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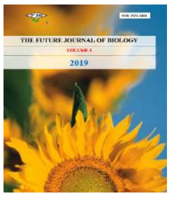

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INTEGRATED USE OF SOIL HUMIC ACID RATES UNDER FOLIAR ZINC OXIDE AND NANOPARTICLES ZINC OXIDE CONCENTRATIONS ON TOMATO LEAF CHEMICAL CONSTITUENTS AND FRUIT QUALITY

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ABSTRACT: Two fields experiments were achieved during the Nili season of 2017 and 2018 at Experimental Farm of Faculty of Agriculture, Fayoum University, Fayoum Gornorate to investigate the effect of soil humic acid rates (0, 25, 50 and 75 kg fed^{-1}), foliar zinc oxide and nanoparticles zinc oxide concentrations (50 and 100 ppm) on tomato leaf chemical constituents and fruit quality. The interaction between soil humic acid at 75 kg/fad. and foliar spray with zinc oxide at 50 ppm increased the concentrations of chlorophylla, b and total a+b in leaf tissues in the 2nd season. The interaction between soil humic acid at 75 kg/fad. and foliar spray with nanoparticles zinc oxide at 50 ppm increased vitamin c, total soluble solids and lycopen contents in tomato fruits as well as fruit firmness.

Key words: Tomato hybrid, soil humic acid, foliar zinc oxide and nanoparticles zinc oxide.

INTRODUCTION

Tenshia and Singaram (1999) reported that, soil humic acid at 20 kg ha^{-1} along with NPK recommended at 75 % on tomato leaf availability and uptake; N, P and K contents improved compared to NPK recommended at 100 % indicating soil humic acid utilization save the quarter of NPK recommended dose. **Dursun *et al.* (2002)** showed that, soil humic acid rate at 100 ml L^{-1}on tomato seedling; N, P and K contents, truly, increased compared to control. **Haghighi and Da Silva (2013)** indicated that, providing nutrient solution along with soil humic acid rate at 50 mg L^{-1} on tomato leaf chlorophyll and photosynthesis contents, significantly, higher than nutrient solution alone. **Feleafel and Mirdad (2014)** referred that, soil humic acid rate at 750 mg L^{-1}on tomato fruits firmness content, significantly, recorded the highest mean value however, soil humic acid at 750 or 1500 mg L^{-1}on fruit total soluble solids content, significantly, reduced compared to control. **Asri *et al.* (2015)** tomato plants treated with soil humic acid rate at 160 L ha^{-1} on fruit titratable acidity content, significantly, gave the maximum mean value while, soil humic acid at various levels on fruit total soluble solids content did not truly respond.

Alarge number of reports have emphasized that, foliar zinc oxide and nanoparticles zinc oxide concentrationsexerts a marked effect on tomato leaf chemical constituents and fruits quality. In this concern,a pot experiment, **Alharby *et al.* (2016)** stated that, foliar nanoparticles zinc oxide at 0, 15 and 30 ppm in the presence of NaCl onfive tomato leaf N, P and K contents did not significantly appreciable effect. **Faizan *et al.* (2017)** proved that, soaking roots in nanoparticles zinc oxide concentration at 8 ppm for 30 minutes on tomato leaf chlorophyll and net photosynthetic rate contents, intersically, enhanced over other treatments.

Therefore, the present study was conducted due to the main and interaction effects of soil humic acid rates, foliar zinc oxide and nanoparticles zinc oxide concentrations on tomato leaf chemical constituents and fruit quality.

MATERIALS AND METHODS

Two similar trials were achieved during the season of 2017 and 2018 at private farm located village Tatoon, El-fayoum Governorate and Egypt to investigate the effect of soil humic acid (Hume Grow company, USA) rates at 0, 25, 50 and 75 kg fed^{-1}, foliar zinc oxide (Alpha Chemical Company, India) and nanoparticles zinc oxide (Sigma Aldrich Company, USA) concentrations at 50 and 100 ppm beside foliar control on tomato leaf chemical constituents and fruit quality. The utilization of tomato hybrid namely SV8320 (Seminis - Bayer). Prior the initiation of each experiment, soil samples at 30 cm depth were collected to identify some physic-chemical features of experimental site.Soil samples were analyzed at Soil Testing Laboratory, Faculty of Agriculture and Fayoum University according to standard published procedures **(Wilde *et al*., 1985)**. The results of soil samples were presented in Table 1.

