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AMELIORATING TOMATO PRODUCTIVITY AND WATER-USE EFFICIENCY UNDER WATER SALINITY

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ABSTRACT

Salinity affects plant growth and productivity through its osmotic effect, a toxicity of salt ions, and changes in soil physical and chemical properties. This work aims to accelerate root development, hence increasing the plant's ability to absorb more nutrients from the soil in order to avoid the deleterious effects of salinity though using starter solutions and humic acid. Four starter solutions (SS); SS_1: control, SS_2: 200-200-200 (1:1:1), SS_3: 150-300-150 (1:2:1) and SS_4: 100-400-100 (1:4:1) mg l^{-1} of N-P_2O_5-K_2O and three rates of humic acid (HA); 0, 750 and 1500 mg l^{-1}, as well as their interactions, were studied on tomato plants irrigated with saline water (EC = 3.8). Tomato plants receiving SS_3 recorded highest mean values of leaf area, root and stem dry matter, fruit mass (161.8 g), fruit yield ha^{-1} (115.5 ton ha^{-1}), and water use efficiency (16.0 kg m^{-3}), as well as caused a reduction in fruit quality (firmness, total soluble solid , dry matter, pH, and the EC. While, tomato plants receiving SS_4 achieved the highest leaf and total dry matter per plant, the number of fruit clusters per plant(6.7), the percentage of fruit yield in 1-2 picks (59.9%), fruit dry matter and fruit EC. Increasing HA rate up to 1500 mg l^{-1} led to significantly increased leaf area, total dry matter, number of fruits per plant(37.3), fruit mass (138.3 g), yield ha^{-1} (103.0 ton ha^{-1}) and WUE (14.3 kg m^{-3}) traits compared to control treatment. However, application of HA at rate 750 mg l^{-1} gave the highest mean values of stem dry matter, fruit number clusters per plant, and fruit firmness. Dual application of SS_3 with HA at 750 mg l^{-1} achieved the best results in alleviating the deleterious effects of salinity stress on tomato plants. This was evidenced by maximum leaf area, fruit number clusters per plant (7.2), fruit mass (180.3 g), fruit yield (140.63 ton ha^{-1}), and WUE (19.5 kg m^{-3}). While application of SS_2 + HA at 1500 mg l^{-1} was shown to be suitable for improving tomato fruit quality.

Key words: NPK starter; humic; dry matter accumulation; yield; fruit quality; yield pattern.

INTRODUCTION

Tomato (*Solanumlycopersicum*) is the most commonly grown greenhouse vegetable crop, preferred for their high consumer demand and high value. High tomato yield and its quality can be produced only by using high quality irrigation water. Tomato productivity in Saudi Arabia (78.1 t ha^{-1}) is still low compared to the world average productivity (335.5 t ha^{-1}); as a result of salinity stress occurring in arid conditions due to use of saline irrigation water (Mitchell *et al*., 1991). The use of low quality water in Saudi Arabia resulted in 39.2% shortage of tomato yield (Al-Omran *et al*., 2010). Whereas, use of saline water in a greenhouse leads to a gradual increase in salinity in the root zone of tomato plants, especially in the mid- season (Shibli, 1993), as a result to high the surface evaporation and unsuitable irrigation practices; over pumping of groundwater (Mitchell *et al*., 1991). High salinity affects plant growth and productivity through osmotic effects, toxicity of salt ions, and changes in soil physical and chemical properties (Keren, 2004), as well as causing an imbalance of nutritional cations in plant tissues (Gad, 2005). It also suppresses phosphorus (P) uptake by plant roots hence reducing availability of P (Grattan and Grieve, 1999). Maas and Hoffman (1977) as cited in Campos *et al*. (2006) stated that the maximum soil salinity level tolerated by tomato is EC = 2.5 dS m^{-1}, without reduction in the yield. Ayers (1977) as cited in Boamah *et al*. (2011) reports that the use of irrigation water with EC: 1.7, 2.3, 3.4, and 5.0 dS m^{-1}led to reductions in tomato yield by 0, 10, 25 and 50%, respectively. Scholberg and Locascio (1999) illustrated that use of saline water (4 dS m^{-1}) for drip irrigation led to a linear reduction in the number of fruits, yield, and average fruit mass of tomato.Using NPK starter solutions and humic acid can contribute to improved uptake and availability of P.

