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INFLUENCE OF HUMIC ACID AND SALICYLIC ACID ON NUTRIENT CONTENT, QUALITY, YIELD ATTRIBUTES AND YIELD OF TOMATO (*LYCOPERSICON ESCULENTUM* MILL.) UNDER SALINITY STRESS

Uttam Kumar *et al.,*

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UTTAM KUMAR*[1], I. J. GULATI[1], PRAHALAD DEWRA[1], VIVEK KUMAR SINGHAL[2]
[1]Department of Soil Science and Agricultural Chemistry, COA, SKRAU,
Bikaner - 334 006, Rajasthan (INDIA)
[2]Department of Soil Science and Agricultural Chemistry, N.M.C.A., NAU,
Navsari - 396 450, Gujrat (INDIA)
e-mail: uttamdewangan.1991@gmail.com

ABSTRACT

A field experiment was conducted during *kharif* 2014-15 to study the response of tomato to different levels of humic acid and salicylic acid under salinity stress condition. Results revealed that plant Na^+, Cl^-, SO_4^{2-}-S, TSS and ascorbic acid increased while, Plant Ca^{2+}, Mg^{2+}, no. of fruits per plant, average diameter, average weight and fruit yield decreased significantly with 4 dSm^{-1} and 8 dSm^{-1} level of salinity of irrigation water respectively, over control. Application of both HA and SA significantly increased plant Ca^{2+}, Mg^{2+}, TSS, ascorbic acid, no. of fruits per plant, average diameter, average weight and fruit yield while, Plant Na^+, Cl^- and SO_4^{2-}-S decreased, over control. The combined effect of saline water 0.25 dSm^{-1} (control) and 1500 ppm HA level recorded maximum no. of fruits per plant (54.88), average diameter (6.15 cm), average weight (61.47 g) and fruit yield (163.13 q ha^{1}). From the study it was concluded that for realizing higher yield and quality of tomato, combined treatment of soil application of HA (1500 ppm) with SA (1.5 ppm), was found most effective which alleviated the deleterious impacts of salinity stress on tomato.

*Corresponding author

INTRODUCTION

Salt stress is one of the major abiotic stress factors that affect almost every aspect of physiology and biochemistry of a plant, resulting in reduction in its yield (Foolad, 2004). It is also well documented that the amount and quality of irrigation water available in the arid and semi-arid regions of the world are the main limiting factors to the agricultural productivity (Ashraf and Foolad, 2007). In India Majority of the underground waters contain high concentration of salts and their continuous use for irrigation adversely affects the crop production (Bali *et al.,* 2015). Tomato is grown under a wide range of production systems. In the areas with optimal climate for tomato cultivation, salinity is a serious constraint (Yurtseven *et al.,* 2005). Salt stress can disturb growth and photosynthetic processes by causing changes in the accumulation of Na^+, Cl^-, nutrients and disturbance in water and osmotic potential. The increasing concentration of Na^+ and Cl^- in the rooting medium suppresses the uptake of essential nutrients and alters ionic relationships. Salinity dominated by Na^+ salts not only reduces Ca^{2+} and Mg^{2+} availability but also reduces their transport and mobility to growing regions of the plant, which affects the quality of both vegetative and reproductive organs. Soil irrigated with water of different salinity containing excessive Cl^- and SO_4^{2-}-S salts, Cl^- concentrations increased in leaves and petioles of the tomato (Kahlaoui *et al.*, 2011). Increasing soil and water salinity affects growth, yield and fruit quality of tomato (Al-Rwahy *et al.*, 1989). Plant growth regulators, such as humic acid (HA) and salicylic acid (SA) can be used to promote growth and yield of plants under various stress conditions including salt stress. HA not only increased macronutrient contents, but also enhanced micronutrient contents of plant organs. However, high levels of HA arrested plant growth or decreased nutrient contents in tomato (Turkmen *et al.*, 2004). Both foliar and soil HA treatments positively affected fruit characteristics including TSS, ascorbic acid, fruit diameter, fruit height, fruit weight and fruit number per plant (Yildirim, 2007). Application of SA could have increased total soluble sugar and soluble protein and also enhanced translocation of photoynthates in to fruit. Exogenous SA applications inhibited Na accumulation and stimulated K, Ca and Mg uptake. An increase in concentration of K^+ and Ca^{2+} in plants under salt stress ameliorated the deleterious effects of salinity on growth and yield (Grattan and Grieve, 1999; Khan *et al.*, 2010). The positive effects of SA on tomato plant have also been reported under salinity stress condition (Stevens *et al.,* 2006). Lower concentrations of Brassinosteroides (BS) and SA should be tried in order to further enhance pod yield in groundnut and derive more economic benefit (Mulgir *et al.,* 2014). The present investigations were, therefore, undertaken to evaluate the role of HA and SA in mitigating the adverse effect of saline water, cation and anion content, quality parameters and yield of tomato under different levels of saline water irrigation.