Table 1. Some physical and chemical characters of soil properties

Physical characteristics (%)	Value	
	2017	2018
Silt	8.08	9.11
Clay	53.01	52.90
Fine sand	29.34	30.36
Coarse sand	9.65	7.63
Soil texture	Clayey	Clayey
Chemical characteristics		
pH [at a soil: water (w/v) ratio of 1:2.5]	8.01	7.88
ECe (ds m^{-1}; soil – paste extract)	3.22	2.95
Organic matter (%)	0.6٧	0.73
N (%)	0.007	0.010
$CaCO_3$ (%)	10.10	11.02

The respective source of humic acid was 100 %. Weight 2 g humic acid and added 2 liters distilled water to obtain solution at 1000 ppm. Take 250, 500 and 750 ml from previous solution and complete 9.750, 9.500 and 9.250 liters distilled water to obtain humic acid solution at 25, 50 and 75 ppm, orderly. Added the soil humic acid concentrations at 25, 50 and 75 ppm of two times; 35 and 45 days after transplanting. Soil humic acid solution 250 ml for each tomato transplant. Added soil 250 ml distilled water as control for transplant with the same previously times. The respective source of zinc oxide and nanoparticles zinc oxide were 80.34 and 100 %, orderly. Weight 2.490 g zinc oxide and added 2 liters distilled water to give zinc oxide solution at 1000 ppm. Take 1000 ml from previous solution and complete 9 liters distilled water and take 500 ml from previous solution and complete 9.5 liters distilled water to give zinc oxide solution at 100 and 50 ppm, orderly.

Weight 2 g nanoparticles zinc oxide and added few distilled waters. Put nanoparticles zinc oxide on ultrasonic apparatus for 20 minutes till complete solubility. Complete solution to 2 liters distilled water to obtain nanoparticles zinc oxide solution concentration at 1000 ppm. Take 1000 ml from previous solution and complete 9 liters distilled water and take 500 ml from previous solution and complete 9.5 liters distilled water to obtain nanoparticles zinc oxide solution concentrations at 100 and 50 ppm, respectively. The foliar zinc oxide and nanoparticles zinc oxide concentrations at 50 and 100 ppm of two times; 35 and 45 days after transplanting. Foliar distilled water as control with the same previously times.

The experimental layout was a split-plot system based on Randomized Complete Blocks Design with three replications. Humic acid rates was randomly to main plots where, foliar zinc oxide and nanoparticles zinc oxide concentrations was allocated to sub-plots. Each two adjacent experimental unites were separated by 1m alley. The area devoted for experimental unit was 12 m^2 including 3 rows of 4 long. A basal soil dressing of 180 N (ammonium nitrate 33%), 60 P_2O_5 (mono calcium phosphate 15.5 %) and 96 K_2O (potassium sulfate 48 %) kg fed^{-1} was applied. Other agro-management practices were performed. In each experimental unit, the plants of middle were allocated to measure leaf chemical constituents while, the plants of two outer rows were allocated to measure fruit quality.

Data Recorded

Leaf chemical constituents

In experimental treatment, five randomly leaf samples after 60 days of transplanting, leaf chemical constituents comprised the following traits:

1. Leaf chlorophyll A, B and total (A + B) contents; leaf sample weighed 0.5 g was soaked in 1 ml N, N-Dimethyl fomamide for more 2 days in dark at 4 Cº. Read absorbance using chlormitricaly apparatus at wave lengths 664 and 647 nm. Leaf chlorophyll A, B

and A + B concentrations calculated according the following formulas of **Moran (1982)**

Leaf chlorophyll A concentration = 11.65 × A664 – 2.69 × A647

Leaf chlorophyll B concentration =20.81 × A647– 4.53 × A664

Total Leaf chlorophyll (A + B) concentration = leaf chlorophyll A + leaf chlorophyll B concentrations.