Starter solutions (SS) are compound fertilizers, rich in phosphorus (P), applied around the roots of seedlings after transplanting. Using SS supplies small doses of nutrients before the root system is developed (Dufault and Schulthesis, 1994) and helps to overcome transplanting shock. Generally, P helps to develop a strong root (Shaheen *et al*., 2007). Increasing the root system is very important during early growth of the tomato plant. Mohammad *et al*. (1998) found that increasing the P level enhanced tomato root growth through increasing both root length and surface area. Awad *et al*. (1990) concluded that increased P fertilization enhanced the tolerance of tomato plants to high levels of NaCl. Phosphorus is important in metabolic processes because it is a main constituent of energy biomolecules (ATP and ADP), phospholipids, nucleic acids, nucleotides and co-enzymes (Shaheen *et al*., 2007). The enhancing effect of P on increasing total yield of tomato was previously stated by Feleafel and El-Araby (2003). AVRDC (1999 -2004) indicated that one of the effects of the SS was to accelerate root development, hence increasing the plant's ability to absorb more nutrients from the soil. Stone (2000) found that applying small quantities of P and N fertilizers at sowing under the seed level led to improved early growth and yield of bulb onion, salad onion, leek, and lettuce. Stone (2000) further showed that the use of starter fertilizer gave higher yields of bulb onion, crisp lettuce and forage maize crops, comparable with higher rates of base N.

Humic acid (HA) is an effective agent used as a complement to mineral or organic fertilizers. Soil application of HA led to improved soil properties such as aggregation, aeration, permeability, water-holding capacity, ion transport, and availability through pH buffering (McDonnell *et al*., 2001; Tan 2003). The uptake of humic substances in the plant tissue resulting in various biochemical effects through an increase nutrient uptake and maintaining vitamins and amino acids level in plant tissues thus stimulate rootsgrowth and whole plant (Nardi *et al*., 1996). Many researchers clarified several beneficial effects of HA such as increasing cell membrane permeability (Sial *et al*., 2007), oxygen uptake and photosynthesis (Russo andBerlyn, 1990; Chen *et al*., 1994), P uptake and the root elongation (Bohme andLue, 1997; Liu *et al*., 1998). HA has hormone-like activity not only enhance plant growth and the nutrients uptake but also anti-stress effect under abiotic stress conditions; unfavorable temperature, salinity, and pH by ameliorating the negative effect of any stress (Serenella *et al*., 2002; Kulikova *et al*., 2005; El-Hefny, 2010), but the physiological mechanism has not been well established (Delfine *et al*., 2005). Salama (2009) reported that soil application of humate led to alleviate the negative effects of salinity on tomato plants. Therefore, the application of HA improved both the nutrient balance and plant vitality (Boehme *et al*., 2005). Erik *et al*. (2000), on onion plant and Hafez (2003), on squash reported that HA applications led to a significant increase in soil organic matter, thus improve plant growth and productivity. Moreover, because of multiple roles of HA, it can greatly benefit plant growth and yield of vegetable (Hayes and Wilson, 1997; Zandonadi *et al*., 2007).

This work conducted to evaluate the productivity and water-use efficiency (WUE) of tomato, grown under saline water in a greenhouse, as well as to minimize the deleterious impacts of salinity stress by using soil application of NPK starter and humic acid solutions.

MATERIALS AND METHODS

An experiment was carried out at Agricultural Experiment Station, Hada-Alsham, King Abdulaziz University, Saudi Arabia, during the agricultural season of 2011/2012, under the evaporative cooling greenhouse, irrigated with saline water. This trial consisted of 12 treatments comprising combinations of four starter solutions, similar in concentration and differing in analyses; SS_1: control, SS_2: 200-200-200 (1:1:1), SS_3: 150-300-150 (1:2:1) and SS_4: 100-400-100 (1:4:1) mg l^{-1} of N- P2O5-K2O and three rates of humic acid (HA); control, 750 and 1500 mg l^{-1}. Starter solution was used as a drench to the seedling root area, one day after transplanting, at a rate 0.1 l per plant. The control plants were treated with tap water. While, HA was used as a drench to the plant root area at rate 0.25 l per plant. The application of HA was executed three times at 10, 25, and 40 days after transplanting. The control plants were treated with tap water.

