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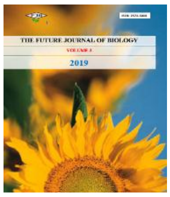

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INTEGRATED USE OF SOIL HUMIC ACID RATES, FOLIAR ZINC OXIDE AND NANOPARTICLES ZINC OXIDE CONCENTRATIONS ON VEGETATIVE GROWTH AND POTENTIAL FRUITS PRODUCTIVITY OF A NEW TOMATO HYBRID (*Solanum lycopersicum* L.)

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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 hybrid growth and productivity. The interaction between soil humic acid at 50 kg/fad. and foliar spray with zinc oxide at 100 ppm increased leaf area / plant and canopy dry weight / plant in the 2nd season. The interaction between soil humic acid at 50 kg/fad. and foliar spray with nanoparticles zinc oxide at 100 ppm increased fruit yield / pant, whereas the interaction between soil humic acid at 50 kg/fad. and foliar spray with zinc oxide or nanoparticles zinc oxide at 50 ppm of each increased early fruit yield and total fruit yield / fad. of tomato hybrid SV8320.

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

INTRODUCTION

The application of humic substance is increasingly used in agricultural practices and have direct and indirect effects on soil and development plant life. Humic acid has direct effect on soil properties as beneficial organism, increase water holding capacity and increase availability nutrients **(Duplessis and Mackenzie, 1983; Piccolo *et al.*, 1992)**. Soil humic acid has indirect effect on development plant life as available hormone-like, activation photosynthesis, adequate plant permeability cell membranes, improving nutrients uptake and response to salinity **(Haghighi and Da Silva, 2013). The results of Saheinet *al.* (2014)** showed that, increasing soil humic acid from 60 to 120 mg kg^{-1} accompanied gradually increased in tomato dry matter yield ha^{-1}of cv. Bandita by 39.9 and 32.9 % and cv. Bestone by 15.8 and 43.7% compared to control. **Saheinet *al.* (2015)** reported that, the combined treatment among repellant salinity agents (potassium humate, polyethylene glycol and humic acid), intrinsically, caused the maximum of plant height, shoots fresh and dry weight plant^{-1}while, the individual treatment and combined treatments of repellant salinity agents, generally, caused the more of number branches plant^{-1} than control. Obtained results on tomato, **Asri *et al.* (2015)** clarified that, soil humic acid at levels 160 and 200 L ha^{-1}, significantly, recorded the highest fruits yield plant^{-1} and fruit weight compared to other treatments.

Zinc element is serving as essential structure and cofactor for more than 70 enzymes **(Vallee. and Auld, 1990; Vallee and. Falchuk, 1993)**. Also, zinc element is involved in the synthesis of indole acetic acid and appeared to be necessary for normal chlorophyll production **(Gilbeart and Collings, 1962)**. Zinc element deficiency initially called rosette plants due to are short internodes. Many investigators have shown that, the beneficial effect of foliar zinc oxide (ZnO) and nanoparticles zinc oxide in improving the vegetative criteria of tomato either directly or indirectly. In this concern, working on tomato, **Harris and Mathuma (2015)** illustrated that, foliar zinc, irrespective of the concentration used, truly, resulted in higher plant height, total dry weight, leaves number and branches plant^{-1} than control with preferable the foliar of zinc at concentration 250 ppm. In vitro study, **Alharbyet *al.* (2016)** the effect of five tomato cultivars to concentrations of salt (control, 3.0 and 6.0 g L^{-1}NaCl) and providing in presence nanoparticles zinc oxide (15 and 30 mg L^{-1}). All callus criteria in four cultivars; Edkawy, Australische Rosen, Sankt Ignatius and Sandpoint, significantly, increased fresh weight, percentage water content and dry weight $plant^{-1}$ compared to standard treatment indicating nanoparticles zinc oxide mitigated the effects of NaCl especially under **Shams and Morsy (2014)** higher concentration (30 mg L^{-1}). displayed that, significantly higher tomato grown under low plastic nanoparticles zinc oxide tunnels than grown under low plastic polyethylene tunnels on fruit weight, early fruits yield and total fruits yield fed^{-1}. Reversely, **Elmer *et al*. (2016)** reported that, no significant difference between foliar nanoparticles zinc oxide and normal zinc oxide at 0, 100 and 1000 µg ml^{-1} on the yield $plant^{-1}$ of eggplant.