2. Leaf N, P and K contents; leaf sample was washed tap water, rinsed three times with distilled water and dried in a forced oven at 70 C^{o} till weight became constant. Dried leaf sample was ground in a Wiley mill to pass 30 mesh screen. Weight 0.5 g dried fine powder, digested using a mixture from sulfuric and per chloric acids. The following determinations were achieved; leaf N content using Microkjeldahal apparatus, leaf P and K contents through stannous molybdate chloride as described in **A.O.A.C (1985).**

Fruit quality

In experimental plot, five randomly fruit samples at 3rd harvest in red ripe stage, fruit determinations comprised the following traits:

1- Fruit vitamin C content; fruit sample measured by titration with 2, 6 - dichloro phenol indophenol as outlined by **Srivastava and Kumar (2015).**

2- Fruit total soluble solids content; measured by hand refractometer in fruit sample.

3- Fruit firmness content; measured by a tester plunger 6 mm diameter Model 53200 fruit penetrometer, range till 13 kg (T. R. Turoni srl, Via 26 Copernio 26, 47122, Italy).

4- Fruit lycopene content; fruit sample was extracted by a mixture of hexane, acetone, ethanol (Volume 2:1:1, orderly) and butylated hydroxyl toluene. The extracted sample was measured by modified **Perkins-Veazia *et al.* (2001).**

5- Fruit total titratable content; determined by titration with 0.01 N Noah as outlined by **Sirvastava and Kumar (2015).**

Statistical analysis

The results of both experiments subjected to analysis of variance by computer Genstat Release12.1. Revised Least Significant test was utilized to verify difference among treatments as outlined by **Al-Rawi and Khalf-Allah (1980).**

RESULTS AND DISCUSSION

Leaf chemical constituents

Table 2 shows the main effect of soil humic rates at 50 and/or 75 kg fed^{-1} on leaf chlorophyll A, significantly, increased while, the main effect of soil humic rates at 25 and/or 50 kg fed^{-1} on leaf total chlorophyll (A + B), intrinsically, augmented compared to control, in 1st season. The main effect of soil humic rates on leaf chlorophyll B content varied between 1st and 2nd season. Soil humic rates at 25 and/or 50 kg fed^{-1} on leaf chlorophyll B content, truly, higher than other humic acid rates, in 1st season whilst, soil humic rates at control and/or 75 kg fed^{-1} on leaf chlorophyll B content, significantly, higher than other humic acid rates, in 2ndseason. The main impact of zinc oxide and nanoparticles zinc oxide, irrespective of the concentration, did not truly respond, in both seasons.

Table 2. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato leaf chlorophyll A, B and A + B contents at 90 days after transplanting during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Leaf chlorophyll A Content (mg mm^{2})		Leaf chlorophyll B content (mg mm^{2})		Leaf chlorophyll A+B content (mg mm^{2})	
		1st	2nd	1st	2nd	1st	2nd
0		0.075^{B}	0.265^{A}	0.122^{C}	0.094^{A}	0.197^{C}	0.359^{A}
25		0.079^{AB}	0.265^{A}	0.134^{A}	0.083^{c}	0.213^{AB}	0.348^{A}
50		0.086^{A*}	0.269^{A}	0.136^{A}	0.085^{Bc}	0.222^{A}	0.354^{A}
75		0.082^{AB}	0.280^{A}	0.128^{B}	0.092^{AB}	0.210^{B}	0.372^{A}
	0	0.078^{A}	0.253^{A}	0.130^{A}	0.084^{A}	0.207^{A}	0.337^{A}
	100 Gr	0.079^{A}	0.258^{A}	0.129^{A}	0.080^{A}	0.208^{A}	0.338^{A}
	100 Np	0.076^{A}	0.272^{A}	0.128^{A}	0.091^{A}	0.204^{A}	0.363^{A}
	50 Gr	0.080^{A}	0.291^{A}	0.134^{A}	0.096^{A}	0.214^{A}	0.388^{A}
	50 Np	0.089^{A}	0.274^{A}	0.130^{A}	0.091^{A}	0.220^{A}	0.365^{A}

* Values marked with the same letter(s) within the main effect is statistically similar using Revised LSD test at P = 0.05. Uppercase letter(s) indicate differences between main effect. Gr= zinc oxide ‹Np=nanoparticles zinc oxide.

The statistical analysis of results in Table 3 indicated that, interaction between soil humic acid rates at 50 and/or 75 kg fed^{-1} × foliar zinc oxide and/or nanoparticles zinc oxide concentrations at 50 ppm on leaf chlorophyll A and total (A + B) contents, intrinsically, the best mean value while, interaction between soil humic acid rates at 25 and/or 75 kg fed^{-1} × foliar nanoparticles zinc oxide and/or zinc oxide concentrations at 50 ppm, significantly, the upper mean mean value, in both seasons.

