J. of Agricultural Chemistry and Biotechnology, Mansoura Univ., Vol. 11 (3): 63 - 70, 2020

Journal of Agricultural Chemistry and Biotechnology

Journal homepage: www.jacb.mans.edu.eg
Available online at: www. jacb.journals.ekb.eg

The Impact of Inoculation with *Arbuscular mycorrhizal* Fungi on Tomato Tolerance to Salt Stress and Nutrients Uptake in Sandy Soil

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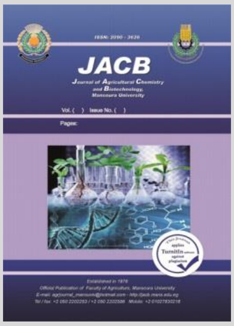

ABSTRACT

To evaluate the effect of mycorrhiza (*Glomus macrocarpium*) with two phosphorus and nitrogen levels (50 and 75 % Optimal dose) and two water salinity levels (2800 ppm (S1) and 3800ppm (S2)) on yield, nutrients uptake and growth parameters of tomato plant. A field experiment was conducted at El Sheikh Zowaied Research Station, North Sinai, Egypt during two successive seasons. The obtained results showed that inoculation with mycorrhizal fungi reduces the negative impact of salinity in growth parameters, nutrient contents and yield of tomato by increasing significantly the shoot and root weights by 38.6, 48.65% and 38.7, 47.86%; leaf area and chlorophyll content by 12.36, 29.90% and 12.93, 30.87%; root/shoot ratio by 19.17 and 11.43% and marketable yield by 29.99 and 33.63%. While significantly reduce the loss of unmarketable yield from 11.05 to 8.86% for the two seasons, respectively. Also, mycorrhizal inoculation increases significantly the plant N by 6.34 and 5.31%; P by 23.66 and 22.03% ad K by 3.64 and 3.15% for both seasons respectively. Similarly, mycorrhizal inoculation significantly improved microbial activities in the soil rhizosphere area of tomato plants. The total microbial counts, phosphatase enzyme, root colonization and soil mycorrhizal spores increases by 33.60 and 35.00%; 45.92 and 52.88%; 257.14 and 257.89% and 34.18 and 34.47% for two seasons, respectively. Mineral fertilizers at 75% of optimal dose increase all traits parameters compared with 50%. In general, these results showed that mycorrhizal fungi represent a promising resource for improving both sustainable food production under salt conditions and human nutritional needs.

Keywords: Tomato ; Mycorrhizae; Phosphorous ; Nitrogen ; Salinity Stress ; Sandy Soil

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and widely grown vegetable crops in Egypt. Arbuscular - mycorrhizal fungi are soil microorganisms that launch mutual symbiosis with majority of plants, providing a direct physical linkage between soil and plant roots (Dudhane *et al*., 2013). The bio-fertilizers including mycorrhiza fungi provide nutrients to the grown plants, increase soil fertility and maintain soil structure. The Vesicular - Arbuscular Mycorrhiza (VAM) improves the properties of soil in rhizosphere, enlarges root areas of host plants, and improves the efficiency of water absorption, enhances the absorption of phosphorus and other nutritional elements, and then improves nutritional status of host plant; activates defense system of host plant quickly; protects against oxidative damage generated by drought, able to alter water relations and played a great role in the growth of host plants(Augé, 2001). Phosphatase produced by VAM fungi play an important role in transform fixed or insoluble phosphate into soluble form, which can be used by plant freely. Other elements such as zinc and copper can also not flow freely in soil (Wu and Xia, 2004). The absorption of Ca, Si, Ni, Co etc. were also increased by mycorrhizal symbiosis (Li *et al*., 1991).

Salinization arising from sodium chloride highly concentrations in irrigation water and unnecessary use of chemical fertilizers causes serious problems in agriculture and has increased progressively in many parts of the world, particularly in arid and semi-arid areas (Oztekin *et al*., 2013). In addition, climate change is causing agricultural damage worldwide as a result of more frequent flooding and drought cycles and increased soil salinity. Saline soils exist in more than 7% of the Earth's surface and signify a major limiting factor that decreases 20% of crop production worldwide under irrigated land (Feng *et al*., 2002; Porcel *et al*., 2012). Therefore, the utilization and development of saline land has been important challenge for researchers throughout the world (Singh *et al*., 2011).

