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Response of Tomato Plants to Water Irrigation Levels and some Foliar Applications under Drip Irrigation System: 1- Vegetative Growth and Chemical Constituents ofL.

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ABSTRACT

This experiment was conducted during the summer seasons of 2015 and 2016 to investigate the effect of various water irrigation levels (60%, 80% and 100% from ET_o) and some foliar application treatments (chitosan, salicylic acid, silicon and proline) and their interactions on vegetative growth characteristics and leaf chemical constituents of tomato plants (*Solanum lycopersicum* L) " Fayruz " hybrid under surface drip irrigation system in a private farm at Gemiana village near El-Mansoura city, Dakahlia Government, Egypt. All treatments under investigation significantly affected vegetative growth parameters, *i.e.,* plant height, number of branches, number of leaves, leaf area, fresh and dry weights, as well as chemical constituents of leaves as photosynthetic pigments (Chl. a, Chl. b and total Chl. a+b), leaf minerals content (N, P and K), proline and peroxidase activity. Results indicated that the highest values of all aforementioned parameters except proline and peroxidase were recorded when plants irrigated with 80% from ET_O compare to 60% and 100 from ET_O in both season of study, while the highest values of proline and peroxidase activity were recorded with 60% from ET_O. All foliar applications treatments significantly increased vegetative growth traits, leaf mineral and pigments content compared to control (without foliar spray) which recorded the highest values of proline content and peroxidase activity. Foliar application of chitosan at 500 ppm was the most effective treatment on all aforementioned parameters followed with SA at 100 ppm. Concerning the interaction effect among water irrigation levels and foliar application treatments, the best result of all studied parameters were recorded when plants irrigated with 80% from ET_O and sprayed with chitosan at 500 ppm. Therefore, this treatment could be recommended to increase tomato plant growth and improve its performance.

Keywords: Tomato, Irrigation levels, Deficit irrigation, Evapotranspiration, ET_o, Chitosan, Salicylic Acid, Silicon, Proline.

INTRODUCTION

Tomato (*Solanum lycopersicum* L) is an important vegetable crop, not only because of its economic importance, but also for the nutritional value of its fruits, which is an excellent source of natural colors and antioxidant compounds, like vitamin C, polyphenlos and carotenoids (Tommonaro *et al.,* 2012). Tomato as one of the most widely produced and consumed 'vegetable' in the world (Heuvelink, 2005). According to the United Nations Food and Agricultural Organization statistics, around 340 billion pounds (170 million tons) of fresh and processing tomatoes were produced globally in 2014. The world production of tomatoes has been consistently increasing over the last decades. It grew more than 54% from 2000 to 2014 (FAO 2017).

At present and more so in the future, irrigated agriculture will implement under water scarcity. Especially since irrigated agriculture consumes more than two-thirds of the total fresh water on the planet. This issue causes substantial conflict in freshwater allocation between agriculture and other economic sectors (Chai *et al*., 2016).

Egypt as a part of Central West Asia and North Africa region, where irrigated agriculture is critical for food security in these regions. In these areas plant water use efficiency (WUE) is becoming a substantial issue, because crop production relies on the use of great volumes of water. Hence, most countries of these regions cannot have a productive form of agriculture without secure and sustainable irrigation supplies so the competition for fresh water this precious resource is increasing tremendously.

Several studies have shown that water deficit reduced plant vegetative growth and dry matter accumulation of tomato plants (Abdel-Razzak *et al*., 2016, Farrag, 2016, Hui *et al*., 2017 and El zopy *et al*., 2017).

Therefore, as stated by Fereres and Soriano (2007) irrigation management will shift from emphasizing production per unit cultivated area towards maximizing the production per unit of water consumed. Especially since the water productivity, it is becoming critically important to optimize WUE in agriculture (Pascale *et al*., 2011).

Water is the most limiting factor in these regions, so improving the productivity of existing water resources is an attractive alternative procedure to sustain irrigated agriculture. So, there is a strong need to shift agriculturists thinking from "maximizing crop yields" to "optimizing crop yields". Substantial and sustainable improvement of water productivity and or WUE can be achieved through integrated farm resources management.

IN recent years, a numbers of studies have indicated that application of some exogenous foliar applications to plants can enhance the plant growth, productivity, quality, and stress resistance of many crops.

Proline is the most important amino acids that accumulate in various tissues of the plant Crops are accumulating proline as a first physiological reaction when they are exposed to water stress. It is reported that proline has significant function in stabilizing osmotic effects by balancing of ion concentrations such as Na, K, Mg, and Ca in strengthening the cell wall and in other enzymatic actions (Iba, 2002). As the proline is concentrated in the cytoplasm to counterbalance effort osmosis cell sap. Also, proline protects enzymes under conditions of water stress (Meister, 2012).

Salicylic acid (SA) is a plant endogenous growth regulator of phenolic nature which is normally produced in plants in very small quantities and regulates various physiological and biochemical processes in plants (Hayat *et al.,* 2010). Moreover, salicylic acid use is safe with respect to human health and is likely to improve the quality and stress resistance of crops (Peng and Yueming, 2006). In recent years, a number of studies have indicated that application of exogenous salicylic acid at non-toxic concentrations to plants can enhance the plant growth and productivity of many crops.

