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Impact of potassium humate and silicate on alleviation of salt stress in tomato plants

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Abstract—This study was carried out in the Experimental Farm, Faculty of Agriculture, South Valley University, Qena Governorate, Egypt during the two seasons of 2017-2018 to evaluate the effect of potassium humate and potassium silicate either alone or combined on growth and yield of tomato plants under salinity stress. Watering tomato plants with saline water i.e. 0.3, 5.5 and 9.2 $dS.cm^{-1}$ significantly decreased plant height by 34.2 %, stem diameter by 8.9 %, fruit volume by 49.17 % and total fruits yield by 71.5%. Chlorophyll content of leaves significantly increased in response to salinity levels in both seasons. Seedlings root dipping and foliar spraying of potassium humate and potassium silicate did not have a potent effect on vegetative growth. Tomato plants treated with potassium humate as root dipping (300 mg L^{-1}) and foliar spray with mixture of potassium humate and potassium silicate at rate of 250 mg L^{-1} for both of them during growing season increased total fruits yield under salt stress.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important and widely cultivated vegetable crops in the world which was introduced to the Middle East around the end of the 18th century. Tomato is now by far the largest vegetable crop in Egypt, with an area of 475,505 Feddan, with an average production of 7.9 million tons. Egypt ranked 5th in the world tomatoes production in 2016 (FAOSTAT, 2018).

It has been perceived that saline water is constraining of growth, development and productivity of tomato plants. Notwithstanding, the continuous increase in food demands and the parallel decrease in freshwater resources focus the attention on the possibility of using saline water for irrigation purposes. Salinity is one of the abiotic stresses limiting growth and productivity of several agricultural crops especially in arid and semiarid areas. Under the scarcity of water supplies and the tendency to use groundwater with high salinity levels that expose plants to salt stress and had a negative effect on vegetative growth, some of these plants can tolerate these stresses in different ways depending upon plant species and level of salt stress **(Rhoades, 1992; Shahbaz *et al.*, 2012)**. Tomato is moderately sensitive to salinity **(Maas and Hoffman, 1977)**. Many studies reported that tomato plants exposed to high concentrations of salt in their root zone caused the reduction of growth **(Albacete *et al.*, 2008; Pérez-Alfocea *et al.*, 2010)**. Humic acid and Silicon might play a role as bio-stimulant substances which were used to alleviate a biotic stress resulting in ~~reduce~~ reduction of metal toxicity, uptake of water and improvement of nutrient imbalance **(Canellas *et al.*, 2015; Etesami and Jeong, 2018)**. Therefore, the aim of this study to investigate the influences of potassium humate and potassium silicate either alone or combined on vegetative growth of tomato plants, and its role in alleviating salt stress.

MATERIALS AND METHODS

This study was carried out in the net house at the Experimental Farm, Faculty of Agriculture, South Valley University, Qena Governorate, Egypt, (Latitude 26° 11' 22.2" N to Longitude 32° 44' 25.5" E), and 81 m above sea level, during successive two winter seasons of 2016 and 2017.

Plant material and growing conditions:

Seeds of tomato (*Solanumly copersicum L*.), cv. ‘El Otts (E448) F_1 Hybrid (Imported from Netherlands by Syngenta company, Egypt.), were sown in Styrofoam trays (209 cells) filled with sowing medium peat moss and vermiculite (1:1). One seed was place in one cell and covered with sowing medium in nursery 20th August during the two seasons and then transplanted in the 1st week of October~~,~~ in both seasons. Tomato seedlings were transplanted into plots 15 m^2 (=1/280 of feddan) in randomized complete block design. Three plots were assigned for each treatment and each plot had thirty plants having inter row spacing of 1 m, and inter plant spacing of 50 cm. The physical and chemical analyses of the soil used in this study are presented in Table 1 and the water analysis of experimental irrigation sources is listed in Table 2.

Table 1. The Physical and chemical properties of the soil.

Physical Properties:			
Sand%		74.72	
Silt%		14.4	
Clay%		10.88	
Texture		Sandy loam	
Chemical Properties:			
EC $dS.m^{-1}$		2.02	
pH		8.00	
Soluble cation ($meq.l^{-1}$)			
Na^+	Ca^{++}	Mg^+	K^+
29.1	3.00	3.00	0.5
Soluble anion ($meq.l^{-1}$)		Hco_3^-	11.2
		Cl^-	12

Table 2. Water analysis of the irrigation sources.

