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Impact of Foliar Application with Iron, Zinc, Silicon Nano Particles and Yeast on Growth, Yield and Water Use Efficiency of Tomato Plants under Water Stress Conditions

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ABSTRACT

Two filed experiments were conducted during the two summer seasons of 2015 and 2016 in a private Farm at Gemiana village near Belqas City Dakahlia Governorate, Egypt, to study the effect of interaction between deficit irrigation water (60%, 80%, 100% of ETc) and some foliar spray treatments (nano iron, nano zinc, nano silicon and yeast extract) on plant growth parameters, chemical composition of leaves as photosynthetic pigments (Chl. a, Chl. b, total Chl. a+b), leaf mineral percentages (N, P, K) proline, yield and water use efficiency (WUE) of tomato plants (Fayruz hybrid) under drip irrigation system. A strip-plot design with three replicates was used. The vertical plots were allocated to the deficit irrigation, whereas the horizontal-plots were devoted to foliar spray treatments. Results revealed that the interaction among irrigation tomato plants at the level of 80 % Etc and spraying with different nano particles at different concentration or yeast extract significantly increased all aforementioned parameters, meanwhile deficit irrigation water treatments improved leaves proline content and WUE in both growing seasons. The best interaction treatment for increasing plant growth parameters, chemical constitutes of leaves as photosynthetic pigments (Chl. a, Chl. b, total Chl. a+b) leaf mineral percentages (N, P, K) early and total yield is irrigation treatment with 80 % Etc and spraying with nano Si at 12 ppm and can be recommended to increase growth and productivity tomato plants of under similar conditions of this study.

***Keywords**:* Tomato, Deficit Irrigation, Water Use Efficiency, Nano silicon, Nano iron, Nano zinc, Yeast

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is considered as one of the most important vegetable crops as well as popular vegetative all over the world as well as in Egypt. In addition, tomato represents one of the important vegetable crops for local consumption and export. Tomato is an important source of antioxidants including, lycopene, phenolic, and vitamin C in human diet.

The total cultivated area of tomato in Egypt was about 455,610 fed during 2017 season according to FAO (2018), which produced 7,229,108 tons with an average of 16.016 tons /feddan.

Egypt suffers annually from a water shortage of about 7 billion m^3. In fact, the United Nations has already warned that Egypt may run out of water by the year 2025 (Texas Water Report, 2014).

In recent years, The strategy is to maximize the efficiency of water use due to the water shortage and rise agriculture productivity from unit area with the minimum levels of irrigation water. Thus, it was essential to use less water resources and achieved the highest productivity by the use of application of some nanoparticles (NPs) foliar applications and yeast to increase plant growth, productivity, quality and stress resistance.

Nanoparticles interact with plants which cause many morphological and physiological changes, depending on the properties of nanoparticles, they have important characteristic such as the little size, greater area-to-weight ratio and different shapes, nano particles may have different properties from their bulk material (Roduner, 2006). Likewise, nano silicon particles (Si-NPs) have different physical and chemical properties from their bulky materials and can work better to mitigate different biotic stresses than bulk materials (Abdel-Haliem *et al.*, 2017). Si-NPs have tremendous potential in agriculture and foliar application with silicon reduce adverse impacts of drought circumstance (Bukhari *et al*., 2015), as well as it plays a considerable role in alleviate water stress by decreasing the rate of transpiration, enhancing photosynthesis process by improving light receiving efficiency through keeping the leaf rigid and erect (Siddiqui and Al-Whaibi, 2014).

Micronutrient deficiencies in plants may result in decreased yields and plant death, too in extreme cases. Fe and Zn deficiencies among the micronutrients have been the most detrimental to the growth and yield of all crops including tomatoes (Alloway, 2009). Nano Iron is an essential micronutrient for plant growth and development, its deficiency contributes to substantial changes in plant metabolism and causes chlorosis. Consequently, elements

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absorption of nano iron in plants under drought stress can play significant role in drought resistance.

Nano Zinc oxide particles (ZnO NPs) with little size and large surface area are considered to be the perfect candidates for use in plants as a Zn fertilizer (Adhikari *et al*., 2015). Zinc also plays a key role in plant survival under conditions of environmental stress, where it helps in strengthening or preparing plants to survive drought stress (Cakmak, 2008). It plays an important role in stomata control because of its ability to preserve membrane integrity and retain the potassium content of the cells and also its role in plant water relations (Khan *et al*., 2004).

yeast extract significantly alleviate water stress by increasing the relative water content, photosynthetic pigments, total carbohydrates, total free amino acids, and enzyme activities in plants (Hammad and Ali, 2014)

Therefore, this study was conducted to investigate the impact of the combination among deficit irrigation water treatments and some foliar application such as nano particles (iron, zinc, silicon) and yeast on plant growth, chemical composition of leaves, yield and WUE of tomato plants grown in clay soil with a system of drip irrigation.