Silicon (Si) is deposited as silica in the plant cell walls, improving cell wall structural rigidity and strength, plant architecture and leaf erectness. Silicon fertilization may improve yield, disease resistance, and tolerance to stresses such as cold, drought, and toxic metals (Balakhnina and Borkowska, 2013). It has been reported that Si applied by external foliar treatments or hydroponic supplementation has beneficial effects on plant growth and plays an important role in tolerance of plants to environmental stresses (Ma and Yamaji, 2008).

Chitosan is a polysaccharide resulting from the deacetylation of chitin, the linear polymer of (1-4)-β-linked N-acetyl-D-glucosamine. It is obtained from the outer shell of crustaceans such as crabs and shrimps. It has been reported as a high potential bio-molecule that increases abiotic stress tolerance, induce pathogen resistance, plant growth and yield (Ibrahim and Ramadan, 2015). That has been used to improve vegetative growth and performance of tomato plants (Dawa *et al*., 2017).

Considering the above facts, the present study was carried out to investigate the possible effects of irrigation regimes and some foliar applications (chitosan, Salicylic acid, Silicon and Proline) on plant growth and some chemical constituents of leaves of tomato plants grown under drip irrigation system.

MATERIALS AND METHODS

Two field experiments were carried out at a private farm at Gemiana village near El-Mansoura city, Dakahlia Governorate, Egypt, during the summer seasons of 2015 and 2016 to investigate the effect of various water irrigation levels (60%, 80% and 100% from ET_o) and some foliar application treatments (chitosan applied at 250 and 500 ppm, salicylic acid applied at 50 and 100 ppm, silicon applied at 50 and 100 ppm and proline applied at 200 and 400 ppm and control) and their interaction on vegetative growth characteristics, *i.e.,* plant height, number of branches, number of leaves, leaf area, fresh and dry weights, as well as chemical constituents of leaves as photosynthetic pigments (Chl. a, Chl. B and total Chl. a+b), leaf minerals content (N, P and K), proline and Peroxidase activity on tomato plants (*Solanum lycopersicum* L) " Fayruz " hybrid under surface drip irrigation system.

The experimental layout was split system in a randomized complete block design with 3 replicates, the experiment included 27 treatments which were the simple possible combinations between three levels of water irrigation (60, 80 and 100% from ET_o) as main plots, four foliar applications with two concentrations for each (Chitosan, proline, salicylic and silicon) plus the control treatment (sprayed with tap water) as sub plots. The experimental unit area was 12.6 m^2 it contains one dripper line with 9 m length and 1.4 m width. Seedlings were transplanted at spacing 50 cm on one side of dripper line (16/50).

Seedlings of 45 days old were transplanted into open field at the beginning of July in the two seasons of study. During the two growing seasons all plants received normal agricultural practices whenever they needed except of irrigation levels and foliar treatments.

Irrigation water treatment:

After 7 days from transplanting date, all experimental plots were divided into three main groups which were subjected to three levels of irrigation water, *i.e.,* 100%, 80% and 60% from ET_o. The irrigation water requirement was calculated according to Food and Agricultural Organization (FAO) Penman- Monteith (PM) procedure, FAO 56 (Allen *et al*., 1998).

Soil status:

Some physical and chemical properties of the experimental soil area were determined before transplanting in the two growing seasons according to AOAC, (2000) and shown in Table 1.

Table 1. some physical and chemical analysis of the experimental soil during 2015 and 2016 seasons.

Seasons	OM g kg-1	Clay (%)	Silt (%)	Sand (%)	Texture class	EC dS m-1	pH	Available (mg kg^{-1})		
								N	P	K
2015	1.35	28.92	48.79	19.22	Clay-loam	0.97	7.88	45.8	3.87	173.4
2016	1.39	27.70	49.32	20.01	Clay-loam	0.92	7.93	46.1	3.78	175.2

Recorded data:

Vegetative characteristics:

75 days after transplanting of tomato plant, representative samples (three plants) were randomly taken from each experimental plot and the following parameters were recorded plant height (cm), number of leaves/plant, number of branches/plant, total fresh weight of plant (g/plant), total dry weight of plant (g/plant), total leaf area/plant (m^2).

Chemical constituents of leaves:

All studied chemical constituents parameters in tomato leaves were determined at 75 days after transplanting during both seasons. Chlorophylls a, b, total chlorophyll were determined according to the methods described by Goodwine (1965). Nitrogen was determined according to Pregle (1945). Phosphorus was determined according to the method of Jackson (1967). Potassium was determined by the method described by Black (1965). Peroxidase enzyme (POX Δ absorbance unit/min/g) was determined according to the methods described by Hammerschmidt *et al.* (1982). Free proline content was determined according to the methods described by Bates *et al.* (1973).

Statistical analysis:

Data were statistically analyzed according to the technique of analysis variance (ANOVA) and the least significant difference (L.S.D) method was used to compare the deference between the means of treatment values according to the methods described by Gomez and Gomez (1984). All statistical analyses were performed using analysis of variance technique by means of CoSTATE Computer Software.