MATERIALS AND METHODS

The present investigation was conducted at College of Agriculture, S.K. Rajasthan

Agricultural University Bikaner, during *kharif* season 2014-15. The soil of experimental site was sand in texture with pH_2 8.17, EC_2 0.43 dSm^{-1} and CEC 4.39 cmol (p^+) kg^{-1}. Tomato plants variety Pusa ruby was transplanted in open field during 1st week of august with 30 cm x 30 cm spacing. The experiment was carried out using 18 treatment combinations comprising three levels of saline water (control 0.25 dSm^{-1}, 4 dSm^{-1} and 8 dSm^{-1}). Three levels of HA (control, 750 ppm and 1500 ppm) and two levels of SA (control and 1.5 mM) were tested. The treatment combinations were replicated three times in Factorial RBD and allocated randomly to different plots. All the three levels of saline water (control 0.25 dSm^{-1}, 4 dSm^{-1} and 8 dSm^{-1}) were applied in field after transplanting of tomato as per crop irrigation requirement. HA (750 ppm and 1500 ppm) were applied in soil just after transplanting along with fertigation. SA (1.5 mM) was applied twice as foliar application first at 30 DAT and second at 55 DAT.

Plant samples were collected from each plot as per plan of work and presented for subsequent analysis. Digestion of plant sample, Sodium and Magnesium was measured according to methods of Bhargava and Raghupati (1993), Calcium according to the method of Richard (1954) using flame photometer, Chloride according to the method of Chapman and Pratt (1961), Sulphate-Sulphur was measured as described by Tabatabai and Bremner (1970) using spectro photometer. TSS was determined with the help of digital refractometer. Ascorbic acid in fruits was determined using the standard methods as given by A.O.A.C. (1970). Five fresh fruits harvested randomly from selected five plants were taken during harvesting and to get the total number of fruit per plant, average diameter and average weight. The yield of fruits per hectare was calculated by multiplying the average yield of fruits per sq. meter and expressed in q ha^{-1}.

RESULTS AND DISCUSSION

Nutrient content

Salinity dominated by Na^+ salts not only reduces Ca^{2+} and Mg^{2+} availability but also reduces their transport and mobility to growing regions of the plant, which affects the quality of both vegetative and reproductive organs. The Na^+ content in tomato increased while, Ca^{2+} and Mg^{2+} content decreased significantly with the increase in the level of salinity in irrigation water (Table 1). The Na^+ content in plant increased by 22.32 and 52.68 per cent, Ca^{2+} content decreased by 29.05 and 60.38 per cent and Mg^{2+} content decreased by 16.41 and 34.33 per cent with 4 dSm^{-1} and 8 dSm^{-1} level of salinity of irrigation water respectively, over control. Application of saline water, being high in total soluble salts causes increase in the absorption of Na^+ from roots. Na^+ transport from root to shoot is unidirectional and thus resulted in the buildup of Na^+ in leaves (Flowers *et al.,* 1991). Ions at high concentrations in the external solution (e.g. Na^+ or Cl^-) are taken up at high rates, which may lead to excessive accumulation in tissues. These ions might impaired the uptake of other ions (Ca^{2+} and Mg^{2+}) into the root and their transportation to the shoot and leaves (Grattan and Grieve, 1999; Hassan and Ali, 2014).Increase in the amount of soluble salts in soil due to saline irrigation water has resulted in increase in the Cl^- and SO_4^{2-}- S in tomato (Table 1). The Cl^- content in plant increased by 39.19 and 89.19 per cent, The SO_4^{2-}- S content by 26.44 and 43.68 per cent with 4 dSm^{-1} and 8 dSm^{-1} level of salinity of irrigation respectively, over control. Soil irrigated with water of different salinity containing excessive Cl^- and SO_4^{2-} salts, Cl^- concentrations increased in leaves and petioles of the tomato, indicating that tomato was unable to exclude Cl^- ions from leaves (Maggio *et al.,* 2007). The transport of Cl^- occurs mainly in the transpiration stream, which could be the reason of high concentration of these ions in leaves (Tuncturk *et al.,* 2011).

