fruit quality. Data indicated that potassium contents of tomato varied with the utilization of water of different qualities with respect to salt concentrations. In this same way, various mulching techniques also affected potassium contents of tomato plants. These differences in potassium contents of tomato remained statistically significant (Table 8). Usage of W1 proved superior to W2 and W3 in building potassium contents of tomatoes. Maximum potassium contents of 3.7 % followed by 3.4 % was noted for W1. However, minimum potassium contents of 1.8 % were observed with irrigation of water having EC = 3.0 dS m^{-1}. Differences among all values of potassium contents showed statistically significant differences. Potassium contents of tomato continued to decline with increasing level of salts in irrigation water in systematic manner. Implication of mulching techniques also proved beneficial and significant in enhancing potassium contents of tomato plants. Adoption of plastic and crop residues mulching proved superior to non-utilization of mulching at either mode of application (normal level of irrigation and 10 % lesser water per irrigation). This technique of mulching proved significant results for all three types of waters with regard to potassium contents of tomatoes. Crop residues mulching remained the best at both levels (normal level of irrigation and 10 % lesser water per irrigation) when compared with others (Table 8). Study of previous researchers favoured the following results. Rajor & Bhalla (2016) investigated the effects of wastewater on wheat and mustard crops. Their findings demonstrated that treating wastewater positively increased levels of organic matter, potassium, and phosphorus. On the other hand, applying wastewater also significantly increased the nutrients in the wheat and mustard crops. Howell et al. (2018) reported similar outcomes. They asserted that because wastewater has such a high nutrient content, it may promote plant development. Applying winery wastewater increased the concentrations of potassium and salt, which raised the pH and EC of the soil.

Table 8 Effect of saline water irrigation on potassium (%) in tomato plants

Saline water treatments	M_1 (No mulching)		M_2 (Plastic mulching)		M_3 (Crop residues mulching)		Mean
	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	IL_1	IL_2 <10 %	
W1	3.1 a	2.6 a	3.3 a	2.9 a	3.7 a	3.4 a	3.17 A
W2	2.5 ab	2.3 ab	2.9 ab	2.7 ab	3.1 b	2.8 b	2.72 B
W3	2.2 b	1.8 b	2.5 b	2.1 b	2.7 b	2.5 b	2.30 C
Mean	2.60 BC	2.23 D	2.90 AB	2.57 C	3.17 A	2.90 AB	2.73

Conclusion

It is concluded from this research that brackish water of EC = 2.0 and 3.0 dSm^{-1} can be used successfully for growing tomato plants when coupled with plastic or crop residues mulches. Mulching practice will minimize the toxic effects of excessive salts found in brackish water by reducing evapotranspiration losses.

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