RESULTS AND DISCUSSION

Vegetative growth parameters:

Concerning the main effect of irrigation water levels, results presented in Table 2 indicated the effect of water irrigation levels, *i.e.,* 60%, 80% and 100% from ET_O on tomato vegetative growth parameters, *i.e.,* plant height, number of leaves, number of branches per plant, fresh and dry weights as well as leaf area of tomato plant foliage.

The irrigation level of 80% from ET_O recorded the highest values of all previously mentioned growth parameters followed by 100% from ET_O while 60% from ET_O recorded the lowest ones.

The increasing values of plant vegetative growth parameters with increasing irrigation levels may be due to that irrigation water is a substantial factor in plant life where it must be offered at a secure level to enable the plant roots to absorb water dissolved nutrients which contributes in plant growth and when water uptake is restricted the delivery of the nutrients to the root also is limited. The obtained results are consistent with Man *et al.* (2016) who reported that moderate soil water content increases root distribution over soil layers. Also, Li *et al.* (2010) mentioned that deficit irrigation (80% from irrigation requirement) recorded the suitable values of plant growth parameters compared to either full or deficit irrigation severely. Similar results were obtained by Xiukang and Yingying (2016) and Abdelhady *et al.* (2017) on tomato.

Regarding the main effect of foliar application treatments (chitosan, salicylic acid, silicon and proline at the various concentrations) on vegetative growth parameters on tomato plants, it's clear from such results that all vegetative growth traits were significantly increased in response to all foliar applications in the two growing seasons comparing to control treatment (sprayed with tap water).

Table 2.Average values of vegetative growth parameters as affected by irrigation levels, some foliar applications and their interactions during 2015 and 2016 seasons.

Parameters Treatments			Plant height (cm)		No. of leaves/plant		No. of branches/plant		Fresh weight g/plant		Dry Weight g/plant		Leaf area /plant (cm2)	
			2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Irrigation levels % from ET_O														
60%			87.65	92.71	69.37	77.33	4.67	5.56	695.42	724.65	91.10	95.58	2116.46	2150.67
80%			94.53	103.01	78.78	81.52	5.33	6.67	729.75	743.48	94.99	98.53	2387.61	2288.06
100%			92.04	98.57	74.67	79.04	5.00	6.00	717.17	730.48	93.45	97.01	2197.58	2213.70
LSD at 5%			1.55	0.97	0.32	0.25	0.02	0.03	0.20	0.47	0.17	0.32	25.03	20.53
Foliar applications														
Chitosan		250ppm	91.03	98.35	73.89	79.00	5.00	6.11	714.44	732.37	93.10	96.89	2234.08	2215.97
		500 ppm	102.20	109.19	90.22	95.55	6.33	7.22	765.82	789.13	1 00.27	104.69	2354.29	2267.14
SA		50 ppm	88.95	95.46	70.11	75.22	4.67	5.78	701.15	719.26	91.53	95.04	2202.78	2200.78
		100 ppm	99.33	107.03	85.22	91.11	6.00	7.11	753.16	773.24	98.57	102.53	2322.71	2263.54
Si		50 ppm	83.25	89.54	63.22	67.44	4.00	5.11	675.27	692.34	87.66	91.43	2140.41	2176.79
		100 ppm	93.73	101.08	77.78	83.00	5.33	6.44	727.14	745.62	95.25	99.01	2267.94	2231.16
Proline		200 ppm	85.95	92.12	66.89	71.22	4.33	5.44	689.02	705.73	89.53	93.20	2171.19	2191.18
		400 ppm	97.20	103.83	81.78	87.22	5.67	6.78	737.50	758.37	96.69	100.98	2298.72	2243.15
Control			81.03	81.03	86.26	63.89	3.67	4.67	4.67	663.49	679.76	89.59	2112.83	2167.60
LSD at 5%			1.12	1.48	0.23	0.25	0.02	0.02	0.02	0.47	0.97	0.31	17.69	14.52
Interaction effects														
60% from ET_O	Chitosan	250 ppm	87.83	92.19	68.67	77.00	4.67	5.67	697.48	724.12	91.19	94.97	2105.20	2148.01
		500 ppm	98.61	104.08	86.33	94.00	6.00	6.33	741.53	784.70	98.38	103.39	2240.35	2201.98
	SA	50 ppm	84.98	89.02	65.00	73.33	4.33	5.33	684.75	711.77	89.44	93.38	2079.64	2132.41
		100 ppm	95.69	101.75	79.33	89.00	5.67	6.67	730.08	765.31	96.47	101.37	2206.77	2187.58
	Si	50 ppm	79.78	84.15	59.00	65.33	3.67	4.67	660.15	682.61	85.52	89.83	2029.27	2115.62
		100 ppm	90.85	95.83	72.33	81.00	5.00	6.00	710.49	737.35	92.85	97.45	2154.00	2167.20
	Proline	200 ppm	81.97	87.12	62.67	69.67	4.00	5.00	672.75	697.46	87.36	92.11	2053.26	2128.82
		400 ppm	92.37	98.93	76.00	85.00	5.33	6.33	713.18	748.13	94.51	99.50	2177.99	2176.79
	Control		76.79	81.33	55.00	61.67	3.33	4.00	648.35	670.41	84.21	88.25	2001.69	2097.63
80% from ET_O	Chitosan	250 ppm	93.66	102.60	78.00	81.00	5.33	6.67	728.96	743.57	95.14	98.62	2389.07	2290.73
		500 ppm	104.45	114.05	94.67	97.33	6.67	8.00	785.91	796.93	101.50	106.09	2487.42	2333.90
	SA	50 ppm	92.07	101.27	74.33	77.67	5.00	6.33	715.83	729.28	93.61	96.69	2362.69	2272.74
		100 ppm	102.10	111.41	91.00	93.00	6.33	7.67	770.59	783.64	100.37	104.09	2467.03	2349.49
	Si	50 ppm	86.58	94.42	67.00	70.33	4.33	5.67	688.91	703.48	89.92	92.78	2309.92	2241.55
		100 ppm	96.48	106.21	82.33	85.00	5.67	7.00	740.83	756.06	96.67	100.66	2413.06	2297.92
	Proline	200 ppm	90.20	97.10	70.67	73.67	4.67	6.00	702.73	716.71	91.50	94.41	2332.70	2255.95
		400 ppm	100.30	108.99	87.33	89.00	6.00	7.33	756.85	770.93	98.32	102.54	2441.84	2313.51
	Control		84.92	91.05	63.67	66.67	4.00	5.33	677.14	690.73	87.86	90.91	2284.73	2236.76
100% from ET_O	Chitosan	250 ppm	91.59	100.24	75.00	79.00	5.00	6.00	716.89	729.43	92.96	97.08	2207.97	2209.17
		500 ppm	103.54	109.44	89.67	95.33	6.33	7.33	770.02	785.76	100.91	104.59	2335.10	2265.54
	SA	50 ppm	89.81	96.09	71.00	74.67	4.67	5.67	702.88	716.74	91.54	95.06	2166.00	2197.18
		100 ppm	100.20	107.93	85.33	91.33	6.00	7.00	758.81	770.77	98.86	102.13	2294.32	2253.55
	Si	50 ppm	83.37	90.04	63.67	66.67	4.00	5.00	676.77	690.91	87.54	91.69	2082.04	2173.19
		100 ppm	93.86	101.20	78.67	83.00	5.33	6.33	730.10	743.44	96.24	98.91	2236.76	2228.36
	Proline	200 ppm	85.67	92.15	67.33	70.33	4.33	5.33	691.58	703.03	89.71	93.09	2127.62	2188.78
		400 ppm	98.93	103.57	82.00	87.67	5.67	6.67	742.47	756.05	97.24	100.89	2276.33	2239.16
	Control		81.37	86.41	59.33	63.33	3.67	4.67	664.97	678.14	86.03	89.60	2052.06	2168.39
LSD at 5%			1.95	2.57	0.39	0.43	0.04	0.04	0.82	1.67	0.55	0.54	30.65	25.15