Tomatoes are one of the most globally important crops that are known to benefit from a mycorrhizal symbiotic relationship (Nzanza *et al*., 2012). An electrical conductivity (EC) of greater than 2.5 dSm–1 reduces tomato yields, as reported by (Sonneveld and Welles, 1988). Therefore, the حذف salt-tolerant soil microbes could be a good alternative for plant development under conditions of extreme salinity (Giri *et al*., 2003). The arbuscular - mycorrhizal fungi have been studied for their ability to reduce the effects of salt on tomatoes (Daei *et al*., 2009; Feng *et al*., 2002). The mycorrhizal fungi symbiosis with lettuce (*Lactuca sativa L.*) and maize (*Zea mays L.*) plants have been reported to alleviate salt stress and improving the dry weights of the hosts (Aroca *et al*., 2013; Estrada *et al*., 2013). (Liu *et al*., 2016) reported that mycorrhizal fungal community endorsed leaf proline accumulation in cotton and a higher K+/Na+ ratio. Also improved P uptake derived from mycorrhizal fungi were related to alleviating salt stress and promoted the growth of cotton and maize in saline soils. (Vuksani *et al*., 2015) found that the production of open field tomato can be improved by

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DOI: 10.21608/jacb.2020.86998

the pre inoculation of mycorrhizal fungi to tomato transplants at the nursery stage. The tomato seedlings can then benefit a faster stand formation rate and higher vigor which is additional reflected to a prolonged harvesting stage and higher yield.

In salt-stressed soil, mycorrhizal fungi enhance the supply of mineral nutrients to plants, particularly the supply of P, as it tends to be precipitated in phosphate salts (Al-Karaki and Hammad, 2001). (Hart *et al*., 2015) found that AM fungal inoculation increased the nutrient quality of tomato fruits for most nutrients particularly N, P, and Cu. Mycorrhizal fungi counterbalance the contrary effects of salinity stress, and then, increase plant growth (Giri *et al*., 2003). VAM fungi also protect the host plants against the detrimental effects of stresses (Rabie, 2005) by enhancing the antioxidant responses (García-Sánchez et al., 2014) and/or via the induction of acquired systemic tolerance (Hashem *et al*., 2016).

The aim of this study was to investigate the effect of Mycorrhizae, nitrogen and phosphate levels on the productivity of tomato plants under two salinity levels at El-Sheikh Zowaied research station, North Sinai , Egypt.

MATERIALS AND METHODS

A field experiment was carried out for two successive seasons of 2017 and 2018 at El-Sheikh Zowaid research station, North Sinai. During program work at Desert Research Center (DRC), Cairo ,Egypt to investigate the effect of Mycorrhizae, some nutrient of elements (nitrogen and phosphorus) levels and irrigation water salinity levels on the productivity of tomato (*Solanum lycopersicum* L. super hybrid cultivar). Seeds were sown in polystyrene trays on 10th and 5th of February, 2017 and 2018, respectively. Seedlings and germination stages were conducted in the greenhouse. Seedlings were transplanted by hand at the third true leaf stage on 10th and 8th of March 2017 and 2018, respectively in oriented rows, 1.3 m apart, with 0.4 m between plants in the row, giving a plant density of 2 plants m^{-2}. Some physical and chemical properties of the experimental soil and irrigation water were determined according to (Klute, 1986; Page *et al*., 1982) as shown in (Tables 1 and 2).

Table 1. Some physical and chemical properties of the experimental soil.

Physical analysis (%)													
Sand						**Silt**		**Clay**		**Soil Texture**			
97.2						1.3		1.5		Sand			
Chemical analysis													
pH	EC dSm^{-1}	O.C %	T.N%	C/N ratio	Cations (me/L)				Anions (me/L)				
					Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	
7.69	1.71	0.53	0.020	26.5	7.94	2.68	3.71	1.62	0.00	4.99	5.52	5.66	

Table 2. Chemical analysis of irrigation water of the field experiment

Wells	pH	EC (ppm)	Cations (me/L)				Anions (me/L)				TDS (ppm)
			Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	CO_3^{-2}	HCO_3^-	Cl^-	SO_4^{-2}	
Well 1	8.13	4.38	12.4	5.2	0.1	27.1	0	3.7	27.9	14.2	2800
Well 2	8.50	5.94	16.0	7.8	0.1	37.5	0	4.9	37.2	19.3	3800

Phosphatic fertilizer as calcium super-phosphate (15.5% P_2O_5) was added at two levels in the rate of 50 and 75% of 30 kg P_2O_5 ha^{-1} during seed bed preparation, Also, nitrogen fertilizer was applied as ammonium sulfate (20.5% N) at two levels in the rate of 50 and 75 % of 120 kg N ha^{-1} through three equal doses during plant growth. 50 Kg of potassium sulphate (50.0% K_2O) was added at flowering stage. The following data were recorded; root and shoot weight, leaf area, chlorophyll content, fruit wt., and yield.