Soil and Irrigation Water analysis: Some important physical and chemical properties of the experimental site soil up to 30 cm depth and chemical properties of irrigation water, which obtained from a local well, were estimated according to the published procedures by (Page *et al*., 1982).The soil texture is sandy clay-loam (67.4 % sand, 19.1 % silt and 23.5% clay) with pH= 7.8 and organic matter = 0.22 %.EC of the soil, before and at the end of experiment was 2.1 and 3.2 dSm^{-1},respectively. Available soil N, P and K were 36, 7 and 16 mg kg^{-1}, respectively. The irrigation water had an EC value of 3.8dS m^{-1} and contained: Na= 22.1, Mg= 0.92, Ca= 6.15, HCO_3= 0.68, Cl=36.1 and SO_4= 9.21meql^{-1}.

Experimental Design: The experimental design was a split-plot system arranged in a randomized complete block design with three replications. The starter solutions were, randomly, arranged in the main plots, while concentrations of HA were, randomly, distributed in the sub-plots. Each sub-plot contained two rows having an area of 6 m^2. Tomato (cv. Leen F_1) seedlings were transplanted into the soil in the greenhouse on 10 December 2011, in two lines on each row. The row spacing was 50 cm between the seedlings and 70 cm between the lines in a row. Each sub-plot contained 16 plants. The average temperature and relative air humidity inside the greenhouse were 25 ± 2.1°C and 74 ± 2% throughout tomato growth stages, respectively.

Irrigation and fertilization: The actual evapotranspiration of tomato crop (ETc), under greenhouse at Hada-Alsham area conditions, was calculated and adjusted at the start of each growth stage.

It was calculated by multiplying reference evapotranspiration (ET_0) for different growth stages through the growing season (December, 2011 – May, 2012) by a crop coefficient (K_C); $ET_c = ET_0 \times K_C$, as indicated in Allen *et al*., (1998) and Razmi and Ghaemi, (2011) (Table 1). The drip irrigation network consisted of lateral's GR of 16 mm in diameter, with emitters at 0.5 m distance, with two laterals per row. The emitters had a discharge rate of 4 l h^{-1}. Irrigation frequency was every alternate day, to maintain soil water above 50% soil water depletion, according to Qassim and Ashcroft, 2002, which is the optimum level of tomato plants.

All sub-plots received N, P and K fertilizers at the rates of 280-90-400 kg ha^{-1} as NPK (20-20-20), urea (46%N), phosphoric acid (58% P_2O_5), potassium sulfate (48% K_2O). NPK fertilizers were injected directly into the irrigation water (fertigation) using a venture injector at two doses weekly starting in the 2^{nd} week after transplanting (WAT) up to the 14^{th} week. Other recommended agricultural practices were followed as commonly used in the commercial production of tomato.

Data Recorded:

Leaf area and dry matter accumulation: After 10 WAT, five plants were randomly chosen, in each sub-plot, then uprooted from the soil to determine the leaf area (cm^2) and root, stem and leaves dry weights (g) per plant.

Yield and yield components: Tomato fruits were harvested at 10 day intervals starting from 90 days after transplanting, at the end of the growing season the following data were recorded: number offruit clusters per plant, number of fruits per plant, average fruit weight (g) and fruit yield (ton ha^{-1}).

Water-use efficiency (WUE):WUE (kg m^{-3}) was calculated by dividing the total fruit yield (kg ha^{-1}) by total water applied (7209 m^3 ha^{-1}).

Fruit quality: A random sample of ten fruits from each sub-plot was taken to estimate the fruit firmness, dry matter, EC, and pH. Moreover, a total soluble solid (T.S.S.) was measured by using a hand refractometer. Titrable acidity was determined by titration against NaOH using phenolphthalein as indicator according to the method described in AOAC (2005).

Statistical Analysis: Data recorded during the study were subjected to analysis of variance techniques according to the design used by the MSTATC computer software program (Bricker, 1991). The Revised LSDtest at $P<0.05$ was used to compare differences among means of various treatment combinations.