The highest significant values of the previous mentioned parameters were obtained with spraying chitosan at 500 ppm followed by salicylic acid at 100 ppm. Foliar application of proline at 400 ppm came in the third order.

The positive effect of chitosan may be come from providing some amino acid compounds required for plant growth. Also, the significant effect of chitosan on plant growth parameters may be attributed to an increase in the key enzyme activities of nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and increased photosynthesis which enhanced the plant growth (Mondal *et al*., 2012). In addition, chitosan induce synthesize plant hormones such as gibberellins, cytokinins and auxin in tomato leaves (Swelam, 2018).

The enhancement of tomato growth characters by foliar application of chitosan are in accordance with those found by Dawa *et al.* (2017) on tomato who reported that foliar application of chitosan at 250 ppm had the best effect on plant vegetative growth (plant height, number of branches, number of leaves and fresh and dry weights).

The stimulating effect of spraying salicylic acid on tomato plants may be due to that salicylic acid is considered as a plant growth regulator which involved in the regulation of many physiological processes in plants such as activating cell division, biosynthesis of organic compounds and availability and movement of nutrients in the leaves. The increasing of vegetative growth parameters due to spraying salicylic acid are supported by finding of Singh *et al*. (2017) on tomato and Dawa *et al.* (2017) on cucumber.

As for the effect of proline, it was found that proline is one of the organic molecules accumulated in crops when they exposed to abiotic stresses such as irrigation regime (Nanjo *et al.* 1999). Applied proline foliar application enhanced the plant to tolerate the harmful effect of high osmotic pressure. Similar results were reported by Sakr *et al.* (2007) reported that proline accumulation is one of the most frequently reported modifications induced by water deficit and salt stress resistance mechanisms. Our results are in line with those findings by Kahlaoui *et al.* (2013) on tomato.

As for the interaction effects among different irrigation levels and some foliar concentrations on vegetative growth parameters under investigation (Table 2), generally, it was noticed that all the interactions among irrigation water levels and foliar applications significantly affected vegetative growth parameters, *i.e.,* plant height, number of leaves, number of branches per plant, fresh and dry weights as well as leaf area of tomato plant foliage as compared with untreated plants in the two growing seasons.

The highest values of the aforementioned parameters were recorded by plants irrigated with 80 % from ET_O and sprayed with chitosan at 500 ppm followed by SA at 100 ppm and proline at 400 ppm in descending order.

