RESPONSE OF TOMATO PLANTS TO DIFFERENT RATES OF IRON NANOPARTICLES SPRAYING AS FOLIAR FERTILIZATION

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ABSTRACT

A field experiment was carried out on a clayey soil in Egypt cultivated with tomato plants (Lycopersicon esculentum Mill.), and furrow irrigation with Nile water, to study the potential benefits of iron nutrient in nanoparticles form(FeNPs) Vis. mineral [$FeSO_4.7H_2O$ (20.14%Fe)]. The iron nutrient forms were applied as foliar application and the studied parameters were growth, yield, days to flowering and some quality parameters. The obtained results reveal that the tomato parts dry matter, yield of fruits, and some quality properties including pigment content (Chlorophyll and lycopene), total sugars and total soluble solids (TSS) were greatly increased, in general with additions of FeNPs at 50% of recommended mineral form.

1-INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the world's most important vegetables, with an estimated total production of about 159.347 million Mg in 2011 **(FAO-STAT 2011)**. Foliar fertilizers are concentrated aqueous solution or suspension which must be diluted with water before applied to plant **Ali and Rihaneh (2008)** defined that the foliar fertilization as the method which used the nutrients as foliar sprays to plant. Major advantage of nutrients applied through foliar feeding are instantly available to plants. This property of foliar feeding makes this method better than others especially when distributed small quantities through wide area **Kurepa (2010)**. Nanotechnology is defined by **Chinnamuthu and Murugesa (2009)** as the branch of science which is dealing with smallest particles.

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They added the term "nanotechnology" is used to mean technology at the nanometer level to achieve something useful through the manipulation. **Halvin et al. (1999)** showed that iron is critical for chlorophyll formation and photosynthesis and it is important in enzymes and respiration of plants. Because of iron, zinc and manganese have a main effect on photosynthesis process and carbohydrate production. **Mahdi et al. (2011)** indicated that the iron and zinc foliar application may be the key enzymes of the glutamate way of praline made in plant cell because of positive reaction to iron and zinc foliar application in this way. **Pedro et al. (2014)** reported that iron deficiency reduced dry weight and chlorophyll content or fruit trees leaves. While increased organic acids content of leaves and roots with the exception of 2-oxoglutaric and tartaric acid. **Fang et al. (2008)** indicated that the iron application increased the rice grain, iron content significantly ash content of rice products. **EL Sheikh et al. (2007)** demonstrated that spraying of Fe or other micronutrients on peach trees twice or three times yearly was more effective than control and also spraying of micronutrients once a year improved leaf minerals and chlorophyll a and b. The Fe or micronutrients treatments markedly by 37.1% compared to control without affecting the grain yield, grain protein and increased the yield, fruit weight, fruit size and fruit firmness. **Patil et al. (2009)** found that the tomato yield and quality parameters like number of fruits per plant, total solid substances (T.S.S) and acidity were influenced significantly due to iron and other micronutrients treatments. **Zhu et al. (2008)** studied the uptake of magnetite (Fe_3O_4 NPs) by pumpkin. They found that the uptake of magnetic nanoparticles through the root system of cucurbita maxima plants was significantly only in the case of plants growing in liquid media. They added that the uptake of the NPs was depended on the growth medium, because no uptake was observed when grown in soils and reduced uptake when grown on sands. This may be attributed to the adherence of Fe_3O_4NPs to the soil and sand grains. **Wang et al. (2010)** found that the Fe oxide nanoparticles (Fe_2O_3NPs) at higher concentration induced oxidative stress and higher anti-oxidative enzyme activity than the bulk Fe_2O_3 particles. The Fe_2O_3NPs adsorbed on the root surface or absorbed by the roots were thought to disturb the metabolic activities in roots, leading to local instability of the cell wall and/or membrane, eventually producing oxidative stress. **Buger et al. (2011)** studied effect of iron chelate nano fertilizer on qualitative and quantitative properties of various cut flowers and found that treatments by 1 and 1.5 gr.L^{-1} iron chelate nano fertilizer with possibility of 95% have a positive and significant effect on increasing these indices. **Sheykhbaglou et al. (2010)** studied the effect of nano iron oxide particles on soybean plants. They found significantly increase of growth parameters such as; plant height number of branches per plant, pods length and pods width. Also yield per plant was significantly increased by foliar spraying of nano iron chelate fertilizer. **Hamid (2012)** investigated the application of nano iron chelate fertilization as a foliar spraying on growth and yield of eggplant. The results revealed that the application of nitrogen and iron fertilizer showed significant effects on all studied traits at 1% probability level. Interaction effect of nitrogen and iron nano chelate on fruit yield, number of fruits per plant, plant height and number of branches per plant showed significant differences at 5% probability level.