To ensure a good level of growth under saline medium, the plant have to maintain a high K^+ and low Na^+ content in the cytosol. In the present study Na^+ content in tomato decreased, Ca^{2+} and Mg^{2+} content increased significantly with increase in the level of HA application (Table 1). The Na^+ content in plant decreased significantly by 13.66 and 24.84 per cent, Ca^{2+} content increased by 58.82 and 110.92, Mg^{2+} content

Table 1: Effect of saline water irrigation, humic acid and salicylic acid on nutrient content and quality parameters of tomato

Treatments	Cations (%)			Anions (%)		Quality parameters	
	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}-S	TSS(%)	Ascorbic acid (mg 100 g^{-1})
Saline water (dS m^{-1})							
Control	1.12	2.65	0.67	0.74	0.44	4.48	17.24
4	1.37	1.88	0.56	1.03	0.68	4.89	19.02
8	1.71	1.05	0.44	1.40	0.88	5.23	20.13
S.Em.±	0.05	0.09	0.02	0.07	0.04	0.06	0.22
C.D. (p = 0.05)	0.15	0.25	0.05	0.21	0.12	0.16	0.64
Humic acid (ppm)							
Control	1.61	1.19	0.44	1.45	0.87	3.92	16.67
750	1.39	1.89	0.58	1.05	0.64	4.98	18.81
1500	1.21	2.51	0.66	0.68	0.49	5.71	20.91
S.Em.±	0.05	0.09	0.02	0.07	0.04	0.06	0.22
C.D. (p = 0.05)	0.15	0.25	0.05	0.21	0.12	0.16	0.64
Salicylic acid (mM)							
Control	1.52	1.55	0.52	1.21	0.74	4.65	18.21
1.5	1.28	2.17	0.60	0.91	0.60	5.08	19.38
S.Em.±	0.04	0.07	0.01	0.06	0.03	0.05	0.18
C.D. (p = 0.05)	0.12	0.20	0.04	0.17	0.10	0.13	0.53

Note: TSS – Total soluble solids.

Table 2: Effect of saline water irrigation, humic acid and salicylic acid on yield attributes and fruit yield of tomato

Treatments	Number of fruits per plants	Average diameter (cm)	Average fruit weight (g)	Fruit yield($q\ ha^{-1}$)
Saline water ($dS\ m^{-1}$)				
Control	49.66	5.53	59.33	154.85
4	46.38	4.91	52.86	148.90
8	38.50	3.88	44.66	142.12
S.Em.±	0.42	0.07	0.50	0.93
C.D. (P = 0.05)	1.20	0.21	1.43	2.66
Humic acid (ppm)				
Control	40.80	3.88	48.52	143.38
750	45.19	4.73	52.43	148.96
1500	48.54	5.72	55.91	153.54
S.Em.±	0.42	0.07	0.50	0.93
C.D. (P = 0.05)	1.20	0.21	1.43	2.66
Salicylic acid (mM)				
Control	43.36	4.28	51.13	146.19
1.5	46.33	5.27	53.44	151.06
S.Em.±	0.34	0.06	0.41	0.76
C.D. (P = 0.05)	0.98	0.17	1.16	2.17

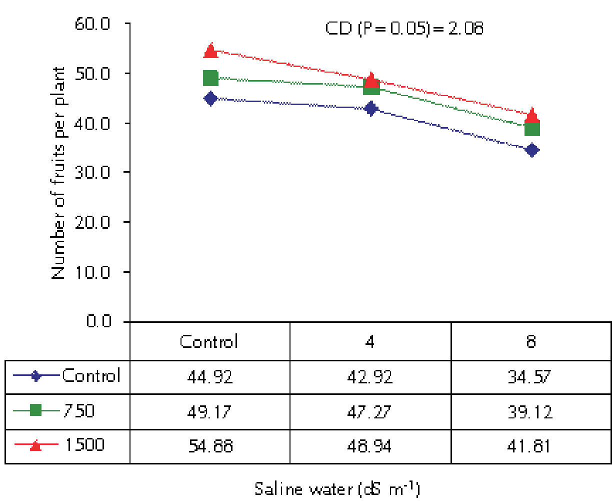

Figure 1: Combined effect of saline water irrigation and HA on no. of fruits per plant of tomato