Chemical constituents of leaves:

1- Photosynthetic pigments:

Concerning the effect of irrigation water levels, it is obvious from such results in Table 3 that chlorophyll content in tomato plants was significantly increased with increasing irrigation levels from 60% ET_O up to 100% ET_O. Meanwhile, irrigation level at 80% from ET_O recorded the highest mean values of chlorophyll a, b and total chlorophyll.

The stimulating effect of irrigation water with 80% from ET_O may be duos to that application of suitable irrigation level ensure mineral nutrients availability and uptake plant roots which enhanced chlorophyll formation. Similar results reported by Abdelhady *et al*. (2017). Also, Xiukang and Yingying (2016) reported that tomato leaf expansion more sensitive to irrigation amount and the main function of plant leaves is photosynthesis process and construction the organic compounds mainly carbohydrates, so that any factors or practice primarily fertilization and irrigation improves leaves growth then increases net assimilation of organic nutrients and subsequently plant growth and yield and quality.

Respecting the effect of foliar applications on leaf photosynthetic pigments, it is clear that all applied compounds have a positive and significant effect on leaf photosynthetic pigments compared to control treatment. Chitosan at 500 ppm was superior in its effect on chlorophyll content followed by salicylic acid at 100 ppm and proline at 400 ppm came in the third order.

These results are consistent with Farouk *et al*. (2012) and Dawa *et al.* (2017) who reported that application of chitosan at (250 and 500 ppm) on tomato plants increased photosynthetic pigments (Chl. a, Chl. b, total chlorophyll and carotenoids).

Photosynthetic pigments as affected by interaction among different irrigation levels and some foliar applications (Table 4) showed that irrigation with 80% and spraying plants with chitosan at 500 ppm gave the highest values of chlorophyll content (Chl. a, Chl. b, total chlorophyll) followed by SA at 100 ppm and proline at 400 ppm in descending order.

2- N, P and K concentrations:

Results in Table 4 showed that the effects of irrigation with 60, 80 and 100% from ET_O on N, P and K concentrations were significant in the two tested seasons. Irrigation treatment of 80% from ET_0 recorded the highest values of N, P and K concentrations in the leaves followed with 100% from ET_0 treatment, while 60% from ET_0 recorded the lowest values. This may be due to the reduced of root development due to water stress which limits the plant's ability for nutrients uptake as mentioned by Erdem *et al*. (2006). Our results are in agreement with Abdelhady *et al.* (2017) and Elzopy *et al.* (2017) on tomato. Also, Jayramaiah *et al*. (2005) on potato who showed that growing potato with 80% irrigation regime on the basis of cumulative pan evaporation recorded significantly higher NPK content when compared with lower irrigation levels.

Table 3. Average values of chlorophyll content as affected by irrigation levels, some foliar applications and their interactions during 2015 and 2016 seasons.

Parameters / Treatments			Chlorophyll a (mg/g FW) 2015	Chlorophyll a (mg/g FW) 2016	Chlorophyll b (mg/g FW) 2015	Chlorophyll b (mg/g FW) 2016	Total chlorophyll (mg/g FW) 2015	Total chlorophyll (mg/g FW) 2016
Irrigation levels % from ET_O								
60%			0.559	0.603	0.363	0.426	0.922	1.030
80%			0.613	0.686	0.406	0.476	1.019	1.161
100%			0.580	0.647	0.385	0.452	0.966	1.100
LSD at 5%			0.003	0.003	0.003	0.007	0.004	0.008
Foliar applications								
Chitosan		250 ppm	0.584	0.645	0.385	0.450	0.969	1.095
		500 ppm	0.620	0.682	0.416	0.484	1.036	1.166
SA		50 ppm	0.575	0.638	0.376	0.442	0.952	1.080
		100 ppm	0.611	0.673	0.408	0.483	1.020	1.156
Si		50 ppm	0.559	0.618	0.363	0.425	0.922	1.043
		100 ppm	0.592	0.653	0.392	0.459	0.984	1.112
Proline		200 ppm	0.568	0.627	0.370	0.434	0.938	1.061
		400 ppm	0.601	0.665	0.400	0.468	1.001	1.133
Control			0.548	0.608	0.353	0.416	0.902	1.025
LSD at 5%			0.005	0.004	0.004	0.009	0.006	0.008
Interaction effects								
60% from ET_O	Chitosan	250 ppm	0.559	0.604	0.364	0.421	0.923	1.025
		500 ppm	0.595	0.640	0.396	0.456	0.991	1.096
	SA	50 ppm	0.551	0.596	0.354	0.416	0.905	1.012
		100 ppm	0.589	0.631	0.386	0.470	0.975	1.102
	Si	50 ppm	0.531	0.577	0.343	0.398	0.874	0.975
		100 ppm	0.567	0.612	0.371	0.433	0.938	1.045
	Proline	200 ppm	0.540	0.583	0.346	0.410	0.886	0.993
		400 ppm	0.576	0.622	0.379	0.443	0.955	1.065
	Control		0.522	0.566	0.331	0.390	0.854	0.956
80% from ET_O	Chitosan	250 ppm	0.613	0.684	0.408	0.476	1.021	1.160
		500 ppm	0.650	0.722	0.437	0.510	1.087	1.232
	SA	50 ppm	0.606	0.679	0.397	0.469	1.003	1.148
		100 ppm	0.641	0.713	0.431	0.501	1.071	1.214
	Si	50 ppm	0.586	0.660	0.382	0.449	0.968	1.108
		100 ppm	0.622	0.693	0.411	0.485	1.033	1.178
	Proline	200 ppm	0.596	0.670	0.391	0.458	0.987	1.128
		400 ppm	0.630	0.704	0.421	0.494	1.051	1.198
	Control		0.576	0.648	0.377	0.439	0.953	1.087
100% from ET_O	Chitosan	250 ppm	0.579	0.647	0.385	0.452	0.963	1.100
		500 ppm	0.614	0.684	0.415	0.487	1.029	1.171
	SA	50 ppm	0.570	0.638	0.377	0.442	0.947	1.080
		100 ppm	0.604	0.676	0.409	0.477	1.013	1.154
	Si	50 ppm	0.559	0.618	0.363	0.428	0.922	1.046
		100 ppm	0.588	0.654	0.393	0.460	0.981	1.114
	Proline	200 ppm	0.568	0.629	0.372	0.434	0.940	1.063
		400 ppm	0.596	0.668	0.401	0.469	0.997	1.137
	Control		0.546	0.611	0.352	0.420	0.898	1.031
LSD at 5%			0.008	0.007	0.007	0.007	0.011	0.015