MATERIALS AND METHODS

Two field experiments were conducted under clay soil conditions during the two summer seasons of 2015 and 2016in a private Farm at Gemiana village near Belqas City Dakahlia Governorate, Egypt, to study the effect of the interaction between deficit irrigation water treatments (60%, 80% and 100% from ETc) and some foliar spray treatments nano Fe_2O_3, nano ZnO, nano SiO_2 and Yeast extract) on growth parameters, leaf pigments, leaf mineral percentages (N, P, K) and yield of tomato. Samples analysis of soil is shown in Table (1)

1. The experimental design and treatments:

This experiment included 27 treatments, which were the combinations among deficit irrigation water and eight foliar application treatments, beside control treatment (without foliar) as follows:

a. deficit irrigation treatments

60 % of ETc , 80 % of ETc and 100 % of ETc

b- Foliar spray treatments

Nano Fe_2O_3 at 1000 ppm , Nano Fe_2O_3 at 2000 ppm, Nano ZnO at 500 ppm, Nano ZnO at 1000 ppm, Nano SiO_2 at 6 ppm, Nano SiO_2 at 12 ppm, Yeast extract at 5 g/l, Yeast extract at 10 g/l and control (without foliar).

Table 1. some physical and chemical properties of the experimental soil in 2015 and 2016 seasons:

Seasons	Silt %	Clay %	Sand %	Texture soil	F.C mgkg^{-1}	Fe mgkg^{-1}	Zn mg kg^{-1}	PH	E.C (dSm^{-1})	O.M %	$CaCO_3$ g kg^{-1}	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{1}
2015	48.79	28.92	22.29	Clay loamy	29.2	18.9	16.8	7.88	0.97	1.35	3.05	45.8	3.87	173
2016	49.32	27.70	22.98	Clay loamy	31.3	18.4	16.8	7.93	0.92	1.39	2.85	46.1	3.78	175

F.C: Field Capacity; OM: Organic

A strip-plot design with three replicates was used. The vertical plots were allocated to the deficit irrigation, whereas the horizontal-plots were devoted to foliar spray treatments. The experimental unit area was 12.6 m^2. It contained one dripper line with 9 m length and 1.4 m in width.

Seeds of tomato were (Fayruz hybrid F_1) sown on June 1st and transplanted on July 8th in both seasons. Seedlings were transplanted at 50 cm apart on one side of the dripper line (drip tubing GR type, 16 mm diameter with 50 cm emitter spacing built in discharge at 4 l /h.

Tomato plants were sprayed with the foliar application treatments six times after 7days from transplanting and repeated after 10 days intervals.

2. Irrigation water treatments:

The irrigation water requirements were calculated according to Food and Agricultural Organization (FAO) Penman-Monteith (PM) procedure, FAO 56 (Allen *et al.* 1998), the results are shown in Table (2).

Table 2. Irrigation requirements (m^3 /fed) for irrigation treatments (100 %, 80 and 60 % of ETc) for tomato plants grown under clay soil during 2015 and 2016 seasons.

Irrigation requirements	2015 season			2016 season		
	100 %	80 %	60 %	100 %	80 %	60 %
Total (m^3/fed)	4289.55	3431.64	2573.73	4635.21	3708.17	2781.13

Recorded Data:

1. Growth Parameters

A random sample of three plants was taken from each plot at 75 days after transplanting, in both seasons of study, for measuring the growth characters of tomato plants expressed as follows: Number of leaves/plant, fresh and dry weights of plant (g/plant).

2. Chemical composition of leaves:

1. Leaf Pigments Determination:

Chlorophyll a and b were determined according to the method described by Lichtenthaler and Wellburn (1983).

2. Nitrogen, phosphorus and potassium contents:

Nitrogen, phosphorus and potassium were determined according to the methods described by Bremner and Mulvaney (1982), Olsen and Sommers (1982) and Jackson (1970), respectively.

3. Proline amino acid content:

Proline was determined according to the method described by Bates *et al.* (1973).