Biofertilization

Vesicular Arbuscular Mycorrhiza (VAM) spores were isolated from soil pre-inoculated with mycorrhiza (*Glomus macrocarpium*) by the wet-sieving and decantation method described by (Gerdemann and Nicolson, 1963) from the upper layer of the experimental area. The VAM inocula was mixed with pure sand and kept in the refrigerator to be used in the inoculation.

Assessment of VAM infection

The staining method of (Phillips and Hayman, 1970) was used for preparing soil (number of spores per gram) and root (colonization percentage) samples for microscopic observation. The gridlines intersect method of (Giovannetti and Mosse, 1980) was used to estimate the VAM infection percentage, using the equation:

$$\textbf{Root colonization}\ \% = \frac{\textbf{No. of positive intersect points}}{\textbf{Total number of observed intersect points}}$$

Rhizosphere soil sample were collected at harvest and analyzed for: total microbial counts on Bunt and Rovira medium (Nautiyal, 1999). Soil samples were analyzed for determination of phosphatase activity using disodium phenyl phosphate served as enzyme substrate (Őhlinger, 1996)**.** Chlorophyll content was measured by using Minolta chlorophyll meter (SPAD-502) to determine the total chlorophyll in fresh leaves.

Plant samples were taken at harvesting time from each treatment, dried at 70°, and ground using stainless steel equipment for the determination of N, P, and K. Plant nutrients were determined as follows: Total nitrogen using the micro kjeldahl method (A. O. A. C., 2005). Phosphorus and potassium, using dry ashing technique according to (Cottenie *et al.*, 1982). The phosphorus measured colorimetric using Vanado-molybdate method and potassium using Flame photometer apparatus.

Statistical analysis

The collected data in both seasons of study were exposed to analysis of variance as a factorial experiment in split-split plot design and significant difference among means were determined according to (Snedecor and Cochran, 1969) with the aid of Costat software. In addition, significant difference among mean were distinguished and least significant differences LSD between means were compared at 5%.

RESULTS AND DISCUSSION

Growth parameters of tomato plants

Data presented in Table (3 a & b) showed a significant difference among all studied parameters (shoot weight, root weight, leaf area and chlorophyll content) under mycorrhizal inoculation, two mineral fertilizers doses (50 and 75 %) and two salinity levels, 2800 ppm (S1) and 3800 ppm (S2). Maximum increase of shoot and root weight were obtained with mycorrhizal inoculation at mineral fertilizer 75% compared with mineral fertilizer without inoculation at salinity level S1. Also , increasing salinity with S2 significantly shoot and root weight. However, mycorrhizal inoculation reduces the negative impact of salinity in shoot and root weight by increasing shoot and root weights by 38.6, 48.65% and 38.7, 47.86% for both seasons, respectively compared to without inoculation.

Mycorrhizal inoculation at two levels of salinity, significantly improve tomato plant growth under the terms of leaf area and chlorophyll content of tomato plant. The mycorrhizal inoculation increases leaf area and chlorophyll content by 12.36, 29.90% and 12.93, 30.87% for first and second seasons, respectively compared to without inoculation. Also, mycorrhizal inoculation led to increase root/shoot ratio by 19.17 and 11.43% for first and second seasons, respectively when compared to without inoculation treatment. Increasing mineral fertilizers (N and P) from 50 to 75% increase root and shoot weight, leaf area and root/shoot ratio by 21.45 & 18.94%; 18.91 & 18.94%; 23.17 & 23.66%; 23.77 & 23.43%; and 3.88 & 4.14% for the both seasons, respectively. These results in accordance with that reported by many researchers, that VA mycorrhizal fungi could enhance the ability of plants to cope with salt stress (Asghari *et al*., 2005; Enteshari and Hajbagheri, 2011; Rabie, 2005; Yano-Melo *et al.*, 2003) by improving plant nutrient uptake, protecting enzyme activity and empowering water uptake. Mycorrhizal inoculation to *Capsicum annuum* showed enhanced chlorophyll contents, and Mg and N uptake and reduced Na transport under saline conditions (Çekiç *et al.*, 2012).

