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ALLEVIATION SALINITY STRESS ON TOMATO PLANTS BY SOME ORGANIC AND BIO - FERTILIZERS APPLICATION

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ABSTRACT: A pot experiment was carried out in two summer seasons of 2020 and 2021, to study the effect of organic {compost (COM) and humic acid (HA)} and biological {arbuscular mycorrhizal (AM) and plant growth promotion rizobacteria (PGPB)} fertilization on mitigation salinity hazard of tomato plants. Saline solutions were prepared by using NaCl to induce an EC of 3 and 6 dSm^{-1}, in addition to tap water (0.56 dSm^{-1}) as a control. Data on plant growth and development, and leaf water, mineral and chemical contents, and fruit yield and quality were determined. Comparable to un-saline treatment (tap water), salinity (at 3.00 and 6.00 dSm^{-1}) decreased plant growth, fruit set (%), water, and mineral nutrition contents in leaves, as well as fruit yield. However, salinity increased water use efficiency, leaf proline content, electrolyte leakage in leaves, and fruit contents of TSS and Vit.C. Also, salinity enhanced Na and Cl contents in all leaves, particularly old ones. Treatments of alleviation salinity all mitigated salinity detrimental effect as they enhanced growth, fruit set (%), water, N, P, K and Ca contents in leaves as well as fruit yield. Also, these treatments reduced Na and Cl contents in both young and old leaves particularly in former ones, beside leaf proline content and leaf electrolyte leakage. The combined treatments i.e., AM+PGPR and COM+HA both seems to be of a synergistic effect as they were the most effective treatments in terms of alleviation salinity hazards on plants followed by AM and COM applied alone.

Kew words: Tomato, salinity alleviation treatments, plant growth, chemical contents and fruit yield, organic and bio-fertilizers.

INTRODUCTION

The continuous increase in the earth's human population, including the developing countries of the Mediterranean region, requires increasing quantities of water for domestic, industrial and agricultural needs. The progressive requirement for more water to irrigate crops for food when water resources are limited has led to use low quality water for irrigation, such as saline field drainage or brackish water, etc. Irrigation with saline water has become necessary in parts of the world with limited supplies of good quality water.

According to Gama *et al.* (2007), plants grown under salinity conditions are basically stressed in three ways. These are, (1) osmotic effect; reduction of water potential in the root zone and causing water deficit, i.e. excess salts in the root zone hinder roots from withdrawing water from surrounding soil, (2) specific ion effect; phototoxicity of ions such as Na^+ and Cl^- , and (3) nutrient imbalance by depression ion uptake. Therefore, salinity stress involves changes in various physiological and metabolic processes, depending on severity and duration of the stress, and ultimately inhibits crop growth and production (Rozema and Flowers, 2008, Rahnama *et al.*, 2010 and James *et al.*, 2011). Osmotic stress causes various physiological changes, impairs the ability to detoxify reactive oxygen species (ROS), decreased photosynthetic activity, and decrease in stomatal aperture (Munns and Tester 2008 and Rahnama *et al.*, 2010). Also, salinity altered the mineral nutrient composition by decreasing N,P,K and Ca content and increased Na and Cl content of the tomato plants compared to the unsalted control (Tartoura *et al.*, 2014 and Ors *et al.*, 2021). The accumulation of proline in plants (Ali and Rab, 2017 and Torre-Gonzalez *et al.*, 2018), and increasing electrolyte leakage from plasma membranes proportionally in tomato leaves has been observed (Tartoura *et al.*, 2014., and Ors *et al.*, 2021) under salinity stress conditions. As a result, several studies showed that tomato plant

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growth was reduced by salinity (Feigin *et al.*, 1987 and Magan *et al.,* 2008), as well tomato yield is quite sensitive to salinity, i.e., at 3.0 dS m^{-1} and above (Malash *et al.,* 2012, El-Mogy *et al.*, 2018 and Pengfei *et al.,* 2019). While there was a clear reduction in yield, the fruit quality of tomato fruit (in most cases) including TSS and vitamin C., were enhanced with increasing salinity (Mizrahi *et al.*, 1988, De Pascale *et al.*, 2001, Malash *et al.*, 2002 and Maggio *et al.*, 2004). Consequently, great effort has been devoted to overcome the deleterious effects of salinity on crop plants. Bio-fertilizers such as arbuscular mycorrhizal (AM) and plant growth promoting rhizobacteria (PGPR) were mentioned to be have alleviation effect of salt stress on crop plants. The symbiotic association of crop plants with AM fungi improves the uptake of almost essential nutrients by plants (Balliu *et al.*, 2015), Whereas decrease the uptake of Na and Cl (Evelin *et al.*, 2012), In addation AM increases water uptake bymaize plant roots (Ruiz-Lozano and Azcon, 1995 and Marulanda *et al.,* 2003). reduced electrolyte leakage in plant leaves (Ahmad *et al.*, 2019 and Kaya *et al.,* 2009). PGPB treatment can directly fixing atmospheric nitrogen, producing some phytohormones, solubilizing minerals such as phosphorus and synthesizing enzymes that can modulate plant growth and development (Mayak *et al.,* 2004a). Furthermore, PGPR reduced salt toxicity in various plants by lowering the Na^{+} concentration and increasing the K^{+} concentration in crop plants (Bano and Fatima, 2009 and Kohler *et al.,* 2009). The combined treatment of both mycorrhiza and PGPR seems to be has a synergistic effect that was confirmed by improved plant growth, nutrition, and yield as well as mitigated salinity stress than using one component of them alone (Baradar *et al.*, 2015, Calvo-Polanco *et al.,* 2016 and Desai *et al.,* 2020).

Application of composted organic matter (OM) leads to improve soil physical, chemical and biological properties, increasing soil water-holding capacity and bulk density and improving plant nutrient use efficiency (Qadir and Oster 2004, Tejada *et al.*, 2006, Clark *et al.,* 2007, and Altome *et al.,* 2015). Application of compost increased the N, Ca, P, K, Mg, Fe, Zn, and Cu contents in plants grown under saline conditions (Dursun *et al.*, 2002, and Du Jardin, 2015), while it reduces the uptake of some toxic elements (Knicker *et al.,* 1993, and Friedel and Scheller, 2002), and reduces electrolyte leakage (EL) in plants that were grown in saline soil (Rady *et al.*, 2016). Regarding, humic acid (HA) it was able to stimulate nutrient uptake such as N, Ca, P, K, Mg, Fe, Zn, and Cu (Padem *et al.*, 1997, and Dursun *et al.*, 2002), and their use efficiency by plants, meanwhile reduced the uptake of some toxic elements (Knicker *et al.,* 1993, and Friedel and Scheller, 2002). Also, HA improved RWC in strawberry plants (Saidimoradi *et al.,* 2019) significantly reduced electrolyte leakage in bean (Phaseolus vulgaris L.) plants (Aydin *et al.*, 2012), besides decreasing membrane damage (Canellas *et al.,* 2015) which can mitigate the deleterious effects of salt stress (Du Jardin, 2015).

This study was undertaken to provide information about the possibility of organic and bio-fertilizers in enhancing salt tolerance in plants, thus we hypothesized that AM, PGPR, COM and HA can alleviate salinity hazard in tomato plants grown under saline conditions.

MATERIALS AND METHODS

A pot experiment was carried out in two successive years in early summer seasons of 2020 and 2021, under protected conditions (theram house), at the Agricultural Experimental farm, Faculty of Agriculture Menofia University Shebin EL-Kom, Egypt. This experiment was conducted to study the effect of two sources of fertilizers; i.e., organic and biological fertilizers on reducing salinity hazard on tomato.

In this study, seeds of tomato "hybrid 186" were sown in seedling trays (209 holes) on the 10^{th} and 8^{th} of February in 2020 2021 yearsears, respectively. The trays were filled with a mixture of peat moss, vermiculite and mineral nutrients.The seedlings were transplanted (45 days after seed sowing) in perforated plastic pots 35cm in diameter, under theram house conditions. Each pot contained 12kg mixture of field soil and washed sand (1: 2 by weight), some washed gravels (with different sizes) were added at the bottom of each pot to optimize the leaching process. The experiment was designed in a split plot design with 6 replicates. Each subplot consisted of 6 pots and each pot contained 5 seedlings. Salinity treatments (3 levels) were devoted to main plots whereas, fertilization sources treatments were devoted to the sub- plots. Unless otherwise indicated, fertilizers rates were added as commonly used in tomato production field i.e, 120 unit of N (600kg /fed as ammonium sulphate), 50 units of P (320 kg/fed as calcium super phosphate), and 150 units of K (300kg/fed as potassium phosphate). In addition micro – elements (iron –zinc –manganese) at a rate of 1-2g per liter of water were applied as spray on plant foliages, after a month of transplanting and repeated three times every 15 days thereafter.

At the beginning all pots were irrigated with fresh water, while salinity treatments started 20 days after transplanting. Saline solutions were prepared by using NaCl to induce EC equal to 3 and 6 dSm^{-1}, in addition to tap water (0.56 dSm^{-1}) as a control. To avoid salinity chock, saline irrigation water was applied gradually; i.e., 2 dSm^{-1} every 3 days till final concentration. Moisture content of pots was determined by weigh pots at 2 days intervals and irrigation was applied when soil moisture depleted to 70% of field capacity, the amount of irrigation water added was enough to raise moisture to 100% field capacity. In addition, excess of water (15% as leaching fraction) was also applied (if needed). After each irrigation the drain water was gathered in the dish below each pot and its EC was determined. The 15% leaching fraction was sufficient to keep salinity level in drain solution as in irrigation one, under condition of this experiment.

Salinity alleviation treatments were

1-Biological fertilizers

1-1- Endo-Mycorrhizae, (Arbuscular mycorrhizal) (AM)

The fungus was added (before transplanting) to the soil in each pot at rate of 1g/kg soil, and mixed thoroughly with the soil surface.

1-2-Plant growth promoting rhizobacteria (PGPR)

Roots of seedlings before transplanting were dipped in the *Bacillus subtilis* suspension of 10^8 CFU ml^{-1} for 5 min amended with Arabic gum solution (1%) as a sticker.

1-3- Mycorrhiza + Plant growth promoting rhizobacteria

Both of them (as a bilateral treatment) were added at dates previously mentioned for each, and with the same quantities.

2- Organic fertilizers

2-1-Compost (COM)

Compost contains 1% nitrogen, it was added before planting in a rate of 6 ton/fed^{-1}, which is consider only as 50% of the necessary nitrogen needed for tomato production fields. The compost was mixed well in the surface layer of the potted soil.

2-2-Humic acid (HA)

Humic acid “Agro Master” is a water soluble potassium humate crystals (K_2O) 10%W/W, Humic acid was added at 15- 20 days after transplanting at a rate of 1 kg $/fed^{-1}$ (0.01 g / pot), and the application was done every 2 weeks during the growing season.

2-3- Compost + humic acid

Compost and humic acid (as a bilateral treatment) were added at the dates previously mentioned for each material and with the same quantities.

Data recorded

I. Vegetative growth characters

A plant sample was taken at 50 days after transplanting (after three weeks of reaching the final concentration of salts) in both seasons of study, whereas in the 2^{nd} season two plant samples were taken; at 50 and 60 days after transplanting (DAT). The sample consisted of 2 plants from each replicate (pot), then the following measurements were recorded:

1-Plant height: was measured from cotyledon leaves scar to terminal bud.

2- Total plant dry weight: dry weight was determined by put all the plant organs in an oven at 70 C° till constant weight.