As regard to the effect of foliar applications, chemical analysis of the leaves showed positive responses to all applied foliar application treatments comparing to the control. Nitrogen, phosphorus and potassium contents in the leaves recorded the highest significant values under treatments of chitosan at 500 ppm. All measured nutrient contents were positively correlated to the applied concentrations of each substance

Chitosan has specific properties of being environmentally friendly and easily degradable. In agriculture, chitosan has been used as fertilizer and in controlled agrochemical release, to increase plant productivity and to stimulate plant growth (Farouk *et al*., 2012) on tomato plant.

The increase in ion content may be due to enhanced nutrient uptake by improving membrane permeability and/or giving better development root system. Increase in nitrogen percentage may be brought about by the amino components in chitosan and/or higher ability of the plant to absorb N from the soil when chitosan was degraded. The increase in P uptake may be due to the prevention of P fixation in the soil and the formation of humophospho complexes, which are easily assimilable by the plants and this explains the excess of P content and uptake by tomato plant. Similar results were also obtained by Shehata *et al.* (2012) who reported that foliar application of chitosan at rates of 4ml/l gave the highest contents of P in cucumber plants.

The interaction effect among irrigation levels and some foliar applications with different rates under study on N, P and K percentages showed that the average values of N, P and K percentages were significantly affected due to the addition of all investigated treatments. Such effect was more pronounced for the treatment of 80% from ET_O with all foliar applications. However, the highest mean values of such traits were recorded for the plants treated with the combination of 80% from ET_O + chitosan 500 ppm. Whereas the lowest values were recorded with plant treated with 60% from ET_O without foliar applications.

The favorable effect of interaction between 80% from ET_O and chitosan at 500 ppm could be attributed to providing optimum water requirements, maximum uptake of nutrient, reducing leaching of mineral elements and drought resistance which in turn led to higher plant growth parameters.

Table 4. Average values of N, P and K content as affected by irrigation levels, some foliar applications and their interactions during 2015 and 2016 seasons.

Parameters			N%		P%		K%	
Treatments			2015	2016	2015	2016	2015	2016
Irrigation levels % from ET_O								
60%			1.88	2.11	0.302	0.319	1.68	2.79
80%			2.27	2.53	0.353	0.359	2.06	3.27
100%			2.02	2.35	0.335	0.341	1.82	3.12
LSD at 5%			0.02	0.02	0.009	0.003	0.01	0.04
Foliar applications								
Chitosan		250 ppm	2.06	2.35	0.328	0.338	1.87	3.05
		500 ppm	2.46	2.73	0.366	0.378	2.21	3.46
SA		50 ppm	1.97	2.22	0.320	0.329	1.78	2.97
		100 ppm	2.36	2.60	0.356	0.368	2.01	3.36
Si		50 ppm	1.72	2.04	0.300	0.313	1.61	2.78
		100 ppm	2.17	2.43	0.339	0.348	1.96	3.15
Proline		200 ppm	1.86	2.14	0.311	0.321	1.69	2.86
		400 ppm	2.26	2.54	0.346	0.358	2.05	3.24
Control			1.65	1.94	0.322	0.305	1.51	2.69
LSD at 5%			0.04	0.03	0.011	0.004	0.04	0.05
Interaction effects								
60% from ET_O	Chitosan	250 ppm	1.91	2.12	0.301	0.318	1.68	2.81
		500 ppm	2.27	2.52	0.340	0.357	2.04	3.19
	SA	50 ppm	1.79	1.99	0.292	0.310	1.58	2.68
		100 ppm	2.18	2.41	0.330	0.344	1.93	3.07
	Si	50 ppm	1.54	1.81	0.274	0.292	1.42	2.51
		100 ppm	2.03	2.22	0.311	0.328	1.77	2.88
	Proline	200 ppm	1.69	1.91	0.285	0.300	1.49	2.59
		400 ppm	2.05	2.34	0.317	0.338	1.87	2.96
	Control		1.49	1.70	0.270	0.285	1.30	2.44
80% from ET_O	Chitosan	250 ppm	2.28	2.54	0.351	0.357	2.07	3.24
		500 ppm	2.66	2.90	0.390	0.396	2.43	3.69
	SA	50 ppm	2.21	2.44	0.343	0.349	1.95	3.19
		100 ppm	2.56	2.75	0.379	0.389	2.31	3.58
	Si	50 ppm	1.93	2.26	0.328	0.332	1.81	2.98
		100 ppm	2.38	2.64	0.363	0.366	2.13	3.36
	Proline	200 ppm	2.05	2.35	0.335	0.339	1.92	3.07
		400 ppm	2.50	2.72	0.371	0.377	2.24	3.43
	Control		1.86	2.14	0.320	0.323	1.72	2.88
100% from ET_O	Chitosan	250 ppm	2.02	2.36	0.332	0.338	1.86	3.10
		500 ppm	2.45	2.76	0.367	0.381	2.15	3.51
	SA	50 ppm	1.91	2.23	0.325	0.328	1.80	3.03
		100 ppm	2.34	2.65	0.359	0.371	1.79	3.42
	Si	50 ppm	1.68	2.04	0.299	0.314	1.60	2.84
		100 ppm	2.11	2.42	0.342	0.349	1.96	3.20
	Proline	200 ppm	1.84	2.16	0.314	0.323	1.67	2.93
		400 ppm	2.23	2.54	0.351	0.359	2.05	3.31
	Control		1.61	1.97	0.331	0.306	1.52	2.77
LSD at 5%			0.06	0.06	0.018	0.006	0.07	0.08