3. Early and total yield:

Early yield: the sum of the first three harvestings (ton/fed).

Total yield (ton/fed).

4. Water Use Efficiency (WUE)

Water use efficiency was determined according to equation of Begg and Turner (1976) as follows:

Water use efficiency = Yield (kg/fed) /Water quantity (m^3/fed) = kg m^{-3}

Statistical analysis:

All obtained data in the two experiments were subjected to proper statistical analysis of variance technique by means of Costat computer software. according to Snedecor and Cochran (1980) and means separation were done according to LSD at 5 % level.

RESULTS AND DISCUSSION

Vegetative growth parameters:

Data in Table (3) indicate the influence of interaction between deficit irrigation water, foliar application of nano particles and yeast extract on plant growth characters of tomato. Data clearly demonstrate that the interaction among deficit irrigation water treatments and foliar application with nano particles and yeast extracts had significant effect on number of leaves, fresh weight/plant and dry weight/plant compared to control in the two seasons. The interaction between irrigation at 80 % Etc level and spraying with nano Si at 12 ppm produced the maximum values of number of leaves; fresh weights/plant and dry plant weighs in the two seasons.

These results agree with those reported by Wahb-Allah and Al-Omran (2012),), Abdelhady *et al.* (2017), Dawa *et al*. (2019) and Ragab *et al*. (2019) who mentioned that the irrigation level of 80% of ETo gave the maximum values of plant height, number of leaves, number of branches per plant, fresh and dry weights as well as leaf area followed by 100% of ETo, while 60% of ETo gave the lowest values of all aforementioned parameters. Similar results were reported by Haghighia and Pessarakli (2013) reported that treated tomato plants with silicon (Si) and nano silicon (N-Si) recorded the best values of fresh and dry weights, root volume than untreated. Also, Lu *et al.* (2016) mentioned that application of nano silica at 5 g/L produced the maximum values of fresh weights and dry weights of tomato plant.

The increment in water supply led to increase vegetative growth parameters may be attributed to that water plays key role for transferring the mineral elements from the soil to plants leave and trans locating the photosynthetic assimilates from the leaves to the other parts in the plant, which lead to increment in the plant growth.

Table 3. Effect of interaction between deficit irrigation and foliar applications of some Nano particles and yeast on growth parameters of tomato plant after 75 days from transplanting during 2015 and 2016 seasons.

Parameters Treatments		No. of leaves/plant		Fresh weight g/plant		Dry Weight g/plant	
		2015	2016	2015	2016	2015	2016
60% of ETc	Nano Fe 1000 ppm	65.00	62.33	541.50	583.25	85.30	94.78
	Nano Fe 2000 ppm	63.17	61.34	541.50	558.25	88.60	92.35
	Nano Zn 500 ppm	55.50	53.33	520.75	525.00	81.43	87.06
	Nano Zn 1000 ppm	61.67	57.66	541.50	583.25	83.51	90.80
	Nano Si 6 ppm	69.84	71.84	608.25	650.00	86.33	95.83
	Nano Si 12 ppm	67.17	71.50	625.00	642.00	84.80	94.13
	Yeast 5 g\l	56.50	58.50	458.25	488.25	76.87	81.22
	Yeast 10 g\l	59.33	61.34	512.50	531.50	79.67	83.43
	Control	53.50	54.5.00	345.75	350.00	65.00	71.05
80% of ETc	Nano Fe 1000 ppm	85.33	84.67	766.50	791.50	98.40	102.22
	Nano Fe 2000 ppm	86.67	87.50	778.25	790.00	99.20	104.78
	Nano Zn 500 ppm	85.50	79.84	756.50	688.25	94.77	91.29
	Nano Zn 1000 ppm	84.67	82.34	625.00	600.00	97.33	92.04
	Nano Si 6 ppm	114.50	116.66	833.25	845.00	119.47	121.06
	Nano Si 12 ppm	117.67	118.67	851.50	861.50	122.27	125.74
	Yeast 5 g\l	78.34	74.84	625.00	606.50	87.87	92.63
	Yeast 10 g\l	82.66	77.17	645.00	625.00	93.70	91.01
	Control	61.67	69.17	333.25	375.00	61.80	68.60
100% of ETc	Nano Fe1000 ppm	80.84	81.34	583.25	666.50	88.17	84.51
	Nano Fe 2000 ppm	81.84	88.34	625.00	683.25	88.10	88.89
	Nano Zn 500 ppm	83.17	80.34	600.00	608.25	87.13	86.72
	Nano Zn 1000 ppm	79.67	81.50	625.00	625.00	85.00	86.55
	Nano Si 6 ppm	96.67	108.50	738.25	790.00	94.77	97.42
	Nano Si 12 ppm	94.67	115.00	750.00	799.00	101.30	102.45
	Yeast 5 g\l	55.67	66.67	500.00	541.50	75.67	83.99
	Yeast 10 g\l	79.34	77.17	541.50	625.00	82.67	91.76
	Control	59.17	64.84	391.50	433.25	62.13	67.85
	LSD at 5%	7.73	6.79	71.59	76.22	9.68	8.22