Sources	Fresh water	Well 1	Well 2
EC $dS.m^{-1}$	0.3	5.5	9.2
pH	7.15	8.9	8.98
Cations ($meq.l^{-1}$):			
Na^+	0.95	39.8	57.6
Ca^{++}	0.65	5	6
Mg^+	0.62	9	17
K^+	0.15	0.59	0.97
Anions ($meq.l^{-1}$):			
Hco_3^{--}	3	3.62	5.43
Cl^-	1.5	32	51.54
SO_4^-	1.06	18.79	24.68

Treatments were as follow:
Control (freshwater 0.3 $dS.m^{-1}$), and two saline groundwater wells (5.5 and 9.2$dS.m^{-1}$) were used. In this study drip irrigation system was used for watering plants. Root dipping treatments: The ball roots of tomato seedling were dipped immediately before for 10 mints in distilled water (control) (D-DW), potassium humate (Pow-humus WSG-85 71.5% humic acid, Humintech, Germany) (D-HA) , and Potassium silicate (SiO_2 23.27%, Lobachemie, India) (D-Si).The rates used in this study were 300 mg l^{-1} for both treatments. Foliar spray treatments: distilled water (F-DW), potassium humate (F-HA), potassium silicate (F-Si) and a mixture of both (F-Mix) were applied to plants as foliar spray for four times at 20, 40, 60 and 80 days after transplanting. The rates of application used were 250 mg l^{-1}, for individual treatment, and for the mixture.

Experimental design: The experiment was designed as spilt-split plot with three replicates. The salinity treatments occupied the main plots which subsequently subdivided into 3 sub plots, each contained one of the dipping treatments, while foliar spray treatments were assigned to the sub-sub plots.

Measurements:
In the net plot area, five plants were randomly taken from each different treatment to measure the following parameters.

Plant height (cm): It was measured as the distance between the soil surface and the tip of the plants.

Stem diameter: It was measured with digital caliper in area separated between the stem and the root and expressed in millimeters (mm).

Chlorophyll content: The chlorophyll content was determined by chlorophyll Meter (Minolta SPAD-502 meter, Tokyo, Japan). in several areas (or leaflets) of the sixth leaflet (do you mean leaf?). The values were averaged as SPAD

Fruit volume : The length and diameter of tomato fruits were measured with digital caliper and the fruit volume was calculated according to **(Mutschler *et al.*, 1986)** by formula as follow: Fruit Volume (cm^3) = (1/6) x (height) x $(diameter)^2$.

Total fruits yield fed. $^{-1}$: The total fruit yield $fed.^{-1}$ was calculated, by adding total weights of fruit yield $plot^{-1}$ or per plot from four harvests and expressed, in ton $fed.^{-1}$.

Statistical Analysis:
All obtained data were statistically analyzed with the technique of analysis of variance (ANOVA) by using "SAS" computer software package SAS 9.1 program software, **(SAS, 2004)**. Least Significant ~~of~~ Difference (LSD) method was used to test the differences between treatment means at 5 % level of probability as described by **(Gomez and Gomez, 1984)**.

RESULTS AND DISCUSSION

Effect of saline water irrigation

Data presented in (Table 3) show the response of plant height, stem diameter and chlorophyll content of tomato E448 hybrid to different saline water irrigation levels, root dipping and foliar spray with bio-stimulants in winter seasons of 2016/2017 and 2017/2018. Concerning the effect of saline water irrigation levels (0.3, 5.5 and 9.2 $ds.m^{-1}$), data clearly show that plant height was gradually and significantly decreased with increasing salinity level from 0.3 to 9.2 $dS.m^{-1}$. Under normal irrigation (favorable conditions), the mean value was 119.82 and 119.79 cm, while under saline water irrigation (unfavorable conditions) was 100.15 to 99.98 cm and 79.17 to 78.82cm for the first and second wells respectively. These results indicated that salt stress significantly reduced plant height by 33.9 and 34.2 % under higher salinity level in the first and the second seasons, respectively. The stem diameter increased significantly with saline water (5.5d $S.m^{-1}$),from 8.83 to 8.90 mm. while, watering tomato plants with 9.2 $dS.m^{-1}$decreased stem diameter by 10 and 8.9 %, as compared with control (0.3$dS.m^{-1}$), in both seasons, respectively. As for chlorophyll content of leaves at 45 days after transplanting, results showed significant increase with increasing salinity level. When tomato plants watered with saline water 9.2 $dS.m^{-1}$, the chlorophyll content was increased (62.27 and 62.06), in both seasons, respectively. While the lowest values were recorded (56.43 and 56.26) unit of SPAD, with control treatment 0.3 $dS.m^{-1}$, in both seasons, respectively. It is clear that values of fruit volume gradually and significantly decreased with increasing salinity level from 0.3 to 9.2 $dS.m^{-1}$. The yields under different saline water irrigation varied from (29.082- 28.947 ton $fed.^{-1}$) for freshwater, (13.770 - 13.722 ton fed^{-1}) for 5.5 $dS.m^{-1}$, to (8.276- 8.285 ton fed. $^{-1}$) for 9.2 $dS.m^{-1}$, in both seasons respectively. Reducing plant height and other vegetative growth characters may be due to that salinity stress increases the osmotic pressure of soil solution, which prevents the absorption of water and nutrients by plants root. Also, ion toxicities when excessive amounts of salt enter the plant will cause injury to cells in the transpiring leaves **(Shabala and Munns, 2017)**. In addition, the changes of phytohormone concentrations in tomato plants which affect cells division and enlargement under salt stress, may indirectly reflect negative effects on yield **(Albacete *et al.*, 2008; Pérez-Alfocea *et al.*, 2010)**. Stem diameter increases as a result of increment in stem cortex thickness, because of cortical cells which become higher in size and number **(Al-Tardeh and Iraki, 2013)**, . Also this may be due to the ~~also~~ increment in the number of lignified xylem cells which leaves **(Sánchez-Aguayo *et al.*, 2004)**.. Increasing salinity levels exhibited more green leaves (chlorophyll content) as compared with non-saline conditions. **(Romero-Aranda *et al.*, 2001)** suggested that the effect of salinity on leaf area expansion is more obvious than on the structural components of the leaf. Additionally, the partly offset salinity stress effect on plant appears in thicker leaves with a higher number of cells per unit area, as well as decreased cell size in plant leaves and increased the total leaf pigments (total chlorophyll and carotenoid). The obtained results were in full agreement with those obtained by **(Babu *et al.*, 2012; Malash *et al.*, 2012; Moniruzzaman *et al.*, 2013; Shalaby *et al.*, 2015; Nandhitha *et al.*, 2018)**. For the reduction of plant height of tomato plants, similar findings were reported by **(Foolad, 2004; Chookhampaeng *et al.*, 2008; Hajiaghaei-Kamrani *et al.*, 2013; Rashwan and Abo-Baker, 2016)**. These investigators, also, found that increasing of salinity levels increased stem diameter of plants, as compared with control treatments. Regarding of chlorophyll content on in tomato leaves, the results are in harmony with those of **(Siddiky *et al.*, 2012; Hajiaghaei-Kamrani *et al.*, 2013; Zhang *et al.*, 2017; Jiang *et al.*, 2017)**.