Table 3a. Effect of Mycorrhizal inoculation, two salinity levels and mineral fertilizer levels on growth parameters of tomato plants at first season.

Salinity	Myco	MF±	Root wt./plant (g)	Shoot wt./plant (g)	Leaf area (cm^2)	Chlorophyll	Root/Shoot ratio (DW§ basis)
S1	Without	50	87.1	654.3	14.22	24.53	0.124
		75	95.2	730.7	17.25	24.5	0.119
	With	50	109.1	817.3	15.64	28.3	0.133
		75	138.3	1051.3	19.2	33.1	0.131
S2	Without	50	26.4	203	12.5	21.6	0.128
		75	37.7	236.7	15.9	30.26	0.110
	With	50	53.3	314.2	14.6	29.2	0.150
		75	64.5	346.1	17.82	40.43	0.157
LSD at 5% Salinity			1.546	13.375	0.034	0.0687	0.0002
Mycorrhizae			0.339	2.130	0.021	0.0868	0.0003
Mineral Fertilizers (MF)			0.113	0.834	0.022	0.0498	0.00006
Interaction			0.226	1.667	0.044	0.100	0.0001

(±) mineral fertilizers, (§) dry weight

Table 3b. Effect of Mycorrhizal inoculation, two salinity levels and mineral fertilizer levels on growth parameters of tomato plants at second season.

Salinity	Myco	MF±	Root wt./plant (g)	Shoot wt./plant (g)	Leaf area (cm2)	Chlorophyll	Root/Shoot ratio (DW§ basis)
S1	Without	50	89.4	665.3	14.5	25	0.134
		75	95.8	745.2	17.6	24.9	0.129
	With	50	112.4	834.8	16	29.2	0.135
		75	138.7	1066.2	19.6	33.7	0.130
S2	Without	50	28.3	206.8	12.7	21.9	0.137
		75	38.9	246.5	16.1	30.1	0.158
	With	50	55.7	322.8	14.8	29.2	0.154
		75	66.5	356.2	18.4	41.3	0.160
L.S.D. at 5% Salinity			1.533	13.534	0.035	0.060	0.0008
Mycorrhizae			0.344	2.164	0.023	0.091	0.0003
Mineral Fertilizers (MF)			0.103	0.833	0.023	0.051	0.0001
Interaction			0.206	1.666	0.043	0.099	0.0001

Yield components:

Salinity significantly reduced marketable yield and increased the unmarketable yield, while, inoculation with mycorrhiza had enhanced the marketable yield under two salinity levels and both mineral fertilizers. Data presented in Table (4) and Figure (1) clearly showed that, increasing salinity from S1 to S2 led to decrease significantly marketable yield of tomato by 42.71 and 42.31% in two seasons. While, marketable yield was increased by inoculation with mycorrhizal fungi, with an overall mean value of 29.99 and 33.63% in both seasons, respectively.

Also, application of 75% of mineral fertilizers increase significantly the marketable yield by 18.067 and 18.85% compared with 50% of mineral fertilizer. Mycorrhizal inoculation proved to be effective in improving fruit weight and yield of tomato plant under two salinity levels. Maximum marketable yield was recorded with mycorrhizal inoculation and mineral fertilizer 75% at first salinity level being 5104.3 and 4951.2 kg/ha for two seasons, respectively.

Table 4. Effect of Mycorrhizal inoculation, two salinity levels and mineral fertilizers levels on yield of tomato plants

Salinity	Myco.	MF	marketable yield (ton/ha) 1st Season	marketable yield (ton/ha) 2nd Season	unmarketable yield (%) 1st Season	unmarketable yield (%) 2nd Season
S1	Without	50	48.78	47.59	9.39	9.12
		75	62.93	62.14	8.18	7.97
	With	50	56.93	57.53	8.57	8.08
		75	76.14	76.60	6.69	6.41
S2	Without	50	28.69	28.10	13.63	12.92
		75	27.27	26.77	13.02	12.10
	With	50	41.94	42.49	11.42	10.29
		75	42.93	43.34	8.78	8.35
L.S.D. at 5% Salinity			0.65	0.64	0.05	0.05
Mycorrhizae			0.14	0.16	0.01	0.01
Mineral Fertilizers (MF)			0.08	0.08	0.01	0.01
Interaction			0.16	0.16	0.01	0.01