The simulative effect of nano silicon under water stress conditions may be due to the effect of silicon in alleviate the negative effects of environmental stress and decrease the loss of nutrients in the soil (Guntzer et al., 2012). Moreover, silicon maintain mineral balance (Shi et al., 2014) and improving the absorption of water by roots (Liu et al., 2014), restriction in toxic ions uptake and efficient functioning of anti-oxidative mechanisms (Sacala, 2009).

Chemical Composition of leaves:

1. Leaf pigments:

The impacts of interaction among deficit irrigation and foliar application treatments on leaf pigments in leaf tissues of tomato are presented in Table (4). It is obvious from the data that the interaction between deficit irrigation water treatments and foliar application with Nano Fe, Zn, Si and yeast extract had significant effect on chlorophyll a, b and total chlorophyll (a+b) in leaf tissues of tomato at 75 days after transplanting in the two seasons. In this connect, the interaction between irrigation at 80 % Etc and spraying with nano Fe at 2000 ppm gave the best concentration of chlorophyll a, b and total chlorophyll (a+b) in leaf tissues of tomato, followed by the interaction between the same level of irrigation and spraying with nano Si at 12 ppm and the interaction between 100 % Etc and spraying with nano Fe at 2000 ppm came in the third rank in the two seasons.

The lowest concentration of all leaf pigments were obtained with the interaction between 60 % Etc and unsprayed plants in the two seasons.

The result are supported by the findings of sibomana *et al.* (2013) Who observed that water stress (40% F.C) reduced chlorophyll content of tomato plants compared to control. Dawa *et al.* (2019) Highlighted that the highest values of chlorophylls contents in leaves of tomato were recorded with irrigation at 80% of ETc than 60 or 100 % ETc. On the other side, Abdelhady *et al.* (2017) and Ragab *et al.* (2019) reported that the maximum concentrations of chlorophylls in leaves were obtained with the highest levels of irrigation 100% of ETo. Furthermore, Ejraei (2013) and Rahmatizadeh *et al.* (2019) suggested that foliar spray with nano Fe_3O_4 at 20 mg/L improved chlorophyll a, b and total chlorophyll contents of tomato plants. The stimulation impact of irrigation water at 80% Etc may be due to the fact that applications of an acceptable level of irrigation ensure the availability of mineral nutrients and the uptake of plant roots which enhanced chlorophyll formation.

The improvement of chlorophyll in response to the foliar application of nano iron than unsprayed plants may be attributed to Fe increased leaf surface, plant growth, net photosynthetic speed, and plant chlorophyll content (Huda *et al*., 2009). Iron nutrients also play a key role in tomato plant physiology and are essential for plant activities such as respiration, meristematic growth, formation of chlorophyll, photosynthesis, production of gossypol, tannin and phenolic compounds (Bhatt *et al*., 2005).

Table 4. Effect of interaction between deficit irrigation and foliar applications of Nano particles and yeast on leaf pigments (mg/g FW) of tomato plants after 75 days from transplanting during 2015 and 2016 summer seasons.