II- Flowering date and fruit setting

1- Flowering date (F_{50}): is the date (number of days) at which 50% of plants produce the first flower.

2- Fruit set (%): flowers of the 3rd and 4th clusters were tagged and fruits that set were calculated.

III- Plant water relations

1-Relative water content (RWC): the 5th leaf from the plant top were taken from three randomly selected plants from each treatment at 50 day after transplanting in both seasons of study. The RWC was calculated by the following equation as cited after Barrs and weatherly (1962).

$$RWC = \frac{FW - DW}{TW - DW} \times 100$$

Where: **FW**= fresh weight of leaflet.

DW= dry weight of leaflet (leaflets were dried up in an oven at 70^{0}C till constant weight)

TW= full-turgor weight; i.e., turgor weight was determined by floated leaflet on distilled water in for 6h petri dishes under laboratory conditions, and then weighed every 15 minutes. At constant weight, leaflets were got out of the water and were blotted before reweighing.

2-Water use efficiency (WUE): It was measured at the end of the season according to the following formula: **WUE**=Total Yield (kg)/ $Total\ Water\ /m3$

IV-Chemical composition of tomato leaves

1) Mineral elements contents: Total nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), sodium (Na) and chloride (Cl) were all determined in young active leaves (the 4th and 5th leaves from the tip of plants) and old leaves (7th , 8th and 9th from the tip of plants). These elements were determined at 50 days after transplanting (DAT) in 2020 season and at 50 days and 60 DAT in 2021. The methods used in their determinations were according to those mentioned by Pergel (1945) for N, Page *et al.,* (1982**)** for K, Ca and Cl, Chapman and Pratt (1961) for P, and Johanson and Ulrichs (1959) for Na.

2) Proline content: Proline content was measured at 50 days after transplanting in both seasons, according to the method described by Bates *et al.* (1973).

V- Electrolyte leakage (EL): Was determined at 50 days after transplanting in both seasons of study. Electrolyte leakage is an index of physiological stresses which reflecting the damage of cell membranes and stability results in leakage of cell contents. Electrolyte leakage was determined as described by Sun *et al.,* (2006).

VI- Yield and its components

1) Average fruit weight: Was obtained by dividing total weight of the marketable fruits (from each treatment) by their number.

2) Total yield: was the weight of the all harvested fruits (ripe fruits were harvested every 2-3 days/week) throughout the entire harvesting season

VII-Fruit quality was determined in firm mature red fruits once at the harvesting

1) Total soluble solids content (TSS) was measured using an abbe hand Refractometer.

2) Ascorbic acid content in tomato juice (vitamin C): its determination was carried out using 2, 6, dichlorophenol indophenol dye and oxalic acid as extractor as described in AOAC (1995).

Data Statistical analysis

The data of the two seasons were statistically analyzed using the CoStat Package program, version 6.311(Cohort software, USA). The differences among the means of treatments were tested using the least significant differences (L.S.D) at 0.05 level of probability according to the method described by Snedecor and Cochran (1980).

RESULTS AND DISCUSSIONS

1-Plant vegetative growth

1-1- Plant height

Data in Table 1 show that increasing salinity level significantly decreased plant height of tomato plants compared to those of un-salinized plants, in both sampling dates and seasons. The proportion of the reduction in plant height also was more pronounce by increasing time of exposure to salinity; i.e., at 60 DAT than at 50 DAT in 2021 season. Similar results were obtained by Malash *et al.* (2008), Oztekin and Tuzel (2011) and El-Mogy *et al*. (2018) who reported that salinity stress reduces the height of tomato plants. The reduction in plant height by salinity was mainly due to reduce water potential, which causes ion imbalance and ion toxicity (Gama *et al.,* 2007, Rahnama *et al.,* 2010 and James *et al.,* 2011).

Concerning, the effect of salinity alleviation treatments. Table (1) shows that all these treatments increased significantly plant height than that of the untreated control, in both years of study. Also, the most effective treatment in alleviation salinity’s detrimental effect on the stem length of tomato plants was combined COM and HA in both seasons. The second highest value was recorded to plants treated with COM, followed by those treated by the combination of AM+PGPR treatment in 2020 season, me,anwhile the differences between these two particular treatments were not significant (Table 1).

Table (1): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on plant height of tomato plants determined at 50d (in 2020 & 2021) and 60d (in 2021 only) after transplanting.

Salinity levels dS/m (A)	Salinity alleviation treatments (B) plant height (cm) Sample taken at 50 d after transplanting in 2020							
	Mycorrhizal Inoculation	B. subtilis Inoculation	Mycorrhizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated Control	Mean A
0.56*	71.40	68.71	74.46	76.33	70.58	76.58	66.63	72.10
3.00	68.67	67.25	69.17	69.25	67.92	74.17	60.58	68.14
6.00	66.17	62.50	66.25	66.71	65.83	69.75	55.00	64.60
Mean B	68.74	66.15	69.96	70.71	68.11	73.50	60.74	
L.S.D A	0.390							
L.S.D B	0.596							
L.S.D AxB	1.032							
Season 2021 1st sample taken at 50 d after transplanting								
0.56*	69.00	58.25	73.25	68.25	67.25	82.75	50.75	67.07
3.00	60.66	56.25	64.75	63.50	59.75	67.25	44.00	59.45
6.00	53.50	52.50	56.25	52.50	53.00	59.50	37.50	52.11
Mean B	61.06	55.67	64.75	61.42	60.00	69.83	44.08	
L.S.D A	1.898							
L.S.D B	2.899							
L.S.D A x B	5.022							
Season 2021 2nd sample taken at 60 d after transplanting								
0.56*	70.18	65.68	74.75	71.00	67.63	84.50	52.25	69.43
3.00	62.25	57.25	65.88	64.38	60.00	68.55	43.65	60.28
6.00	54.00	53.00	57.50	54.25	53.33	60.13	39.25	53.06
Mean B	62.14	58.64	66.04	63.21	60.32	71.06	45.05	
L.S.D A	1.110							
L.S.D B	1.695							
L.S.D A x B	2.936							

*= tap water (control)

However, using *B.subtilis* (which belongs to PGPR group) alone gave the lowest value of plant height among the other treatments (Table 1). These results are similar to the data obtained in an earlier studies regarding to the favorable effect of these salinity alleviation treatments on stem length of tomato plants, e.g., Basak *et al.* (2011) and Hadad *et al*. (2012) for using AM, Tank and Saraf (2010), Pandy and Gapta (2020) and Yilmaz *et al*. (2020) for using PGPR, Arancon *et al.* (2003) and Tu *et al*. (2006) for using compost and Ashraf and Mohamed (2008) and Feleafel and Mirdad (2014a), for using HA. The favorable effect of AM on plant height of tomato plants was mainly attributed to its efficiency in providing nutrition to the host plant, increasing water uptake, production of hormones and enhancing adaptation to environmental stress including salinity (Garg and chandel 2010). Moreover, PGPR as well, enhances biological N2 fixation, increasing the availability of nutrients in the rhizosphere (Glick, 2012 and Vessey, 2003). In addition, Richardson *et al.* (2009) and Glick, (2012) added that PGPR can enhancing other beneficial symbioses of the host such as inhibition of cell wall-degrading enzymes, lowering plants ethylene levels, by which abiotic stress tolerance increased in plants.

It was also found that compost can improve soil fertility and increase the crop accessibility to nutrients, leading to good plant growth as well as reducing the damaging effects of salt stress (Cimrin *et al*., 2010) on pepper. HA application also, has favorable effect on plants under stress conditions, as it increased nutrients uptake, (Adani *et al.*, 1998 and Dursun *et al.*, 2002), changing ion balance, promoting plasma membrane proton pumps activity and enhancing photosynthesis of tomato plants grown under salt stress (Souza *et al.,* 2021).

The highest value of plant height of tomato plants (Table1) was obtained by the combined treatment of COM+HA at 0.56 dS/m level of salinity i.e. 76.6, 82.7 and 84.5 cm at 50 DAT in 2020 and 2021 seasons and at 60 DAT in 2021 respectively, however the lowest values were 55.0, 37.5 and 39.25 in the same order were recorded to the untreated control with 6.0 dS/m.

1-2-Total plant dry weight

It is obvious from results presented in Table 2 that salinity, (regardless salinity alleviation treatments) significantly decreased total plant dry weight with increasing salinity level in irrigation water, in both seasons and sampling dates. The reduction in total plant dry weight of tomato by salinity were 26.7 and 46.9% (as average of values obtained in the two seasons at 50 DAT) at salinity levels 3 and 6 dSm^{-1} respectively compared to those plants irrigated with tap water. The reduction was augmented when dry weight of tomato plant was determined at 60 DAT in 2021 season as such reductions were 31.0 and 55.0 % at 3 and 6 dSm^{-1} levels of salinity respectively (Table 2).These findings support the observations made by Cruz *et al*. (1990), Saranga *et al*., (1993), Malash et al., (2008), Eraslan *et al*. (2015) and El.Mogy *et al*. (2018) who mentioned that dry weight of tomato plants was reduced in proportion to the increase in salinity of the irrigation water. Also, De Pascale *et al*. (2003) found that irrigation pepper plants by saline water (EC of 4.4 dSm^{-1}) resulted in 46% reduction in plant dry weight. The reduction in plant dry weight due to increasing salinity levels may be a result of a combination of osmotic and specific ion effects of Cl and Na on plants (Cruz *et al*., 1990 and Saranga *et al*., 1993).

Salinity alleviation treatments used in this study all resulted in a significant increase in salt tolerance of tomato plants as they enhanced total plant dry weight than those of untreated control (Table 2). Also, salinity alleviation treatments enhanced total plant dry weight in both saline and non-saline conditions. The combined treatment between COM+HA was the most effective treatment in increasing the dry weight of tomato plants, grown under saline conditions, among other treatments in both seasons and sampling dates i.e. at 50 and 60 DAT (Table 2). Also, the combined treatment of AM+PGPR gave the 2nd highest total plant dry weight in the 2021 season in both sampling dates, but the such treatment gave the 3rd. highest value of plant dry weight at 50 DAT of the 2020 season.