Table 3. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato leaf chlorophyll A, B and A + B contents at 90 days after transplanting during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Leaf chlorophyll A Content (mg mm^2)		Leaf chlorophyll B content (mg mm^2)		Leaf chlorophyll A+B content (mg mm^2)	
		1st	2nd	1st	2nd	1st	2nd
0	0	0.077c	0.250ef	0.127def	0.093c	0.204efg	0.343fgh
	100Gr	0.084bc	0.250ef	0.126ef	0.076g	0.210cdefg	0.325ghi
	100Np	0.056e	0.274bcd	0.097h	0.102b	0.153h	0.375bcde
	50 Gr	0.074d	0.264de	0.127def	0.091cde	0.201fg	0.355def
	50 Np	0.084bc	0.287bc	0.136abcd	0.109b	0.220bcd	0.396b
25	0	0.078bc	0.280bcd	0.135abcde	0.092cd	0.213cdefg	0.372bcde
	100Gr	0.077c	0.220g	0.132bcde	0.066h	0.210cdefg	0.286j
	100Np	0.086b	0.264de	0.142a	0.082fg	0.228b	0.346fg
	50 Gr	0.080bc	0.292b	0.135abcde	0.090cde	0.215bcdef	0.381bc
	50 Np	0.073d	0.271cd	0.126ef	0.084ef	0.199g	0.354ef
50	0	0.081bc	0.242f	0.133abcde	0.076g	0.213cdefg	0.318hi
	100Gr	0.078bc	0.289bc	0.131cde	0.091cde	0.209defg	0.380bcd
	100Np	0.083bc	0.279bcd	0.141ab	0.089cde	0.224bc	0.368cdef
	50 Gr	0.081bc	0.263de	0.137abc	0.082fg	0.218bcde	0.345fg
	50 Np	0.104a*	0.271cd	0.139abc	0.088cdef	0.243a	0.358cdef
75	0	0.074d	0.239fg	0.124fg	0.075g	0.199g	0.314i
	100Gr	0.076c	0.275bcd	0.126ef	0.087cdef	0.202fg	0.361cdef
	100Np	0.081bc	0.272bcd	0.131cde	0.092cd	0.211cdefg	0.363cdef
	50 Gr	0.084bc	0.347a	0.137abc	0.121a	0.221bcd	0.468a
	50 Np	0.096a	0.268de	0.121g	0.085def	0.217bcde	0.353ef

* Values marked with the same letter(s) within the interaction effect is statistically similar using Revised LSD test at $P = 0.05$. lowercase letter(s) indicate differences between interaction effect. Gr= zinc oxide ، Np=nanoparticles zinc oxide.

The results in Table 4 illustatre the main impact of humic acid rate at 75 kg fed^{-1} on leaf N and K contents, intrinsically,the distingushed mean value while, the main effect of hmic acid rate at control on leaf P content, truly, the mamaxium mean value, in both seasons.The main effect of foliar nanoparticles zinc oxide concentration at 50 ppm on leaf N and K contents, significantly, the best mean value whlist, the main effect of foliar concentration at control on leaf P content, intrinsically, the pioneer mean value, in both seasons.

The anaylsis of variance in Table 5 indicated that, interaction between soil humic acid rate at 75 kg fed^{-1} × foliar nanoparticles zinc oxide concentraion at 50 ppm on leaf N and K contents, truly, higher than other interaction effects meanwhile, interaction between soil humic acid rate at 75 kg fed^{-1} × foliar concentraion at control on leaf P content, significantly, higher than other interaction effects, in both seasons.

The enhancing main effect of humic acid rates at 25, 50 and 75 kg fed^{-1}, generally, leaf chlorophyll A, B and total (A + B) contents probably to increase availability and uptake nutrients **(Reddy and Vora, 1986)** and may be soil humic acid to improve N content which main structure of leaf chlorophyll content. Similar findings werereported in tomato **(Dursun*et al*., 2002; Haghighi and Da Silva, 2013; Saheinet *al*., 2014)**. The pronounced positive effect of soil humic acid up 75 kg fed^{-1} on leaf N and K contents were in harmony with the findings of numerous investigators as such **Castro *et al*. (1988), Tenshia and Singaram (1999), Dursun*et al*. (2002)** on tomato. The synergical effect main of foliar nanoparticles zinc oxide concentration at 50 ppm on leaf N and P contents. Reversely, **Alharby *et al.* (2016)** who indicated that, foliar nanoparticles zinc oxide concentrations at 0, 15 and 30 ppm in the presence of NaCl on five tomato cultivars, no significant differences on leaf N and K contents.