Effect of seedlings root dipping in bio-stimulants

Data in (**Error! Reference source not found.**) show that the seedlings root dipping in bio-stimulants-had no positive stimulation on plant height. The plants height was reduced by 3.02% and 1.78% for silicate and humate applications, respectively, as compared with control treatment, in both seasons. , meanwhile the stem diameter increased significantly by root dipping application. The highest value of stem diameter was obtained from dipping in humic acid .On the contrary, the chlorophyll content decreased slightly by dipping root applications. It is evident that the volume of tomato fruit increased with followed by (D-HA) in both seasons. However, the root dipping in bio-stimulants had no positive influence on the total fruits yield per fed. The lowest values for tomato fruit yield and its components were recorded in (D-Si), in both growing seasons. The negative effect of dipping root in silicate (Si) and humate (HA) on vegetative growth, could be explained based on the higher concentration of silicon decreased leaf net photosynthetic rates slightly, and didn't have a positive role in increasing growth .On the contrary, the lower level of Si had significantly increased the plant height and photosynthetic pigments **(Cao *et al.*, 2013)**. While, humic acid have auxin-like hormone effect; thus, at high doses, It may reduce the plant growth **(Baldotto and Baldotto, 2014)**. Tomato plant length was reduced with applying high doses of humic acid to root medium according to **(Loffredo *et al.*, 1997; Dursun *et al.*, 2002)**. Similar stem diameter results were reported by **(Osman and Ewees, 2008; Kamal and El-Shazly, 2013)**.

Effect of foliar application with bio-stimulants**.**

Data presented in (Table 3) show clearly that, foliar spray with bio-stimulants had significantly decreased all vegetative growth characters except for foliar spray of a mixture of HA and Si that was recorded an increment, in stem diameter by 10 -10.33 % in both seasons, respectively. The lowest values for plant height and stem diameter were observed in plants treated with silicate as a foliar spray (F-Si). The shortest plants were 94.71 and 94.26 cm, and the lowest stem diameters were 7.96 and 8.01, in both seasons, respectively. Meanwhile, the lowest chlorophyll content recorded with spraying humic acid (F-HA) 58.2 and 58.07 SPAD unit in both seasons respectively. The fruit volume increased with (F-Mix) application as compared with spraying with distilled water (control). In the total fruits yield fed.$^{-1}$, F-Mix recorded increment by (0.738 to 0.615 ton fed. $^{-1}$) as compared with F-DW in both seasons, respectively. The other foliar applications reduced total fruits yield per fed., in both seasons. The negative impact of Si as a foliar spray on tomato growth, may be attributed to decreased transpiration and leaf net photosynthetic rates **(Cao *et al.*, 2013)**. The reduction of chlorophyll of tomato plants that treated with humic acid may suggest decreasing the accumulation of N. Also, The positive effect of such materials might be more effective when application to soil than by foliar application **(Lee and Bartlett, 1976; Khaled and Fawy, 2011)** and may the high doses decreased Chlorophyll content ~~on~~ in tomato leaves **(Liu *et al.*, 2016)**.

Effect of the interactions among treatments:

Interaction between saline water irrigation and dipping root withbiostimulants.