RESULTS AND DISCUSSION

Leaf areaanddry matter accumulation: Soil application of starter solutions had marked and significant effect on leaf area and dry matter accumulation of different organs of tomato plants(Table 2).The dry matter was mainly distributed in the stem, followed by the leaves, and root. Tomato plants receiving the soil application of SS_3(1:2:1 NPK) recorded significant maximum increments in the leaf area anddry matter ofroot and stem. Whereas, tomato plants receiving SS_4(1:4:1 NPK) achieved higher values of the leaves and total dry matter per plant. This can be explained based on starter solutions (rich in P) were used as a drench to the seedling root area one day after transplanting, a view to accelerate root development (Table 2) and boosting plant growth, hence increasing the plant's ability to absorb more nutrients and water from the soil. Thus, that could encourage the vegetative growth of tomato plants to go forward and accelerate the photosynthetic rate, which contribute in increasing the meristematic activity of the plant tissues and in building protein molecules (Marschner 1986). This appeared in the improvement of the leaf and total dry matter contents per plant.

Application of HA significantly increased leaf area and dry matter of the root, stem and leaves as well as total dry matter of tomato compared to the control (Table 2). Generally, application of HA up to 1500 mg l^{-1} resulted in the highest leaf area and dry matter of the root, leaves and total per plant compared to the other treatments. In addition, the highest stem dry matter per plant was observed in response to application of HA at a rate 750 mg l^{-1}. The beneficial effects of HA could be related to their indirect effect (an increase of fertilizers use efficiency), or direct effect (an improvement of the overall plant biomass). HA has hormone-like activity not only enhances plant growth and the nutrient uptake but also anti-stress effects of salinity by reduced negative effect (Serenella *et al*., 2002; Kulikova *et al*., 2005; El-Hefny, 2010). HA is abundant in functional groups, which leads to the active interaction with a diverse range of mineral components. The major functional groups of HA include carboxyl, phenolic hydroxyl, alcoholic hydroxyl, and ketone groups with the ability to chelate positively charged ions (Russo and Berlyn, 1990).

The interaction effects of various starter solutions and HA rates on leaf area and dry matter accumulation of different organs of tomato plants, were found to be significant (Table 2). Higher leaf area per plant (6321.1 cm^2 per plant) was observed in tomatoes receiving SS_3 + HA at a rate of 750 mg l^{-1}, compared with the lower leaf area (4363 cm^2 per plant) observed for control plants. The most significant results for the root, stem, leaves, and total dry matter per plant were attained due to the combined soil application of SS_4(1:4:1 NPK) with 1500 mg l^{-1} of HA.

Yield and yield components: Tomato plants receiving SS_4 (P level tripled theN or K) achieved a significantly higher number of fruit clustersper plant compared to tomato plants in control or plants receiving SS_2 (1:1:1 NPK). Maximum number of fruits per plant (36.5) was recorded in SS_2 (1:1:1 NPK)followed by SS_3 (1:2:1 NPK) and SS_4(1:4:1 NPK) with 35.8 and 34.5 fruits per plant, respectively(Table 3). Tomato plants receiving SS_3(1:2:1 NPK) recorded significantly higher fruit mass (g) and fruit yield ha^{-1} with an increase of 39.6 and 50.6 %, respectively, over the tomato plants irrigated with saline water only.Theseresults are in line with those reported by Awad *et al*. (1990) who concluded that increased P fertilizer enhanced the tolerance of tomato plant to NaCl. In addition, the enhancing effect of P on increasing the total yield of tomato was previously stated by Feleafel and El-Araby (2003). Similarly, Stone (2000) showed that a good response to the establishment, early growth and often increased yield in some vegetable crops with soil application of starter fertilizer.