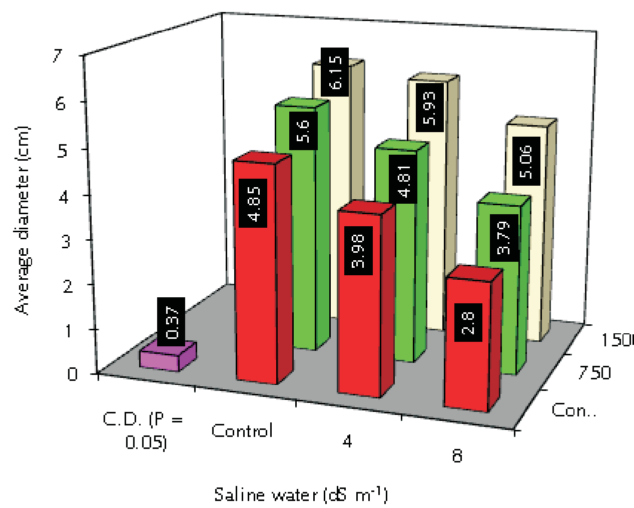

Figure 2: Combined effect of saline water irrigation and HA on average diameter (cm) of tomato

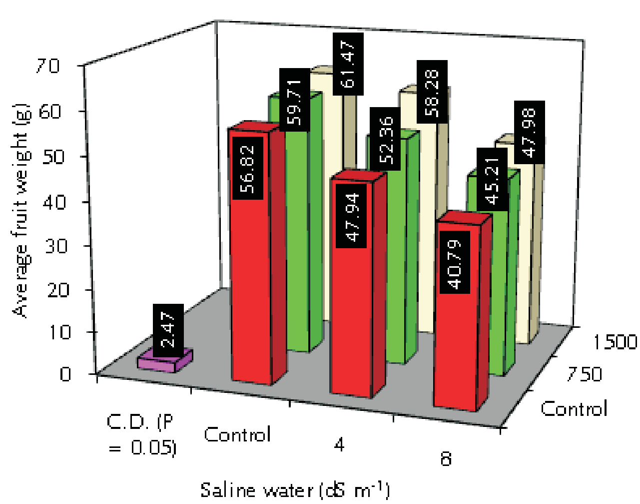

Figure 3: Combined effect of saline water irrigation and HA on average fruit weight (g)

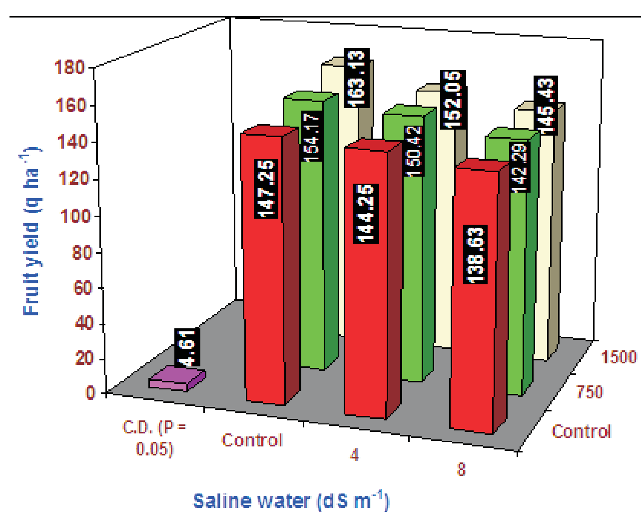

Figure 4: Combined effect of saline water irrigation of tomato and HA on fruit yield ($q\ ha^{-1}$) of tomato

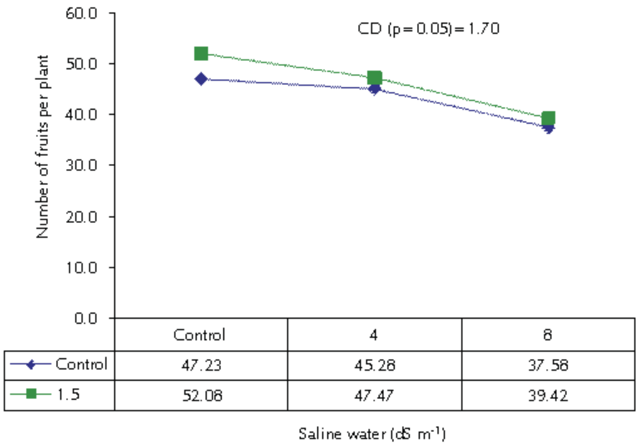

Figure 5: Combined effect of saline water irrigation and SA on number of fruits per plant of tomato