Parameters		Chlorophyll a		Chlorophyll b		Total chlorophyll (a+b)	
Treatments		2015	2016	2015	2016	2015	2016
60% of ETc	Nano Fe 1000 ppm	0.631	0.580	0.420	0.358	1.051	0.938
	Nano Fe 2000 ppm	0.653	0.607	0.430	0.383	1.083	0.989
	Nano Zn 500 ppm	0.540	0.540	0.370	0.398	0.910	0.938
	Nano Zn 1000 ppm	0.544	0.560	0.368	0.420	0.912	0.980
	Nano Si 6 ppm	0.587	0.589	0.395	0.440	0.982	1.029
	Nano Si 12 ppm	0.609	0.613	0.413	0.418	1.021	1.031
	Yeast 5 g\l	0.591	0.558	0.385	0.443	0.976	1.000
	Yeast 10 g\l	0.593	0.593	0.398	0.465	0.991	1.058
	Control	0.511	0.520	0.345	0.348	0.856	0.868
80% of ETc	Nano Fe 1000 ppm	0.656	0.651	0.443	0.430	1.098	1.081
	Nano Fe 2000 ppm	0.676	0.693	0.460	0.453	1.136	1.146
	Nano Zn 500 ppm	0.591	0.593	0.400	0.390	0.991	0.983
	Nano Zn 1000 ppm	0.604	0.624	0.415	0.405	1.019	1.029
	Nano Si 6 ppm	0.644	0.651	0.430	0.410	1.074	1.061
	Nano Si 12 ppm	0.667	0.671	0.443	0.403	1.098	1.074
	Yeast 5 g\l	0.611	0.598	0.405	0.413	1.016	1.010
	Yeast 10 g\l	0.636	0.618	0.423	0.425	1.058	1.043
	Control	0.560	0.573	0.383	0.413	0.943	0.986
100% of ETc	Nano Fe 1000 ppm	0.620	0.627	0.420	0.393	1.040	1.019
	Nano Fe 2000 ppm	0.656	0.658	0.443	0.400	1.098	1.058
	Nano Zn 500 ppm	0.571	0.573	0.380	0.375	0.951	0.948
	Nano Zn 1000 ppm	0.589	0.587	0.398	0.395	0.986	0.982
	Nano Si 6 ppm	0.600	0.604	0.403	0.413	1.003	1.017
	Nano Si 12 ppm	0.642	0.624	0.425	0.395	1.067	1.019
	Yeast 5 g\l	0.596	0.589	0.395	0.408	0.991	0.996
	Yeast 10 g\l	0.618	0.602	0.410	0.445	1.028	1.047
	Control	0.527	0.536	0.360	0.358	0.887	0.893
	LSD at 5%	0.043	0.051	0.031	0.029	0.083	0.086

2. N, P and K percentages and proline:

Data in Table (5) show the impact of interaction among deficit irrigation water and foliar application treatments on N, P and K percentages leaves as well as proline amino acid in leaves in both seasons. The interaction among deficit irrigation and spraying with nano particles as well as yeast extract reflected significant effect on N, P and K percentages in leaves as well as proline amino acid in leaves in the two seasons. The highest values of, N, P and K percentages in leaves were obtained with the interaction between 80 % Etc and spraying with nano Fe at 2000 ppm. On the other hand, the combination among deficit irrigation water at 60 % Etc and unsprayed plants recorded the lowest values of N, P and K percentages and highest values of proline amino acid in leaves in the two growing seasons.

The beneficial effects of high irrigation levels on mineral absorption may be due to its enhancing effect on transport of dissolved nutrients by mass flow also, the suitable balance of moisture in plant creates favorable conditions for photosynthesis and metabolites translocation, which accelerate the rate of nutrients absorption.

These results are in harmony with those reported by Abdelhady *et al*. (2017), Elzopy *et al.* (2017), Dawa *et al* (2019), and Ragab *et al*. (2019) they found that moderate or high levels of irrigation increased N, P and K contents in shoots of tomato plants grown under stress. Also, our result in parallel line with findings by Gao *et al.* (2012) who revealed that the content of proline increased in the leaves of processing tomato under drought stress. In addition to, Ghorbanli *et al.* (2013) who mentioned that proline is an antioxidant against drought stress. Furthermore, Kazemi (2013) showed that the highest concentrations of N and K in leaf were recorded with cucumber plants when sprayed with iron at 100 ml/l than 50 ml/l or unsprayed plants.

The conversion of proline to glutamic acid and hence to other soluble compounds (proline oxidation) proceeds readily in turgid leaves and it is stimulated by higher concentrations of proline. This suggests that proline oxidation could function as a control mechanism for maintaining low cellular levels of proline in turgid tissues. In water stressed, however proline oxidation is reduced to negligible rates. It seems likely that inhibition of proline oxidation is necessary in maintaining high levels of proline found in stressed levels. Proline accumulates under stressed conditions supplies energy for growth and survival and thereby helps the plant to tolerate stress (Stewart, 1977).