The effect of interaction of saline water irrigation with root dipping on growth characters and chlorophyll content of tomato plants is presented in (Table 4). The interaction had a significant effect on plant height, in both seasons. The tallest plants (121.71 and 121.67cm) were recorded in the control in non-stress conditions. While, the shortest plants were (75.21 and 75.02 cm) in root dipping in silicate (D-Si) under saline water irrigation 9.2 $dS.m^{-1}$ in both seasons respectively. As for stem dimeter, results indicated that significant differences were observed in root dipping in bio-stimulants The highest value of stem dimeter was obtained from treated plants with distilled water (D-DW), followed by dipping root in humate (D-HA)~~,~~ both under saline water 5.5 $dS.m^{-1}$.~~,~~ the lowest value was recorded in (D-DW) under saline water irrigation 9.2 $dS.m^{-1}$~~,~~ in both seasons.

It is clear from data in (Table 4) that chlorophyll content of tomato leaves shows the highest value obtained from D-Si under the saline water 9.2 $dS.m^{-1}$~~.~~ While the lowest value was recorded in D-Si under the freshwater, in both seasons respectively.

Remarkably, alleviating harmful effect of salinity increased the plant height and stem diameter with the application of humic acid. This finding further support the results of **(Shafshak *et al.*, 2008)** on tomato plant height, **(Paksoy *et al.*, 2010)** on okra, for stem diameter. It's evident from data the higher volume of fruit resulted from combination between (D-Si and freshwater 0.3 $dS.m^{-1}$).The lowest values of fruit volume was resulted from only saline water 9.2 $dS.m^{-1}$~~,~~ in both seasons. Furthermore, under saline water (5.5 $dS.m^{-1}$) the fruit volume was increased when plants treated with (D-HA) as compared with (D-DW) in both growing seasons. Similar results were reported by **(Liang *et al.*, 2015; Weerahewa and David, 2015)** who applied Si to root in nutrient solution or in field trail where it increased tomato fruit size. But the reduction occurred may reflect the negative effect of interaction between high salinity and root dipping in Si on growth characters in the current study. Regarding the total fruits yield, the highest value was recorded in D-Si (30.204 and 30.113 ton $fed.^{-1}$) followed by D-HA under the freshwater (0.3 $dS.m^{-1}$) compared with D-DW (28.233 and 27.953 ton $fed.^{-1}$). In contrast, the lowest fruit yield (7.736 and 7.740 ton $fed.^{-1}$) was recorded with D-Si under the saline water (9.2 $dS.m^{-1}$) in both seasons, respectively.

Interaction between saline water irrigation and foliar spray with bio-stimulants.

The effects of interactions between saline water irrigation and foliar application of bio-stimulants on vegetative growth of tomato plants are shown in (Table 5). Results show that the plant height was significantly decreased by all interactions of saline and foliar treatments compared with control treatment. Spraying plants with (F-Si) under saline water 9.2dS.m^{-1} gave the shortest plants, and the values were 76.78 and 76.26 cm, in both seasons, respectively. On the other hand, spraying plants with (F-HA) recorded the best values, as compared with control treatment (F-DW), under saline water 5.5dS.m^{-1}, in both seasons. Stem diameter was significantly increased, to the highest values (9.92 and 10.02) when (F-mix) interacted with saline irrigation water 5.5dS.m^{-1}, in both seasons followed by freshwater 0.3dS.m^{-1}. On the other hand, the lowest value obtained when plants treated with (F-Si) under the highest salinity levels 9.2 dS.m^{-1}. As for chlorophyll content of leaves it is clear from data in (Table 5) that the highest chlorophyll content resulted from (F-Mix.) and watering with saline water 9.2 dS.m^{-1}) in both seasons. However, it is worth mentioning that the lowest values of chlorophyll contents were obtained when (F-HA) interacted with freshwater, in both seasons. Application of Si as a foliar spraying, which occurred especially under salinity stress, could be explained based on their role in decreasing transpiration rate, and osmotic pressure increased as a result from salt stress, theses could lead to decline water and nutrient uptakes **(Cao *et al.*, 2013; Shabala and Munns, 2017)**. Increasing of stem diameter with spraying of (F-Mix) under 5.5 dS.m^{-1} saline water may have resulted from salt effects on increasing the thickness of stem cortex. Furthermore, application mixture of silicate and humic acid increased the strength of cell walls, by enhancing various processes into plants tissues viz., suberization, lignification, and silicification **(Goodwin, 2009; Al-Tardeh and Iraki, 2013; Guerriero *et al.*, 2016)**. Data presented in (Table 5) show that, tomato fruit diameter, volume and pH values were increased significantly with application of (F-Mix.) under salt stress and non-stress conditions in both growth seasons. The highest values of fruit diameter and volume resulted from (F-Mix) and fresh water (0.3 dS.m^{-1}) the high highest pH value was obtained from the interaction between (F-HA) and freshwater (0.3 dS.m^{-1}in both seasons. the lower values of fruit diameter, volume and pH were recorded with the combination of (F-Si) and saline water (9.2 dS.m^{-1}) in both seasons, respectively. The total fruit yield per fed. was increased with F-Mix application under favorable and unfavorable conditions. The best yield was recorded with F-Mix under freshwater 0.3 dS.m^{-1} (32.400 and 32.247 ton fed.$^{-1}$. Meanwhile, the lowest values (6.801 and 6.766 ton fed.$^{-1}$) were obtained with F-Si and watering with saline water 9.2 dS.m^{-1}, in both seasons respectively. The positive effect of the mixture Silica-humic in increasing tomato yields under all salinity conditions has been noticed. This mixture recorded the best fruit yield. It may be due to, the chelating of the silicon by humic acid, gave a greater chance to accumulate Si in tomato, which greatly benefited from the positive effect of both materials, in alleviate stress and increasing the productivity of plants **(Mccormack, 1971; Goodwin, 2009; Matichenkov, 2010)**.The reduction noticed in the treatment F-Si and saline water (9.2 dS.m^{-1}) may be due to, the effects of salt stress and accumulation of Si in tomato plants **(Ma and Yamaji, 2006; Pérez-Alfocea *et al.*, 2010)**. Also, this reduction may be a result of depressed plant growth with applied foliar Si under high saline water which observed in current study. This result on tomato is fully consistent with **(Jerry and Abbas, 2018)**. Si applied to foliage is unlikely to be effective in either increasing Si status of plants or their tolerance to biotic/abiotic stresses **(Haynes, 2017)**.

