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Effect of Saline Water Irrigation, Humic Acid and Salicylic Acid on Soil Properties, Yield Attributes and Yield of Tomato (*Lycopersicon esculentum* Mill.)

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Abstract The present investigation was carried out during *kharif* season of 2014-15 to study the response of tomato to different levels of humic acid and salicylic acid under salinity stress condition. Results revealed that soil pH_2, organic carbon, and CO_3^{2-} + HCO_3^- could not influence significantly while, EC_2, Na^+, $Ca^{2+} + Mg^{2+}$, Cl^- and SO_4^{2-} of soil after harvest of crop increased significantly with increase in the level of salinity of irrigation water. HA could not influence the pH_2, EC_2, organic carbon and $CO_3^{2-} + HCO_3^-$ significantly while, Na^+, Cl^- and SO_4^{2-} decreased significantly and Ca^{2+} +MG^{2+} of soil after harvest of crop increased significantly with increase in the levels of HA application. SA could not influence the pH_2, EC_2, organic carbon, $CO_3^{2-} + HCO_3^-$, Na^+, $Ca^{2+} + Mg^{2+}$, Cl^- and SO_4^{2-}, of soil after harvest of crop. 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 no. of fruit per plant, average diameter, average fruit weight and fruit yield. 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 mM), was found most effective which alleviated the deleterious impacts of salinity stress on tomato.

Keywords Saline water irrigation, Humic acid, Salicylic acid, Organic carbon, Yield.

Introduction

Salinity is a major abiotic stress reducing the yield of wide variety of crops all over the world. Approximately one-third of the earth's land mass consists of arid and semi-arid lands. The majority of these lands may be affected by salt-related problems, partially due to irrigation practices. Saline-sodic irrigation water, coupled with low annual rainfall and high evapo-tran-

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Table 1. Effect of saline water irrigation, HA and SA on pH_2, EC_2, organic carbon content, cations and anions of soil after harvest of tomato.

Treatments	pH_2	EC_2 (dSm^{-1})	Organic carbon (%)	Cations (me L^{-1}) Na^+	$Ca^{2+} + Mg^{2+}$	Cl^-	Anoins (me L^{-1}) SO_4^{2-}	$CO_3^{2-} + HCO_3^-$
Saline water (dS m^{-1})								
Control	8.20	0.47	0.12	1.84	2.04	2.41	1.53	1.17
4	8.17	0.74	0.11	3.57	4.72	5.84	2.29	1.47
8	8.14	1.03	0.10	6.25	6.04	8.26	3.80	1.83
SEm±	0.08	0.02	0.01	0.16	0.09	0.12	0.05	0.25
CD (p=0.05)	NS	0.06	NS	0.47	0.25	0.34	0.15	NS
Humic acid (ppm)								
Control	8.21	0.77	0.10	5.28	3.59	6.33	3.32	1.80
750	8.17	0.74	0.11	3.82	4.37	5.47	2.49	1.45
1500	8.13	0.72	0.12	2.56	4.84	4.70	1.81	1.23
SEm±	0.08	0.02	0.01	0.16	0.09	0.12	0.05	0.25
CD (p=0.05)	NS	NS	NS	0.47	0.25	0.34	0.15	NS
Salicylic acid (mM)								
Control	8.17	0.75	0.11	3.96	4.25	5.48	2.51	1.51
1.5	8.16	0.74	0.10	3.81	4.28	5.52	2.57	1.47
SEm±	0.06	0.02	0.00	0.13	0.07	0.10	0.04	0.20
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

spiration in the arid and semi-arid regions, not only results in accumulation of soluble salts in soil solution but also exhibit external signs of salt toxicity in the plants. Soil salinity build up increased with increasing the salinity of water and maximum build up was recorded at surface while pH decreased with increasing salinity. Contents of water soluble cations (Ca^{2+}, Mg^{2+}, Na^+) and anions (Cl^-, SO_4^{2-}) increased with increasing ECiw. Tomato is grown under a wide range of production systems. In the areas with optimal climate for tomato cultivation, salinity is a serious constraint [1]. Increasing soil and water salinity affects growth, yield and fruit quality of tomato. The maximum soil salinity level that is tolerated by tomatoes without yield reduction is ECe=2.5 dSm^{-1}.

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. Humic substances have high cation exchange capacity (CEC), improvement in CEC could have promoted cations retention capacity of the soil and regulated better nutrient supply to plants. In salt affected soil, the Na percentage in water generally increases, under such condition; there is a tendency for great adsorption of Na ions on the humus complex leading to the salinization of the soil and the toxicity of plants [2]. The HA application, decreases soil Na, EC and pH probably due to high supplies of Ca, Mg and K. Both foliar and soil HA treatments positively affected fruit characteristics including fruit diameter, fruit height, fruit weight and fruit number per plant of tomato [3]. The positive effects of SA on tomato plant have also been reported under salinity stress condition [4]. 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 [5]. The present investigations were, therefore, undertaken to evaluate the role of HA and SA in mitigating the adverse effect of saline water, soil properties, yield attributes 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 Univer-

Table 2. Effect of saline water irrigation, HA and SA 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
SEm±	0.42	0.07	0.50	0.93
CD (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
SEm±	0.42	0.07	0.50	0.93
CD (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
SEm±	0.34	0.06	0.41	0.76
CD (p=0.05)	0.98	0.17	1.16	2.17

Table 3. Combined effect of saline water irrigation and HA on number of fruits per plant and average diameter (cm) of tomato.