Table (2): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on total plant dry weight of tomato plants determined at 50 d (in 2020 & 2021) and 60 d (in 2021only) after transplanting.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	Total plant dry weight g/plant							
	Sample taken at 50 d after transplanting in 2020							
	Mycorrhizal Inoculation	B. subtilis Inoculation	Mycorrhizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	21.19	17.42	22.03	25.18	19.90	26.28	11.14	20.45
3.00	15.87	14.20	16.95	17.97	15.25	20.32	8.69	15.61
6.oo	13.31	12.48	14.30	14.89	11.56	15.91	6.05	12.64
Mean B	16.79	15.22	17.13	18.79	16.38	19.72	11.40	
L.S.D A	0.362							
L.S.D B	0.553							
L.S.D AxB	0.957							
Season 2021 **1st sample taken at 50 d after transplanting**								
0.56*	24.52	20.07	32.84	31.48	23.33	38.38	16.33	26.71
3 .00	19.01	15.46	24.20	21.67	17.09	25.23	10.34	19.00
6 .00	12.60	9.45	15.56	14.21	10.81	17.67	6.44	12.39
Mean B	18.71	14.99	22.83	20.59	18.51	25.46	12.90	
L.S.D A	1.038							
L.S.D B	1.585							
L.S.D. AxB	2.746							
Season 2021 **2nd sample taken at 60 d after transplanting**								
0.56*	35.07	29.01	41.04	38.14	32.25	47.11	21.84	34.92
3 .00	23.65	20.48	29.31	27.09	21.94	32.45	13.85	24.11
6 ,00	16.13	13.74	18.21	16.96	15.51	20.42	9.05	15.72
Mean B	24.95	21.07	29.52	27.40	23.23	33.33	14.91	
L.S.D A	1.168							
L.S.D B	1.785							
L.S.D A xB	3.089							

*= tap water (control)

These findings suggest that such combined treatments had a synergistic effect as values of plant dry weight obtained by these particular treatments, were higher than that obtained by each factor (one of its components) used alone (Table 2). AM inoculation and COM application treatments gave also high values of plant dry weight. Similar results were obtained by Altome *et al*. (2015) regarding the favorable effect of COM application on shoot dry weight of tomato plants, and by Padem *et al*. (1997), Adani *et al*. (1998) and Dursun *et al*. (2002) regarding the favorable effect of HA application on tomato plant growth, which all were grown under saline conditions. The role of both organic fertilizers i.e. COM and HA in mitigation of salinity effect is to enrich the soil with organic matter and humic substances which improve soil physical, chemical and biological properties which enhances macro and micronutrients uptake (Walker and Bernal, 2008 and Wright *et al.,* 2008) and increase moisture conservation which stimulates crop growth and quality (Zribi *et al*., 2011). Similarly, the synergistic effect of the combined treatment of AM+PGPR was also observed by Desai *et al.* (2020) who confirmed that both AM and PGPR applied together improved tomato plant growth, grown under salinity conditions than used each of them alone. Moreover, it was reported (Altunlu, 2020) that PGPR enhanced AMF positive effect which positively improved plant growth and physiological parameters of pepper plants under all studied salinity stress levels. The favorable effect of AM on plant growth particularly under saline conditions is mainly due to providing nutrients to the host plant, increasing water uptake, production of hormones and enhancing adaptation to environmental stresses (Garg and Chandel 2010). PGPR as well reduces synthesis of harmful ethylene which increases under stress conditions (Glick, 2014), fixing atmospheric nitrogen, phytohormone production, solubilizing minerals, modulate plant growth (Mayak *et al.*, 2004a) and enhanced scavenging activities of reactive oxygen species (ROS) (Jianmin *et al*., 2014). It was also observed that salinity alleviation treatments increased total tomato plant dry weight in both normal and saline conditions (Table 2), but it seems that these treatments were somewhat more effective in saline than in normal conditions.

According to the data of the interaction between salinity levels and salinity alleviation treatments, Table 2 shows that the highest total plant dry weight obtained was a result of using the combined treatment of COM+HA along with 0.56 dS/m salinity level (un-saline), the 2nd highest value of total plant dry weight was recorded to the COM treatment at 50 DAT in 2020 season, but this ranked was recorded to the combined treatment of AM+PGPR at 50 and 60 DAT in 2021 season, all along with 0.56 dS/m salinity level. While, the lowest values of total plant dry weight were due to those plants subjected to the highest salinity level (6.0 dS/m) and those untreated with any of salinity alleviation treatments (Table 2). HA application and PGPR inoculation along with the highest salinity level gave also lower total plant dry weight (Table 2).

2- Flowering date and fruit set

2-1- Number of days from transplanting to appearance of the first flower in 50 % of the plants (F_{50})

According to the date given in Table 3, increasing salinity levels significantly decreased number of days required to first flower appearance of 50% of plants. In other words, salinity enhanced early flowering in tomato plants when compared with those grown under normal (non-saline) conditions.

Such result seems to be logical outcome as salinity dramatically affected vegetative growth, which predisposing to accelerate flowering. Similar results were obtained by Mostafizar Rahman *et al*. (2018) who found that salinity (i.e. 2 to 8 dS/m) decreased number of days required to flowering of five tomato varieties, and the effect was more pronounced with increasing salinity levels up to 8 dS/m.

Because salinity alleviation treatments improved water content, enhanced physiological and biochemical processes and reduced toxic elements in plant tissue which in turn promoting plant vegetative growth, all treatments increased No of days required to F_{50} of tomato plants (Table 3). Also, the treatments which gave highest growth parameters under saline stress, previously mentioned, also gave the longer period to F_{50}, in both seasons.

2-2- Fruit set (%)

Fruit set (%) of tomato plants was significantly decreased by salinity (Table 4), and the decrease was more pronounced at 6 dS/m than at 3dS/m^{-1} compared to those of non-saline control. These findings support the observations made by Adams and Ho, (1992) who mentioned that fruit set % of tomato was reduced by extreme salinity. The reduction in fruit set by salinity may owing to a reduction in number of flowers (Mostafizur Rahman *et al*., 2018), or to flower loss or drop as a result of the restriction of water supply (Saito and Ito 1967) or for a reduction in potassium (Besford and Maw, 1975) and phosphorus uptake (Menary and Stalen 1976).

Table (3): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on number of days from transplanting to appearance of first flower in 50% of plants (F_{50}) in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	F_{50} (days)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	31.17	31.00	30.00	31.50	29.83	34.17	29.00	30.95
3.00	27.83	27.33	28.67	28.50	28.33	31.17	26.50	28.33
6.00	26.67	26.83	28.50	27.67	27.33	27.00	25.50	27.07
Mean B	28.56	28.39	29.06	29.22	28.50	30.78	27.00	
L.S.D A	0.284							
L.S.D B	0.434							
L.S.D AxB	0.751							
Season 2021								
0.56*	34.75	33.75	37.25	36.50	35.00	40.50	31.50	35.61
3.00	33.75	31.75	36.50	35.25	32.25	37.50	25.50	33.21
6.00	28.50	27.00	31.00	29.50	27.50	32.75	21.50	28.25
Mean B	32.33	30.83	34.92	33.75	31.58	36.92	26.17	
L.S.D A	0.985							
L.S.D B	1.505							
L.S.D A x B	2.607							

*= tap water (control)

Table (4): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on tomato fruit set (%) of the 3rd, and 4th clusters in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	Fruit set (%)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	65.51	61.72	69.70	78.39	64.35	91.12	57.75	69.79
3.00	60.14	56.95	60.97	61.74	58.48	63.65	47.00	58.42
6.00	50.02	42.82	50.90	52.82	47.13	53.87	36.47	47.72
Mean B	58.56	53.83	60.52	64.32	56.66	69.55	47.07	
L.S.D A	0.845							
L.S.D B	1.290							
L.S.D AxB	2.235							
Season 2021								
0.56 *	77.48	71.67	87.26	83.75	83.75	92.26	46.67	77.55
3.00	56.25	52.50	62.92	56.65	50.00	74.98	31.72	55.00
6.00	43.33	31.09	50.00	46.67	37.30	56.65	27.97	41.86
Mean B	59.02	51.75	66.73	62.36	57.02	74.63	35.45	
L.S.D A	4.817							
L.S.D B	7.359							
L.S.D A x B	12.745							

*= tap water (control)

Salinity alleviation treatments enhanced tomato fruit set percent in plants either grown in normal or in saline conditions (Table 4). The combined treatment of COM+HA gave significantly the highest fruit set (%) of tomato plants either grown in normal cultural media i.e., non-saline (control treatment) or in both levels of salinity, in both seasons. The 2nd highest fruit set was due to COM application treatment in 2020 season and the combined treatment of AM+PGPR in 2021 one.

The favorable effect of salinity alleviation treatments on tomatoes was depend on enhancing water and mineral nutrition uptake, photosynthetic activity which improved physiological and biochemical process, such as photosynthetic activity and subsequently improve male and female gametophyte viability and increase number of clusters /plant and number of flowers in cluster, Such modifications enhanced fruit set (%) of tomato plants grown under saline conditions. These results seem to be similar to those obtained by Feleafel and Mirdad (2014a) and Ashraf and Mohamed (2008) who mentioned that humic substances improve a number of clusters/plant and the number of flowers/clusters of tomato plants grown under saline conditions, which is reflected on fruit set improvement.

3- Plant water relations

3-1- Relative water content (RWC)

As expected salinity reduced relative water content (RWC) and the reduction was more pronounced with the highest salinity level i.e. 6dS/m in both seasons (Table 5). RWC is also called relative turgidity and is perhaps the most widely accepted method of expressing the quantity of water in plant tissue (Boyer, 1969). The findings of this study are in agreement with those reported by Yurtseven *et al.* (2005), Eraslan *et al.* (2015) and Pengfei *et al.* (2019) who reported that RWC in tomato plants was decreased by NaCl salinity. Psarras *et al.* (2008) clarify that salinity in soil or in irrigation water particularly high levels reduce water uptake by plant roots and consequently reduces water potential in tomato plant tissues.

Table (5): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on relative water content (RWC) in tomato leaf determined at 50 d after transplanting in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	RWC values (%)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	79.75	75.30	80.88	81.75	77.69	87.69	66.95	78.57
3 .00	64.32	63.43	66.22	67.01	64.15	68.20	53.54	63.84
6 .00	46.34	41.23	52.38	54.81	45.44	55.61	32.71	46.93
Mean B	63.47	59.99	66.49	67.86	62.43	70.50	51.06	
L.S.D A	0.843							
L.S.D B	1.289							
L.S.D AxB	2.231							
Season 2021								
0.56*	71.95	67.45	79.83	73.58	70.58	83.66	55.90	71.85
3 .00	60.65	56.13	66.08	63.33	58.21	68.12	44.14	59.52
6 .00[1]	46.76	39.49	54.69	49.82	42.61	57.94	28.96	45.75
Mean B	59.79	54.36	66.87	62.24	57.14	69.91	43.00	
L.S.D A	1.173							
L.S.D B	1.792							
L.S.D A x B	3.104							

*= tap water (control)

Using salinity alleviation treatments can manage salinity hazard on the water content of tissues in tomato leaves, as they increased significantly RWC than untreated plants, also such treatments enhanced water content (RWC) in plants grown under normal conditions (non-saline) as shown in Table 5. The most effective treatments in increasing RWC were the combined treatment of COM+HA, followed by the combined treatment of (AM+PGPR) and then the compost application treatment.

This study confirmed the previous reports regarding the enhancement of AM for water uptake by improving root water flow to colonized roots directly to plants (Koide, 1993 Marulanda *et al.*, 2003). Also, it was observed that PGPR inoculation treatment resulted in a significant improvement of RWC in leaves of sweet pepper plants (AL-Kahtani *et al*. 2020) and strawberry plants (Karlidag *et al*., 2013) grown under saline conditions, comparable to the control (untreated). This favorable effect of bacteria treatment has been related to timprovedove root development and net water uptake in plants that suffer from salinity (Marulanda *et al*., 2006). The combined treatment of AM+PGPR i.e. *Glomus spp + Bacillus subtilis,* , resulted in enhanced RWC in both lettuce and tomato irrigated with 25 and 50 mM NaCl, rather than the control untreated, (Miceli *et al*. 2021). Also, COM when replace about 50% of NPK dose revealed a significant increase in RWC in bean plants grown in saline soil (Rady *et al*., 2016).

The improvement of HA on RWC in plants even grown under saline conditions was also reported by Saidimoradi *et al*. (2019), on strawberries and by Feleafel and and Mirdad (2014b) on tomato, compared to those of untreated plants .The role of both COM and HA in enhanced RWC may be due to the effect on increasing soil with organic matter and humic substances which improve soil physical properties in a way that improves water holding capacity and bulk density under salt stress conditions (Altome *et al*., 2015).