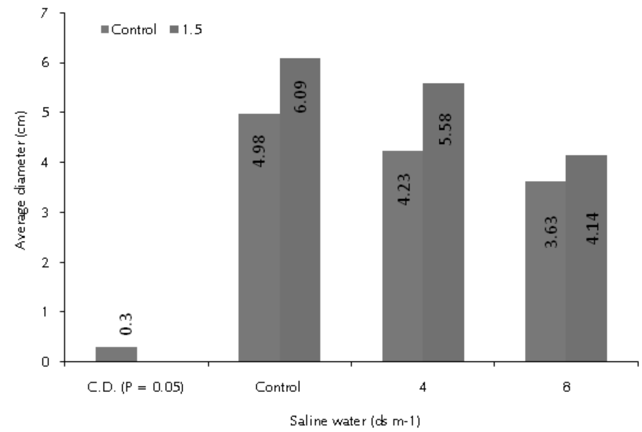

Figure 6: Combined effect of saline water irrigation and SA on average diameter (cm) of tomato

increased by 31.81 and 50.00 per cent with the application of 750 ppm and 1500 ppm levels of HA respectively. Further due to application of HA significantly decreased Cl^- and SO_4^{2-} - S content in tomato (Table 1). The Cl^- content in plant decreased by 27.59 and 53.10 per cent and SO_4^{2-}- S content decreased by 26.44 and 43.68 per cent with 750 ppm and 1500 ppm levels of HA application respectively, over control. This behavior is probably due to the specific permeability of membranes of root cells, which is related to the surface activity of humic substances resulting from the presence of both hydrophilic and hydrophobic sites (Chen and Schnitzer, 1978; Ali *et al.,* 2013). This could be because HA maintain an additional enrichment of the rhizosphere with Ca^{2+} in saline condition, which tends to replace exchangeable Na^+ on the root adsorption sites (Ouni *et al.*, 2014).

The Na^+ content in tomato decreased, Ca^{2+} and Mg^{2+} content increased significantly with increase in the level of SA (Table 1). The Na^+ content in plant decreased significantly by 15.79 per cent, Ca^{2+} content increased by 40.00 per cent, Mg^{2+} content increased by 15.38 per cent. Further SA application significantly decreased the Cl^- and SO_4^{2-}- S content in tomato (Table 1). The Cl^- content decreased by 24.80 per cent and SO_4^{2-}- S content decreased by 18.92 per cent with 1.5 mM SA application, over control. Exogenous SA applications inhibited Na^+ accumulation, and stimulated K^+, Ca^{2+} and Mg^{2+} uptake. An increase in concentration of K^+ and Ca^{2+} in plants under salt stress might have ameliorated the deleterious effects of salinity on growth and yield (Grattan and Grieve, 1999). Alteration of mineral uptake from SA applications may be one mechanism for the alleviation of salt stress (Abdi *et al.,* 2011; Simaei *et al.*, 2012).

Quality parameters

Saline water irrigation resulted in significant increase in TSS and ascorbic acid content of tomato (Table 1). The TSS increased by 9.15 and 16.74 per cent and ascorbic acid content increased by 10.32 and 16.76 per cent with 4 dSm^{-1} and 8 dSm^{-1} level of salinity of irrigation water respectively, over control. This might be due to reduced water uptake in plants irrigated with saline water led to increase in solute concentrations (particularly sugars) and hence increased TSS and ascorbic acid contents (Sangtarashani *et al.,* 2013; Nangare *et al.,* 2013). In the present investigation HA application significantly increased the TSS and ascorbic acid content of tomato (Table 1).TSS increased significantly by 27.04 and 45.66 per cent and ascorbic acid by 12.84 and 25.43 per cent with 750 ppm and 1500 ppm levels of HA application respectively, over control.