The interaction of difference between maximum and control mean value on leaf chlorophyll A, B, total (A + B), N, P and K contents, as an averaged of both seasons, increased by 36.93, 20.69, 27.78, 63.88, 13.22 and 75.24 %, respectively.

Table 4. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato leaf N, P and K contents at 90 days after transplanting during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Leaf N (mg g^{-1} d.w.)		Leaf P (mg g^{-1} d.w.)		Leaf K (mg g^{-1} d.w.)	
		1st	2nd	1st	2nd	1st	2nd
0		17.02^{D}	16.34^{C}	2.026^{A}	1.874^{A}	13.91^{D}	13.93^{B}
25		17.58^{C}	16.58^{C}	1.968^{B}	1.860^{A}	13.39^{C}	15.30^{AB}
50		18.78^{B}	17.50^{B}	1.887^{C}	1.824^{B}	14.97^{B}	16.48^{A}
75		19.62^{A*}	18.16^{A}	1.777^{D}	1.786^{C}	15.63^{A}	17.09^{A}
	0	15.50^{C}	14.42^{D}	2.398^{A}	2.385^{A}	12.91^{C}	12.49^{C}
	100 Gr	17.82^{B}	18.75^{B}	1.920^{B}	1.558^{D}	14.38^{B}	17.02^{B}
	100 Np	18.17^{B}	15.07^{D}	1.939^{B}	2.058^{B}	14.47^{B}	13.29^{C}
	50 Gr	17.62^{B}	16.25^{C}	1.978^{B}	1.933^{C}	14.14^{B}	14.65^{BC}
	50 Np	22.12^{A}	21.22^{A}	1.338^{C}	1.248^{E}	16.48^{A}	21.03^{A}

Table 5. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato leaf N, P and K contents at 90 days after transplanting during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Leaf N (mg g^{-1} d.w.)		Leaf P (mg g^{-1} d.w.)		Leaf K (mg g^{-1} d.w.)	
		1st	2nd	1st	2nd	1st	2nd
0	0	14.50^{j}	13.70^{l}	2.350^{b}	2.180^{d}	12.37^{j}	11.23^{i}
	100Gr	16.60^{h}	18.20^{f}	2.100^{d}	1.630^{i}	13.70^{gh}	12.30^{hi}
	100Np	17.40^{g}	14.70^{ij}	1.993^{e}	2.100^{e}	14.00^{fg}	12.77^{hi}
	50 Gr	15.90^{i}	15.30^{hij}	2.180^{c}	2.010^{f}	13.00^{h}	13.70^{gh}
	50 Np	20.70^{d}	19.80^{d}	1.507^{i}	1.450^{k}	16.50^{c}	19.63^{bc}
25	0	15.00^{j}	13.90^{kl}	2.360^{b}	2.300^{c}	12.70^{hij}	11.80^{i}
	100Gr	17.30^{g}	18.30^{f}	2.000^{e}	1.620^{i}	14.03^{fg}	17.50^{de}
	100Np	17.50^{g}	14.60^{jk}	1.980^{e}	2.090^{e}	14.10^{f}	12.70^{hi}
	50 Gr	16.50^{hi}	15.50^{h}	2.120^{d}	2.000^{f}	13.60^{g}	13.80^{gh}
	50 Np	21.60^{c}	20.60^{c}	1.380^{j}	1.290^{l}	12.50^{ij}	20.70^{ab}
50	0	15.90^{i}	14.60^{jk}	2.387^{b}	2.440^{b}	12.93^{hi}	12.90^{hi}
	100Gr	17.60^{g}	18.90^{ef}	1.990^{e}	1.540^{j}	14.20^{f}	18.90^{cd}
	100Np	18.80^{f}	15.40^{hi}	1.903^{f}	2.020^{f}	14.80^{e}	13.80^{gh}
	50 Gr	18.90^{f}	16.80^{g}	1.870^{f}	1.940^{g}	14.90^{e}	15.20^{fg}
	50 Np	22.70^{b}	21.80^{b}	1.287^{k}	1.180^{m}	18.00^{b}	21.60^{a}
75	0	16.60^{h}	15.50^{h}	2.497^{a}	2.620^{a}	13.63^{g}	14.03^{gh}
	100Gr	19.80^{e}	19.60^{de}	1.590^{h}	1.440^{k}	15.60^{d}	19.40^{bc}
	100Np	19.00^{f}	15.60^{h}	1.880^{f}	2.020^{f}	14.97^{e}	13.90^{gh}
	50 Gr	19.20^{ef}	17.40^{g}	1.740^{g}	1.780^{h}	15.07^{e}	15.90^{ef}
	50 Np	23.50^{a*}	22.70^{a}	1.180^{l}	1.070^{n}	18.90^{a}	22.20^{a}