Therefore, the current study was proposed in order to examine of main and interaction of soil humic acid rates and foliar zinc oxide and nanoparticles zinc oxide concentrations on tomato growth and fruits productivity.

MATERIALS AND METHODS

Two fields experiments were achieved during the Nili season of 2017 and 2018 to investigate the effect of soil humic acid (Hume Grow company, USA) at rates; 0, 25, 50 and 75 kg fed^{-1}, foliar zinc oxide (Alpha Chemical Company, India) and nanoparticles zinc oxide (Sigma Aldrich Company, USA) at concentrations; 50 and 100 ppm beside foliar control (water) on the morphological growth and fruits yield and its components of tomato hybrid 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 (%)	0.67	0.73
N (%)	0.007	0.010
$CaCO_3$ (%)	10.10	11.02

Humic acid was 100%, weight1g humic acid and added 1000 ml distilled water to obtain solution at 1000 ppm. Again, the same of steps to another solution to give at 1000 ppm. Take 250, 500 and 750 ml from previous of solutions and complete 9.750, 9.500 and 9.250 distilled water liters to obtain humic acid solution at 25, 50 and 75 ppm, orderly. Added the soil humic acid concentrations at25, 50 and 75 ppm of two times; 35 and 45 days after transplanting. Each tomato transplant was added 250 ml soil humic acid solution. Added soil distilled water as control (250 ml $transplant^{-1}$) with the same times. The respective source of zinc oxide and nanoparticles zinc oxide were 80.34 and 100 %, orderly. Weigh 1.245 g zinc oxide and added 1000 ml distilled water to give zinc oxide solution at 1000 ppm. Again, the same of steps to another solution to give at 1000 ppm. Complete both solutions 9 and 9.5 distilled water liters to give zinc oxide solution at 100 and 50 ppm, orderly. Weight 1 g nanoparticles zinc oxide and added few distilled water. Put nanoparticles zinc oxide on ultrasonic apparatus for 20 minutes till complete solubility. Complete solution to 1000 ml distilled water to obtain nanoparticles zinc oxide solution concentration at 1000 ppm. Again, the same of steps to another solution at 1000 ppm. Complete both solutions 9 and 9.5 distilled water liters to obtain nanoparticles zinc oxide solution concentration at 100 and 50 ppm, respectively. The foliar zinc oxide and nanoparticles zinc oxide solution at concentrations; 50 and 100 ppm of two times; 35 and 45 days after tomato transplanting. Foliar distilled water as control with the times of zinc oxide and nanoparticles zinc oxide.

The experimental layout was a split-plot system based on Randomized Complete Blocks Design with three replications. Soil humic acid rates was randomly occupied main plots where, foliar concentrations of zinc oxide and nanoparticles zinc oxide were allocated to sub-plots. In order to protect against border effect, 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 experiment unit, the plants of middle row were allocated to measure morphological characters while, the plants of two outer rows were achieved to measure fruits total yield and its components.

Data Recorded

Morphological traits

In each experimental unit, four randomly plants were chosen after 90 days from transplanting, cut off at soil surface and the following morphological measurements were recorded:

1- Plant height (cm); measured from soil surface to longest leaf tip.

2- Shoots, leaves and canopy dry weight (g) plant^{-1}; fresh shoots and leaves samples were placed in a forced oven at 70 C^o till weight became constant, weight shoots and leaves plant^{-1}. Canopy dry weight was calculated by the summation of dry weight shoots and leaves plant^{-1}.

3- Leaves number plant^{-1}; measured by counted.

