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Full Length Article

Alleviating the Deleterious Effects of Water Salinity on Greenhouse Grown Tomato

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Abstract

Use of saline water in greenhouse led to the gradual increase of salinity in tomato roots zone. The salinity suppresses the phosphorus (P) uptake and reduces available P, causing a decrease in growth of roots and plants. This research evaluated rapid early growth of tomato to avoid the deleterious effect of water salinity by using four NPK starter solutions (SS); SS_1: without SS, 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. The vegetative growth, flowering, leaf mineral contents and fruit yield characters of tomato plants was increased significantly and successively as P concentration in starter solutions increased. Tomato plants receiving SS_4 recorded maximum plant height; at 6, 8 and 10 weeks after transplanting (WAT), and leaves number; at 6 and 8 WAT, as well leaf P content. While, tomato plants receiving SS_3 achieved maximum root and shoot fresh weight and highest mean values of the number of flowers per cluster, leaf NK contents and fruit yield per plant. Increasing the HA level up to 1500 mg L^{-1} was able to improve plant height, number of leaves, fresh weight of root and shoot, earliness, number of flowers per cluster, leaf N, P and K contents and fruit yield per plant of tomato under salinity stress compared to control treatment. The interaction between SS and HA indicated that with any SS, increasing level of HA, significantly increased plant height, the number of leaves, fresh weight of root and shoot, earliness, number of flowers per cluster, N, P and K contents of leaf and fruit yield per plant. Nonetheless, the application of SS_3 with HA at 750 or 1500 mg L^{-1} was the most efficient treatment combination, to alleviate the deleterious impacts of salinity on tomato plants irrigated with saline water.

Keywords: NPK starter; Humic; Growth; Flowering; Leaf chemical Constituents; fruit yield

Introduction

Tomato (*Solanum lycopersicon* L.) is the most important vegetable crops in many countries. In 2010, it represented about 50% of the cultivated area of greenhouses in Saudi Arabia. However, the tomato productivity of Saudi Arabia is still low as compared to the world average productivity; as a result of exposure to salinity stress occurring under arid region conditions (Ehret and Ho, 1986) due to use of saline irrigation water (Mitchell *et al.*, 1991). Moreover, high salinity effect on plant growth through osmotic effect, a toxicity of salt ions, and the changes in physical and chemical properties of soil (Keren, 2000). It also suppresses the phosphorus (P) uptake by plant roots and reduces the available P (Grattan and Grieve, 1999). Improving the management agricultural practices of tomato production under greenhouse by using the NPK starter solutions rich in P and humic acid; will contribute to increase the availability and uptake of P may be a key to strong roots formation and overcome the deleterious effect of salinity stress.

Starter fertilizers are the compound fertilizers, rich in P and used in small amount in solution form, applied near the roots of seedlings after transplanting (Stone, 2000). Using starter fertilizers will supply small doses of NPK nutrients before the root system is developed (Dufault and Schulthesis, 1994) and help to overcome transplant shock in the early start of plant growth. The young root system may lead to an increased P uptake (Jokela, 1992) and development of strong roots. Saga (1972) and Mohammad *et al*. (1998) found that increasing the P levels enhanced root growth through increasing both root length and root surface area. Clarkson and Scattergood (1982) stated that P deficient plants displayed a lack in growth of roots. Similarly, Alan (1989) indicated that, plants suffering from P deficiency showed retardation in growth and reduction in shoot/root dry weight ratio. AVRDC (1999 - 2004) indicated that using NPK as starter solutions can accelerate root development, hence increasing the plant's ability to absorb nutrients from the soil. Likewise, Stone (1998, 2000) found that injection of small quantities of P and N fertilizers, at sowing, lead to increase in the early growth of bulb onion, salad onion, leek and lettuce.