Interaction between bio-stimulants root dipping and foliar spray.

The effect of interaction of root dipping with foliar application of bio-stimulants on plant vegetative growth parameters of tomato plants is presented in (Table 6). The interaction had a negative significant effect on plant height, in both seasons. However, the results indicated that plants treated with potassium humate as dipping with spraying potassium silicate gave the shortest plants, in both seasons. In connection with stem diameter of tomato plants, data show that, the highest value of stem diameter recorded with (D-HA and F-Mix). On the other hand, the lowest results obtained from (D-HA and F-HA), in both seasons. Also, the results show showed that the chlorophyll content recorded the highest values with control (D-DW and F-DW). The highest fruit volumes (37.62 and 38.38cm3) were resulted from the combination between (D-Si and F-Mix) in both seasons respectively. While, the lowest fruit volume (31.57and 32.25 cm^3) were resulted from the control treatment in both seasons, respectively. Regarding the total fruits yields, the highest values (19.603 - 19.496 ton fed.-1) were recorded with the combination of (D-DW and F-Mix.) while, the lowest values (14.490-14.463 ton $fed.^{-1}$) were obtained from (D-Si and F-HA) in both seasons, respectively.

Interaction effect among saline water irrigation, root dipping and foliar spray with bio-stimulant

As for interaction effect of the three studied factors, data presented in (Table 7) reveal that plant height, stem diameter and chlorophyll content were significantly influenced by the interactions, in both seasons. Plants treated with D-DW, F-Mix., and watering with freshwater, gave values (127.83 and 127.63 cm), of plant height trait, in both seasons., while, plants treated with D-Si, F-Si and watering with saline water 9.2 $dS.m^{-1}$ gave the lowest values (72.67 and 72.67 cm), in both seasons, respectively. Furthermore, under saline water 5.5 $dS.m^{-1}$, the highest plant resulted from the (D-HA and F-HA), in both seasons. Also, results indicated that plants were treated with D-HA, F-Mix., and watering with saline water 5.5 $dS.m^{-1}$, gave the highest values for stem diameter. While applications of D-DW, F-DW and irrigation with saline water 9.2$dS.m^{-1}$, gave the lowest values, in both seasons. Additionally, the higher chlorophyll content was obtained from the combined of (D-DW and F-DW, followed by D-DW and F-Si with non-significant, both under the saline water 5.5$dS.m^{-1}$) while lower chlorophyll content was recorded in (D-Si & F-HA under freshwater), in both seasons, respectively. Tomato fruit volume had significant differences between treatments under all salinity levels. The highest fruit volume (53.22 and 54.18 cm^3) recorded from the combination of (D-Si & and F-HA under freshwater 0.3 $dS.m^{-1}$) in both seasons respectively. While, the lowest fruit volume (21.84 and 22.37 cm^3) were obtained from the combination of (D-Si and F-Si under saline water 9.2 $dS.m^{-1}$) in both seasons respectively–followed by (D-DW & and

F-DW under saline water 9.2 dS.m^{-1}) with non-significant between them in both seasons. Under salinity stress conditions, the highest fruit volume resulted from the (D-HA and F-Mix. under saline 5.5 dS.m^{-1}) and (D- Si and F-Mix. under saline 9.2 dS.m^{-1}) in both seasons, respectively. The highest total fruits yield (33.813 - 33.640 ton fed.$^{-1}$) were obtained from the interaction of (D-DW and F-Mix. under freshwater 0.3 dS.m^{-1}) followed by (33.553- 33.530 ton fed.$^{-1}$), from the interaction of (D-Si and F-Mix. under freshwater 0.3 dS.m^{-1}). Meanwhile, lower total fruits yield (6.117 - 6.137 ton fed.$^{-1}$) recorded with the interaction of (D-Si and F-Si under saline water 9.2 dS.m^{-1}) in both seasons, respectively.