2-MATERIALS AND METHODS

2-1-1 Treatments:- A field experiment was carried out on clayey soil cultivated with tomato plants (Lycopersicon esculentum Mill.) irrigated with Nile water. The applied treatments of the studied zinc nutrient included zinc sulfate $ZnSO_4.7H_2O$ (22.75%Zn) and zinc nanoparticle which supplied by *Sigma Aldrich Int. Co* as zinc oxide (ZnO), spherical shape with size (<100 nm) were added as foliar application, with special reference to the control treatment (untreated plants) and normal recommended dose of mineral fertilization (MNRD). The recommended dose in spraying solution was 2g.l^{-1} with the rate of 600liter.fed^{-1}. Zinc sulfate was added in the recommended dose (RD) from mineral sulfate salts fertilization as a traditional foliar fertilizer. While zinc nanoparticle (ZnNP) was added as a fraction of mineral salts rate in normal recommended dose as [ZnNP at 10%RD, 25%RD, 50%RD, 75%RD and 100%RD]. Foliar application of micronutrients sprayed among four times, after 30 days from planting and every 15 days uptill fruit stage. Observations were recorded for many parameters such as; dry weights of roots and shoots, fruit yield, days to flowering and some quality characters. The experiment was designed in randomized complete block design with three replicates was used, with an area of 100m^2 having the dimensions (10x10). This area was divided into 20 bands, each band extended 10m. The distance between each two successive bands was 50cm. Tomato plants were transplanted at the distance of 50cm apart. Furrow irrigation was used after leveling by laser. Soil fertilizer was applied according the recommendation of agricultural research center (**ARC2003)** for tomato plant production. The days from transplanting (the end of vegetative growth), flowering stage were determined. During this growth stage the dry weight of tomato shoots and roots were evaluated also, macro and micro nutrients content and uptake of shoots and roots were analyzed. The first fruit ripened taken after the date of transplanting (mature or reproduction stage). At this stage the fruit yield per plant was determined while other plant parts (shoots and roots) were determined as dry weight. The selected youngest fully expanded leaves were taken from each treated plant for determining nutrients (N, P, K, Fe, Mn and Zn) and total chlorophyll; also roots content of these nutrients were determined. Tomato fruits were subjected to the different analysis to estimate the total of soluble solids (TSS), Lycopene content, total sugars and nutrient contents (Macro and Micro Nutrients). The different treatments illustrated in table (1).

Table (1) applied treatments in the experiment.

Sr	**Treatments No.**	**Treatments Symbol**		**Rate of applied micronutrient sand nanoparticles**
1	**T0**	Control (Cont.)		Control (without foliar fertilization treatments)
2	**T1**	MNRD		Mineral fertilizers in Normal Recommended Dose.
3	**T2**	ZnNPs	10%RD	10% RD of Zn as Zn nanoparticles + RD of Fe and Mn.
4	**T3**		25%RD	25%RD of Zn as Zn nanoparticles + RD of Fe and Mn.
5	**T4**		50%RD	50% RD of Zn as Zn nanoparticles + RD of Fe and Mn.
6	**T5**		75%RD	75% RD of Zn as Zn nanoparticles+ RD of Zn and Mn.
7	**T6**		100%RD	100% RD of Zn as Zn nanoparticles + RD of Fe and Mn.

2-1-2 Methods of analysis:- Soluble cations and anions in soil and water were measured according to **Page et al.(1982)** while soil organic matter and calcium carbonate content according **Black (1982).** Soil samples were extracted by DTPA according to **Lindsay and Norvell (1978)** and micronutrients in water and soil were analyzed by inductively coupled argon plasma spectroscopy (ICP) (perking elmer - 400) according to **Cottenie et al. (1982)**. Sub samples of dried plant were wet digested using sulphoric acid mixture to analyze N, P, K, Ca, Mg, Fe, Zn and Mn. Total nitrogen was determined using micro Kjelddahl apparatus **(Chapman and Part 1961)**. Potassium was evaluated using flame photometer, while Ca, Mg, Fe, Zn and Mn were determined by atomic absorption spectrophotometry **(AOAC, 1980)** . Leaves were cut into small pieces and appropriate weight (1gm each) were subjected to extraction of 80% solution of acetone and spectrophotometrically determination of chlorophyll a,b and total at wave lengths of (663 and 645) nm according to the method of **(Arnon, 1965).** The content of chlorophyll in solution was calculated as the following formula

Chlorophyll a (mg.g-1) = [12.7(A663) – 2.69(A645)] x V/1000 x W.