3- Proline content and Peroxidase activity:

Results in Table 5 indicate proline and peroxidase activity as affected by the investigated irrigation levels in the presence of some foliar treatments (chitosan, salicylic acid, silicon and proline at different concentrations) in tomato leaves during both seasons of study. The highest values of proline and peroxidase activity increased in tomato leaves were connected with irrigation level of 60 % from ET_O followed with 100% from ET_O, while the less accumulation of proline and peroxidase activity was realized for the plants irrigated with 80% from ET_O.

The role of proline in adaptation and survival of plants under drought stress reported by many researchers. Mousa and Abdel-Aziz (2008) reported that high levels of proline enable the plant to maintain low water potentials causing the accumulation of compatible osmolytes that allows additional water to be taken up from the environment, thus buffering the immediate effect of water deficit within the organism.

Irrigation levels, like other environmental stresses induce oxidative stress. To be able to endure oxidative damage under unfavorable conditions, plants possess both nonenzymatic antioxidants such as carotenoid, flavonoids, α-tocopherol, ascorbic acid and glutathione, and enzymatic antioxidants such as CAT and peroxidase (POX) (Munné-Bosch and Alegre, 2002). Reddy *et al*. (2000) indicated that higher antioxidant enzyme activity has a role in imparting tolerance against environmental stress. Mechanisms that reduce oxidative injury may play a secondary role during drought tolerance.

Concerning the effect of applied foliar applications (chitosan, salicylic acid, silicon and proline), the obtained results showed that all foliar application treatments significantly enhanced proline content but decreased the average values of peroxidase activity than those obtained for the control treatment. As for peroxidase activity, the highest mean values were recorded with control then decreased with applying foliar substances. Plants sprayed with chitosan at 500 ppm recorded the lowest values of peroxidase activate. While foliar application of proline at 200 and 400 ppm recorded the highest significant values of proline content compared to other foliar applications.

Table 5. Average values of proline content and peroxidase activate as affected by irrigation levels, some foliar applications and their interactions during 2015 and 2016 seasons.

Parameters / Treatments			Proline µ/g DW		peroxidase activate POX Δ absorbance unit/min/g FW	
			2015	2016	2015	2016
Irrigation levels % from ET_O						
60%			12.18	11.70	6.76	6.27
80%			9.83	10.70	5.63	5.49
100%			10.64	11.27	6.32	5.89
$LSD_{at\ 5\%}$			0.04	0.08	0.11	0.07
Foliar applications						
Chitosan		250 ppm	10.76	11.11	6.22	5.85
		500 ppm	10.55	10.66	4.60	4.25
S.A		50 ppm	10.38	10.89	6.41	6.24
		100 ppm	11.31	11.72	5.81	4.64
Si		50 ppm	9.90	10.44	6.67	7.19
		100 ppm	11.02	11.35	6.09	5.43
Proline		200 ppm	12.38	12.51	6.60	6.78
		400 ppm	11.98	12.14	5.93	5.01
Control			9.64	10.20	7.84	7.58
$LSD_{at\ 5\%}$			0.09	0.09	0.07	0.09
Interaction effect s						
60% from ET_O	Chitosan	250 ppm	12.24	11.57	6.74	6.29
		500 ppm	11.34	11.18	5.07	4.66
	SA	50 ppm	11.73	11.38	7.24	6.70
		100 ppm	13.00	12.08	5.49	5.04
	Si	50 ppm	10.92	10.98	8.03	7.50
		100 ppm	12.66	11.74	6.32	5.85
	Proline	200 ppm	13.79	13.01	7.68	7.07
		400 ppm	13.44	12.55	5.94	5.44
	Control		10.51	10.78	8.36	7.88
80% from ET_O	Chitosan	250 ppm	9.46	10.58	5.58	5.37
		500 ppm	10.16	10.12	4.08	3.82
	SA	50 ppm	9.05	10.34	5.24	5.78
		100 ppm	9.88	11.31	6.88	4.18
	Si	50 ppm	8.83	9.90	4.46	6.95
		100 ppm	9.59	10.83	6.03	4.95
	Proline	200 ppm	11.73	11.99	4.86	6.53
		400 ppm	11.06	11.62	6.38	4.53
	Control		8.67	9.63	7.21	7.32
100% from ET_O	Chitosan	250 ppm	10.58	11.18	6.34	5.88
		500 ppm	10.16	10.68	4.64	4.27
	SA	50 ppm	10.36	10.94	6.75	6.24
		100 ppm	11.04	11.76	5.07	4.70
	Si	50 ppm	9.96	10.45	7.52	7.12
		100 ppm	10.82	11.49	5.94	5.49
	Proline	200 ppm	11.62	12.52	7.25	6.72
		400 ppm	11.44	12.26	5.46	5.06
	Control		9.75	10.18	7.96	7.55
$LSD_{at\ 5\%}$			0.16	0.15	0.13	0.16