Table 1.Length of the growth stages, crop coefficients (Kc), reference evapotranspiration (ET0) and water requirements of tomato crop (ETc), under the greenhouse at Hada-Alsham region conditions, Saudi Arabia

Growth stages	Establishment	Vegetative	Flowering	Fruits formation	Ripening
Number of days per stage	35	45	35	35	30
Crop Coefficients (K_C)	0.41	0.92	1.11	0.95	0.95
Reference evapotranspiration (ET_0) mm day^{-1} on the inside of the greenhouse =73% from outside the greenhouse (Razmi and Ghaemi, 2011)	3.1	4.2	4.8	5.1	5.1
Water requirements of tomato crop (ET_c) mm day^{-1}	1.27	3.87	5.33	4.85	4.85
Total water requirements per growth stage	44.5	174.2	186.6	169.8	145.5

Increasing rate of HA up to 1500 mg l^{-1} significantly increased the number of fruit per plant, fruit mass and fruit yield ha^{-1} by 13.4, 19.3 and 33.6%, respectively, over the tomato plants in the control (Table 3). However, tomato plants that treated with 750 mg l^{-1} of HA achieved a significantly higher number of fruit clusters per plant compared to other treatments. It has been reported that application of HA increased the growth and yields of various vegetable crops (Hayes and Wilson, 1997; Zandonadi *et al*., 2007). Furthermore, Salama (2009) indicated that soil application of humate led to alleviate the negative effects of salinity on tomato plants.

The interaction of the SS and HA rates on yield and yield components of tomato plants, showed much variation (Table 3). Tomato plants of control (SS_1), increasing soil application level of HA up to 1500 mg l^{-1}, led to increase the number of fruits per plant, fruit weight and fruit yield ha^{-1}, addition decrease in the number of fruit clusters per plant. Tomato plants receiving SS_3(1:2:1 NPK) + 750 mg l^{-1} of HA, gave the highest number of fruit clusters per plant, fruit weight, and fruit yield ha^{-1}. The increase in fruit mass and fruit yield ha^{-1} were 84.2 and 143.5%, respectively, relative to the controltreatment. The highest number of fruits per plantwas observed for tomato plants receiving SS_3 or SS_4 + 1500 mg l^{-1} of HA.The positive effects of interaction between SS and HA may be attributed to remaining concentrated near the point of application, thus help in improved nutrient availability in the root zone and avoiding the deleterious effects of saline water, thus reflected this effect on increasing the vegetative growth and flowering characters and increase fruit yield and its quality.

Water use efficiency (WUE): The results showed that there were significant differences in WUE of tomato plants based on soil application of starter solutions (Figure 1). Tomato plants receiving SS_3(1:2:1 NPK) or any of the 750 or 1500 mg l^{-1} of HA had high WUE (16.0, 14.2 and 14.3 kg m^{-3}, respectively) compared to tomato plants irrigated with saline water only (Figure 1, A).This may be due to effects of starter solution and HA on accelerating root development (Table 2) and boosting plant growth, hence increasing the plant's ability to absorb more nutrients and water from the soil. The comparison among the means of the various combined treatments of the SS and HA showed significant differences in WUE of tomato plants grown under saline water (Figure 1, B). Application of SS_3(1:2:1 NPK) + HA at a rate 750 mg l^{-1} was shown to be the most effective treatment combination; it resulted in the highest WUE (19.5 kg m^{-3}) compared to other treatments (Figure 1, B).

Fruit quality: Application of SS had a significant effect on all measured fruit quality characteristics;fruit firmness, T.S.S., dry matter of fruit, pH, and EC (Table 4). Application of SS_2 (1:1:1 NPK) or SS_3(1:2:1 NPK) resulted in significantly lower fruit firmness, T.S.S. and pH of tomato fruit juice compared to other starter solution treatments. Application of SS_4(1:4:1 NPK) led to significantly higher fruit dry matter and EC of fruit juice

Table 2.Effect of starter solutions and humic acid rates on the leaf area and dry matterdistribution of tomato plants grown under saline water