Humic acid (HA) is very large and complex molecules. It is an effective agent to use as a complement to mineral or organic fertilizers. HA is also a source of plant nutrients essential for the plant growth (Yildirim, 2007). The uptake of HA in plant tissue results in various biochemical effects through an increase in nutrient uptake, maintaining vitamins and amino acids level in plant tissues thus stimulate the growth of roots and whole plant (Nardi *et al*., 1996). Many researchers indicated several beneficial effects of HA such as increasing cell membrane permeability (Sial *et al.*, 2007), oxygen uptake and photosynthesis (Russo and Berlyn, 1990; Chen *et al.*, 1994), phosphorus uptake and root elongation (Bohme and Lue, 1997; Liu *et al.*, 1998; Cimrin and Yilmaz, 2005). HA has hormone-like activity not only enhances plant growth and the nutrient uptake but also anti-stress effects under unfavorable temperature, salinity, and pH by reducing the negative effect of stress (Serenella *et al*., 2002; Kulikova *et al*., 2005; El-Hefny, 2010). Salama (2009) reported that soil application of humate led to alleviate the negative effects of salinity on tomato plants. Because of multiple roles of HA, it can greatly benefit plant growth (Knicker *et al.*, 1993; Tan 1998; Friedel and Scheller, 2002).

The present study was conducted therefore with the objectives to alleviate the deleterious impacts of salinity stress on the vegetative growth and flowering characters, the leaf chemical constituents and fruit yield of tomato plants, irrigated with saline water, by using soil application of NPK starter and humic acid.

Materials and Methods

To achieve the goal, an experiment was conducted at Agricultural Experiment Station, Hada-Alsham, King Abdulaziz University, Saudi Arabia, during the agronomic season of 2011/2012, under greenhouse irrigated with saline water. The experiment was comprised of 12 treatments; including the combinations of four NPK starter solutions and three humic acid rates.

Four NPK starter solutions (SS) similar in the concentration and differed 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- P_2O_5-K_2O, were used in this study. It was used as drench to the seedling root area one day after transplanting at rate 100 mL per plant.

Three concentrations of humic acid (HA) used in this study were; 0, 750 and 1500 mg L^{-1} used as a soil application. The applications were executed three times in 10, 25, and 40 days from transplanting. The HA was applied as drench to the plant root area at rate 0.25 l per plant. The control plants were treated with tap water.

Soil and Irrigation Water Analysis

Before the trial, some physical and chemical properties of the experimental soil up to 30 cm depth, and chemical properties of irrigation water were estimated according to the procedures by Page *et al.* (1982). Furthermore, EC of the soil was measured after 70 days from transplanting.

Experimental Layout

The experimental layout was split-plot system 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 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. Each sub-plot contained 16 plants. The average temperature and relative air humidity inside the greenhouse were 25±2.1°C and 74±2% through tomato growth stages, respectively.

Irrigation and Fertilization

The drip irrigation network consisted of lateral's GR of 16 mm in diameter, with emitters at 0.5 m distance, allocating two laterals for each row. The emitters had a discharge rate 4 l h^{-1}. Irrigation water was obtained from a local well. Irrigation frequency was every alternate day, to maintain soil moisture above 50% soil moisture 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), source of water soluble fertilizers in fertigation. The solutions were injected directly into the irrigation water using a venture injector at two doses weekly, starting the second week and continued till 14th week after transplanting (WAT). Other recommended agricultural practices were followed as commonly used in the commercial production of tomato.

Data Recorded

Vegetative growth and flowering traits: Five randomly chosen plants, in each sub-plot, were tagged and the following morphological characters were recorded; plant height (cm) and number of leaves per plant at 6, 8 and 10 WAT, as well as the number of leaves under first cluster (earliness) and number of flowers per cluster. After 10 WAT, these plants were uprooted to determine the root and shoot fresh weight (g) per plant.

Leaf Chemical Analysis

From the same plant sample taken to record the vegetative features, random samples of the youngest expanded mature leaves were collected, washed with distilled water, weighed, oven dried at 70°C until constant weight.

The dried leaf materials were grinded and homogenized, wet digested; using concentrated sulfuric acid and H_2O_2, then the contents of N, P and K were determined according to the methods described in Cottenie (1980).

Fruit Yield

Tomato fruits were harvested at 10 days intervals starting from 90 days after transplanting at the end of growing season to record the fruit yield per plant.

Statistical Analysis

All the data recorded during the study was subjected to the analysis of variance techniques by the MSTATC computer software program (Bricker, 1991). The revised LSD test at $P < 0.05$ was used to compare the differences among the means of the various treatment combinations.