Concerning the interaction among irrigation water levels and foliar applications on tomato leaf proline content and peroxidase activity, results in Table 5 revealed a considerable effect for the mean values of proline content and peroxidase activate with the different irrigation levels under any applied foliar substance.

The highest accumulation of proline was connected with the combination between 60% from ET_O and 200 ppm proline, while the lowest accumulation was happened due to the addition of 80% from ET_O in the absence of foliar substances (check treatment). Generally, the lowest values of peroxidase activity were realized for the treatment of 80% from ET_O and 500 ppm chitosan, while the highest ones were associated with the treatment of 60% from ET_O without foliar (check treatment). Such effect was true during both seasons.

CONCLUSION

It could be concluded that all applied materials have a positive and growth promoting effects on tomato plants, however, the highest results which gave the best values of plants growth parameters and nutritional values of leaves were obtained by application of Chitosan at 500 ppm and irrigation water with 80% from ET_O under same condition of this study.

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استجابه نباتات الطماطم لمستويات مياه الري وبعض معاملات الرش الورقي تحت نظام الري بالتنقيط:
1- النمو الخضري والمحتوى الكيماوي للأوراق.

كوثر كامل أحمد ضوه ، طه محمد السيد عمر الجزار و أحمد محمد أحمد عبد الفتاح
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أجريت تجربتان حقليتان خلال موسمى النمو الصيفى 2015 و 2016 لدراسه تأثير الري بمستويات مختلفه (60، 80، 100% من البخر والنتح) والرش ببعض الاضافات الورقيه (شيتوزان، سالسليك، سيليكون، برولين) و التفاعل بينهم على النمو الخضرى والتركيب الكيميائى لاوراق نبات الطماطم هجين (فيروز) تحت نظام الرى بالتنقيط بمزرعه خاصه بقريه جميانه بالقرب من مدينه المنصوره- محافظه الدقهليه- مصر. جميع المعاملات المستخدمه تحت الدراسه أدت الى زياده معنويه في صفات النمو الخضري وهي طول النبات ,عدد الافرع ,عدد الاوراق ,المساحه الورقيه ,الوزن الطازج والجاف بالاضافه الي التركيب الكيميائى للاوراق مثل صبغات البناء الضوئي (كلوروفيل أ, كلوروفيل ب, الكلوروفيل الكلي أ+ ب) ومحتوي الاوراق من العناصر (النيتروجين ,الفوسفور ,البوتاسيوم) كذلك محتوى البرولين ونشاط انزيم البيروكسيداز. بينت النتائج ان اعلي القيم للصفات السابق ذكرها فيما عدا البرولين ونشاط انزيم البيروكسيداز سجلت عندما تم ري النباتات بمستوي 80% من البخر والنتح بالمقارنه بباقي مستويات الري خلال موسمي الدراسه، بينما سجلت اعلي القيم لمحتوي البرولين ونشاط انزيم البيروكسيداز عند الري بمستوي 60% من البخر والنتح. جميع معاملات الرش الورقي سجلت اعلي النتائج معنويه علي صفات النمو الخضري ومحتوي الاوراق من العناصر ومحتوي الصبغات بالمقارنه بالنباتات التي لم ترش والتي بدورها سجلت اعلي قيم لمحتوي البرولين ونشاط انزيم البيروكيبداز. كذلك وجد أن استخدام الشيتوزان رشا بمعدل 500 جزء في المليون يعد من اكثر معاملات الرش الورقي تأثيرا علي جميع الصفات تحت الدراسه ويليه استخدام حمض السالسيك بمعدل 100 جزء في المليون. بخصوص التفاعل بين مستويات الري ومعاملات الرش الورقي وجد ان افضل النتائج المتحصل عليها عند ري النباتات بمستوي 80% من البخر والنتح مع الرش الورقي بالشيتوزان بمعدل 500 جزء في المليون. ولهذا يمكن التوصيه باستخدام هذه المعامله لزياده نمو نباتات الطماطم وتحسين ادائها تحت نفس ظروف هذه الدراسه.