Salicylic acid (mM)	Saline water (dS m^{-1}) Control	4	8	Control	4	8
	Number of fruits per plant			Average diameter (cm)		
Control	44.92	42.92	34.57	4.85	3.98	2.80
750	49.17	47.27	39.12	5.60	4.81	3.79
1500	54.88	48.94	41.81	6.15	5.93	5.06
SEm±	0.72			0.13		
CD (p=0.05)	2.08			0.37		

sity 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 × 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 0.35 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 treansplanting along with fertigation. SA (1.5 mM) was applied twice as foliar application first at 30 DAT and second at 55 DAT.

Composite soil sample was collected at harvest from each experimental plot from 0 to 15 cm depth. The soil was mixed thoroughly and samples of about 0.5 kg were obtained by quartering technique and stored in neatly labeled polythene bags for soil analysis. Collected soils were sieved in a 2 mm mesh removing root hair as much as possible and assayed for pH_2, EC_2 [6]. organic carbon [7], soil Ca^{2+} + Mg^{2+} (Versenate titration method), Na^+ (Flame photometer method). Soluble anion CO_3^{2-} + HCO_3^- (titration with standard H_2SO_4), Cl^- (titration with standard $AgNO_3$) and sulfate sulfur [8]. 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

Soil properties

The soil pH_2 decreased with increase in the level of saline water irrigation non-significantly (Table 1). This might be due to lower proportion of Na in total salt concentration of soil solution and neutral nature of electrolytes [9]. This decrease in pH_2 may further be ascribed to the depression of thickness of diffuse double layer at higher concentration of soluble salts in the soil. Significant increase in EC_2 of soil have occurred with the increase in levels of salinity of irrigation water (Table 1). The EC_2 of soil after harvest of crop increased significantly by 57.45 and 119.15% with 4 dS m^{-1} and 8 dS m^{-1} level of salinity of irrigation water respectively, over control. It appears that by increasing levels of EC of irrigation water, more quantity of salts were delivered to the soil which ultimately resulted in higher EC_2 of soil [10].

Application of increasing level of salinity of irrigation water resulted in increase of the Na^+ and $Ca^{2+} + Mg^{2+}$ in soil significantly (Table 1) as compared to the initial status of soil. The Na^+ control of soil after harvest of crop increased significantly by 94.02 and 239.67%, $Ca^{2+} + Mg^{2+}$ content by 131.37 and 196.07% with 4 dS m^{-1} and 8 dS m^{-1} level of salinity of irrigation water respectively, over control. This could be due to more adsorption of Na^+ and $Ca^{2+} + Mg^{2+}$ on exchange complex of soil colloids [11]. With the increasing levels of salinity of irrigation water the Cl^- and SO_4^{2-} content increased significantly in soil at each level over its preceding level (Table 1). The Cl^- content of soil after harvest of crop increased significantly by 142.32 and 242.74% and SO_4^{2-} content by 49.67 and 148.37% with 4 dS m^{-1} and 8 dS m^{-1} levels of saline water irrigation respectively, over control. But the $CO_3^{2-} + HCO_3^-$ did not change much with salinity. This might be due to prominence of Cl^- in the irrigation water [11]. HA application resulted in significant decrease of Na content of soil while, Ca and Mg content increased significantly (Table 1). The Na^+ content of soil after harvest of crop decreased significantly by 27.65 and 51.51%, $Ca^{2+} + Mg^{2+}$ content increased by 21.27 and 34.82%. Further HA application significantly decreased the Cl^- and SO_4^{2-} content of soil after harvest of crop (Table 1). The Cl^- content decreased by 13.59 and 25.75%, SO_4^{2-} content decreased by 25.00 and 45.48% with 750 ppm and 1500 ppm levels of HA application respectively, over control. Humic substances have high cation exchange capacity (CEC), with addition of HA to saline soil, might have resulted in increase of CEC. Improvement in CEC could have promoted cations retention capacity of the soil and regulated better nutrient supply to plants. In salt affected soil, the Na percentage in water generally increases, under such condition; there is a tendency for great adsorption of Na ions on the humus complex leading to the salinization of the soil and the toxicity of plants [2]. The HA application, decreases soil Na, EC and pH probably due to high supplies of Ca, Mg and K. Beside this HA have multiple properties, especially their "sequestering" capacity (adsorbent, chelating) with organic compounds and mineral confer to them an essential role in the solubilization, the biodisponibility, the degradability, the transport and the exchanges of these compounds in water and soil [12]. SA could not influence the pH_2, EC_2, organic carbon, $CO_3^{2-}+HCO_3^-$, Na^+, $Ca^{2+}+Mg^{2+}$, Cl^- and SO_4^{2-}, of soil after harvest of crop.

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%, average diameter by 11.21 and 29.84%, average fruit weight by 10.90 and 24.73% and fruit yield by 3.84 and 8.24% with 4 dSm^{-1} and 8 dSm^{-1} level of salinity of irrigation water respectively, over control. Salinity adversely affected 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 [13, 14].

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%, average diameter by 21.90 and 47.42%, average fruit weight by 8.05 and 15.23% and fruit yield by 3.89 and 7.08% 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 [15]. 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 [16]. 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%, average diameter by 23.13%, average fruit weight by 4.52% and fruit yield by 3.33% with 1.5 Mm SA applications, over control. SA is a potent signaling molecule in plants and is involved in eliciting specific

Table 4. Combined effect of saline water irrigation and HA on average fruit weight (g) and fruit yield (q ha^{-1}) of tomato.

Salicylic acid (mM)	Saline water (dS m^{-1}) Control	4	8	Control	4	8
	Average fruit weight (g)			Fruit yield (q ha^{-1})		
Control	56.82	47.94	40.79	147.25	144.25	138.63
750	59.71	52.36	45.21	154.17	150.42	142.29
1500	61.47	58.28	47.98	163.13	152.05	145.43
SEm±	0.86			1.60		
CD (p=0.05)	2.47			4.61		

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 [5]. 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 [17].

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 (Table 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 [15].

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