Chlorophyll b (mg.g-1) = [22.9(A645) – 4.68(A663)] x V/1000 x W.

Total chlorophyll (mg.g-1) = [20.2(A645) – 8.02(A663)] x V/1000 x W.

Where: A= Absorbance of specific wavelength. V= final volume of chlorophyll extract in 80% acetone. W= weight of sample.

The TSS of the harvested fruit juice was determined by hand refractometer (Atago N-20E) and the measured values (%Brix) were converted to a standard temperature condition of 20^{o}C **Ranganna (1994)**. Lycopene concentration of tomato fruits were measured spectrophotometrically using a modified method based on **Fish et al (2002).** Total sugar were extracted in 10 ml of 80% anhydrous alcohol by boiling 0.1 g dry powdered sample for 30 min at 80°C followed by centrifugation at 5,000 g for 10 min and subsequent procedures was followed using the Anthrone reagent method **(Sen et al., 2005).** Nanoparticles manufacturing by **(Sigma Aldrich Methods of Nanomaterials 2009).**

Table (2) Materials which were used in the studied experiment

<table>
<tr><th colspan="2" rowspan="2">characteristics</th><th rowspan="2">Soil Values</th><th rowspan="2">Irrigation Water Values</th><th colspan="2">Some Properties of nanoparticles</th></tr>
<tr><td>Chemical formula</td><td>Fe_2O_3</td></tr>
<tr><td colspan="2">pH(1:2.5soil:water susp.)</td><td>7.93</td><td>7.23(irrig.water)</td><td>Form</td><td>Nano powder</td></tr>
<tr><td colspan="2">ECe dS/m (soil sat. paste extract.)</td><td>2.91</td><td>0.93(irrig.water)</td><td>Image (TEM)</td><td>Spherical</td></tr>
<tr><td colspan="2">Organic matter%</td><td>1.47</td><td>----</td><td>Size</td><td>(50-100) nm</td></tr>
<tr><td colspan="4">Soluble ions (soil $me.L^{-1}$,Water $m.mole.L^{-1}$)</td><td>MP (melting point)</td><td>1538^{o}C(lit)</td></tr>
<tr><td colspan="2">Ca^{++}</td><td>9.69</td><td>2.39</td><td>Surface Area</td><td>60 $m^2.g^{-1}$</td></tr>
<tr><td colspan="2">Mg^{++}</td><td>4.76</td><td>1.84</td><td rowspan="2">Assay</td><td rowspan="2">97% trace metal basis</td></tr>
<tr><td colspan="2">Na^{+}</td><td>12.73</td><td>4.64</td></tr>
<tr><td colspan="2">K^{+}</td><td>0.81</td><td>0.62</td><td rowspan="4">Density</td><td rowspan="4">4.8-5.1 $g.m^{-1}$ at 25 ^{o}C (lit)</td></tr>
<tr><td colspan="2">CO^{--}</td><td>0.00</td><td>0.00</td></tr>
<tr><td colspan="2">HCO_3^{-}</td><td>3.75</td><td>5.30</td></tr>
<tr><td colspan="2">Cl^{-1}</td><td>14.45</td><td>3.65</td></tr>
<tr><td colspan="2">$SO4^{--}$</td><td>9.81</td><td>0.54</td><td>Bulk Density</td><td>0.84 $g.mL^{-1}$</td></tr>
<tr><td colspan="2">Available soil nutrients ($mg.kg^{-1}$)</td><td colspan="2">Available water elements($mg.kg^{-1}$)</td><td colspan="2" rowspan="7"></td></tr>
<tr><td>N</td><td>39.01</td><td>Cd</td><td>0.019</td></tr>
<tr><td>P</td><td>6.13</td><td>Ni</td><td>0.087</td></tr>
<tr><td>K</td><td>248.63</td><td>Co</td><td>0.036</td></tr>
<tr><td>Fe</td><td>2.16</td><td>Fe</td><td>0.711</td></tr>
<tr><td>Zn</td><td>0.78</td><td>Zn</td><td>0.907</td></tr>
<tr><td>Mn</td><td>1.34</td><td>Mn</td><td>0.346</td></tr>
</table>