Results

Soil and Irrigation Water Analysis

The soil was sandy clay-loam texture, slightly saline, weakly alkaline and very low in total nitrogen (TN), available P, exchangeable K and organic matter (OM) percentage. The pH of 7.8 was moderate for tomato production. This soil analysis indicated that the soil fertility status of experimental site was low. EC of soil in the root zone, after 10 WAT, was increased by about 50% by use of saline irrigation water. Furthermore, the results showed that the irrigation water was saline and had an EC value of 3.8 dS $m^{-1}$and contained Na=22.1, Mg=0.92, Ca=6.15, HCO_3=0.68, Cl=36.11 and SO_4=9.21 meq L^{-1} (Table 1).

Effects on Vegetative Growth

The comparisons among the four NPK starter solutions indicated clearly that, plant height of tomato plants significantly differed within all variant growth stages at 6, 8 and 10 weeks after transplanting. At all growth stages, tomato plants receiving SS_4 (1:4:1 NPK) recorded maximum plant height followed by plants receiving SS_2 (1:1:1 NPK). In case of the number of leaf character; at 6 and 8 WAT, tomato plants supplied with SS_4 (1:4:1 NPK) produced the highest number of leaves per plant (Fig. 1B). While, 10 WAT, number of leaves per plant of tomato receiving SS_2 (1:1:1 NPK) or SS_3 (1:2:1 NPK), or SS_4 (1:4:1 NPK) were not different significantly, but achieved the highest number of leaves per plant compared with control treatment. Root and shoot fresh weight (Fig. 1C and D), were recorded the heaviest for tomato plants receiving SS_3 (1:2:1 NPK) followed by plants receiving other treatments.

The root and shoot fresh weight (Fig. 1C and D) showed a significant increase with an increment of HA up to 1500 mg L^{-1} compared to control treatment. The influence of HA rates on plant height and the number of leaves per plant was significant and approximately similar in all growth stages of tomato plants i.e., at 6, 8 and 10 WAT (Fig. 1E and F). At any growth stage of tomato plants, increasing the HA level up to 1500 mg L^{-1} lead to a significant progressive increase in plant height and number of leaves per plant over control.

The interactive effect of the NPK starter solutions and humic acid rates on vegetative growth characters of tomato plants, were significant in all growth stages (Fig. 2A and H). At 6 and 8 WAT (Fig. 2A-D), tomato plants without any starter solutions, increasing soil application doses of HA, generally, caused an increase in the plant height and number of leaves, with an exception of SS_2 (1:1:1 NPK), Fig. 2 (A, D). Tomato plants with supply of SS_4 (1:4:1 NPK) + HA at 1500 mg L^{-1}, gave the highest mean values of previous characters. Whereas, at 10 WAT, the tomato plants receiving the SS_4 + HA at 1500 mg L^{-1} resulted in the tallest plants (Fig. 2E), while the highest number of leaf achieved with SS_3 + HA at 1500 mg L^{-1} (Fig. 2F). However, interactions of the starter solutions and HA rates had significant influences on the root and shoot fresh weight of tomato plants (Fig. 2G and H) showed that the. The combined application of SS_3 (1:2:1 NPK) + HA at 750 mg L^{-1} was the most beneficial treatment for increasing root and shoot fresh weight per plant.

Effects on Flowering Traits

Responses of flowering traits of tomato to the different soil application of the NPK starter solutions showed that there were some significant differences in the number of leaves below the first flower cluster (earliness) and number of flowers per cluster of tomato plants by soil application of starter solutions (Table 2). Tomato plants with application of SS_3 (1:2:1 NPK) recorded the highest number of flowers per cluster compared with control or other treatments.

The effect of humic acid on the flowering traits of tomato plants, under saline irrigation water, was significant (Table 2). Comparisons among different HA rates, clearly illustrated that, increasing HA rate up to 1500 mg L^{-1} improved the flowering of tomato plants under salinity stress, resulting in earlier flowering and increase the number of flowers per cluster, compared with control.

Interaction effect of NPK starter solution and humic acid rates on the flowering characters, was significant (Table 2). For tomato plants without any starter solutions, increasing dose of HA up to 1500 mg L^{-1}, generally decreased the number of leaves up to first flower cluster i.e., increased earliness of flowering and increased the number of flowers per cluster. Tomato plants receiving SS_3 (1:2:1 NPK) + 1500 mg L^{-1} of HA, gave the highest number of flowers per cluster.