* Values marked with the same letter(s) within the interaction effect is statistically similar using Revised LSD test at P = 0.05. lowercase letter(s) indicate differences between interaction effect. Gr= zinc oxide ، Np=nanoparticles zinc oxide.

Fruit quality

The results arranged in Table 6 show that, the main effect of soil humic level from control to 25 and further to 50 to 75 kg fed^{-1} on fruit vitamin C and total soluable solids contents, sgnificantly, gradually increased, in both seasons but, different the main effect of humic acid level at contol or 25 kg fed^{-1} on fruit total soluable solids content was at par, in 1st season. The main gerenral of humic acid level at control on fruit firmness content, significantly, higher than other humic acid levels, in 2nd season while, main effect of humic acid at various rates on fruit firmness content was not significantly respond, in 1st season. The main impact of foilar nanoparticles zinc oxide concrtraion at 50 ppm on fruit vitamin C and total soluable solids contents, sgnificantly, the best mean value meanwhile, foliar zinc oxide and nanoparticles zinc oxideat various contrations on fruit firmness content was not significantly respond, in two investigated seasons.

Table 6. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato fruit vitamin C, total soluble solids and firmness contents during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruit vitamin C (mg ml^{-1} juice)		Fruit total soluble solids (%)		Fruit firmness (kg cm^2)	
		1st	2nd	1st	2nd	1st	2nd
0		0.145^{D}	0.148^{C}	3.261^{C}	2.919^{D}	3.050^{A}	3.020^{A}
25		0.147^{C}	0.148^{C}	3.268^{C}	3.100^{C}	3.070^{A}	2.720^{B}
50		0.156^{B}	0.159^{B}	3.459^{B}	3.252^{B}	3.030^{A}	2.657^{B}
75		0.162^{A}*	0.164^{A}	3.560^{A}	3.398^{A}	6.500^{A}	2.727^{B}
	0	0.120^{B}	0.120^{D}	2.700^{D}	2.418^{D}	3.067^{A}	2.792^{A}
	100 Gr	0.160^{AB}	0.170^{B}	3.545^{A}	3.335^{B}	6.960^{A}	2.887^{A}
	100 Np	0.160^{AB}	0.160^{B}	3.400^{B}	3.258^{B}	3.158^{A}	2.800^{A}
	50 Gr	0.140^{AB}	0.140^{C}	2.995^{C}	2.740^{C}	2.806^{A}	2.804^{A}
	50 Np	0.190^{A}	0.190^{A}	4.295^{A}	4.086^{A}	3.567^{A}	2.621^{A}

* Values marked with the same letter(s) within the main effect is statistically similar using Revised LSD test at P = 0.05. Np=nanoparticles zinc oxide.‹Uppercase letter(s) indicate differences between main effect. Gr= zinc oxide

Table 7 shows the interaction effect of 1st order between soil humic acid rate at 75 kg fed^{-1} × foliar nanoparticles zinc oxide concentration at 50 ppm on fruit vitamin C and total soluble solids contents, significantly, the highest concentration mean value, in both investigated seasons. Interaction effect of 1st order varied between 1st and 2nd season. Comparisons interaction between soil humic acid at different rates × foliar zinc oxide and nanoparticles zinc oxide at various concentrations on fruit firmness content was not intersically respond, in 1stseason while, interaction between soil humic acid rate at 50 kg fed^{-1} × foliar zinc oxide concentration at 100 ppm, truly, the highest averaged value, in 2nd season.