4- Leaves area plant^{-1}(cm^2) plant^{-1}; utilized the relationship of fresh leaves weight and area 20 disks by a borer known its diameter and weight of 20 disks **(Wallace and Munger,1965).**

Fruits yield and its components

In each experimental unit, the observations of fruits yield and its components comprised the following traits:

1- Fruits early yield fed^{-1}(tone); expressed as fruits weight in each experimental unit during 1st and 2nd picking together and converted to early fruits early yield fed^{-1}.

2- Fruits number plot^{-1}; measured as counted in each plot^{-1} through whole harvesting period.

3- Fruits weight plot^{-1}(kg); obtained as fruits weighed in each plot^{-1} during entire harvesting period.

4- Fruit weight(g); obtained by dividing fruits weight in each plot^{-1} by number plot^{-1}.

5- Fruits yield plant^{-1}(kg); preformed as total fruits yield in each plot^{-1} by number of existed plants plot^{-1}.

6- Total fruits yield fed^{-1} (tone); expressed as the total fruits yield in each plot^{-1} and converted to total fruits yield fed^{-1}.

Statistical analysis

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

RESULTS AND DISCUSSION

1- Morphological traits

Plant height and dry weight shoots, leaves and canopy plant^{-1}

Table 2 shows the effect main of soil humic acid at rate 75 kg fed^{-1} on leaves and canopy dry weight plant^{-1}, significantly, the maximum mean value however, difference between soil humic acid at rate 50 or 75 kg fed^{-1}on leaves and canopy dry weight plant^{-1}was at par, in 2nd season. Meanwhile, humic acid, irrespective of the rate used, on plant height and shoots dry plant^{-1} did not significantly appreciable effect, in both seasons. The effect main of foliar zinc oxide and nanoparticles zinc oxide at various concentrations beside control on plant height, shoots, leaves and canopy dry weight plant^{-1} was not intrinsically, in both season

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 nanoparticles zinc oxide concentration at 100 ppm on plant height, significantly, produced the maximum value while, soil humic acid at rates 50 and/or 75 kg fed^{-1} × foliar nanoparticleszinc oxideconcentrations at 50 and/or 100 ppm on shoots dry weight plant^{-1}, significantly, attained the upper values neverthless, soil humic acid at rates control (soil distlled water) and/or 50 kg fed^{-1} × foliar nanoparticles zinc oxide concentration at 100 ppm and/or zinc oxide concentration at 100 ppm onleaves and canopy dry weight plant^{-1}, truly, gave the best value, in both seasons.

Table 2. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato plant height, shoots, leaves and canopy dry weight plant^{-1} at 90 days after transplanting during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Plant height (cm)		Shoots dry weight Plant^{-1} (g)		Leaves dry weight Plant^{-1} (g)		Canopy dry weight Plant^{-1} (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
0		97.2^{A}*	87.1^{A}	80.9^{A}	40.6^{A}	168.9^{A}	104.3^{B}	267.9^{A}	145.0^{B}
25		97.2^{A}	80.6^{A}	77.3^{A}	53.8^{A}	155.3^{A}	109.5^{B}	232.6^{A}	163.2^{B}
50		99.1^{A}	87.2^{A}	85.5^{A}	55.0^{A}	164.6^{A}	125.4^{AB}	250.0^{A}	180.3^{AB}
75		97.0^{A}	95.7^{A}	80.3^{A}	62.5^{A}	160.4^{A}	133.0^{A}	240.7^{A}	195.5^{A}
	0	95.6^{A}	92.9^{A}	80.1^{A}	54.8^{A}	167.4^{A}	105.6^{A}	247.5^{A}	160.4^{A}
	100 Gr	99.5^{A}	78.6^{A}	74.3^{A}	56.2^{A}	158.1^{A}	129.9^{A}	232.3^{A}	186.1^{A}
	100 Np	101.1^{A}	92.5^{A}	83.6^{A}	62.8^{A}	160.5^{A}	114.7^{A}	244.1^{A}	177.5^{A}
	50 Gr	97.0^{A}	86.2^{A}	75.5^{A}	46.6^{A}	166.3^{A}	126.8^{A}	241.9^{A}	173.4^{A}
	50 Np	95.0^{A}	88.1^{A}	91.5^{A}	44.3^{A}	181.6^{A}	113.2^{A}	273.2^{A}	157.6^{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 main effect. Gr= zinc oxide ، Np=nanoparticles zinc oxide.