Leaf Chemical Constituents

Leaf NPK contents, were significantly affected by starter solution. Leaf NK contents, significantly, increased in

Table 1: Soil physical and chemical properties of the experimental site

Soil Properties										
Sand %	Silt %	Clay %	Texture	EC* $dS\ m^{-1}$		pH	TN %	P $mg\ kg^{-1}$	K $mg\ kg^{-1}$	Organic matter %
				Before	After					
67.4	19.1	33.5	Sandy Clay- loam	2.1	3.2	7.8	0.036	7	16	0.22

*EC of the soil before the start of the experiment and after 10 WAT

Table 2: Effect of starter solutions and humic acid rates on the number of leaves up to first flower cluster (earliness) and number of flowers per cluster of tomato

Starter solutions (NPK)	Humic acid rates $mg\ l^{-1}$			Mean of SS
	0	750	1500	
Earliness				
SS_1(control)*	7.4bcd**	6.7e	7.0cde	7.0b
SS_2 (1:1:1)	7.3bcd	7.5bc	7.1b-e	7.3ab
SS_3(1:2:1)	7.6b	7.6b	6.9de	7.4ab
SS_4(1:4:1)	8.3a	7.2bcd	7.2b-e	7.5a
Mean of HA	7.7a	7.2b	7.0b	
Number of flowers per cluster				
SS_1(control)	4.3g	5.6abc	6.0ab	5.3b
SS_2(1:1:1)	4.9ef	5.4cd	5.8abc	5.4b
SS_3(1:2:1)	5.6bcd	5.7abc	6.1a	5.8a
SS_4(1:4:1)	4.4fg	5.1de	5.9abc	5.1b
Mean of HA	4.8c	5.5b	6.0a	

*Starter solutions; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 $mg\ l^{-1}$ of N- P_2O_5-K_2O

**Values having the same alphabetical letter in common do not significantly differ at $P<0.05$

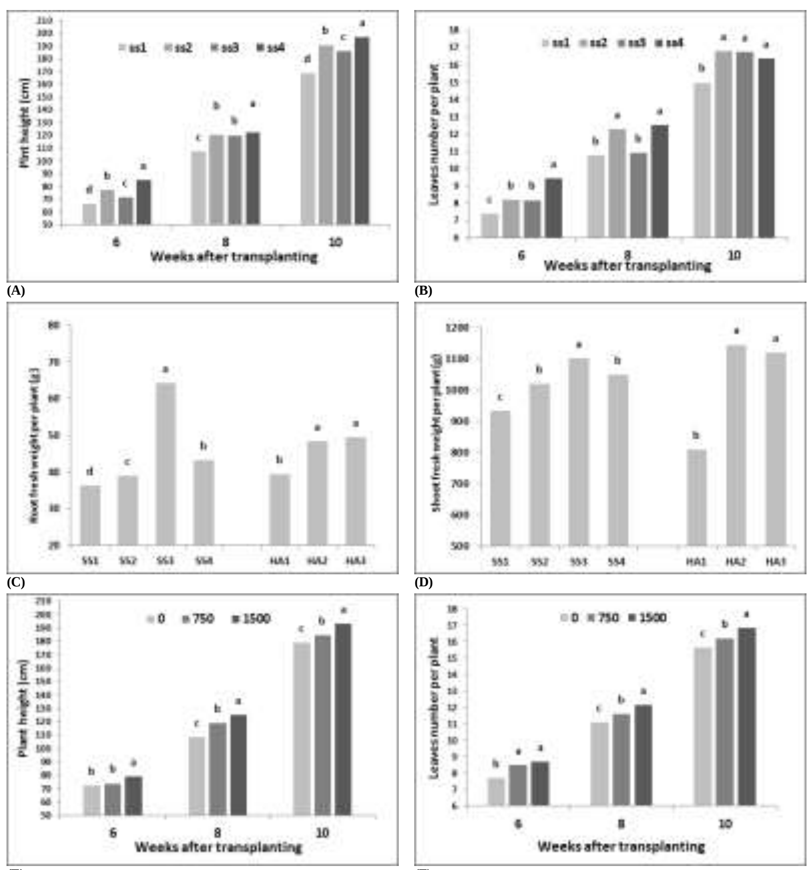


Fig. 1: Effect of starter solutions and humic acid rates on plant height (A, E) and the number of leaves per plant (B and F) at 6, 8 and 10 WAT, orderly, as well as root and shoot fresh weight (C, D) of tomato cv. '*leen*'