3-RESULTS AND DISCUSSIONS

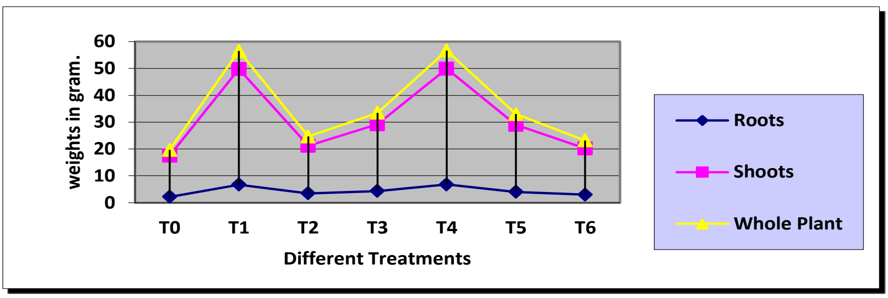
3-1 Effect of nanoparticles as a foliar fertilization at different rates of mineral fertilizers on growth and yield of tomato plants:

3-1-1-Effect on growth of tomato plants. Data of tomato growth parameters are presented in table (3) and figure (1) revealed that the treatments (No. 5) including the half dose of mineral fertilizers in normal recommended dose (MNRD) were the best treatments of nanoparticles fertilizations with the respect to dry weights (DWs) of tomato shoots, roots and whole plants. The treatment No.5 consisted of iron nanoparticles in the rate of 50%RD of Fe was the highest value of tomato (DWs), followed with treatments No.2. Considering the treatments of nanoparticles foliar fertilization spraying on tomato plants, we can notice that the nanoparticles in the half dose nearly equal with the fully dose of recommended mineral fertilization.

Table (3) Effect of different treatments on dry matter of tomato roots, shoots and whole plant at flowering stage.

Ser.	Treatments Number	Treatments Symbol		Dry weights of tomato (g plant^{-1})					
				Roots	Relative increase	Shoots	Relative increase	Whole plant	Relative increase
1	T0	Control.		2.17	0.00	17.51	0.00	19.68	0.00
2	T1	**MNRD**		6.71	209.21	49.81	184.46	56.52	187.19
3	T2	Fe NPs	**0.10 RD**	3.45	58.98	21.18	20.96	24.63	25.15
4	T3		**0.25 RD**	4.31	98.62	29.17	66.59	33.48	69.72
5	T4		**0.50 RD**	6.77	211.98	49.87	184.80	56.64	187.80
6	T5		**0.75 RD**	4.01	84.79	29.00	65.62	33.01	67.73
7	T6		**100%RD**	3.00	38.25	20.19	15.31	23.19	17.84

Dry weights evaluated per one plants **NPs**=Nanoparticles **R.D**=Recommended Dose **MNRD**= Mineral fertilizers in Normal Recommended Dose



Fig(1) Effect of different treatments on tomato dry weights

While when the rate of nanoparticles reduced or increased over the rate of half mineral recommended dose, the values of tomato parts dry weight will be reduced. Referring to the rate of increase (relative increase) in tomato growth parameters as resulted to control, it is clear that this increase ranged from about 38.25, 15.13 and 17.84 % over the control, in case of treatment No.7 [which received iron nanoparticle in the rate of mineral fertilization at recommended dose] up to 211.98, 184.80 and 187.80% for the treatment No.5 including iron nanoparticle in the rate of half mineral fertilization at recommended dose, with respect to the dry weights of tomato roots, shoots and whole plant. In general, the investigated treatments could be arranged descendingly according to their positive effect on tomato growth (DWs of tomato parts) as:-FeNPs at 50%RD > MNRD> 25%RD>75%RD>10%RD >100%RD>Cont.