Table 5. Effect of interaction between deficit irrigation and foliar applications of Nano particles and yeast on N,P , K percentages as well as proline in leaves of tomato plants during 2015 and 2016 summer seasons:

Parameters		N (%)		P (%)		K (%)		Proline amino acid mg/100 g DW	
Treatments		2015	2016	2015	2016	2015	2016	2015	2016
60% of ETc	Nano Fe 1000 ppm	2.93	3.02	0.305	0.326	2.30	2.59	106.00	109.00
	Nano Fe 2000 ppm	3.32	3.42	0.348	0.372	2.65	2.99	105.60	106.80
	Nano Zn 500 ppm	2.72	2.80	0.288	0.308	2.12	2.39	118.00	116.92
	Nano Zn 1000 ppm	3.13	3.22	0.325	0.325	2.47	2.79	115.24	115.32
	Nano Si 6 ppm	2.65	2.73	0.277	0.292	2.04	2.30	101.88	109.76
	Nano Si 12 ppm	3.02	3.11	0.337	0.360	2.41	2.72	96.44	95.36
	Yeast 5 g\l	2.81	2.89	0.297	0.318	2.21	2.49	112.20	118.56
	Yeast 10 g\l	3.23	3.32	0.288	0.308	2.51	2.84	114.00	117.56
	Control	2.51	2.58	0.269	0.284	1.93	2.18	145.44	138.72
80% of ETc	Nano Fe 1000 ppm	3.34	3.44	0.344	0.368	2.77	3.13	87.28	90.56
	Nano Fe 2000 ppm	3.73	3.84	0.387	0.414	3.16	3.57	80.40	73.64
	Nano Zn 500 ppm	3.14	3.23	0.324	0.346	2.59	2.92	89.32	84.00
	Nano Zn 1000 ppm	3.55	3.65	0.368	0.393	2.96	3.34	86.16	80.80
	Nano Si 6 ppm	3.05	3.14	0.313	0.335	2.50	2.83	73.44	70.64
	Nano Si 12 ppm	3.43	3.53	0.356	0.381	2.87	3.24	65.12	62.84
	Yeast 5 g\l	3.26	3.36	0.335	0.358	2.68	3.03	89.44	89.44
	Yeast 10 g\l	3.62	3.73	0.375	0.401	3.07	3.48	79.84	87.96
	Control	2.94	3.03	0.304	0.325	2.41	2.72	112.40	115.56
100% of ETc	Nano Fe 1000 ppm	3.07	3.16	0.335	0.358	2.45	2.77	78.56	75.12
	Nano Fe 2000 ppm	3.52	3.62	0.377	0.403	2.83	3.19	66.20	70.96
	Nano Zn 500 ppm	2.86	2.94	0.303	0.325	2.25	2.54	83.88	85.76
	Nano Zn 1000 ppm	3.29	3.38	0.357	0.382	2.68	3.03	75.60	72.60
	Nano Si 6 ppm	2.75	2.83	0.303	0.324	2.17	2.45	65.76	68.92
	Nano Si 12 ppm	3.18	3.27	0.346	0.370	2.57	2.90	60.24	62.52
	Yeast 5 g\l	2.95	3.04	0.323	0.345	2.36	2.66	73.08	78.32
	Yeast 10 g\l	3.41	3.51	0.368	0.393	2.75	3.10	72.20	74.76
	Control	2.66	2.74	0.294	0.314	2.08	2.35	96.16	88.12
	LSD at 5%	0.16	0.14	0.024	0.023	0.13	0.14	1.71	2.84

3. Early and total yield:

Results in the Table (6) cleared that early and total yield per feddan were significantly affected by the interaction among deficit irrigation water and foliar application treatments (nano Fe, nano Zn, nano Si and yeast extract) as compared with control in the two growing seasons.

In general, results showed that the most suitable irrigation treatment at 80% ETc with all different foliar applications which achieved significant higher mean values of early and total yield compared to other same treatments 60% and 100% of ETc. The highest mean values of the early and total yield were recorded for the treatment of 80% of ETc irrigation with nano Si at the rate of 12 ppm, while the lowest ones were connected with control plants (without foliar applications) under all different irrigation treatments.

These results are agreeable with those reported by Abdelhady *et al*. (2

017), Hui *et al*. (2017), Liu *et al*. (2019) and Ragab *et al*. (2019) who observed that increasing water quantity (soil moisture content) or irrigation frequency increased total yield of tomato. Furthermore, Lu *et al.* (2016) on tomato, Tantawy *et al*. (2015) on sweet pepper and Yassen *et al*. (2017) on cucumber who showed that foliar application plants with Si recorded the maximum values of yield and its components compared to control (without foliar).