Starter solutions; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 $mg\ l^{-1}$ of N- P_2O_5-K_2O, Humic acid rates; control, 750 and 1500 $mg\ l^{-1}$

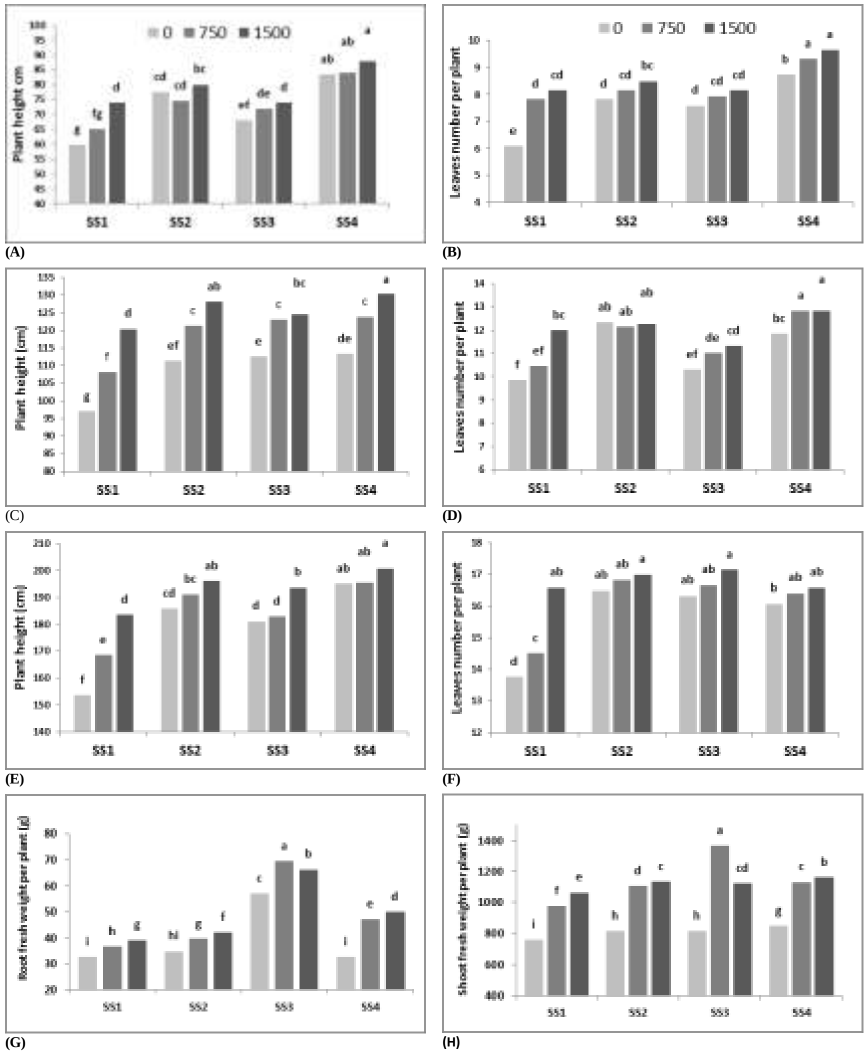


Fig. 2: The interaction effects of starter solutions and humic acid rates on the plant height at 6, 8 and 10 WAT(A, C, E), and number of leaves at 6, 8 and 10 WAT (B, D and F), as well as root and shoot fresh weight per plant(G, H) of tomato cv. '*Leen*'

Starter solutions; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg l^{-1} of N- P_2O_5-K_2O, Humic acid rates; control, 750 and 1500 mg l^{-1}

tomato plants receiving SS_3 (1:2:1 NPK) compared to control. Leaf P contents, also, were significantly higher in the tomato plants with SS_4 (1:4:1 NPK) than other treatments. However, tomato plants in control treatment were suffering from the inhibitory effect of salinity stress on the leaf NPK contents and recorded the lowest values; this might be due to the least amount of available nutrients and low absorption of elements.

The comparisons among the three humic acid treatments, within each of the HA treatments, leaf N, P and K contents were significantly higher with soil application of HA up to 1500 mg L^{-1} (Table 3). However, leaf K content was not significantly affected by soil application of HA at 750 and 1500 mg L^{-1}.