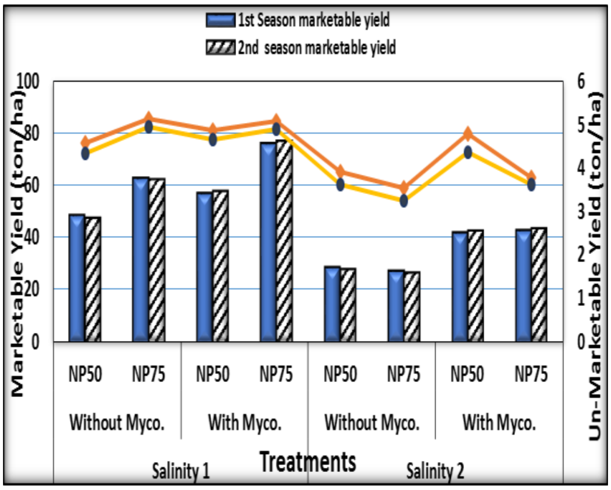

Fig. 1. Effect of bio and mineral fertilizers application on marketable and unmarketable yield of tomato (ton ha^{-1})

On contrast, significantly increasing salinity with S1 & S2 without inoculation the unmarketable yield increased from 8.21 to 11.71% and from 7.89 to 10.92% for two seasons, respectively. At the same time, inoculation with mycorrhiza and high level of mineral fertilizer (75%) were significantly decrease the unmarketable yield from 11.05 to 8.86% and 10.75 to 9.17% for the first season and from 10.53 to 8.258% and from 10.10 to 8.75% for the second season (Table 4 and Fig. 1). Obtained results are in agreement with those found by with (Al-Karaki *et al.*, 2001) they found that, AMF improved shoot growth and fruit yield and nutrient acquisition in fruits of inoculated tomato. AMF colonization also demonstrated the potential for protection of plants from salt stress in arid and semiarid regions.

Soil macro-nutrients:

Results in Table (5) showed that soil nitrogen, phosphorus and potassium concentrations were higher in the soil of inoculated plants than uninoculated ones. Inoculation with mycorrhiza increases significantly the soil N, P and K by 13.29 & 14.56%; 21.01 & 21.77% and 7.42 & 7.65% for first and second seasons, respectively. At the same time, high dose of mineral fertilizer (75%) is significantly increase the soil N, P and K by 7.95 & 7.40%; 14.38 & 14.42% and 1.87 & 1.91% for both seasons, respectively. While, increase salinity from S1 to S2 decrease the soil N, P and K by 4.64 & 5.02%; 28.07 & 27.92% and 1.86 & 1.48% at two seasons, respectively. The mycorrhizal inoculation with mineral fertilizer at 75% treatments recorded significantly the highest soil N, P and K concentrations (197.4, 59.2 and 248.3 ppm; 200.1, 60.7 and 253.6 ppm) for two seasons, respectively. Tawaraya *et al.,* (2006) reported that mycorrhiza associated with plants rises the availability of phosphate by solubilizing the insoluble fraction of inorganic phosphate, which significantly increase phosphate uptake and phosphate concentration in the plant tissue.

Table 5. Effect of Mycorrhizal inoculation, two salinity levels and mineral fertilizer levels on macronutrient concentration (ppm) in rhizosphere of tomato plants.

Water Salinity	Myco	MF	1st season N	1st season P	1st season K	2nd season N	2nd season P	2nd season K
S1	Without	50	161.6	42.3	224.3	163.1	43.5	227.5
		75	176.4	54.2	229.1	178.2	55.4	231.4
	With	50	188.3	57.3	242.2	191.3	59.2	246.5
		75	197.4	59.2	248.3	200.1	60.7	253.6
S2	Without	50	156.4	35.4	221.4	157.5	35.8	226.3
		75	169.1	40.4	226.4	168.4	41.1	231.2
	With	50	174.3	42.5	238.2	178.6	43.1	242.2
		75	191.4	49.6	239.8	194.5	50.2	244.4
L.S.D. at 5% Salinity			0.20	0.29	0.11	0.22	0.30	0.09
Mycorrhizae			0.25	0.10	0.19	0.28	0.11	0.20
Mineral Fertilizers (MF)			0.01	0.05	0.03	0.09	0.05	0.03
Interaction			0.18	0.10	0.06	0.17	0.10	0.06

Plant macro-nutrient content:

Regarding to the mycorrhizal inoculation, mineral fertilizers and salinity effects on NPK level in tomato leaves. The obtained data in Table (6) illustrated that plant nitrogen, phosphorus and potassium concentrations were higher in the inoculated plants than uninoculated ones. Mycorrhizal inoculation showed stimulating effect in increasing NPK content in tomato leaves at first and second salinity levels. Mycorrhizal inoculation significantly increases the plant N, P and K by 6.34 & 5.31%; 23.66 & 22.03% and 3.64 & 3.15% for first and second seasons, respectively. At the same time, mineral fertilizers at 75% significantly increase the plant N, P and K by 7.12 & 7.12%; 19.72 & 19.34% and 5.07 & 4.99% for first and second seasons, respectively. While, increase salinity from S1 to S2 decrease the plant N, P and K by 6.60 & 5.82%; 5.26 & 5.17% and 5.96 & 4.55% at two seasons, respectively. The influence of mycorrhizal fungi to plant nitrogen nutrition differs widely in diverse symbiotic systems, but mycorrhizal fungi can transfer significant amounts of nitrogen to their host plants (Chen *et al.,* 2018). The mycorrhiza inoculation with mineral fertilizers at 75% treatments recorded significantly the highest soil N, P and K concentration (22.23, 7.86 and 12.81 mg/g dry matter and 22.15, 7.81 and 12.91 mg/g dry matter) for two seasons, respectively. The results of current study indicated that mycorrhizal inoculated plants had greater tolerance to salt stress than uninoculated plants, this results in agreement with those found by (Al-Karaki *et al.,* 2001). Earlier studies indicated that the VAM fungi increase the root surface area that increases plant nutrient uptake (Zhang *et al*., 2016).Also, Abdelhameid (2019) found that the application of effective microorganisms reduces the bad effect of salinity and drought on NPK concentration in barley.

Regardless of the mycorrhizal treatment, salinity caused a significant decrease in N, P and K, whereas the reverse was true for the N/P ratio in tomato plants. In either moderate (S1) or severe (S2) salinity levels, the mycorrhizal inoculation encouraged a significant increase in leaf N, P and K. Contrastingly, the N/P ratio decreased with mycorrhizal inoculation, indicating that the mycorrhizae increased P rather than N. Data in Table (6) indicating that, inoculation with mycorrhizal fungi decreased the N/P ration by 16.99 and 16.83% in two seasons, respectively. The interaction of salinity stress and VAM significantly affects the concentrations of P and N and the N/P ratio in plant shoots (Mitra *et al*., 2019; Wang *et al*., 2018).

Table 6. Effect of Mycorrhizal inoculation, two salinity levels and mineral fertilizer levels on macronutrient concentration (mg/g DM £) in leaves of tomato plants.

Treatments			1st season				2nd season			
Water Salinity	**Myco**	**MF**	**N**	**P**	**K**	**N/P ratio**	**N**	**P**	**K**	**N/P ratio**
S1	Without	50	19.41	5.43	11.51	3.59	19.61	5.62	11.61	3.50
		75	21.33	6.33	12.02	3.38	21.52	6.53	12.13	3.31
	With	50	21.14	6.15	12.04	3.46	21.14	6.13	12.12	3.44
		75	22.23	7.86	12.81	2.85	22.15	7.81	12.91	2.84
S2	Without	50	18.71	4.57	11.05	4.16	19.04	4.63	11.33	4.10
		75	19.54	6.18	11.63	3.20	19.82	6.13	11.92	3.23
	With	50	19.42	6.74	11.34	2.90	19.55	6.81	11.55	2.87
		75	21.26	7.03	11.72	3.03	21.41	7.22	11.94	2.97
L.S.D. at 5% Salinity			0.03	0.01	0.02	0.01	0.03	0.01	0.01	0.01
Mycorrhizae			0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01
Mineral Fertilizers (MF)			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Interaction			0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01

(£) dry matter

Total microbial counts

Data presented in Table (7) clearly showed that there are high variations of total microbial counts between all treatments in tomato plant rhizosphere at two salinity levels, two mineral fertilizers doses and mycorrhizal inoculation. Highest total microbial counts recorded with mycorrhizal inoculation at first salinity level and 75% mineral fertilizer being 180 × 10^5 cfu / g dry soil, increasing salinity level causes significant decrease in total microbial counts. Mycorrhizal inoculation treatments increase significantly the total microbial count by 33.60 and 35.00% compared with uninoculated treatments. While increasing salinity level from S1 to S2 decreases the total microbial counts by 11.18 and 11.33%, in two seasons, respectively. Whereas the mineral fertilizers have slightly affected the total microbial counts. When mineral fertilizers increase from 50 to 75% of recommended dose, increases the total microbial counts by 0.34 and 1.51% in two seasons, respectively. This finding is in accordance with Abd El-Gawad (2014) who reported that, microbial inoculants increase number and biological activities of desired microorganisms and improve the fertility in the root zone.