Humic substance might have various biochemical effects either at cell wall, membrane level or in the cytoplasm which in turn result in to enhanced photo-synthesis and respiration rate in plants. Application of HA under saline environment increased the carbohydrates in plants, resulted from a higher conversion of starch to sugar under the treatment (Kazemi, 2013). Also SA application significantly increased the TSS and ascorbic acid content of tomato (Table 1). The TSS increased significantly by 9.25 per cent and ascorbic acid content by 6.42 per cent with 1.5 mM SA application, over control. SA application could have increased total soluble sugar and soluble protein and also enhanced translocation of photoynthates in to fruit. Higher TSS and ascorbic acid may be due to the higher conversion of starch to sugar with SA (Javaheri *et al.,* 2012; Kazemi 2013).

Yield attributes and yield

Saline water irrigation resulted in significant decrease in no. of fruits per plant, average diameter, average weight and fruit yield (Table 2). The no. of fruits per plant decreased significantly by 6.60 and 22.47 per cent, average diameter by 11.21 and 29.84 per cent, average fruit weight by 10.90 and 24.73 per cent and fruit yield by 3.84 and 8.24 per cent with 4 dSm^{-1} and 8 dSm^{-1} level of salinity of irrigation water respectively, over control. Salinity adversely affects the plant growth and these adverse effects may be attributed to non availability of water, disturbance in nutrients causing deficiency or ion toxicity in plants. Extra expenditure of energy for osmotic adjustment or in repair system under salinity causes significant reduction in yields (Azeem *et al.,* 2011; Al-Busaidi *et al.,* 2010). HA application significantly increased the no. of fruits per plant, average diameter, average fruit weight and fruit yield (Table 2). No. of fruits per plant increased significantly by 10.75 and 18.97 per cent, average diameter by 21.90 and 47.42 per cent, average fruit weight by 8.05 and 15.23 per cent and fruit yield by 3.89 and 7.08 per cent with 750 ppm and 1500 ppm levels of HA application respectively, over control. Under salinity stress condition applications of HA probably not only improved the antioxidant defense enzymes system but also triggered the non-enzymatic antioxidants in plants. HA increases the yield attributes by activating hormones like auxine and cytokinine and by increasing the cell division and enlargement (Feleafel and Mirdad, 2014). HA improve plant physiological processes by enhancing the availability of major and minor nutrients as well as enhancing the vitamins, amino acids and ABA contents of the plants (Vanitha and Mohandass, 2014). Application of SA resulted in to significant increase in no. of fruits per plant, average diameter, average fruit weight and fruit yield (Table 2). The no. of fruits per plant increased significantly by 6.84 per cent, average diameter by 23.13 per cent, average fruit weight by 4.52 per cent and fruit yield by 3.33 per cent with 1.5 mM SA application, over control. SA is a potent signaling molecule in plants and is involved in eliciting specific responses to abiotic stresses. Therefore increased tomato yield receiving SA, might be due to enhancing the antioxidant and build-up of a protective mechanism to reduce oxidative damage induced by salt stress (Agamy *et al.,* 2013). The positive effect of SA could be attributed to an increased CO_2 assimilation and photosynthetic rate and increased mineral uptake by the stressed plant. Yield is the final manifestation of the growth and photosynthetic processes. (El-Hak *et al.*, 2012).

The combined effect of saline water irrigation and HA application was found significant in enhancing no. of fruits per plant, average diameter, average fruit weight and fruit yield (fig. 1, 2, 3, 4). Significant maximum no. of fruits per plant (54.88), average diameter (6.15 cm), average weight (61.47 g) and fruit yield (163.13 q ha^{-1}), were recorded with the good quality of irrigation water 0.25 dSm^{-1} (control) and 1500 ppm HA level. In the absence of saline water irrigation application of HA increases the yield attributes by improved antioxidant defense enzymes system in plants and thereby reduce the formation of reactive oxygen species.HA not only activate hormones like auxine and cytokinine but also maintains higher soil water potential and increase nutrient holding capacity of soils, thus plant grow well and yield more (Feleafel and Mirdad, 2014).The combined effect of saline water irrigation and SA application was found significant in improving the no. of fruits per plant and average diameter (fig. 5, 6). Significant maximum no. of tomato per plant (52.08) and average diameter (6.09 cm) were recorded with the good quality of irrigation water 0.25 dSm^{-1} (control) and 1.5 mM SA level. The positive effect of SA could be attributed to an increased antioxidant enzymatic activity, detoxification of ROS, CO_2 assimilation and photosynthetic rate and increased mineral uptake by the stressed plant. Also SA is a phenolic compound altered the auxine, cytokinine and ABA balances in plants and increased the growth and yield under both normal and saline conditions (Yildirim and Dursun, 2009; Qados, 2015).

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