Starter solutions	Humic acid rates mg l^{-1}	leaf area per plant (cm^2)	Dry matter per plant (g)			
			Root	Stem	Leaves	Total
SS1		5269.5C	13.8C	67.2B	62.6C	143.6B
SS2		5911.2A	15.7B	76.6A	71.3B	163.6A
SS3		5957.4A	16.3A	77.1A	71.7B	165.1A
SS4		5791.1B	15.8B	75.8A	73.7A	165.3A
	0	5068.8C	14.4B	62.4B	60.0B	136.7B
	750	5929.8B	15.9A	80.3A	73.9A	170.1A
	1500	6198.3A	15.9A	79.8A	75.7A	171.4A
	0	4363.0j	12.6g	54.2j	50.0h	116.9j
SS1	750	5339.2g	13.8f	70.5f	65.9e	150.2g
	1500	6106.3d	15.1e	76.8e	71.8d	163.7f
	0	5275.6h	15.3de	67.8g	62.7f	145.7h
SS2	750	6198.3c	15.7cd	79.9d	74.7c	170.3d
	1500	6259.7b	16.1bc	82.0c	76.6b	174.7c
	0	5414.2f	14.9e	65.8h	60.9g	141.5i
SS3	750	6137.0a	18.0a	89.0a	78.6a	185.6a
	1500	6321.1d	15.9c	76.6e	75.7bc	168.2e
	0	5222.2i	15.0e	61.6i	66.3e	142.9i
SS4	750	6044.9e	16.0bc	81.7c	76.4b	174.2c
	1500	6106.3d	16.5b	84.0b	78.5a	178.9b

*Starter solution; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg l^{-1} of N- P2O5-K2O.
**Values having the same alphabetical letter in common do not significantly differ, using LSD test at P<0.05.

Table 3. Effect of starter solutions and humic acid rates on the fruit yield and its components of tomato plants irrigated with saline water

Starter solutions	Humic acid rates mg l^{-1}	Fruit clusters number per plant	Fruits number Per plant	Relative Fruits No. (%)	Fruit weight (g)	Relative Fruit weight (%)	Fruits yield (ton ha^{-1})	Relative Fruits yield (%)
SS_1*		6.2B**	32.8C	100.0	115.9C	100.0	76.7D	100
SS_2		6.3B	36.5A	111.3	147.3B	127.1	107.0B	139.5
SS_3		6.6A	35.8AB	109.1	161.8A	139.6	115.5A	150.6
SS_4		6.7A	34.5B	105.2	116.7C	100.7	81.1C	105.7
	0	6.3B	30.3B	92.4	131.9C	113.8	80.2B	104.6
	750	6.8A	37.1A	113.1	136.2B	117.5	102.0A	133.0
	1500	6.3B	37.3A	113.7	138.3A	119.3	103.0A	134.3
SS1	0	6.9bc	29.5g	100.0	97.9l	100.0	57.76j	100.0
	750	6.0ef	34.0f	115.3	106. 1j	108.3	72.15h	124.9
	1500	5.8fg	34.8e	118.0	143.8e	146.9	100.08e	173.3
SS2	0	6.1de	33.7f	114.2	160.8c	164.2	108.38c	187.6
	750	6.9bc	39.0b	132.2	134.0g	136.9	104.52c	181.0
	1500	6.0ef	36.7cd	124.4	147.2d	150.4	108.04c	187.0
SS3	0	5.7g	28.1h	95.3	165.3b	168.8	92.90g	160.8
	750	7.2a	39.0b	132.2	180.3a	184.2	140.63a	243.5
	1500	7.0ab	40.4a	136.9	139.9f	142.9	113.04b	195.7
SS4	0	6.7c	29.8g	101.0	103.4k	105.6	61.63i	106.7
	750	7.2a	36.5d	123.7	124.4h	127.1	90.81f	157.2
	1500	6.3d	37.1c	125.8	122.4i	125.0	90.82f	157.2

*Starter solution; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg l^{-1} of N- P2O5-K2O.
**Values having the same alphabetical letter in common do not significantly differ, using LSD test at P<0.05.

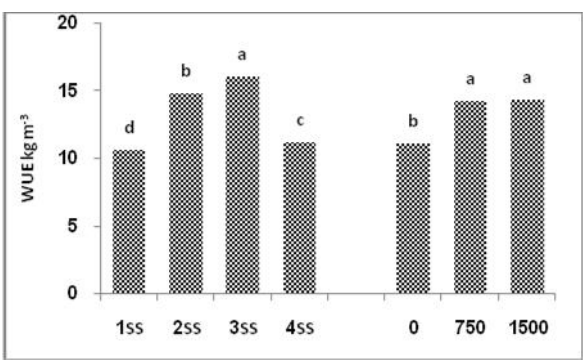
relative to the other treatments. Increasing levels of HA up to 1500 mg l^{-1}, progressively and significantly lowered T.S.S., fruit dry matter, and EC of tomato fruit juice compared to the control treatment. Tomato plants receiving HA at a rate of 750 mg l^{-1} produced firmer fruits compared to other treatments. However, EC of fruit juice did not respond significantly to application of HA.There was no clear and consistent trend for the interaction between the SS and HA rates on all studied tomato fruit quality characteristics (Table 4). Nevertheless, the interaction effect was clear for tomato plants receiving SS_2 (1:1:1 NPK) + 1500 mg l^{-1} of HA; it led to an increase in T.S.S., fruit dry matter, pH and EC. On the other hand, tomato plants without any starter solution and treated with HA scored poorly in all fruit quality characteristics with an increase the rate of HA up to 1500 mg l^{-1}.