The comparisons among the various combined treatments, showed some significant interactive effect between NPK starter solution and humic acid treatments on leaf NPK contents. The soil application of SS_3 (1:2:1 NPK) with HA at 1500 or 750 mg L^{-1} seems the best treatment combination for the contents of N K in the tomato leaves, orderly. However, tomato plants receiving SS_4 (1:4:1 NPK) + HA at 1500 mg L^{-1} had the highest leaf P content.

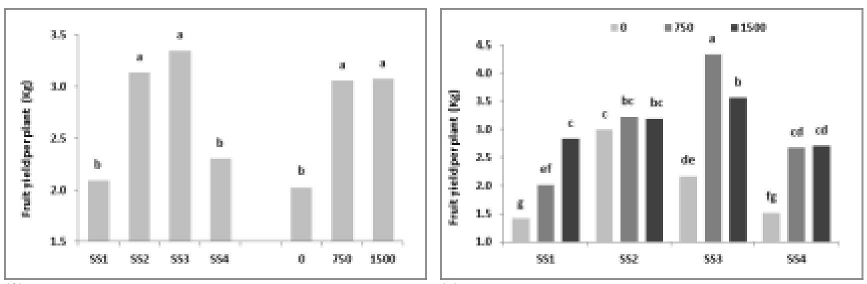
Fruit Yield

NPK starter solutions had a significant effect on the fruit yield of tomato plants (Fig. 3A). Tomato plants with supply of SS_2 (1:1:1 NPK) and SS_3 (1:2:1 NPK) achieved

Table 3: Effect of starter solutions and humic acid rates on the percentages of N, P and K contents in the leaves of tomato

Starter solutions (NPK)	Humic acid rates mg l^{-1}	N (%)	P (%)	K (%)
SS_1 (control)*		1.14b**	0.85c	2.52b
SS_2 (1:1:1)		1.25b	1.01b	2.76a
SS_3 (1:2:1)		1.49a	1.01b	2.89a
SS_4 (1:4:1)		1.46a	1.17a	2.62b
	0	1.17c	1.00b	2.48b
	750	1.33b	0.96b	2.75a
	1500	1.51a	1.06a	2.85a
SS_1 (control)	0	1.19c-f	0.91de	2.44e
	750	0.97f	0.84ef	2.51de
	1500	1.27cde	0.78f	2.60de
SS_2 (1:1:1)	0	1.10def	1.35b	2.60de
	750	1.08def	0.86ef	2.72cd
	1500	1.56ab	0.83ef	2.97ab
SS_3 (1:2:1)	0	1.03ef	0.89de	2.72cd
	750	1.82a	0.96d	2.95ab
	1500	1.62ab	1.19c	3.03a
SS_4 (1:4:1)	0	1.35bcd	0.87e	2.18f
	750	1.44bc	1.20c	2.85abc
	1500	1.60ab	1.45a	2.81bc

*Starter solutions; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg l^{-1} of N- P_2O_5-K_2O
**Values having the same alphabetical letter in common do not significantly differ at P<0.05



(A) (B)

Fig. 3: Effect of starter solutions and humic acid rates on fruit yield per plant of tomato cv. '*leen*'
Starter solutions; SS_1: control, SS_2: 200-200-200, SS_3: 150-300-150 and SS_4: 100-400-100 mg L^{-1} of N- P_2O_5-K_2O, Humic acid rates; control, 750 and 1500 mg L^{-1}

significantly higher fruit yield per plant with an increase of 50 and 60.1%, respectively, over the tomato plants irrigated with saline water.

Results showed that HA could increase the yield of tomato plants irrigated with saline water. Increasing rate of HA up to 1500 mg L^{-1} led to significantly increase the fruit yield per plant by 34.6% over the control treatment (Fig. 3A).

Concerning the interaction effect on the fruit yield of tomato plant, differed significantly (Fig. 3B). For tomato plants without any starter solutions, increasing doses of HA up to 1500 mg L^{-1} increased the fruit yield per plant. While, tomato plants, receiving SS3 (1:2:1 NPK) + 750 mg L^{-1} of HA, gave the highest fruit yield (202.8%), over control treatment.

Discussion

If the strong roots are formed in early growth stage of plant tolerant the effect of salinity, which piling with continued irrigation with saline water (Shibli, 1993). This clearly appeared from EC analysis of the soil before the start of the experiment and after 10 WAT (Table 1). The salinity suppresses the phosphorus (P) uptake by plant roots and reduces the available P (Grattan and Grieve, 1999), causing reduction in the root growth and slow growth of plants. This research proposed to promote rapid early growth (especially root system). Using the NPK starter solutions; rich in P and humic acid (HA); which contribute to increase the root volume and availability and uptake of P is one of the physiological mechanisms to avoid deleterious effect of saline water.