The highest value of RWC (Table 5) was obtained by the combined treatment of COM+HA at 0.56 dS/m level of salinity in 2020 and 2021 seasons, however the lowest values were recorded to the untreated control with 6.0 dS/m (Table 5).

3-2- Water use efficiency (WUE)

Data in Table 6 show that salinity enhanced WUE (which is: total fruit yield/water amount used throughout the season) and this effect was pronounced at 6 dS/m than 3 dS/m levels of salinity in both seasons of study. These finding are in agreement with those reported by Malash *et al*. (2008) who indicated that water use efficiency (WUE) of tomato plants was increased by using irrigation water with low and moderate salinity levels (2 and 3dS/m) as compared to those obtained with non-saline water (0.55dS/m).

Salinity alleviation treatments significantly increased WUE than those obtained by the untreated control (Table 6). Again, the combined treatments i.e. COM+HA and AM+PGPR as well as AM and COM each applied alone gave higher values of WUE (Table 6). These results seem to be in accordance with those obtained by Hajiboland *et al*. (2010) who found that *arbuscular mycorrhizal* (AM) inoculated improved WUE of tomato plants that grown under saline conditions. PGPR as well increased the WUE of tomato plants grown under saline conditions (Mayak *et al.*, 2004b), also PGPR inoculation resulted in longer roots which might be helpful in the uptake of relatively more water even under salinity stress (Dodd *et al*., 2004 and Abd El-Samad *et al.*, 2004) such conditions lead to better use efficiency. Organic fertilizer (COM+HA) also enhanced WUE by increasing water holding capacity in soil suffering from salinity (Altome *et al.*, 2015) or maintaining better leaf water content under osmotic stress (Canellas *et al.*, 2015). Accordingly, Feleafel and Mirdad (2014b) found that increasing HA rate led to a significant increase in WUE of tomato plants grown under salt stress conditions, than those of untreated control.

Table (6): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on water use efficiency (WUE) of tomato plants determined at the end of both seasons of study.**

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	W.U.E. (kg/m^3)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	1.97	1.77	2.05	2.05	1.84	2.17	1.31	1.88
3.00	2.20	1.95	2.37	2.46	1.96	3.05	1.60	2.23
6.00	2.62	2.46	2.93	3.18	2.69	3.30	1.53	2.67
Mean B	2.26	2.06	2.45	2.56	2.16	2.84	1.48	
L.S.D A	0.015							
L.S.D B	0.023							
L.S.D AxB	0.039							
Season 2021								
0.56*	1.27	0.90	1.43	1.34	1.12	1.72	0.82	1.23
3.00	1.50	1.25	1.78	1.60	1.43	1.97	0.92	1.49
6. 00	1.76	1.35	2.49	2.07	1.58	2.66	0.93	1.84
Mean B	1.51	1.17	1.90	1.67	1.38	2.12	0.89	
L.S.D A	0.023							
L.S.D B	0.036							
L.S.D AxB	0.062							

*= tap water (control)

**WUE= Total yield (kg) / water used throughout the growing season (m^{3}).

4-Effect on leaf chemical content

4-1- Mineral elements contents in young and old leaves

Salinity of irrigation water in this study resulted in decreasing tomato leaf contents of important essential nutrient elements i.e., N, P, K and Ca in both young and old leaves in both seasons, and sampling dates (Tables, 7, 8, 9 and 10). Same tables also show that the reduction of these elements was more pronounced in plant sample taken at 60 DAT than that taken at 50 DAT. It also observed that young leaves had higher levels of nutrient elements i.e., N, P and K than in old leaves (Tables, 7, 8 and 9) however Ca contents show a counter- trend i.e., old leaves had higher content of Ca than those in young leaves in both seasons and sampling dates (Table 10). On the other hand, both Na and Cl contents were found in both young and old leaves of tomato, but their contents were much higher in old leaves than in young ones in both seasons and sampling dates (Tables 11 and 12). These results agreed with former reports regarding the detrimental effect of salinity on nutrient elements uptake and contents in plant leaves such as N, P, K and Ca, while salinity resulted in increasing Na and Cl content in tomato plant tissues (Malash *et al.*, 2008, Tartoura *et al*., 2014 and Ors *et al.*, 2021). The depression of the essential nutrient mineral's contents in plant tissues by salinity may be due to the competition and antagonism between high concentration of Na and Cl ions and such minerals (Grattan and Grieve, 1999 and Tester and Davenport, 2003).

Table (7): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on nitrogen (N) content in young and old leaves of tomato plants determined at 50d (in 2020 & 2021) and 60d (in 2021only) after transplanting.**

Salinity levels dS/m (A)	Salinity alleviation treatments															
	Sample taken at 50 d after transplanting in 2020															
	N content in young leaves (%)								N content in old leaves (%)							
	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM+ HA	Untreat. control	Mean A	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM+ HA	Untreat. control	Mean A
0.56*	2.12	1.83	2.25	2.14	1.91	2.56	1.46	2.04	1.52	1.23	1.86	1.78	1.49	1.96	1.18	1.57
3.00	1.96	1.72	2.09	2.04	1.88	2.25	1.33	1.90	1.41	1.05	1.49	1.49	1.31	1.72	1.10	1.37
6.00	1.70	1.57	1.73	1.70	1.62	1.91	1.25	1.64	1.25	1.20	1.31	1.25	1.23	1.49	0.97	1.24
Mean B	1.93	1.71	2.02	1.96	1.80	2.24	1.35		1.39	1.16	1.55	1.51	1.34	1.72	1.08	
L.S.D. A	0.094								0.084							
L.S.D. B	0.144								0.128							
L.S.D. AxB	0.250								0.222							
	1st sample taken at 50 d after transplanting in 2021															
0.56*	2.40	2.38	2.53	2.43	2.40	3.53	1.70	2.48	1.72	1.49	1.86	1.72	1.65	2.98	1.46	1.84
3.00	2.17	1.93	2.46	2.27	2.04	2.64	1.59	2.16	1.54	1.33	1.67	1.59	1.33	1.72	1.05	1.46
6.00	2.09	1.88	2.27	2.17	1.88	2.27	1.46	2.00	1.49	1.18	1.65	1.41	1.31	1.62	0.91	1.37
Mean B	2.22	2.06	2.42	2.29	2.11	2.81	1.59		1.59	1.33	1.72	1.58	1.43	2.11	1.14	
L.S.D. A	0.080								0.078							
L.S.D. B	0.121								0.120							
L.S.D. AxB	0.210								0.208							
	2nd sample taken at 60 d after transplanting in 2021															
0.56*	1.86	1.70	2.27	2.04	1.83	2.35	1.54	1.94	1.25	1.18	1.41	1.33	1.20	1.65	1.10	1.30
3.00	1.67	1.65	1.78	1.72	1.59	2.04	1.49	1.71	1.25	1.15	1.41	1.33	1.18	1.57	1.07	1.28
6.00	1.65	1.57	1.72	1.70	1.57	1.86	1.33	1.63	1.20	1.10	1.25	1.23	1.10	1.49	0.91	1.18
Mean B	1.72	1.64	1.93	1.82	1.66	2.08	1.45		1.24	1.14	1.36	1.30	1.16	1.57	1.03	
L.S.D. A	0.099								0.053							
L.S.D. B	0.151								0.082							
L.S.D. AxB	0.262								0.141							

*= tap water (control)

**= Young leaves: are the 4th and 5th leaves from plant tip, while old leaves: are the 7th, 8th and 9th leaves from plant tip.

Table (8): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on phosphorus (P) content in young and old leaves[**] of tomato plants determined at 50 d (in 2020 & 2021) and 60 d (in 2021only) after transplanting.

Salinity levels dS/m (A)	Salinity alleviation treatments															
	Sample taken at 50 d after transplanting in 2020															
	P content in young leaves (%)								P content in old leaves (%)							
	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM + HA	Untreat. control	Mean A	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM + HA	Untreat. control	Mean A
0.56*	0.154	0.146	0.171	0.137	0.130	0.138	0.120	0.142	0.119	0.118	0.148	0.100	0.090	0.107	0.085	0.109
3.00	0.145	0.136	0.157	0.134	0.126	0.136	0.116	0.136	0.116	0.116	0.120	0.092	0.086	0.095	0.071	0.099
6.00	0.128	0.091	0.133	0.083	0.079	0.088	0.060	0.094	0.078	0.080	0.083	0.062	0.062	0.074	0.059	0.071
Mean B	0.142	0.124	0.154	0.118	0.112	0.121	0.099		0.104	0.105	0.117	0.085	0.079	0.092	0.071	
L.S.D. A	0.004								0.002							
L.S.D. B	0.006								0.003							
L.S.D. AxB	0.009								0.006							
	1st sample taken at 50 d after transplanting in 2021															
0.56*	0.232	0.230	0.250	0.176	0.170	0.196	0.168	0.198	0.170	0.161	0.177	0.143	0.127	0.145	0.120	0.145
3.00	0.201	0.185	0.215	0.173	0.170	0.174	0.139	0.179	0.167	0.137	0.172	0.126	0.117	0.132	0.112	0.138
6.00	0.199	0.180	0.212	0.157	0.128	0.180	0.108	0.166	0.138	0.124	0.169	0.085	0.083	0.120	0.070	0.113
Mean B	0.210	0.198	0.226	0.168	0.156	0.183	0.138		0.158	0.141	0.173	0.118	0.109	0.132	0.101	
L.S.D. A	0.009								0.003							
L.S.D. B	0.015								0.004							
L.S.D. AxB	0.026								0.007							
	2nd sample taken at 60 d after transplanting in 2021															
0.56*	0.214	0.189	0.230	0.178	0.173	0.189	0.118	0.179	0.131	0.127	0.190	0.119	0.104	0.124	0.060	0.122
3.00	0.186	0.168	0.224	0.134	0.129	0.138	0.097	0.154	0.125	0.120	0.143	0.099	0.075	0.119	0.058	0.106
6.00	0.181	0.142	0.222	0.126	0.122	0.133	0.076	0.137	0.113	0.095	0.133	0.074	0.065	0.078	0.055	0.088
Mean B	0.193	0.166	0.225	0.146	0.141	0.153	0.097		0.123	0.114	0.155	0.097	0.081	0.107	0.058	
L.S.D. A	0.003								0.002							
L.S.D. B	0.004								0.003							
L.S.D. AxB	0.008								0.005							

*= tap water (control)
**=The same foot notes as indicated in Table 7.