Phosphatase enzyme

Presented data in Table (7) clearly showed that, phosphatase activity recorded significant increase with mycorrhizae treatments. Mycorrhizae inoculation treatment with 50% mineral fertilizer level at S1 recorded the highest phosphatase activity being (0.46 and 0.52 mg phenol/g soil/24h) at first and second seasons, respectively. Mycorrhizal inoculation treatments increase the phosphatase activity at S1 by 45.92 and 52.88% in two seasons compared to uninoculated treatments. While increasing salinity level from S1 to S2 decreases the phosphatase activity by 23.15 and 22.88%, in two seasons, respectively. When mineral fertilizers increase from 50 to 75% of recommended dose, increases the phosphatase activity by 7.76 and 8.73% in two seasons, respectively. George *et al.,* (2002) found that Phosphatase enzyme is able to mineralize organic phosphates into inorganic form of phosphates that available high phosphate for plant.

Root colonization and number of spores in soil rhizosphere

The root colonization of tomato plants and number of spores/ g soil in the soil rhizosphere were affected by microbial inoculation. The percent of root colonization was higher in the tomato inoculated with mycorrhiza, where inoculation increases the root mycorrhizal infection by 257.14 and 257.89% compared to uninoculated plants. On the other side, the mycorrhizal infection was found to decrease significantly with increasing salinity (Table 7), although it remained relatively high even at high salinity. Increasing salinity level from S1 to S2 decrease the root mycorrhizal infection by 9.15 and 8.38% for the two seasons, respectively. In contrast, increase the mineral fertilizers from 50 to 75% of recommended dose increase the root mycorrhizal infection by 9.15% in first season while decrease the infection by 4.71% in the second season.

Number of mycorrhizal spores in soil increases with inoculation of mycorrhizal as described in Table (7).

Number of spores increase by 53.65 and 54.48% in inoculated treatments compared to uninoculated treatments. Also, increase mineral fertilizers from 50 to 75% of recommended dose increases the number of spores in soil by 34.18 and 34.47% in two seasons, respectively. On the other hand, increase salinity levels from S1 to S2 decrease the soil number of spores by 18.81 and 18.65% in two seasons, respectively. Kobae *et al*., (2016) recognized that high phosphorus supply has a strong inhibitory effect on mycorrhizal colonization. Nitrogen decrease may be able to generate a signal that responds the inhibition of high phosphorus availabilities on mycorrhiza colonization (Breuillin-Sessoms *et al.,* 2015; Nouri *et al*., 2014). This result is in agreement with ARM (2014) root colonization (percent) was enhanced significantly by the influence of VAM compared to in absence. Solaiman *et al.* (2005) also recorded enhanced root colonization in chickpea due to the influence of VAM.

Table 7. Effect of Mycorrhizal inoculation, two salinity levels and mineral fertilizer levels on microbial determinations in rhizosphere of tomato plants grown at El-Shiekh zowaied , Egypt

Salinity	Myco	MF	Total microbial count cfu/ml		Phosphatase (mg phenol/g soil/24h)		Mycorrhizal Infection %		Mycorrhizal No. of spores/g soil	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
S1	Without	50	129	131	0.23	0.25	17.1	19.3	7.6	8.4
		75	133	130	0.3	0.31	19.2	20.5	14.1	15.5
	With	50	180	182	0.46	0.52	62.5	74.4	15.2	16.7
		75	173	176	0.34	0.37	69.4	68.6	17.4	19.2
S2	Without	50	115	117	0.21	0.23	16.1	18.2	7.6	8.3
		75	123	122	0.24	0.25	18.3	19.4	10.13	11.1
	With	50	161	162	0.35	0.37	58.6	67.5	12.3	13.6
		75	154	155	0.28	0.33	61.4	63.7	15.7	17.4
L.S.D. at 5%Salinity			0.39	0.39	0.002	0.001	0.09	0.09	0.05	0.06
Mycorrhizae			0.48	0.50	0.001	0.001	0.51	0.56	0.06	0.07
Mineral Fertilizers (MF)			0.04	0.04	0.001	0.001	0.03	0.02	0.03	0.03
Interaction			0.09	0.09	0.001	0.001	0.05	0.05	0.05	0.05