The improvment in total yield of tomato plant due to irrigation at 80 % ET might be due to the favorable effect of higher amounts of irrigation water on plant growth (Table 3) and increased leaf mineral nutrient (Table 5) and leaf pigments (Table 4) which resulted in increased tomato yield.

Low water supply content decrease root growth and inhibit leaf elongation rate and is associated with increase in ABA concentration in leaves (Smith and Dale, 1988) and decrease CYT production and export (Atkin *et al.* 1973) and this in turn affect the growth and yield of tomato plants.

Silicon affects yield by its deposition under the leaf epidermis, so it results a physical mechanism of defense, phenols production causing phytoalexin production, decreases water losses (transpiration) and increases plant photosynthesis capacity (Ahmad *et al*., 2012).

Table 6. Effect of interaction between deficit irrigation and foliar applications of Nano particles and yeast on yield of tomato plants after 75 days from transplanting during 2015 and 2016 summer seasons:

Parameters Treatments		Early yield (ton/fed)		Total yield (ton/fed)	
		2015	2016	2015	2016
60% of ETc	Nano Fe 1000 ppm	15.782	14.715	20.879	22.808
	Nano Fe 2000 ppm	17.981	15.969	23.141	26.668
	Nano Zn 500 ppm	12.671	13.634	16.461	20.723
	Nano Zn 1000 ppm	13.513	14.670	21.843	22.299
	Nano Si 6 ppm	17.249	16.404	26.079	27.723
	Nano Si 12 ppm	19.164	17.302	26.793	29.067
	Yeast 5 g\l	10.745	13.946	20.233	22.035
	Yeast 10 g\l	14.724	15.283	22.941	24.758
	Control	10.864	10.231	14.906	15.551
80% of ETc	Nano Fe 1000 ppm	23.089	23.107	31.747	30.270
	Nano Fe 2000 ppm	25.612	27.988	34.048	34.425
	Nano Zn 500 ppm	18.157	20.036	24.288	26.047
	Nano Zn 1000 ppm	19.331	22.122	25.055	30.086
	Nano Si 6 ppm	24.765	26.822	31.893	33.527
	Nano Si 12 ppm	26.330	30.671	34.492	37.725
	Yeast 5 g\l	16.039	22.460	25.912	28.075
	Yeast 10 g\l	17.482	23.249	27.586	28.364
	Control	17.559	17.812	22.019	23.868
100% of ETc	Nano Fe 1000 ppm	18.936	19.133	26.491	28.700
	Nano Fe 2000 ppm	20.096	20.403	28.058	31.829
	Nano Zn 500 ppm	15.884	15.847	22.730	25.196
	Nano Zn 1000 ppm	17.746	16.845	23.754	27.625
	Nano Si 6 ppm	20.413	20.318	27.980	30.680
	Nano Si 12 ppm	23.460	23.905	29.985	30.838
	Yeast 5 g\l	15.810	18.027	25.114	26.320
	Yeast 10 g\l	15.995	18.677	26.764	27.828
	Control	13.329	13.560	19.381	21.696
	LSD at 5%	2.202	2.465	2.332	2.256

Water use efficiency

Presented data in Table (7) illustrate the impact of interaction between deficit irrigation water and spraying with nano particles (Fe, Zn, Si) and yeast extract on water use efficiency. Results revealed that the interaction between irrigation levels and the foliar application treatments recorded a stimulated effect on water use efficiency in the two seasons. In addition, the highest values of WUE were obtained for the treatment of 60% ETc irrigation and 80% ETc in both seasons respectively, with nano Si at 12 ppm while the lowest ones were connected with the treatment without any of applied foliar application substances.

These findings are consistent with those reported by Xiukang and Yingying (2016) found that water stress 50% increased water use efficiency of tomato plant. Also, Romero-Aranda *et al.* (2006) concluded that the application Si increase plant water storage and WUE in tomato plants.

Under water stress conditions, silicon improved plant water status, reduced water loss through transpiration, maintained adequate supply of essential nutrients, and limited uptake of toxic ions and efficient functioning of ant oxidative mechanisms (Sacala, 2009).