Table (9): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on potassium (K) content in young and old leaves of tomato plants determined at 50 d (in 2020 & 2021) and 60 d (in 2021only) after transplanting.**

Salinity levels dS/m (A)	Salinity alleviation treatments															
	Sample taken at 50 d after transplanting in 2020															
	K content in young leaves (mg/kg)								K content in old leaves (mg/kg)							
	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM+ HA	Untreat. control	Mean A	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM+ HA	Untreat. control	Mean A
0.56*	107.22	106.86	109.48	110.32	107.44	112.14	102.41	107.98	102.15	101.58	102.53	102.92	102.15	105.08	97.94	102.05
3.00	103.49	100.98	103.65	107.46	101.84	110.54	98.87	103.83	100.88	99.04	101.43	101.36	100.26	103.93	82.47	98.48
6.00	101.72	100.56	102.53	102.94	100.90	104.88	93.43	100.99	95.51	90.94	100.18	100.45	94.68	102.02	65.98	92.82
Mean B	104.15	102.80	105.22	106.91	103.39	109.19	98.24		99.51	97.18	101.38	101.57	99.03	103.68	82.13	
L.S.D. A	0.074								0.162							
L.S.D. B	0.113								0.248							
L.S.D. AxB	0.196								0.429							
	1st sample taken at 50 d after transplanting in 2021															
0.56*	105.57	105.05	110.77	108.22	105.22	115.83	104.39	107.87	102.78	101.02	104.15	103.35	102.02	104.56	100.40	102.61
3.00	103.79	102.04	108.62	106.49	102.58	111.29	97.92	104.68	100.77	90.10	101.68	101.06	100.34	103.14	68.13	95.03
6.00	100.98	91.77	105.05	101.97	100.44	106.66	83.43	98.61	79.71	71.26	98.77	84.89	76.33	100.80	58.96	81.53
Mean B	103.44	99.62	108.15	105.56	102.75	111.26	95.25		94.42	87.46	101.53	96.43	92.90	102.83	75.83	
L.S.D. A	1.040								2.006							
L.S.D. B	1.589								3.064							
L.S.D. AxB	2.753								5.307							
	2nd sample taken at 60 d after transplanting in 2021															
0.56*	105.05	102.78	107.62	105.92	103.36	111.21	100.80	105.25	98.93	95.51	101.27	101.19	96.67	103.63	81.50	96.96
3.00	102.39	100.59	105.57	103.63	101.37	109.46	93.43	102.35	87.81	81.50	98.93	96.82	82.95	101.26	64.10	87.63
6.00	100.34	87.31	103.19	102.78	98.77	103.35	79.13	96.41	82.47	66.78	93.43	90.94	75.39	100.29	54.79	80.59
Mean B	102.59	96.89	105.46	104.11	101.17	108.00	91.12		89.74	81.27	97.88	96.31	85.01	101.73	66.80	
L.S.D. A	0.684								1.489							
L.S.D. B	1.044								2.275							
L.S.D. AxB	1.809								3.940							

*= tap water (control)

**= The same foot notes as indicated in Table 7.

Table (10): Effect of salinity levels (A) and some salinity alleviation treatments (B) and their interactions (A×B) on calcium (Ca) content in young and old leaves of tomato plants determined at 50 d (in 2020 & 2021) and 60 d (in 2021only) after transplanting.**

Salinity levels dS/m (A)	Salinity alleviation treatments															
	Sample taken at 50 d after transplanting in 2020															
	Ca content in young leaves (mg/kg)								Ca content in old leaves (mg/kg)							
	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM + HA	Untreat. control	Mean A	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM + HA	Untreat. control	Mean A
0.56*	8.75	7.17	9.75	9.25	8.08	12.08	6.33	8.77	13.75	12.17	16.33	14.75	13.08	16.50	9.75	13.76
3.00	7.58	6.50	8.92	8.42	7.08	10.00	5.00	7.64	12.33	11.25	14.08	13.33	11.25	14.92	7.50	12.10
6.00	5.25	5.42	6.33	5.92	4.42	7.33	3.33	5.43	9.58	7.58	11.58	12.42	8.83	12.25	4.83	9.58
Mean B	7.19	6.36	8.33	7.86	6.53	9.81	4.89		11.89	10.33	14.00	13.50	11.06	14.56	7.36	
L.S.D. A	0.572								0.731							
L.S.D. B	0.874								1.117							
L.S.D. AxB	1.514								1.935							
	1st sample taken at 50 d after transplanting in 2021															
0.56*	9.25	7.50	10.50	9.67	8.83	12.50	6.50	9.25	13.67	12.08	16.33	15.33	12.67	17.25	9.25	13.80
3.00	7.00	6.00	9.25	8.58	6.25	10.83	5.25	7.60	12.00	8.42	14.67	12.50	11.08	15.58	7.83	11.73
6.00	6.08	4.92	8.33	7.83	5.42	9.00	2.58	6.31	9.00	6.25	10.33	9.83	8.33	11.33	5.75	8.69
Mean B	7.44	6.14	9.36	8.69	6.83	10.78	4.78		11.56	8.92	13.78	12.56	10.69	14.72	7.61	
L.S.D. A	0.475								0.550							
L.S.D. B	0.725								0.840							
L.S.D. AxB	1.256								1.454							
	2nd sample taken at 60 d after transplanting in 2021															
0.56*	10.08	8.83	10.92	10.67	9.92	11.75	6.67	9.83	13.58	12.08	15.08	12.58	12.92	15.83	8.83	12.99
3.00	8.00	7.08	9.67	9.17	7.50	10.00	5.50	8.13	11.08	9.58	12.67	11.58	10.08	13.75	7.33	10.87
6.00	6.58	4.58	7.92	7.17	5.17	8.58	3.75	6.25	8.33	5.58	10.50	7.92	6.58	10.67	4.63	7.74
Mean B	8.22	6.83	9.50	9.00	7.53	10.11	5.31		11.00	9.08	12.75	10.69	9.86	13.42	6.93	
L.S.D. A	0.465								0.649							
L.S.D. B	0.709								0.991							
L.S.D. AxB	1.229								1.717							

*= tap water (control)

**= The same foot notes as indicated in Table 7

Table (11): Effect of salinity levels (A) and some salinity alleviation treatments (B) and their interactions (A×B) on sodium (Na) content in young and old leaves of tomato plants determined at 50d (in 2020 & 2021) and 60d (in 2021only) after transplanting.**

Salinity levels dS/m (A)	Salinity alleviation treatments															
	Sample taken at 50 d after transplanting in 2020															
	Na content in young leaves (mg/kg)								Na content in old leaves (mg/kg)							
	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM + HA	Untreat. control	Mean A	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM + HA	Untreat. control	Mean A
0.56*	9.12	9.94	7.98	8.29	9.12	7.50	10.83	8.97	21.75	22.05	20.01	20.58	21.81	14.43	23.56	20.60
3.00	28.32	31.47	27.02	26.70	28.00	25.75	35.64	28.99	36.35	41.20	33.48	34.55	38.54	30.68	42.75	36.79
6.00	45.92	54.29	41.19	43.53	53.38	38.17	58.61	47.87	53.82	59.49	46.73	52.97	55.97	42.75	61.74	53.35
Mean B	27.79	31.90	25.40	26.18	30.16	23.81	35.02		37.31	40.91	33.41	36.03	38.77	29.28	42.68	
L.S.D. A	1.274								1.310							
L.S.D. B	1.946								2.002							
L.S.D. AxB	3.371								3.467							
	1st sample taken at 50 d after transplanting in 2021															
0.56*	13.38	16.21	10.84	11.72	13.14	10.38	20.59	13.75	27.02	29.32	22.36	23.25	25.10	18.60	34.16	25.69
3.00	37.45	40.83	34.16	35.60	38.18	26.06	48.01	37.18	44.72	47.94	42.75	43.93	47.39	25.76	52.53	43.57
6.00	42.75	49.18	37.06	38.99	47.94	35.97	54.24	43.73	57.29	64.54	55.18	56.44	59.05	50.42	71.56	59.21
Mean B	31.20	35.40	27.35	28.77	33.09	24.14	40.95		43.01	47.27	40.10	41.21	43.85	31.59	52.75	
L.S.D. A	1.181								2.867							
L.S.D. B	1.804								4.380							
L.S.D. AxB	3.125								7.586							
	2nd sample taken at 60 d after transplanting in 2021															
0.56*	10.60	14.87	9.31	9.74	12.20	8.09	18.04	11.83	20.90	22.05	18.04	19.15	21.45	16.70	24.49	20.40
3.00	44.73	49.60	40.83	42.75	46.72	35.97	57.73	45.48	55.10	71.11	47.94	51.26	58.62	47.94	82.47	59.21
6.00	72.04	76.44	64.51	65.75	74.02	60.44	88.20	71.63	92.93	100.06	82.30	88.70	96.22	75.97	103.37	91.36
Mean B	42.46	46.97	38.21	39.41	44.31	34.83	54.66		56.31	64.41	49.43	53.04	58.76	46.87	70.11	
L.S.D. A	1.536								1.292							
L.S.D. B	2.346								1.974							
L.S.D. AxB	4.064								3.419							

*= tap water (control)

**= The same foot notes as indicated in Table 7.

Table (12): Effect of salinity levels (A) and some salinity alleviation treatments (B) and their interactions (A×B) on chloride (Cl) content in young and old leaves of tomato plants determined at 50 d (in 2020 & 2021) and 60 d (in 2021only) after transplanting.**

Salinity levels dS/m (A)	Salinity alleviation treatments															
	Sample taken at 50 d after transplanting in 2020															
	Cl content in young leaves (mg/kg)								Cl content in old leaves (mg/kg)							
	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM+ HA	Untreat. control	Mean A	MA Inocu.	PGPR Inocu.	MA+ PGPR	COM Applic.	HA Applic.	COM+ HA	Untreat. control	Mean A
0.56*	92.67	100.33	92.33	90.33	99.67	86.00	103.00	95.28	101.67	105.00	98.33	97.67	104.00	91.00	106.33	100.57
3.00	123.67	130.33	120.67	101.33	130.33	89.33	132.33	117.39	132.00	134.67	130.67	117.67	135.00	93.67	138.67	126.05
6.00	133.33	136.67	127.67	118.33	136.00	95.33	139.00	125.50	139.33	141.00	134.67	131.67	140.33	105.00	144.00	133.71
Mean B	116.56	122.44	113.56	103.33	122.00	90.22	124.78		124.33	126.89	121.22	115.67	126.44	96.56	129.67	
L.S.D. A	1.603								2.497							
L.S.D. B	2.448								3.814							
L.S.D. AxB	4.241								6.606							
	1st sample taken at 50 d after transplanting in 2021															
0.56*	98.33	104.33	90.00	98.00	101.00	82.33	107.00	97.29	101.67	117.67	92.33	98.67	107.67	91.33	124.67	104.86
3.00	111.33	116.33	96.33	99.67	111.33	92.00	125.33	107.48	121.67	129.67	108.67	111.33	125.67	96.33	131.67	117.86
6.00	125.33	123.67	103.33	118.00	119.67	95.67	127.67	116.19	128.67	130.67	120.67	124.67	129.67	98.33	133.33	123.71
Mean B	111.67	114.78	96.56	105.22	110.67	90.00	120.00	111.67	117.33	126.00	107.22	111.56	121.00	95.33	129.89	
L.S.D. A	1.469								2.008							
L.S.D. B	2.243								3.056							
L.S.D. AxB	3.886								5.294							
	2nd sample taken at 60 d after transplanting in 2021															
0.56*	101.33	116.33	91.67	99.00	111.33	87.67	119.00	103.76	109.67	116.67	102.67	103.67	114.00	92.33	122.33	108.76
3.00	130.33	136.00	126.33	129.67	130.67	90.67	138.33	126.00	136.67	141.67	129.33	133.00	137.67	98.33	146.33	131.86
6.00	137.67	137.67	136.67	137.00	139.00	102.67	141.67	133.19	143.33	146.67	141.00	142.00	146.67	109.00	148.67	139.62
Mean B	123.11	130.00	118.22	121.89	127.00	93.67	133.00		129.89	135.00	124.33	126.22	132.78	99.89	139.11	
L.S.D. A	1.145								1.347							
L.S.D. B	1.749								2.057							
L.S.D. AxB	3.029								3.563							

*= tap water (control)

**= The same foot notes as indicated in Table 7.

In general, data in Tables 7 - 10 indicated that salinity alleviation treatments enhanced useful mineral nutrient contents in tomato leaves in both normal (non-saline) and saline conditions, but their effect was more pronounced under normal conditions. Also, such treatments increased N, P, K and Ca contents of tomato leaves in both young and old leaves, this increment was slightly decreased in samples taken at 60 DAT than those determined at 50 DAT. As previously mentioned, that salinity alleviation treatments increased N, P and K contents in young and old leaves but the proportion of the increment in young leaves was higher than that observed in old ones. However, Na and Cl contents in both young and old leaves both were decreased by using salinity alleviation treatment and the depression was more pronounced in young than in old leaves, this may be in line with the well-known knowledge that one mechanism in alleviation salinity hazard of plants is to motivate toxic ions e.g. Na and Cl to accumulate in old nonactive leaves. The accumulation of Na and Cl in older leaves while their concentrations remain low in younger leaves is an important physiological trait and salt tolerant mechanism to reduce salt accumulation in young active leaves (Soliman and Does, 1992 and Cuartero and Fernadez-Munoz, 1999).