CONCLUSION

High salt concentration in irrigation water led to significant decrease in tomato growth and fruit yield. On the contrary, chlorophyll content of leaves significantly increased in response to salinity levels in both studied seasons. Besides, silicate applied individually under salinity stress led to the lowest values of plant height and stem diameter and recorded the highest value of chlorophyll content the best interaction of treatments indicated that plants watering plants with saline waters and treated with potassium humate as dipping seedlings root (300 mg L^{-1}) and foliar spray with mixture of potassium humate and potassium silicate (both at rate 250 mg L^{-1}), increased total fruits yield under salt stress

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Table 3.Tomato growth and fruit yield as affected by root dipping and foliar application of bio-stimulant under different saline irrigation waters, during 2016/2017 and 2017/2018 seasons.

Treatments	Plant height (cm)		Stem diameter (mm)		Chlorophyll content (SPAD unit)		Fruit volume (cm^3)		Total fruits yield (ton) $fed.^{-1}$	
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
					Saline water (Factor A)					
0.3 $dS.m^{-1}$	119.82	119.79	8.60	8.58	56.43	56.26	47.94	48.84	29.082	28.947
5.5 $dS.m^{-1}$	100.15	99.98	8.83	8.90	60.16	60.05	31.66	32.34	13.770	13.722
9.2 $dS.m^{-1}$	79.17	78.82	7.74	7.82	62.27	62.06	24.31	24.88	8.276	8.285
L.S.D $_{0.05}$	0.499	0.511	0.092	0.151	0.225	0.412	0.72	0.71	0.20	0.34
					Dipping root (Factor B)					
D-DW	101.33	101.15	8.31	8.36	60.00	59.84	34.03	34.74	17.412	17.272
D-Si	98.31	98.05	8.38	8.42	59.19	59.02	35.13	35.86	16.707	16.692
D-HA	99.49	99.39	8.48	8.52	59.67	59.50	34.75	35.47	17.009	16.990
L.S.D $_{0.05}$	0.861	0.659	0.068	0.096	0.086	0.235	0.21	0.21	0.19	0.17
					Foliar spraying (Factor C)					
F-DW	102.35	102.21	8.39	8.42	60.68	60.51	32.54	33.23	18.353	18.387
F-Si	94.71	94.26	7.96	8.01	60.18	59.95	34.19	34.90	15.300	15.203
F-HA	101.88	101.80	7.98	8.02	58.20	58.07	35.00	35.72	15.426	15.346
F- Mix.	99.91	99.86	9.23	9.29	59.44	59.29	36.83	37.58	19.091	19.002
L.S.D $_{0.05}$	0.497	0.536	0.063	0.057	0.152	0.313	0.19	0.20	0.26	0.21

Root dipping in distilled water (D-DW), potassium silicate (D-Si), humic acid (D-HA), foliar spray with distilled water (F-DW), potassium silicate (F-Si), humic acid (F-HA) and a mixture of humic acid and potassium silicate (F-Mix

Table 4.Tomato growth and fruit yield as affected by the interaction of different saline irrigation waters x root dipping in bio-stimulants applications, during 2016/2017 and 2017/2018 seasons.

Treatments		Plant height (cm)		Stem diameter (mm)		Chlorophyll content (SPAD)		Fruit volume (cm^3)		Total fruits yield (ton) $fed.^{-1}$	
Saline water(A)	**Root dipping (B)**	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
0.3 $dS.m^{-1}$ (control)	**D-DW**	121.71	121.67	8.38	8.35	56.56	56.46	47.23	48.12	28.233	27.953
	D-Si	119.13	118.87	8.69	8.69	55.41	55.22	49.18	50.09	30.204	30.113
	D-HA	118.63	118.85	8.72	8.69	57.32	57.10	47.42	48.32	28.810	28.774
5.5 $dS.m^{-1}$	**D-DW**	97.67	97.62	8.95	9.09	61.19	61.01	31.10	31.77	14.993	14.918
	D-Si	100.60	100.27	8.61	8.63	59.61	59.52	31.81	32.49	12.181	12.222
	D-HA	102.19	102.07	8.91	8.98	59.68	59.60	32.07	32.76	14.136	14.028
9.2 $dS.m^{-1}$	**D-DW**	84.63	84.17	7.59	7.63	62.25	62.06	23.77	24.34	9.009	8.947
	D-Si	75.21	75.02	7.83	7.94	62.54	62.30	24.42	24.99	7.736	7.740
	D-HA	77.67	77.26	7.81	7.89	62.03	61.81	24.74	25.32	8.082	8.169
L.S.D $_{0.05}$		1.31	1.06	0.13	0.20	0.25	0.52	0.78	0.77	0.34	0.41

Root dipping in distilled water (D-DW), potassium silicate (D-Si), humic acid (D-HA

Table 5.Tomato growth and fruit yield as affeted by the interaction of different saline irrigation waters x bio-stimulants foliar application, during 2016/2017 and 2017/2018 seasons.