CONCLUSION

Impact of salinity on growth parameters of tomato plant, mineral contents of shoots, fruit yields and microbial determinations. Mycorrhizal inoculation and mineral fertilizer levels (50 and 75 %) showed positive results at two salinity levels on all studied parameters. Tomato plants treated with mycorrhizal fungi showed mitigative and protective role in counteraction negative salinity effects. Mycorrhiza increased root system activity, and plant access ability to nutrients in addition to producing hormones simulating growth. Finally investigating results of this study indicated that positive effects of mycorrhizal inoculation on growth hold true to tomato. Therefore, the study results indicated that the application of suitable mycorrhizae could be efficient to increasing yield, improving growth traits of tomato.

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تأثير التلقيح بفطر الميكوريزا على تحمل الطماطم للإجهاد الملحي وامتصاص العناصر في أرض رملية

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لتقييم تأثير فطريات الميكوريزا (*Glomus macrocarpium*) مع مستويين من التسميد المعدنى الفوسفورى والنيتروجينى (٥٠ و ٧٥٪ من الجرعة الموصى بها) بالإضافة إلى مستويين من ملوحة الماء (2800 جزء في المليون(S1) و ٣٨٠٠ جزء في المليون (S2))على إمتصاص العناصر الغذائية ومؤشرات النمو وكذلك كمية المحصول لنبات الطماطم. أجريت تجربة حقلية بمحطة أبحاث الشيخ زويد - شمال سيناء – مركز بحوث الصحراء- مصر خلال موسمين متتاليين. أظهرت النتائج التي تم الحصول عليها أن التلقيح بفطريات الميكوريزا يقلل من التأثير السلبي للملوحة في مؤشرات النمو ومحتوى النبات من المغذيات وكذا محصول الطماطم وذلك عن طريق زيادة وزن المجموع الخضرى والجذرى معنوياً بنسبة ٣٨,٦ و ٤٨,٦٥٪ و ٣٨,٧ و ٤٧,٨٦٪. وكذلك مساحة الأوراق ومحتوى الكلوروفيل بنسبة ١٢,٣٦ و ٢٩,٩٠٪ و ١٢,٩٣ و ٣٠,٨٧٪ وايضاً نسبة الجذر/المجموع الخضرى بنسبة ١٩,١٧ و ١١,٤٣٪ والمحصول القابل للتسويق بنسبة ٢٩,٩٩ و ٣٣,٦٣٪. بينما يقلل بشكل كبير من المحصول الغير قابل للتسويق من ١١,٠٥ إلى ٨,٨٦٪ فى الموسمين على التوالي. أيضا يزيد التلقيح بفطريات الميكوريزا بشكل كبير من محتوى النبات من العناصر الغذائية الكبرى مثل N و P و K بنسبة ٦,٣٤ و ٥,٣١ ٪. ٢٣,٦٦ و ٢٢,٠٣٪ و ٣,٦٤ و ٣,١٥٪ للموسمين الأول والثاني على الترتيب. وبالمثل أدى التلقيح بفطريات الميكوريزا إلى زيادة الأنشطة الميكروبية بشكل ملحوظ في منطقة جذور نباتات الطماطم. حيث زاد العدد الكلي للميكروبات ونشاط إنزيم الفوسفاتيز وعدد المستعمرات الجذرية وعدد جراثيم الفطر بالتربة بنسبة ٣٣,٦٠٪ و ٣٥,٠٠٪. ٤٥,٩٢ و ٥٢,٨٨٪ ؛ ٢٥٧,١٤ و ٢٥٧,٨٩٪ و ٣٤,١٨ و ٣٤,٤٧٪ خلال موسمى التجربة على الترتيب. كما أدى إضافة الأسمدة المعدنية بنسبة ٧٥٪ من الجرعة الموصى بها إلى زيادة جميع المؤشرات المقاسة مقارنة بنسبة ٥٠٪. وبشكل عام تظهر هذه النتائج أن فطريات الميكوريزا تمثل موردًا واعدًا لتحسين الإنتاج الغذائي المستدام تحت ظروف الملوحه وكذا الاحتياجات الغذائية البشرية.