All salinity alleviation treatments (either bio or organic fertilizers) enhanced N, P, K, and Ca content in tomato young and old leaves under saline conditions, (Tables, 7, 8, 9 and 10). But N, P and K content was higher in younger leaves than older ones, however, Ca content shows a counter-trend as its content in older leaves was higher than in younger ones (Table 10). The higher concentration of calcium in older leaves (at the bottom of plants) compared to that in younger ones (upper leaves) observed in this study be returned turn to the special trait of calcium which is among those elements that move slowly in plants and its upward movement takes place in the transpiration stream (TS) through the xylem, TS fall down as a response to stomata closure caused by salinity, which more restricted Ca upward movement, this may explains the high concentration of Ca in lower old leaves, under the condition of this study.

It was demonstrated that AM inoculation of tomato plants grown under saline condition improved the uptake of almost essential nutrients (such as nitrogen, potassium, calcium and phosphors) by tomato plants (Balliu *et al*., 2015) while decrease the uptake and transport of Na+ in pepper plants grown under saline conditions (Cekic *et al*., 2012), and reducing the uptake of toxic ions such as Na and Cl in wheat plants irrigated with saline water (Daei *et al*., 2009). Also, similar findings were obtained by Hajiboland *et al*., (2010) who found that AM inoculation alleviated salt-induced reduction of P, Ca and K uptake in tomato and enhanced Ca/Na and K/Na ratios. PGPR in addition, can increased mineral ions via stimulation of proton pump ATPase (Mantelin and Touraine, 2004). Thus, Karlidage *et al.* (2013) reported that strawberry plants grown under salinity stress and inoculated with PGPR significantly increased element contents of leaves such as N, K, P and Ca. Moreover, Bacillus subtilis also enhanced nitrogen fixation and solubilize soil P (Hashem *et al*., 2019).

Enrichment of organic matter in the soil leads to improve soil physical, chemical and biological properties, increased soil dissolved organic C and nutrient retention capacity of salt-effected soil and improving plant nutrient use efficiency (Qadir and Oster 2004, Clark *et al*, 2007 and Wang *et al*., 2014). Therefore, COM application resulted in the enhancement of plant nutrient uptake and accumulation in tomatoes (walker and Bernal, 2008), eggplant (Semida *et al*., 2014) and in barley (Liang *et al.*, 2005 and Tejada *et al*., 2006) plants grown under saline conditions. Similarly, Leogrande *et al.* (2016) mentioned that COM application significantly decreased the sodium adsorption rate and increased potassium and calcium contents on tomato plants which were irrigated with saline water (EC=6.0 dS/m).

While, it was also reported that the mechanism of HA in promoting plant growth may be by enhance the uptake of useful nutrients and reduce the uptake of toxic elements such as Na and Cl (Knicker *et al*., 1993, Tan, 1998 and Friedel and Scheller, 2002). HA application also was able to improve N, P and K contents in tomato plants leaves that were grown in saline conditions

(Ashraf and Mohamed 2008 and Feleafel and Mirdad 2014a) while the reverse was true for Na and Cl (Ashraf and Mohamed 2008).

4-2- Proline content in tomato leaves

Proline is one of the compatible organic solutes that are used by plant as osmoprotectant under stress conditions. The data presented in Table 13 clearly show that proline content in tomato leaves was significantly increased by salinity and its increment was more pronounced with highest salinity level of irrigation water i.e. 6dS/m, in both seasons. Thus, these findings support the previous findings (Azami *et al.*, 2010, Eraslan *et al*., 2015 and Ali and Rab, 2017) regarding the increase of proline content in tomato leaves by salinity stress. This accumulation of osmolytes especially proline is a common phenomenon in plants under salt stress.

The salinity alleviation treatments, however, decreased proline content in tomato leaves than those in untreated plants (Table 13). But it is observed that treatments that did well in enhancing vegetative growth, RWC, uptake of benefit nutrient elements and reduced toxic ions uptake (previously found in this study) gave lower proline content than those treatments that had less influence on growth parameters and other traits that enhancing salt tolerance. Such result seems reasonable since the favorable changes which induced salinity mitigation in plants by combined treatments i.e, COM+HA and other treatments reduced the required of further accumulation of proline content.

However, the response of proline content to bio-fertilizer treatments under salinity stress is somewhat contradictory, i.e., some studies demonstrated that AM inoculation increased proline contents in tomato plants (Barin *et al*., 2006 and Hajiboland *et al.*, 2010, Dargiri *et al*., 2021). On the other hand other studies indicated that AM untreated plants accumulated more proline than those treated (Jahromi *et al*., 2008 on lettuce, Kaya *et al*., 2009 on pepper, and Isfahani *et al*., 2019 and Turan *et al*., 2021 on tomato plants) all grown under saline conditions. Thus, it could be concluded that bio-fertilizers application can reduce the severity of salt stress and enhance mitigation of salinity, this may resulted in reduce proline accumulation.

Table (13): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on proline content in leaves of tomato plants determined at 50 d after transplanting in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	Proline content in leaves (µ/g Dr.Wt)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	122.75	188.97	119.93	100.54	126.45	90.86	212.68	137.46
3.00	353.58	403.25	311.29	268.43	395.79	236.98	502.16	353.07
6.00	398.84	541.17	462.85	437.41	524.60	415.78	893.04	524.81
Mean B	291.72	377.80	298.03	268.79	348.95	247.87	535.96	
L.S.D A	18.913							
L.S.D B	28.891							
L.S.D AxB	50.040							
Season 2021								
0.56 *	103.50	119.20	80.11	90.59	115.58	77.20	138.62	103.54
3.00	238.59	451.96	197.97	217.04	249.64	157.86	442.30	279.34
6.00	451.64	571.87	326.61	337.64	549.58	238.90	746.35	460.37
Mean B	264.58	381.01	201.57	215.09	304.93	157.99	442.43	
L.S.D A	26.673							
L.S.D B	40.744							
L.S.D A x B	70.571							

*= tap water (control)

Proline content in plant leaves also shows a contradictory response toward the effect of organic fertilizer under salinity conditions (Table 13). El-Galad *et al*. (2013) in a similar work found that compost treatment of faba bean plants grown under saline conditions significantly decreased proline content. Hammad *et al.* (2010) explained that organic fertilizer maintains osmotic adjustment to keep continuous water absorption at low soil water potential caused by salinity, such favorable effect of organic fertilizer reduced salinity detrimental effect on plants so that decrease plants requirement of proline. On the other hand Rady (2012) on tomato and Semida *et al*. (2014) on eggplant both grown under saline conditions, showed an increase in proline contents in plants fertilized with organic fertilizer compared to those of untreated control plants.

The interaction effect between salinity levels and salinity alleviation treatments on proline content (Table 13) shows that the significantly highest value of proline content was obtained by untreated control with 6 dS/m in both seasons. However, the lowest value of proline was recorded to the combined treatment of COM+HA with 0.56 dS/m level of salinity (Table 13). Proline in plants treated with salinity alleviation treatments and irrigated with tap water (0.56 dS/m) show lower values than that obtained from counterpart treatments but subjected to salinity levels i.e.,(3.0 and 6.0dS/m).

5- Electrolyte leakage (EL)

According to the data given in Table 14 electrolyte leakage (EL) tended to increase consistently and significantly with each increase in salinity level in irrigation water of tomato, and the proportion of the increment aggravated at 6 dS/m than at 3 dS/m of salinity level. These results seemed to be accordance with those obtained by (Manaa *et al*., 2011, Tartoura *et al*., 2014 and Ors *et al*., 2021) who reported that EL values increased proportionally in tomato leaves with increasing salt concentration.

Table (14): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on electrolyte leakage in tomato leaf determined at 50 d after transplanting in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	Electrolyte leakage values (%)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated Control	Mean A
0.56*	47.43	57.58	46.78	45.96	54.80	32.84	61.54	49.56
3.00	73.84	81.41	67.99	66.38	76.66	66.14	87.33	74.25
6.00	83.84	82.70	78.45	73.39	85.95	69.62	90.64	80.66
Mean B	67.87	73.54	62.36	66.39	72.47	56.20	79.84	
L.S.D A	0.683							
L.S.D B	1.044							
L.S.D AxB	1.808							
Season 2021								
0.56 *	31.04	43.25	27.63	28.25	36.70	26.47	49.57	34.70
3.00	58.33	63.75	50.24	55.55	60.81	45.63	70.91	57.81
6.00	73.00	77.97	69.52	72.70	75.93	66.32	87.08	74.64
Mean B	54.12	61.65	49.13	51.99	57.81	46.14	69.19	
L.S.D A	1.318							
L.S.D B	2.013							
L.S.D A x B	3.486							

*= tap water (control)

According to Manaa *et al*. (2011) EL is known as an indicator of membrane damage caused by salt stress in tomato leaves according to NaCl concentration. Also, salinity induces reactive oxygen species (ROS) formation which can lead to oxidative damage in various cellular components such as proteins and lipids particularly those in cell membrane (Apel and Hirt, 2004, Munns and Tester, 2008, Rahnama *et al*., 2010 and Ahmed and Umar, 2011). These findings may explained why EL is associated with stress conditions particularly salinity.

Salinity alleviation treatments, on the other hand seriously mitigate the hazard effect of salinity so that they all decreased EL. Also, treatments that did well in enhancing growth, useful nutrient uptake and improve water status, previously mentioned in this study (i.e., combined treatments of COM+HA, and AM+PGPR and AM and COM applied alone) gave the lower values of EL (Table 14). These results support the former reports regarding the favorable effect of AM in reducing EL in cucumber plants (Ahmad *et al*., 2019) and in pepper plants (Kaya *et al*., 2009), both grown in saline conditions. Also, similar findings were mentioned by Bano and Fatima (2009) on Zea Maize, Karlidag *et al*. (2013) on strawberry and Ullah *et al*. (2016) on tomato, who observed that PGPR decreased EL in cells of plants suffer from salinity stress. Among the roles of biofertilizers (particularly AM) as salinity alleviation treatment used in this study is to enhance the synthesis of antioxidant enzymes (Aguilar- Aguilar *et al*., 2009) and also increase their activity (Heikham *et al*., 2009) for scavenging of ROS. Also, Rady *et al*. (2016) found that application of organo-mineral fertilizer compost significantly reduced EL in bean plants which grown in saline soil. HA, as well, added to saline soil significantly reduced EL in bean plants (Aydin *et al.*, 2012). In addition, compost as organic fertilizer has the capability to increase antioxidants activities which enhance salt tolerance to salinity and other stress conditions. Moreover, salinity alleviation treatments used in this study reduced toxic elements i.e., Na and Cl uptake, and enhance water content and nutrient element uptake such favorable conditions would reduce salinity detrimental effect on cell membrane and reduce EL.