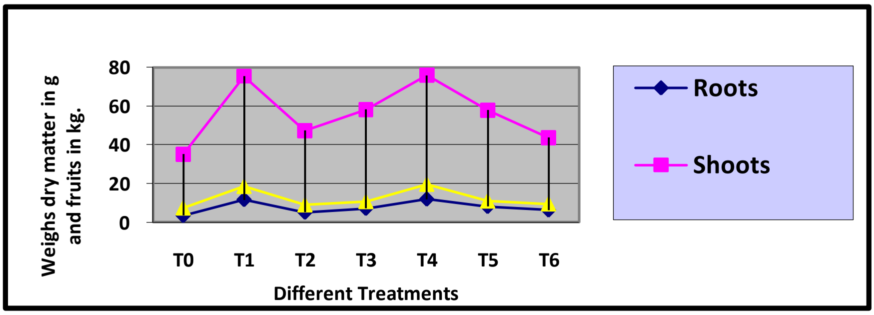
The results may suggest that nanoparticles fertilization in the half rate of recommended mineral fertilization gave the positive effect on growth of tomato plants, while the higher or lower than this rate gave the negative effects. Also the mineral fertilization in the recommended dose nearly gave the equal results with nanoparticles in the rate of half mineral fertilization at recommended dose. The improving in the growth and dry matter yield of tomatoes related strongly with the balance amount of nutrients. An appropriate nutrient supply is always a prerequisite and crucial to reach high yields in tomato, however the deficiency or excess in nutrients requirement affected negatively on growth status and yield of tomato plants. The improvement in the growth may be due to the involvement of micronutrients in different physiological process like enzyme activation, electron transport, chlorophyll formation and stomatal regulation which ultimately resulted in greater dry matter. The effect of nanoparticles has been done by smaller quantities than mineral form may be due to the uptake pathway of foliar nanoparticles which was through stomatal pores along the leaf blade. This pathway differed fundamentally from the cuticle foliar uptake (ionic pathway for mineral fertilization). The stomatal uptake doesn't require infiltration of solutions by dynamic mass flow but is caused by diffusion of solutes or suspended particles probably in water absorbed to the walls of the stomatal pores, therefore this pathway is accessible for any water-soluble solutes even for small particles irrespective of charge or molecular weight and enables transport much higher than across the cuticle. These indications agree with **Eichert et al. (2008).**

3-1-2 Effect on yield of tomato plants. Results scheduled in table (4) and illustrated in figures (2) indicated that the dry matter weights of tomato roots and fruits yield responded to the used treatments almost typically according to the descending order:- FeNPs at 50%RD > MNRD> FeNPs at 75%RD > FeNPs at 25%RD > FeNPs at 100%RD> FeNPs at 10%RD > Control . The shoots dry weight responded somewhat differently due to the differences in plant growth type in the different order arrangement, as the following:- FeNPs at 50%RD > MNRD> FeNPs at 25%RD > FeNPs at 75%RD > FeNPs at 10%RD> FeNPs at 100%RD > Control .

Table (4) Effect of different treatments on yield and dry matter of tomato roots, shoots and whole plant at reproduction stage

S	Treatments Number	Treatments Symbol		Dry weights of tomato (g. plant^{-1})						Yield(Kg. plant $^{-1}$)	
				Roots	R.I	Shoots	R.I	Whole plant	R.I	Yield	R.I
1	T0	Control.		3.50	0.00	35.17	0.00	38.67	0.00	0.75	0.00
2	T1	MNRD		11.61	231.71	75.45	114.53	87.06	125.14	1.86	148.00
3	T2	Fe NPs	10% RD	5.17	47.71	47.43	34.86	59.06	52.73	0.91	21.33
4	T3		25% RD	7.14	104.00	58.34	65.88	65.48	69.33	1.08	44.00
5	T4		50% RD	11.86	238.86	75.96	115.98	87.82	127.10	1.97	162.66
6	T5		75% RD	8.10	131.43	57.88	64.57	65.98	70.62	1.11	48.00
7	T6		100%RD	6.30	22.86	43.71	24.28	50.01	29.33	0.96	28.00

***Dry weight evaluated per one plant and fruit yield evaluated per one plant. R.I= Relative Increase**



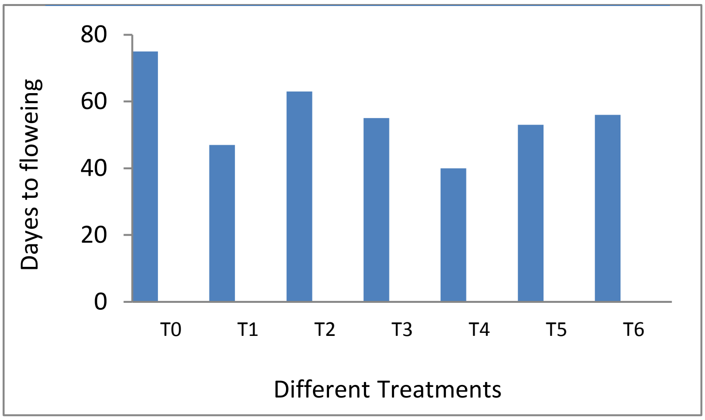
Fig(2) Effect of different treatments on tomato yield and dry matter weights