Table 7. Effect of interaction between deficit irrigation and foliar applications of Nano particles and yeast on water use efficiency (kg fruit /m^3 water) during 2015 and 2016 summer season:

Parameter Treatments		water use efficiency (kg fruit /m3 water)	
		2015	2016
60% of ETc	Nano Fe 1000 ppm	8.115	8.201
	Nano Fe 2000 ppm	8.994	9.589
	Nano Zn 500 ppm	6.398	7.452
	Nano Zn 1000 ppm	8.489	8.018
	Nano Si 6 ppm	10.136	9.969
	Nano Si 12 ppm	10.413	10.452
	Yeast 5 g\l	7.864	7.923
	Yeast 10 g\l	8.916	8.903
	Control	5.793	5.592
80% of ETc	Nano Fe 1000 ppm	9.253	8.163
	Nano Fe 2000 ppm	9.924	9.284
	Nano Zn 500 ppm	7.079	7.025
	Nano Zn 1000 ppm	7.303	8.114
	Nano S i6 ppm	9.296	9.042
	Nano Si 12 ppm	10.053	10.174
	Yeast 5 g\l	7.552	7.571
	Yeast10 g\l	8.040	7.649
	Control	6.418	6.437
100% of ETc	Nano Fe 1000 ppm	6.176	6.192
	Nano Fe 2000 ppm	6.542	6.867
	Nano Zn 500 ppm	5.300	5.436
	Nano Zn 1000 ppm	5.538	5.960
	Nano S i6 ppm	6.524	6.619
	Nano Si 12 ppm	6.991	6.653
	Yeast 5 g\l	5.855	5.679
	Yeast10 g\l	6.240	6.004
	Control	4.519	4.681
	LSD at 5%	0.732	0.615

CONCLUSION

It could be concluded that the irrigation of tomato plants with 80 % from Etc and spraying with Silicon nanoparticles at 12 ppm save more irrigation water and improved plant growth parameters, chemical constitutes of leaves and total yield of tomato plants under similar conditions of this study.

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تأثير الرش الورقي بجزيئات نانو الحديد والزنك والسيليكون والخميرة على النمو والمحصول وكفاءة الاستهلاك المائى لنباتات الطماطم تحت ظروف الإجهاد المائى

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أجريت تجربتان حقليتان خلال موسمى النمو الصيفى 2015 و2016 تحت نظام الرى بالتنقيط بمزرعة خاصة بقرية جميانة بالقرب من مدينة بلقاس- محافظة الدقهلية مصر لدراسه تأثير التفاعل بين معاملات نقص الرى (100%, 80%,60% من البخر نتح) والرش ببعض الإضافات الورقيه (الحديد النانو,الزنك النانو ,السيليكون النانو ومستخلص الخميرة) على النمو الخضرى والتركيب الكيماوى للأوراق مثل صبغات البناء الضوئى (كلوروفيل أ, كلوروفيل ب, الكلوروفيل الكلى أ+ ب) محتوى الأوراق من العناصر (النيتروجين, الفسفور, البوتاسيوم) وكذلك محتوى البرولين فى الأوراق والمحصول لنبات الطماطم هجين (فيروز) تحت نظام الرى بالتنقيط. استخدم تصميم الشرائح المتعامدة في ثلاث مكررات حيث خصصت الشرائح الرأسية لمستويات ماء الري، في حين خصصت الشرائح الأفقية لمعدلات الرش الورقي. أظهرت النتائج أن رى نباتات الطماطم عند مستوى 80 % من البخر نتح والرش بجزيئات النانو المختلفة أو مستخلص الخميرة بالتركيزات المختلفة قد سجلت زياده معنويه. لجميع الصفات المذكورة أعلاه فى هذا الصدد بينما حسنت معاملات نقص الماء محتوى البرولين فى الاوراق و كفاءة الاستهلاك المائى فى كلا موسمى الزراعة. ووجد أن أفضل النتائج المتحصل عليها لزياده النمو الخضرى والتركيب الكيماوى للأوراق مثل صبغات البناء الضوئى (كلوروفيل أ, كلوروفيل ب , الكلوروفيل الكلى أ+ ب) ومحتوى الأوراق من العناصر (النيتروجين ,الفسفور ,البوتاسيوم) ومحصول الطماطم المبكر والكلى عند رى النباتات بمستوى80% من البخر نتح مع الرش الورقى بالنانو سيليكون بمعدل 12 جزء فى المليون ولهذا يمكن التوصية بأستخدام هذه المعاملة لزيادة نمو وانتاجية الطماطم تحت ظروف مماثلة لهذه الدراسه.