Treatments		Plant height (cm)		Stem diameter (mm)		Chlorophyll content (SPAD)		Fruit volume (cm^3)		Total fruits yield (ton) $fed.^{-1}$	
Saline water(A)	**Foliar spray (C)**	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
0.3 $dS.m^{-1}$ (control)	**F-DW**	124.50	124.45	9.21	9.17	58.02	57.79	44.04	44.89	31.847	31.873
	F-Si	111.31	110.81	8.02	8.02	58.01	57.87	47.44	48.33	25.589	25.368
	F-HA	120.64	120.90	7.52	7.49	54.23	54.16	49.93	50.86	26.493	26.299
	F- Mix.	122.83	123.02	9.65	9.62	55.47	55.22	50.36	51.29	32.400	32.247
5.5 $dS.m^{-1}$	**F-DW**	100.39	100.33	8.20	8.27	61.65	61.56	30.36	31.02	14.033	14.090
	F-Si	96.06	95.71	8.45	8.51	61.12	60.89	32.19	32.88	13.510	13.476
	F-HA	105.14	104.95	8.72	8.80	57.85	57.77	31.03	31.70	12.416	12.374
	F- Mix.	99.03	98.95	9.92	10.02	60.03	59.97	33.06	33.76	15.121	14.949
9.2 $dS.m^{-1}$	**F-DW**	82.17	81.83	7.75	7.81	62.36	62.18	23.21	23.76	9.180	9.199
	F-Si	76.78	76.26	7.40	7.49	61.41	61.09	22.94	23.49	6.801	6.766
	F-HA	79.86	79.54	7.68	7.78	62.51	62.28	24.03	24.60	7.370	7.366
	F- Mix.	77.86	77.63	8.13	8.21	62.81	62.69	27.07	27.69	9.751	9.811
L.S.D $_{0.05}$		0.89	0.94	0.13	0.17	0.32	0.62	0.77	0.77	0.43	0.46

foliar spray with distilled water (F-DW), potassium silicate (F-Si), humic acid (F-HA) and a mixture of humic acid and potassium silicate (F-Mix).

Table 6.Tomato growth and fruit yield as affected by the interaction of bio-stimulant root dipping x foliar application, during 2016/2017 and 2017/2018 seasons.

Treatments		Plant height (cm)		Stem diameter (mm)		Chlorophyll content (SPAD)		Fruit volume (cm^3)		Total fruits yield (ton) $fed.^{-1}$	
Saline water(A)	**Foliar spray (C)**	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18
D-DW	**F-DW**	104.72	104.65	8.30	8.35	61.39	61.30	31.57	32.25	18.647	18.521
	F-Si	96.00	95.79	8.00	8.03	61.27	61.07	34.33	35.05	15.069	14.931
	F-HA	103.56	103.25	7.94	8.01	58.08	57.95	34.61	35.33	16.328	16.141
	F- Mix.	101.06	100.90	8.99	9.04	59.25	59.05	35.62	36.35	19.603	19.496
D-Si	**F-DW**	99.56	99.32	8.34	8.36	60.42	60.26	32.49	33.17	17.997	18.029
	F-Si	95.92	94.97	7.94	8.00	59.78	59.44	34.92	35.64	15.530	15.478
	F-HA	101.00	101.00	8.07	8.10	57.82	57.71	35.51	36.24	14.490	14.463
	F- Mix.	96.78	96.92	9.17	9.22	58.73	58.66	37.62	38.38	18.811	18.797
D-HA	**F-DW**	102.78	102.64	8.52	8.54	60.21	59.97	33.55	34.26	18.417	18.612
	F-Si	92.22	92.02	7.93	7.98	59.47	59.33	33.31	34.02	15.301	15.200
	F-HA	101.08	101.14	7.92	7.96	58.68	58.55	34.87	35.59	15.461	15.434
	F- Mix.	101.89	101.77	9.54	9.59	60.33	60.17	37.25	38.01	18.858	18.714
L.S.D $_{0.05}$		1.14	1.04	0.12	0.13	0.24	0.52	0.36	0.37	0.43	0.36

Root dipping in distilled water (D-DW), potassium silicate (D-Si), humic acid (D-HA),foliar spray with distilled water (F-DW), potassium silicate (F-Si), humic acid (F-HA) and a mixture of humic acid and potassium silicate (F-Mix)

Table 7.Tomato growth and fruit yield as affected by the interaction among saline irrigation waters, bio stimulant root dipping and foliar application on during 2016/2017 and 2017/2018 seasons.