Considering the rate of increase in tomato parts and fruit yield as related to control, it is clear that this increase could be arranged as the following:- The relative increase values of the tested nanoparticle treatments ranged from about 22.86, 24.28, and 21.33 up to 238.86, 115.98 and162.66 for tomato roots, shoots and fruits yield, respectively. Such results of iron nutrient effects on growth and yield of tomato plants may be according to its role in physiological and biochemical processes. Adequate quantity of nutrients application produced maximum fruit yield, this may be attributed to enhancement of photosynthesis activity, which resulting to increase in production and accumulation of carbohydrates and favorable effect on vegetative growth and retention of flowers and fruits and consequently to increasing number and weight of fruits which led to improving yield and dry matter production. Nanoparticles offered an improving in yield and growth by spraying lower quantity than mineral fertilization because the application of nanoparticles was more effective to reach the target site of treated plant and can transport to specific other sites throughout the plant vascular system then these nanoparticles can be successfully used to unload chemical into localized areas tissues **(Remya et al. 2010)**.

3-1-2 Effects of nanoparticles as a foliar fertilization at different rates of mineral fertilizers on days to flowering:- Regarding days to flowering, the results obtained from table (5) and figure(3) were indicated that the treatment No.5 (T4) including the iron nanoparticle at half dose of normal mineral fertilization at recommended dose dominated with minimum number of days after transplanting to bear flowers followed by treatments No.2 (T1) which including fully dose of only normal mineral fertilization at recommended dose. However other nanoparticle treatments of lower or higher than the half dose of normal recommended dose were observed delaying in the bearing of flowers. Days to flowering were related to improvement in nutrient metabolism in plant which may result in more growth activation and enhanced the plant flowering status in plant. The escalation in tomato flowers was due to increase vegetative growth of tomato and enhanced nutrients uptake due to foliar application that resulted in increasing assimilation rate and the biosynthesis's accumulation consequently by optimal availability of some required nutrients. Moreover the foliar application of micronutrients enhanced the growth and flowering due to the availability of these nutrients and the easiness of absorbing them via leaves that fulfill the optimal nutritive requirements of tomato plants while the deficiencies of nutrients were impeding the crops growth and yield; therefore the endowment of these nutrients not only fulfilled the nutritional requirements of tomato crop but also helpful in increasing the growth, flowering and yield of tomato. Days to flowering were improving as a result of optimum nutrients requirements which led to improve growth parameters. The application of nanoparticles in small quantity can improve the growth of plant as compared with other formula of elements when sprayed on plant, therefore the application of FeNPs at 50%RD was had a better reflection on tomato growth parameters than mineral formula fertilization.

Table (5) Effect of different treatments on days to flowering

Ser.	Treatments	Symbol		Days to flowering
1	T0	Control		75
2	T1	MNRD		47
3	T2	FeNPs	10%RD	63
4	T3		25%RD	55
5	T4		50%RD	40
6	T5		75%RD	53
7	T6		100%RD	56



Fig(3) Effect of different treatments on the days of flowering

3-1-3 Effect of nanoparticles as a foliar fertilization at different rates of mineral fertilizers on some quality properties of tomato leaves and fruits: Data in table (6) and figure (4) showed that there were positive effects in quality properties of tomato plants due to forms of nutrient treatments as compared with the treatment of control. These effects could be summarized as the following:

1- All treatments indicated a positive response to foliar application of nutrients on tomato plant, as compared with the control treatment, which presented the lowest values of tomato quality properties. These values were [43mg.kg^{-1} ;(2.18 and 2.58) %;(0.58, 0.29 and 1.22) mg.g^{-1}] for lycopene; total soluble solids (T.S.S); total sugars; chlorophyll a, chlorophyll b and total chlorophyll**.**