Table 8 shows the main effect of soil humic rate at 75 kg fed^{-1} on fruit lycopene and total titratable acidity contents, intrinsically, higher than other humic humic rates, in 1st and 2nd season. The main effect of foliar nanoparticles zinc oxide concentration at 50 ppm on fruit lycopene and total titratable acidity contents, intrinsically, the distingushed mean value, in both seasons.

The results in Table 9 shows that, interaction between soil humic acid rate at 75 kg fed^{-1} × foliar nanoparticles zinc oxide concentration at 50 ppm on fruit lycopene and total titratable acidity contents, significantly, occurred the best concentration, in both seasons.

Many investigators reported similar findings by **Asri *et al.* (2015)** who reported that, the main effect of humic acid, irrespective of the rate used, on tomato fruit firmness contentdid not respond significantly. **Abdellatif *et al.* (2017)** showed that, the main effect of soil humic acid at different rates on tomato fruits vitamin C and total soluble solids contents, significantly, increased compared with control. Several investigators were coincides as **Shams and Morsy (2014)** who reported that, grown tomato under tunnels nanoparticles zinc oxide can improve fruit total titratrable acidity due to increase infrared rays transition and low penetration ultraviolet rays compared to ordinary low tunnels.

The interaction of difference between maximum and control mean value on Fruit vitamin C, total soluble solids**,** firmness, lycopene andtotal titratable aciditycontents, as an averaged of both seasons, increased by 90.91, 90.85, 29.81, 90.91 and 191.88 %, orderly.

Table 7. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on fruit vitamin C, total soluble solids and firmness contents during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruit vitamin C (mg ml^{-1} juice)		Fruit total soluble solids (%)		Fruit firmness (kg cm^2)	
		1st	2nd	1st	2nd	1st	2nd
0	0	0.110^{k}	0.110^{i}	2.610^{i}	2.330^{i}	2.580^{a}	3.367^{ab}
	100Gr	0.150^{f}	0.160^{e}	3.400^{e}	3.220^{f}	2.970^{a}	2.717^{cdefg}
	100Np	0.160^{e}	0.160^{e}	3.410^{e}	3.210^{f}	3.400^{a}	3.033^{abc}
	50 Gr	0.130^{h}	0.130^{g}	2.880^{g}	2.560^{h}	2.420^{a}	3.400^{a}
	50 Np	0.180^{c}	0.180^{c}	4.007^{c}	3.273^{f}	3.870^{a}	2.583^{defg}
25	0	0.110^{k}	0.110^{i}	2.620^{i}	2.340^{i}	3.470^{a}	2.750^{cdefg}
	100Gr	0.160^{e}	0.160^{e}	3.390^{e}	3.250^{f}	2.620^{a}	2.917^{cde}
	100Np	0.160^{e}	0.160^{e}	3.410^{e}	3.240^{f}	2.750^{a}	2.817^{cdef}
	50 Gr	0.130^{h}	0.130^{g}	2.880^{g}	2.600^{h}	3.050^{a}	2.500^{fg}
	50 Np	0.180^{c}	0.180^{c}	4.040^{c}	4.070^{c}	3.450^{a}	2.617^{defg}
50	0	0.120^{i}	0.120^{h}	2.701^{h}	2.380^{i}	2.930^{a}	2.483^{fg}
	100Gr	0.170^{d}	0.170^{d}	3.680^{d}	3.390^{de}	3.320^{a}	3.417^{a}
	100Np	0.160^{e}	0.160^{e}	3.400^{e}	3.280^{ef}	2.400^{a}	2.533^{efg}
	50 Gr	0.140^{g}	0.150^{f}	3.100^{f}	2.890^{g}	2.820^{a}	2.350^{g}
	50 Np	0.190^{b}	0.190^{b}	4.413^{b}	4.320^{b}	3.700^{a}	2.500^{fg}
75	0	0.130^{h}	0.130^{g}	2.870^{g}	2.620^{h}	3.280^{a}	2.567^{defg}
	100Gr	0.170^{d}	0.170^{d}	3.710^{d}	3.480^{d}	1.940^{a}	2.500^{fg}
	100Np	0.160^{e}	0.160^{e}	3.380^{e}	3.300^{ef}	4.080^{a}	2.817^{cdef}
	50 Gr	0.140^{g}	0.150^{f}	3.120^{f}	2.910^{g}	2.940^{a}	2.967^{bcd}
	50 Np	0.210^{a}	0.210^{a}	4.720^{a}	4.680^{a}	3.250^{a}	2.783^{cdef}

* Values marked with the same letter(s) within the interaction effect is statistically similar using Revised LSD test at *P* = 0.05. lowercase letter(s) indicate differences between interaction effect. Gr= zinc oxide ، Np=nanoparticles zinc oxide.