The results indicated that starter solution and humic acid as well their interactions, appeared to have a clear effect on the vegetative growth, flowering, leaves mineral contents and fruit yield of tomato (*Leen* cv.).

The vegetative growth, flowering, leaf mineral contents and fruit yield of tomato increased significantly and successively as the P concentration in starter solutions was increased. SS_4 (1:4:1 NPK) recorded significantly maximum tomato plant height, at 6, 8 and 10 WAT, and leaf number, at 6 and 8 WAT, as well as leaf P content. While, tomato plants receiving SS_3 (1:2:1 NPK) recorded the heaviest root and shoot fresh weight and the highest number of flowers per cluster, leaf NK contents and fruit yield. Moreover, tomato plants receiving starter solutions were late in flowering. This can be explained based on starter solutions rich in P used as a drench to the seedling root area after transplanting accelerated root development and increasing the plant's ability to absorb more nutrients from the soil that could encourage the vegetative growth, accelerate the photosynthetic rate, increasing the meristematic activity and building protein molecules (Marschner, 1995). Moreover, starter solutions were able to modify the behavior of tomato plants through increases that clearly noted in previous studied characters with the use of saline water in the irrigation, and avoid the injurious effects of the salinity that clearly appeared on control plants (Mohammad *et al.,* 1998; Ma *et al.,* 2005). Asian vegetable research and development center (AVRDC) reports (1999-2004) indicated that one of the effects of the starter fertilizer was to accelerate root development, hence increasing the plant's capacity to absorb more nutrients from the soil. Ma and Kalb (2006) stated that starter solution effect on plant growth was extremely significant and mostly occurred between one and seven weeks after transplanting, but was not significant at 8 and 9 weeks after transplanting, as clear for leaf number character at 10 WAT (Fig. 1B). Similarly, Stone (1998, 2000) showed that good response to the establishment and early growth in some vegetable crops with soil application of starter fertilizer.

Effects of HA rates on the vegetative growth, flowering, leaf mineral contents and fruit yield of tomato indicated that increasing HA rate up to 1500 mg L^{-1} improved all these traits of tomato under salinity stress compared to control. This can be explained based on fact that HA has hormone-like activity not only enhances plant growth and the nutrient uptake but also anti-stress effects under abiotic stress conditions; unfavorable temperature, salinity, and pH by ameliorating the adverse effect of stress (Serenella *et al.,* 2002; Kulikova *et al.,* 2005; El-Hefny, 2010). HA increasing plant growth enormously due to increase cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus uptake, and supplying root cell growth (Russo and Berlyn, 1990). Salama (2009) reported that soil application of humate led to alleviate the negative effects of salinity on tomato plants. Soil application of HA led to an increase phosphate uptake, root elongation and whole plant (Bohme and Lue, 1997; Liu *et al.,* 1998; Nardi *et al.,* 1996).

The interaction effect between SS and HA showed that tomato plants receiving SS_4 (1:4:1 NPK) + HA at 1500 mg L^{-1} had the highest mean values of the vegetative growth, earliness the flowering, and increase the number of flowers per cluster. Highest root and shoot fresh weight, flower number per cluster, leaf N content and fruit yield, were achieved with SS_3 (1:2:1 NPK) + HA at 750 mg L^{-1}. This interaction effect of the two studied factors was attributed to that SS + HA remain concentrated near the point of application, thus help in improved nutrient availability in the root zone and avoiding the deleterious effects of salt water. Ma and Kalb (2006) also found that effects of starter solution combined with organic fertilizers were generally more obvious than an application with inorganic basal fertilizers. The studies of AVRDC (1999-2004) indicated that starter solutions might promote an increased uptake of nutrients from organic fertilizers.

In conclusion, the combined soil application of SS_3 (1:2:1 NPK) with humic acid at 750 or 1500 mg l^1 is the most efficient combination treatment, which gave the best results to alleviate the deleterious impact of salinity stress on the vegetative growth, flowering characters, leaf chemical constituents and fruit yield of tomato plants irrigated with saline water.

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