Table 4: Effect of starter solutions and humic acid rates on the fruits quality of tomato plants irrigated with saline water

Starter solutions	Humic acid rates mg l^{-1}	Fruits firmness lb in^{-2}	T.S.S. (%)	Fruitdrymatter (%)	pH	EC (ds m^{-1})
SS_1*		6.97A**	3.63B	6.88B	8.91A	5.18C
SS_2		6.07C	3.03C	6.89B	8.77B	5.40B
SS_3		6.49B	3.12C	7.23B	8.69B	5.44B
SS_4		7.06A	4.03A	9.29A	8.74B	6.20A
	0	6.80B	3.69A	7.94A	8.81A	5.81A
	750	6.98A	3.32B	7.32B	8.76A	5.38B
	1500	6.15C	3.36B	7.45B	8.75A	5.18B
SS1	0	8.47a	4.23a	7.60d	9.07a	5.30ef
	750	7.33b	4.23a	6.60ef	9.00ab	5.23fg
	1500	5.07g	2.43d	6.43fg	8.67efg	5.00g
SS2	0	5.37f	2.87c	6.47f	8.67efg	5.37def
	750	6.90c	3.03bc	5.90g	8.80cde	5.27f
	1500	5.93e	3.20bc	8.30bc	8.83cd	5.57bcd
SS3	0	6.37d	3.20bc	7.03e	8.60fg	5.23fg
	750	6.57d	2.87c	8.07cd	8.77cde	5.30ef
	1500	6.53d	3.30b	6.57ef	8.70def	5.80b
SS4	0	7.00c	4.47a	10.67a	8.90bc	7.33a
	750	7.10bc	3.13bc	8.70b	8.53g	5.73bc
	1500	7.07c	4.50a	8.50bc	8.80cde	5.53cde

*Starter solution; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg l^{-1} of N- P2O5-K2O.
**Values having the same alphabetical letter in common do not significantly differ, using LSD test at P<0.05.

A



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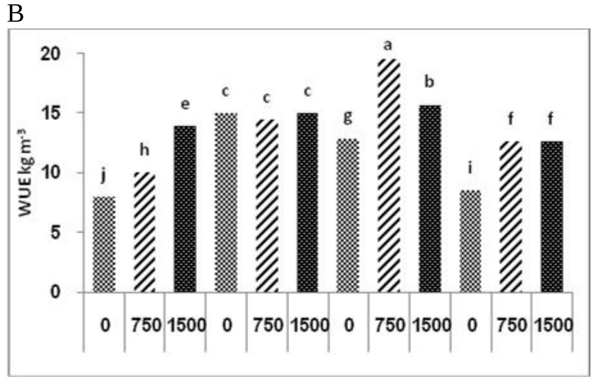

Starter solution; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg $l^{-1}$of N- P2O5-K2O, Humic acid rates; control, 750 and 1500 mg l^{-1}.

Figure 1: Effect of starter solutions and humic acid rates on the water-use efficiency of tomato plants grown under saline water.

Conclusions: The combined treatment of soil application of SS_3(1:2:1 NPK) with HA at 750 or 1500 mg $l^{-1}$was the most efficient combination, which alleviated the deleterious impacts of salinity stress on fruit yield and quality as well as WUE of tomato plants irrigated with saline water. This work recommends that application of starter solutions + HA treatments can ameliorate the effects of salinity on tomato plants and could offer an economical and simple application to reduce problems of tomato production irrigated with moderately saline water.

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