The highest value of electrolyte leakage of tomato plants (Table 14) was obtained by the untreated control with 6 dS/m level of salinity i.e.90.64 and 87.08 % in 2020 and 2021 seasons respectively, however the lowest values were 32.84 and 26.47 in the same order were recorded to the combined treatment of COM+HA with 0.56 dS/m (Table 14).

As expected the combined treatment of COM+HA with 0.56 dS/m level gave significantly the lowest value of electrolyte leakage in tomato leaves, in both seasons.

6- Fruit weight and total yield

6-1- Average fruit weight

Results obtained in Table 15 indicate that salinity reduced average fruit weight, and the reduction tended to decrease consistently and significantly with each increase in salinity level in both seasons. Accordingly, the reduction percentages (average of the two seasons) than that fruit weight of non-saline treatment were 17.9 and 29.0 % at 3 and 6 dS/m respectively.

These results seemed to be in accordance with those obtained by Greenway and Munns (1980), Magan *et al.* (2008) and Zhai *et al.* (2016) regarding the detrimental effect of salinity on average fruit weight of tomato. It was also previously mentioned that the reduction in average tomato fruit weight occurred even at low and moderate salinity levels; i.e., at 3-4 dS/m (Malash *et al.*, 2008, Scholberg and Locascio 1999), but the reduction was more pronounced at higher salinity level i.e. 9.6 dS/m^{-1} (Souza, 1990 and Al-Yahyai *et al.*, 2010). Such reduction in average fruit weight by salinity could be explained by the fact that salinity particularly high levels decreased water potential of tomato plants which reduces water flow into fruit and limit the rate of fruit expansion (Johnson *et al*., 1992 and Al-Ismaily *et al.*, 2014). Also, the accumulation of Na in tomato plant leads to such reduction in mean fruit weight of tomato (Adams, 1991 and Cuartero and Fernandez-Munoz, 1999).

Table (15): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on average fruit weight (g) of tomato in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	Average fruit weight (g)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	28.16	28.23	28.33	27.44	27.59	28.02	23.91	27.38
3.00	23.23	22.47	23.52	23.80	21.72	25.95	20.20	22.99
6.00	20.67	20.68	20.80	21.71	21.56	19.06	17.15	20.23
Mean B	24.02	23.79	24.22	24.32	23.62	24.34	20.42	
L.S.D A	0.409							
L.S.D B	0.624							
L.S.D AxB	1.081							
Season 2021								
0.56*	17.56	16.51	17.63	17.84	16.70	20.10	15.73	17.44
3.00	13.38	13.92	14.11	13.50	13.38	15.38	12.23	13.70
6.00	10.82	10.07	13.82	12.48	10.92	13.25	8.90	11.47
Mean B	17.56	16.51	17.63	17.84	16.70	20.10	15.73	
L.S.D A	0.613							
L.S.D B	0.937							
L.S.D A x B	1.623							

*= tap water (control)

Salinity alleviation treatments significantly increased average fruit weight of tomato of both plants grown under non-saline (0.56 dS/m) and saline (3 and 6 dS/m) conditions than those obtained from plants untreated in both seasons of study (Table 15). But differences between treatments were not significant in most cases in 2020 season; i.e., the highest fruit weight was obtained by the combined treatment of COM+HA which was significantly differ only with that obtained by HA treatment applied alone (Table 15), whereas in 2021 the combined treatment of COM+HA gave significantly the highest fruit weight compared to other treatments. The enhancement of salinity alleviation treatments of average tomato fruit weight was also mentioned; i.e., Barin *et al*., (2006) and Hadad *et al*., (2012) with AM inoculation, Saha *et al*. (2017) with compost application and Kumar *et al*. (2017) with HA application. The favorable effect of such treatments on average fruit weight is expected since these treatments resulted in improving water status in tomato plants (Table 5) and reduced toxic ions (Na and Cl) uptake (Tables 11and 12).

Regarding the interaction between salinity and alleviation treatments Table 15 shows that the highest value of average fruit weight of tomato plants was recorded to the combination between 0.56 dS/m level of salinity and the combined treatments of AM + *B. subtilis,* and COM+HA in 2020 and 2021 seasons respectively. On the other hand, the lowest values were obtained by the combination between 6.0 dS/m and untreated control in both seasons.

6-2- Total fruit yield of tomato /plant

Table 16 shows that total yield of tomato/ plant decreased consistently and significantly with each increase in salinity level. The reduction percentage (average of the 2 seasons) in total yield were 26.9% at 3 dS/m and 46.8% at 6dS/m^{-1}, this implies that each 1dS/m increase in salinity level decreased tomato total yield by 6.6% (among this range of salinity under conditions of this study). These results are in agreement with those reported by Mohammad *et al*. (1998), Malash *et al.* (2008), Viol *et al.* (2017) and Pengfei *et al.* (2019), regarding the reduction of tomato total yield by exposing to salinity in its root zone. Also, Cuartero and Fernandez-Munoz (1999), Del Amor *et al.* (2001) and Malash *et al.* (2008) indicated that tomato yield is quite sensitive to salinity at 3.0 dS/m and above. Moreover, Moghaddam *et al.* (2018) showed that salinity at 4 dS/m and 7dS/m decreased tomato fruit yield by 27.2% and 46.7% respectively (compared to those without salt stress) which are somewhat similar to the corresponding values of this recent study at 3 and 6 dS/m respectively. Also, Zhang et al. (2016) reported that the reduction rate in fruit yield of tomato with increasing EC unit of salinity equal and above 5dS/m was 7.2%, thus this finding is somewhat similar to corresponding values obtained in this study (mentioned above).

The reason of reducing tomato yield by salinity, may return to higher osmotic pressure in plants (Ayers, 1977, Cuartero and Fernandez-Muroz, 1999 and Zhang *et al.,* 2016), or to the reduction in WUE (Al-Harbi *et al.*, 2009 and Al-Omran *et al*., 2012) and to accumulation of toxic ions such as Na and Cl (Niu *et al*., (1995).

Regarding salinity alleviation treatments, Table 16 shows that all treatments increased tomato total yield under saline and non-saline conditions. It is worth mentione hat the effect of combined treatment of COM+HA, as this treatment in particular gave the best performance in alleviation salinity hazard in this study, such treatment increased total yield under saline conditions rather than under normal (non-saline) conditions. This finding was similar to those obtained by Al-Karaki (2006) who indicated that AM inoculated tomato plants showed an enhancement in fruit yield by 24% under non-saline and 60% under saline conditions.

Table (16): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on tomato total yield in both seasons of study.

Salinity levels dS/m (A)	**Salinity alleviation treatments (B) — Total yield (g/plant) — Season 2020**							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	137.58	123.83	143.17	143.78	128.55	152.23	91.50	131.52
3.00	96.68	85.76	104.27	108.29	86.31	134.27	70.59	98.02
6.00	73.36	68.94	81.95	88.92	75.34	92.39	42.77	74.81
Mean B	102.54	92.84	109.80	113.66	96.73	126.30	68.29	
L.S.D A	0.423							
L.S.D B	0.737							
L.S.D AxB	1.277							
Season 2021								
0.56*	112.10	79.38	126.05	118.03	98.64	151.80	71.86	108.27
3.00	77.82	64.77	92.57	83.07	74.52	102.39	44.62	77.11
6.00	48.44	37.36	73.10	58.30	45.56	77.10	26.89	52.39
Mean B	79.45	60.50	97.24	86.46	72.91	110.43	47.79	
L.S.D A	0.931							
L.S.D B	1.421							
L.S.D A x B	2.462							

*= tap water (control)

The enhancement of total fruit yield of tomato grown under saline condition by AM was also mentioned elsewhere (Barin *et al*., 2006, Abdelhameid and El-Shazly, 2020 and Pietrantonio *et al.,* 2020). The beneficial effect of AM on yield of tomato grown in saline conditions were: provides nutrition to the host plants, as well as increasing water uptake, production of hormones and enhancing adaptation to environmental stress including salinity (Garg and Chandel, 2010). The improvement of total fruit yield grown in saline stress induced by PGPR was also mentioned elsewhere (Aini *et al*., 2021, Turan *et al*., 2021 on tomato and Bochow *et al.*, 2001 on eggplant and pepper). PGPR fixing atmospheric nitrogen, producing phytohormones, solubilizing minerals (Mayak *et al.,* 2004a), enhancing reactive oxygen species (ROS) scavenging (Jianmin *et al*., 2014) reduce salt toxicity by lowering the Na concentration in plants (Abd El-Samad *et al.*, 2004, Yildirim *et al.*, 2006 and Kohler *et al*., 2009), and reduces synthesis of harmful ethylene (Glick, 2014). This favorable effect of each treatment applied alone on total yield will be aggravated when both (AM+PGPR) added together which gave a synergistic effect observed in this study.

Compost (COM) application also enhanced tomato fruit yield even grown under saline conditions (Rady,2012 and Saha *et al.,* 2017). Also, the favorable effect of HA application on fruit yield of tomato plants grown under saline stress was also previously reported (Feleafel and Mirdad, 2014a, feleafel and Mirdad, 2014b and Kumar *et al.,* 2017). The benefit obtained by COM application to plants grown under saline conditions was improving soil physical, chemical and biological properties (Qadir and Oster, 2004, Walker and Bernal, 2008, and Wang *et al.,* 2014), such conditions enriched soil by humic substances, macro and micro-nutrients (Walker and Bernal, 2008 and Wright *et al.,* 2008).

The useful advantages of HA application in mitigation salinity hazard which dramatically reduces yield of plants were: enhancing the uptake of beneficial nutrient elements and reduce the uptake of toxic elements (Knicker *et al*., 1993, Tan, 1998 and Friedel and Scheller, 2002), transportation and availability of micro nutrient (Bohme and Lua, 1997) and by changing ion balance and enhancing photosynthesis rate (Souza *et al*., 2021).

Gathering the above mention advantage of COM and HA in one treatment of course will give a synergistic effect that was showed in the recent study.

According to the data of the interaction between salinity levels and salinity alleviation treatments, Table 16 shows that the highest total yield of tomato/ plant obtained was a result of using the combined treatment of COM+HA along with 0.56 dS/m salinity level (un-saline). The 2nd highest value of tomato total yield/plant was recorded to the COM treatment in 2020 season, but such rank was recorded to the combined treatment of AM+PGPR in 2021 season, both along with 0.56 dS/m salinity level. While the lowest values of tomato total yield/plant were due to those plants subjected to the highest salinity level (6.0 dS/m) and untreated with any of these salinity alleviation treatments (Table 16). HA application and PGPR inoculation along with the highest salinity level gave also lower total fruit yield /plant (Table 16).

7- Fruit quality

7-1 Total soluble solids (TSS) content in tomato fruit

Salinity increased TSS content in tomato fruits and the increase was growing with increasing salinity levels in the irrigation water in both seasons (Table 17). This result agreed with former reports regarding the positive effect of salinity on tomato fruit quality including TSS (Mizrahi *et al*., 1988, De Pascale *et al.,* 2001, Malash *et al*., 2002 and Maggio *et al.*, 2004). Table 17 also shows that TSS values were higher in the two salinity levels than those obtained by non-saline treatment whatever was salinity alleviation treatments used. The reason of the increase in TSS content in tomato fruit by salinity was clarified by several researchers, such reasons are:1- salinity promotes starch accumulation in immature tomato fruit which consider as a reservoir for soluble sugars accumulation during fruit ripening ,contributing to the final fruit sugar level (Schaffer *et al.,* 2000 and Petreikav *et al.,* 2009), 2- the increase of tomato fruit soluble solids seems to be associated with the reduction in the water content of the fruit, (Adams and Ho 1989,Cuartero and Fernandez-Munoz,1999 and Magan *et al.*, 2008), and 3- the increasing in total soluble solids by salinity may due to smaller fruit size (Ho *et al.*,1996).