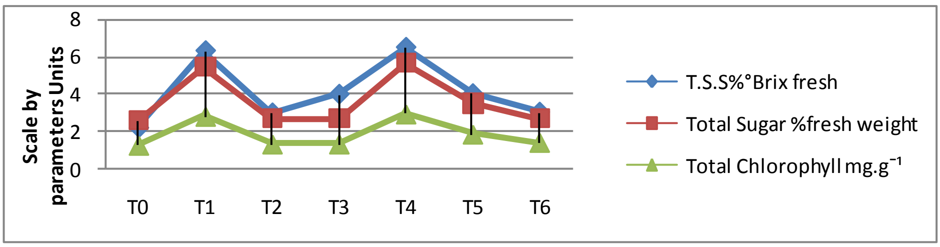
2-The nanoparticle treatment in the rate of half dose of mineral fertilization at the rate of normal recommended dose (50%RD) was the best treatment from all nanoparticle treatments for tomato quality properties. The values of quality properties under this rate of application (FeNPs at 50% RD) were; 216mg.kg^{-1} fresh weight for tomatoes fruit lycopene; 6.49% for total soluble substances (TSS) of tomatoes fruit; 5.63% for total sugars of tomatoes fruit and 1.95; 0.98 and 2.93mg.g^{-1} fresh weight for chlorophyll a; chlorophyll b and total chlorophyll of tomato leaves.

Meanwhile values of tomato quality properties under the treatment of mineral fertilization at the rate of normal recommended dose (MNRD) were: 213 mg.kg^{-1} for tomatoes lycopene; 2.18% for total soluble substances (TSS) of tomatoes fruit; 2.58 % for total sugars of tomatoes fruit and 1.87, 0.93 and 2.80) mg.g^{-1} fresh weight for chlorophyll a, chlorophyll b and total chlorophyll, respectively. 3-The values of tomato quality properties decreased with other rates of nanoparticle treatments.The relative increases of ***tomato fruits lycopene*** under different nanoparticle treatments were were 46.51, 111.63, 127.91 and 81.41% for the treatments of FeNPs at 10%RD, 25%RD, 75%RD, 100%RD, respectively. While the maximum value 402.33 % was accompanied with FeNPs at 50%RD. The same trend was found with ***total soluble substances (TSS) of tomato fruits***, the maximum values of relative increase was 197.71% under the treatments of FeNPs at 50%RD, while other values were36.71, 82.56, 83.94 and 38.53% under the treatments of FeNPs at 10%RD, 25%RD, 75%RD and 100%RD. Also same trend with tomato fruits lycopene and TSS was found for ***total sugars of tomato fruits***, the maximum value of relative increase was 118.22% under the treatments of FeNPs at50%RD. The other values were

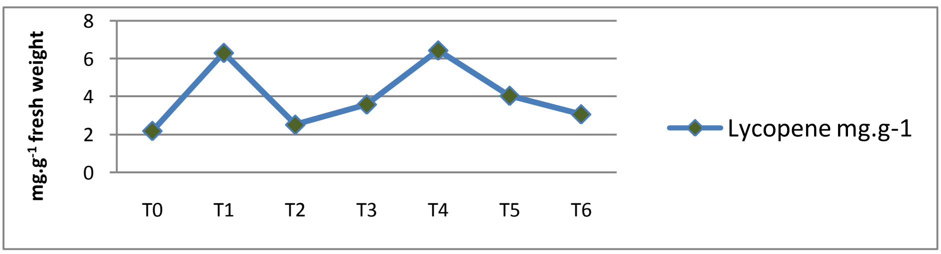
3.48, 42.63, 34.88 and 3.10 % under the treatments of FeNPs at 10%RD, 25%RD, 75%RD and 100%RD, respectively.

Table (6) Effect of different treatments on tomato quality parameters

Sr	Treatments			Fruit Properties			Leaves Properties			
				Lycopene	TSS	Total Sugar	Chlorophyll Contents a	Chlorophyll Contents b	Ratio a/b	Total
١	Control		Content	43.00	2.18	2.58	0.85	0.29	2.93	1.22
			R.I%	0.00	0.00	0.00	0.00	0.00		0.00
2	MNRD		Content	213.00	6.31	5.43	1.87	0.93	2.01	2.80
			R.I %	395.35	189.44	110.46	120.00	220.69		129.51
3	Fe NPs	10% RD	Content	63.00	2.98	2.67	0.88	0.51	1.73	1.29
			R.I %	46.51	36.71	3.48	3.53	75.86		5.74
4		25% RD	Content	91.00	3.98	3.68	0.99	0.63	1.57	1.62
			R.I %	111.63	82.56	42.63	16.47	117.24		32.78
5		50% RD	Content	216.00	6.49	5.63	1.95	0.98	2.00	2.93
			R.I %	402.33	197.71	118.22	129.41	237.93		140.16
6		75% RD	Content	98.00	4.01	3.48	1.12	0.71	1.58	1.83
			R.I %	127.91	83.94	34.88	31.76	144.83		50.00
7		100%RD	Content	78.00	3.02	2.66	0.89	0.49	1.82	1.38
			R.I %	81.41	38.53	3.10	4.70	68.96		13.11