Table 8. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato fruit lycopene and titratable acidity contents during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruit lycopene (mg g^{-1} fruit)		Fruit total titratable acidity (%)	
		1st	2nd	1st	2nd
0		0.183^{C}	0.185^{C}	0.483^{C}	0.376^{C}
25		0.185^{C}	0.185^{C}	0.492^{C}	0.384^{C}
50		0.198^{B}	0.198^{B}	0.527^{B}	0.412^{B}
75		0.206^{A*}	0.207^{A}	0.556^{A}	0.434^{A}
	0	0.150^{B}	0.150^{E}	0.323^{D}	0.253^{D}
	100 Gr	0.200^{AB}	0.200^{B}	0.528^{B}	0.428^{B}
	100 Np	0.190^{B}	0.190^{C}	0.548^{B}	0.413^{B}
	50 Gr	0.170^{B}	0.170^{D}	0.415^{C}	0.324^{C}
	50 Np	0.260^{A}	0.260^{A}	0.755^{A}	0.590^{A}

* Values marked with the same letter(s) within the main effect is statistically similar using Revised LSD test at *P* = 0.05. Uppercase letter(s) indicate differences between main effect. Gr= zinc oxide ، Np=nanoparticles zinc oxide.

Table 9. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato fruit lycopene and titratable acidity contents during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruit lycopene (mg g^{-1} fruit)		Fruit total titratable acidity (%)	
		1st	2nd	1st	2nd
0	0	0.110^{k}	0.110^{i}	0.280^{h}	^{h}،0.22
	100Gr	0.150^{f}	0.160^{e}	0.520^{d}	^{d}،0.41
	100Np	0.160^{e}	0.160^{e}	0.520^{d}	^{d}،0.41
	50 Gr	0.130^{h}	0.130^{g}	0.380^{f}	^{f}،0.30
	50 Np	0.180^{c}	0.180^{c}	0.690^{b}	^{b}،0.54
25	0	0.110^{k}	0.110^{i}	0.290^{h}	^{h}،0.23
	100Gr	0.160^{e}	0.160^{e}	0.540^{d}	^{d}،0.42
	100Np	0.160^{e}	0.160^{e}	0.520^{d}	^{d}،0.41
	50 Gr	0.130^{h}	0.130^{g}	0.390^{f}	^{f}،0.31
	50 Np	0.180^{c}	0.180^{c}	0.700^{b}	^{b}،0.55
50	0	0.120^{i}	0.120^{h}	0.330^{g}	^{g}،0.26
	100Gr	0.170^{d}	0.170^{d}	0.520^{d}	^{d}،0.41
	100Np	0.160^{e}	0.160^{e}	0.520^{d}	^{d}،0.41
	50 Gr	0.140^{g}	0.150^{f}	0.450^{e}	^{e}،0.35
	50 Np	0.190^{b}	0.190^{b}	0.810^{a}	^{a}،0.63
75	0	0.130^{h}	0.130^{g}	0.380^{f}	^{f}،0.30
	100Gr	0.170^{d}	0.170^{d}	0.600^{c}	^{c}،0.47
	100Np	0.160^{e}	0.160^{e}	0.540^{d}	^{d}،0.42
	50 Gr	0.140^{g}	0.150^{f}	0.440^{e}	^{e}،0.34
	50 Np	0.210^{a}	0.210^{a}	0.820^{a}	^{a}،0.64

*Values marked with the same letter(s) within the interaction effect is statistically similar using Revised LSD test at $P = 0.05$. lowercase letter(s) indicate differences between interaction effect. Gr= zinc oxide ، Np=nanoparticles zinc oxide.

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RESEARCH ARTICLE

Integrated use of soil humic acid rates under foliar zinc oxide and nanoparticles zinc oxide concentrations on tomato leaf chemical constituents and fruit quality

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