Tomato plants that subjected to salinity alleviation treatments, however produced fruits with lower TSS content than those produced by untreated plants, but differences were not significant in most cases (Table 17). Such treatments which resulted in reducing TSS may mitigated salinity effect in a way that enhanced water status (Table 5), and increase fruit size and weight (Table 15) such conditions reduced TSS in fruits. The reduction in TSS contents in tomato fruits by salinity alleviation treatments was also observed by Al-karaki and Hammad (2001) who mentioned that TSS content in tomato fruits of plants inoculated with AM was lower than those obtained from plants un-inoculated when both plants grown in saline condition. The same authors added that stress conditions induced by salinity enhances fruit quality of tomato, while AM treatment mitigate the harmful effect of salinity by improve water and nutrient status as well as another physiological and biochemical process, such favorable effect reduced TSS content.

Also, the non-significant differences in TSS content of tomato plants inoculated by AM and those of uninoculated plants both grown under saline conditions were also recorded by Huang *et al.* (2013). On the other hand Ebrahim and Saleen (2017) and Al-Karaki (2006) indicated that TSS in tomato fruits was higher in AM treated plants than those of untreated plants either grown under saline and non-saline conditions.

Table (17): Effect of salinity levels (A), some salinity alleviation treatments(B) and their interactions (A×B) on TSS content in tomato fruits determined in mature red fruits one time during harvesting period in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	TSS content (%)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	6.68	6.37	6.67	6.75	6.62	6.62	6.25	6.56
3.00	7.55	7.65	7.58	7.60	7.13	6.93	7.98	7.49
6.00	8.07	8.23	8.32	8.17	8.05	8.18	8.68	8.24
Mean B	7.43	7.42	7.52	7.51	7.27	7.24	7.64	
L.S.D A	0.169							
L.S.D B	0.259							
L.S.D AxB	0.448							
Season 2021								
0.56*	3.68	4.33	3.73	4.40	4.78	4.83	3.95	4.24
3.00	7.08	6.30	6.60	6.78	7.28	7.10	7.68	6.97
6.00	8.33	7.10	7.50	7.53	7.93	8.18	8.45	7.86
Mean B	6.36	5.91	5.94	6.23	6.66	6.70	6.69	
L.S.D A	0.266							
L.S.D B	0.407							
L.S.D A x B	0.705							

*= tap water (control)

PGPR treatment in this study resulted in produce fruits with TSS values either were not significantly differ (in 1st season) or significantly less (in 2nd season) than those produced by plants of control (untreated). Thus, these results is not in agreement with those of Shen *et al.*, (2012) who suggested that PGPR was able to improve total and water dissolved sugars under saline conditions.

Table 17 shows also that applied both COM and HA decreased significantly TSS content of tomato fruits (in 2020 season) but such treatments resulted in obtaining fruits had TSS values were not significantly different (in 2021 season) than those produced from the untreated plants and grown under saline conditions.

In previous reports, HA effect on TSS of tomato fruit was also differ, i.e. Ashraf and Mohamed (2008) found significant increase in TSS content of tomato fruit with HA treatment under saline conditions, however Casiorra-Posada and Fischer (2009) found that HA application to tomato plants grown under saline conditions reduced total solids in fruits.

The highest value of TSS of tomato plants (Table 17) was obtained by the untreated control at 6 dS/m level of salinity i.e. 8.68 and 8.45 % in 2020 and 2021seasons respectively, however the lowest values in the same order were recorded to the untreated control in 2020 and mycorrhizal inoculation in 2021 season both at 0.56 dS/m^{-1} (Table 17).

7-2 Vitamin C (Vit C) content in tomato fruits

Results in Table 18 show that vit C content in tomato fruit increased by salinity and the increase was consistently and significantly with each increase in salinity level, in both seasons. These results support the former reports regarding the enhancement effect of salinity on Vit.C content in tomato fruits (Eraslan *et al.*, 2015, Zhai *et al*., 2015, Helaly *et al*., 2017 and Rani *et al*., 2017). The increase in vit. C content in tomato fruits under salinity stress may be a consequence of the accumulation of monosaccharides in fruits (Cuartero and Fernandez-Munoz, 1999) such monosaccharides were previously mentioned before in TSS discussion. By the way, the chemical symbol of Vit. C is ($C_6H_8O_6$) which is quite similar to those of monosaccharides ($C_6H_{12}O_6$). In addition, the reduction in plant foliage growth by salinity, may increase the exposure of fruits to sunlight which is effective in increasing Vit. C (Radwan *et al*., 1979 and Malash *et al*., 2002).

Salinity alleviation treatments increased Vit.C content in fruit of tomato plants than those untreated, in both seasons {with one expetion. i.e. the Vit. C value in fruits produced from plants treated with PGPR was not significantly different than those of plants untreated (control) in both seasons}. The enhancement of Vit.C in tomato fruit by salinity alleviation treatments used in this study (under saline conditions) was also observed by Shen *et al*. (2012) who mentioned that, from three PGPR strains studied, WP8 strain had the most significant effect in improving Vit.C in fruits of tomato plants grown under saline conditions. Also, Oztekin *et al.* (2013) found that inoculated tomato plants with AM increased the vitamin C in fruits when plants grown under salinity conditions.

Using organic fertilizers such as COM and HA also enhanced Vit.C content in fruit of tomato plants treated with amended saline irrigation water with humic acid than those obtained without HA application (Ashraf and Mohamed, 2008).

Table (18): Effect of salinity levels (A), some salinity alleviation treatments (B) and their interactions (A×B) on Vit.C content in tomato fruits determined in mature red fruits one time during harvesting period in both seasons of study.

Salinity levels dS/m (A)	Salinity alleviation treatments (B)							
	Vit. C. content(mg/100g f w)							
	Season 2020							
	Mycorrizal Inoculation	B. subtilis Inoculation	Mycorrizal + B. subtilis	Compost Application	Humic Acid Application	Compost + Humic Acid	Untreated control	Mean A
0.56*	21.33	19.87	22.40	23.07	20.00	23.20	19.73	21.37
3.00	24.79	20.02	25.13	27.30	22.62	30.33	19.41	24.23
6.00	30.77	25.65	30.85	29.73	29.21	35.36	29.29	30.12
Mean B	25.63	21.85	26.13	26.70	23.94	29.63	22.81	
L.S.D A	0.755							
L.S.D B	1.154							
L.S.D AxB	1.998							
Season 2021								
0.56*	20.72	17.29	21.30	22	19.71	23.36	16.17	20.08
3.00	26.58	22.18	27.63	28.69	25.87	27.98	20.42	25.62
6.00	31.50	26.22	34.32	36.43	30.80	37.49	25.70	31.78
Mean B	26.27	21.90	27.75	29.04	25.46	29.61	20.76	
L.S.D A	1.305							
L.S.D B	1.994							
L.S.D A x B	3.454							

*= tap water (control)

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تخفيف إجهاد الملوحة على نباتات الطماطم من خلال بعض تطبيقات الأسمدة العضوية والحيوية

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قسم البساتين – كلية الزراعة – جامعة المنوفية – شبين الكوم

الملخص العربى

أجريت هذة التجربة في موسمين زراعين متتالين ٢٠٢٠ و٢٠٢١ في أصص تحت الصوبة السيرام بمزرعة التجارب بكلية الزراعة - جامعة المنوفية - بشبين الكوم. الهدف من هذه الدراسة هو دراسة تأثير التسميد العضوي (الكمبوست والهيوميك اسيد) والتسميد الحيوي (الميكورايزا والبكتريا المنشطة للنمو) لتخفيف الاثار السلبية للملوحة علي هجين الطماطم ١٨٦. تم تجهيز محاليل ملحية بإستخدام كلوريد الصوديوم بتركيزين (٣ و٦ dS/m^{-1}) بالاضافة الي الري بماء الصنبور ككنترول. أظهرت النتائج أن الملوحة أدت الي نقص في كل من: صفات النمو الخضري مثل إرتفاع النبات والوزن الجاف للنبات كذلك حدث نقص في عدد الايام اللازمة لبداية تزهير ٥٠٪ من النباتات (F_{50}) وكذا النسبة المئوية لعقد الثمار، المحتوي المائي النسبي في الاوراق ، محتوي الاوراق الحديثة والمسنة من النيتروجين والفوسفور والبوتاسيوم والكالسيوم بالاضافة الي انخفاض محصول الثمار ومكوناتة. وعلي الجانب الاخر أدت الملوحة الي زيادة في كل من : كفاءة استخدام الماء، محتوي الاوراق من البرولين ، التسريب من الجدر الخلوية في الاوراق بالاضافة الي تحسين جودة الثمار حيث ادت الملوحة الي زيادة محتوي الثمارمن المواد الصلبة الذائبة الكلية (TSS) وفيتامين ج ،كما ادت الملوحة الي زيادة محتوي الاوراق الحديثة والمسنة من عنصري الصوديوم والكلور ولكن كان التركيز أعلي في الاوراق القديمة عن الحديثة. كما أدت معاملات التسميد الحيوي والعضوي (سواء استخدمت فردية أومجمعة ثنائية؛ وهى الكمبوست + الهيوميك اسيد معا وأيضا الميكورايزا + البكتريا المنشطة للنمومعا) الي تخفيف التأثير الضار للملوحة حيث أدت الي زيادة قيم كل من قياسات النمو الخضري ونسبة العقد كما أدت الي تحسين الحالة المائية للنبات وكفاءة استخدام الماء ومحتوي الاوراق الحديثة والمسنة من النيتروجين والفوسفور والبوتاسيوم والكالسيوم والمحصول ومكوناتة وبالنسبة لصفات جودة الثمار فقد أدت معاملات تخفيف حدة الملوحة (الحيوية والعضوية) الي تقليل محتوي الثمار من المواد الصلبة الذائبة الكلية (TSS) في حين أدت الي زيادة محتوي الثمار من فيتامين C. معاملات تخفيف الاثار الضارة للملوحة (التسميد الحيوي والعضوي) أدت الي تقليل محتوي الاوراق الحديثة والمسنة من الصوديوم والكلور،محتوي الاوراق من البرولين والتسريب في الاوراق مما أدي الي تحسين النمو والانتاجية لنباتات الطماطم. المعاملات المجمعة (الميكورايزا مع البكتريا المنشطة للنمو) و(الكمبوست مع الهيوميك أسيد) كان لها تأثير تآزرى حيث أدت الي تخفيف تأثير الملوحة بدرجة افضل من استخدام كل مكون علي حدة. وعلي هذا فقد أدت هذة المعاملات المجمعة (الثنائية) الي أفضل النتائج تلاها المعاملة بكل من الكمبوست والميكورايزا (والتي استخدمت بمفردها) من حيث تخفيف التأثير الضار للملوحة علي نباتات الطماطم.

الكلمات المفتاحية: الطماطم ، معاملات تخفيف الملوحة ، نمو النبات ، المحتويات الكيميائية ومحصول الثمار، التسميد العضوي والحيوي.

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