Treatments			Plant height (cm)		Stem diameter (mm)		Chlorophyll content (SPAD)		Fruit volume (cm^3)		Total fruits yield (ton) $fed.^{-1}$	
Saline water (A)	Root dipping (B)	Foliar spray (C)	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018	2016/ 2017	2017/ 2018
0.3 $dS.m^{-1}$ (control)	D-DW	F-DW	128.83	128.63	9.34	9.34	57.66	57.54	44.80	45.66	31.670	31.263
		F-Si	109.25	109.33	7.54	7.51	58.82	58.53	47.65	48.55	21.700	21.487
		F-HA	120.92	121.09	7.31	7.29	54.69	54.82	47.69	48.58	25.747	25.420
		F- Mix.	127.83	127.63	9.35	9.27	55.09	54.96	48.78	49.69	33.813	33.640
	D-Si	F-DW	120.75	120.75	8.99	8.99	57.38	57.12	42.48	43.30	32.467	32.410
		F-Si	118.92	116.88	8.58	8.58	56.91	56.77	49.91	50.84	28.383	28.237
		F-HA	118.92	119.50	7.75	7.73	53.09	52.89	53.22	54.18	26.413	26.277
		F- Mix.	117.92	118.34	9.45	9.47	54.28	54.10	51.10	52.04	33.553	33.530
	D-HA	F-DW	123.92	123.96	9.29	9.18	59.03	58.70	44.85	45.72	31.403	31.947
		F-Si	105.75	106.21	7.94	7.97	58.29	58.31	44.75	45.60	26.683	26.380
		F-HA	122.08	122.13	7.51	7.46	54.91	54.78	48.89	49.81	27.320	27.200
		F- Mix.	122.75	123.08	10.14	10.14	57.04	56.61	51.20	52.15	29.833	29.570
5.5 $dS.m^{-1}$	D-DW	F-DW	97.58	98.13	8.34	8.49	63.96	63.93	28.55	29.19	15.070	15.117
		F-Si	96.58	96.67	9.04	9.16	63.59	63.33	32.28	32.97	15.507	15.433
		F-HA	103.33	102.46	8.90	9.03	57.76	57.52	31.04	31.71	14.573	14.447
		F- Mix.	93.17	93.21	9.51	9.69	59.44	59.27	32.53	33.22	14.823	14.673
	D-Si	F-DW	101.33	100.83	8.10	8.10	61.20	61.03	30.97	31.64	12.487	12.683
		F-Si	96.17	95.38	7.98	8.01	59.80	59.51	33.01	33.71	12.090	12.060
		F-HA	105.42	105.29	8.64	8.63	57.61	57.70	30.97	31.65	10.203	10.293
		F- Mix.	99.50	99.59	9.74	9.77	59.84	59.86	32.28	32.97	13.943	13.850
	D-HA	F-DW	102.25	102.04	8.17	8.23	59.78	59.73	31.56	32.24	14.543	14.470
		F-Si	95.42	95.09	8.33	8.36	59.96	59.82	31.29	31.97	12.933	12.933
		F-HA	106.67	107.09	8.63	8.73	58.16	58.08	31.07	31.75	12.470	12.383
		F- Mix.	104.42	104.05	10.52	10.61	60.81	60.77	34.37	35.09	16.597	16.323
9.2 $dS.m^{-1}$	D-DW	F-DW	87.75	87.21	7.21	7.23	62.56	62.44	21.37	21.90	9.200	9.183
		F-Si	82.17	81.38	7.43	7.44	61.41	61.36	23.07	23.62	8.000	7.873
		F-HA	86.42	86.21	7.61	7.70	61.79	61.52	25.11	25.69	8.663	8.557
		F- Mix.	82.17	81.88	8.12	8.16	63.23	62.92	25.55	26.15	10.173	10.173
	D-Si	F-DW	76.58	76.38	7.92	7.98	62.69	62.63	24.01	24.57	9.037	8.993
		F-Si	72.67	72.67	7.25	7.40	62.64	62.04	21.84	22.37	6.117	6.137
		F-HA	78.67	78.21	7.81	7.95	62.76	62.53	22.35	22.89	6.853	6.820
		F- Mix.	72.92	72.84	8.32	8.44	62.07	62.01	29.48	30.13	8.937	9.010
	D-HA	F-DW	82.17	81.92	8.11	8.20	61.82	61.48	24.24	24.81	9.303	9.420
		F-Si	75.50	74.75	7.53	7.62	60.18	59.86	23.91	24.48	6.287	6.287
		F-HA	74.50	74.21	7.63	7.69	62.98	62.79	24.63	25.21	6.593	6.720
		F- Mix.	78.50	78.17	7.96	8.03	63.14	63.12	26.18	26.78	10.143	10.250
L.S.D $_{0.05}$			1.80	1.70	0.20	0.22	0.43	0.91	0.68	0.69	0.73	0.63

Root dipping in distilled water (D-DW), potassium silicate (D-Si), humic acid (D-HA), foliar spray with distilled water (F-DW), potassium silicate (F-Si), humic acid (F-HA) and a mixture of humic acid and potassium silicate (F-Mix