Fig(4-A) Effect of different treatments on some quality properties of tomato



Fig(4-B) Effect of different treatments on tomato lycopene content

The same trend with other quality properties of tomato fruits was found for ***total chlorophyll of tomato leaves,*** the maximum value of relative increase was 140.16% under the treatment of FeNPs at 50%RD while other values were5.74, 32.78, 50.00, 13.11% under the treatments of FeNPs at 10%RD, 25%RD, 75%RD, 100%RD, respectively. From the preceding results, it was concluded that the beneficial effects of mineral fertilization at fully dose of normal recommended dose (MNRD) on quality parameters were nearly in the line with nanoparticle treatments in the rate of half dose of mineral fertilization at normal recommended dose (NPs at 50%RD). The contribution of these treatments for improvement the quality parameters were referred to the involvement and stimulating effects of iron in different physiological processes such as enzyme activation, electron transport, photosynthesis process and biochemical reactions in plant cell. Iron nutrient acted as stimulants and catalysts in many metabolic processes of the plant which led to improve chlorophyll formation, synthesis of pigments, production of total sugars and TSS.

Conclusions. The obtained results reveal that: 1- The tomato parts dry matter, yield of fruits, and some quality properties including pigment content (Chlorophyll and lycopene), total sugars and total soluble solids (TSS) were greatly increased. 2- During nanoparticle treatments, the most effective treatment was with the rate of half dose from minerals at recommended dose (FeNPs at 50%RD). 3-Mineral forms in normal recommended dose (MNRD) gave nearly equal effect with FeNPs at 50%RD. 4-About days to flowering treatments, the minimum number of days was accompanied with (FeNPs at 50%RD) followed by (MNRD). 5-The foliar application of iron nutrients in the form of nanoparticles presented equal effects with mineral forms in the rate of half concentration from recommended dose6-Nanoparticles application may save the amount of agrochemical used in fertilizers. 7-The low quantities of nanoparticles were more effective than higher from ordinary source (mineral source).

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الملخص العربي

استجابة نباتات الطماطم لمعدلات مختلفة من التسميد الورقى للحديد النانو.

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عبدالرحمن عبدالرؤف عبدالرحمن [٣] و أحمد أسعد عبدالواحد عرفات[٤]

- تهدف هذة الدراسة لقياس مدى تاثير التسميد الوررقى من الحديد النانو على انتاجية وجودة محصول الطماطم حيث اجريت تجربة حقلية على نباتات الطماطم المنزرعة فى تربة طينية تستخدم الرى بالغمر وتم الرش من الحديد النانو بمعدلات مختلفة من التركيز الموصى بة من الحديد المعدنى (فى صورة كبريتات الحيدوز ٢٠,١٤% حيد) وذلك لتحديد انسب معدل اضافة يمكن استخدامة من الحديد النانو لأعطاء أعلى انتاجية وكذلك أفضل صفات جوده.
- حيث تم استخدام تركيزات مختلفة من الحديد النانو كنسب من التركيز الموصى بة (١٠% ، ٢٥% ، ٥٠% ، ٧٥% ، ١٠٠%) من التركيزالموصى بة من اضافة التسميد الورقى للحديد المعدنى.
- وقد تبين من الدراسة ان استخدام الحيد النانو بمعدل ٥٠% من التركيز الموصى بة من الحديد المعدنى أعطى أفضل نتائج للعوامل موضوع ادراسة على محصول الطماطم (أنتاجية المحصول – بعض صفات الجودة مثل محتوى الأوراق من الكلوروفيل ومحتوى الثمار من الليكوبين والسكريات الكلية والمواد الصلبة – وأخيرا التبكير فى الأزهار).
- كانت النتائج المتحصل عليها من استخدام الحيد النانو بمعدل ٥٠% من التركيز الموصى بة من الحديد المعدنى مساوية تقريبا مع تلك النتائج المتحصل عليها من معدل الأضافة الموصى بة من الحديد المعدنى.
- من النتائج المتحصل عليها يمكن استتنتاج أن استخدام الحديد النانو فى التسميد الورقى لنباتات الطماطم يمكن أن يكون وسيلة لتوفير كميات الأسمدة الورقية المعدنية المستخدمة بصورة تقليدية مما لة من أثر جيد من الناحية الأقتصادية و البيئية.

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