Table 3. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato plant height, shoots, leaves and canopy dry weight plant^{-1} at 90 days after transplanting during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Plant height (cm)		Shoots dry weight Plant^{-1} (g)		Leaves dry weight Plant^{-1} (g)		Canopy dry weight Plant^{-1} (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
0	0	93.3^{de}	92.3^{bcd}	75.8^{defg}	32.8^{i}	188.1^{b}	68.3^{i}	263.9^{bcde}	101.1^{i}
	100Gr	104.3^{ab}	79.3^{fgh}	72.6^{efgh}	38.9^{hi}	166.8^{bcde}	111.0^{defgh}	239.5^{cdef}	150.0^{fgh}
	100Np	104.0^{ab}	79.7^{fgh}	90.0^{abcd}	50.5^{efg}	217.0^{a}	104.2^{fgh}	307.0^{a}	154.7^{efgh}
	50 Gr	100.7^{abcd}	86.7^{cdef}	86.0^{bcde}	39.5^{hi}	173.3^{bcd}	128.0^{cdef}	259.3^{bcde}	167.5^{cdefg}
	50 Np	83.7^{f}	97.3^{b}	80.2^{cdefg}	41.4^{fghi}	189.5^{ab}	110.2^{defgh}	269.7^{abc}	151.6^{efgh}
25	0	98.3^{abcde}	91.3^{bcde}	82.1^{cdef}	53.4^{bcd}	165.8^{bcde}	107.8^{efgh}	247.9^{bcde}	161.2^{defgh}
	100Gr	100.3^{abcd}	75.0^{hi}	75.1^{defg}	48.4^{efgh}	179.3^{bc}	119.4^{cdefg}	254.4^{bcde}	167.8^{cdefg}
	100Np	92.0^{def}	78.0^{gh}	58.3^{h}	64.0^{abc}	108.2^{f}	116.3^{defgh}	166.5^{g}	180.3^{defgh}
	50 Gr	95.7^{bcde}	72.3^{hi}	73.8^{defgh}	50.6^{efg}	152.5^{cde}	97.0^{gh}	226.3^{ef}	147.6^{gh}
	50 Np	99.7^{abcde}	86.3^{cdef}	97.2^{abcd}	52.5^{def}	170.7^{bcde}	106.8^{efgh}	267.9^{bcd}	159.3^{defgh}
50	0	100.3^{abcd}	94.7^{bc}	98.3^{abc}	65.5^{abc}	172.7^{bcd}	109.9^{defgh}	270.9^{abc}	175.4^{bcdefg}
	100Gr	94.3^{cde}	67.7^{i}	61.6^{gh}	67.2^{abc}	143.6^{e}	163.8^{a}	205.1^{f}	231.0^{a}
	100Np	106.0^{a}*	98.7^{b}	86.0^{bcde}	63.4^{abcd}	148.2^{de}	105.9^{efgh}	234.1^{cdef}	169.3^{cdefg}
	50 Gr	93.7^{cde}	91.3^{bcde}	75.5^{defg}	41.0^{ghi}	180.7^{bc}	155.1^{ab}	256.2^{bcde}	196.1^{bc}
	50 Np	101.3^{abcd}	83.7^{efg}	106.1^{a}	37.6^{hi}	177.7^{bc}	92.1^{hi}	283.8^{ab}	129.8^{hi}
75	0	90.3^{ef}	93.3^{bcd}	64.2^{fgh}	67.6^{abc}	143.1^{e}	136.3^{bcd}	207.4^{f}	203.9^{ab}
	100Gr	99.0^{abcde}	92.3^{bcd}	87.7^{bcde}	70.3^{ab}	142.5^{e}	125.3^{cdef}	230.3^{def}	195.6^{bc}
	100Np	102.3^{abc}	113.7^{a}	100.1^{ab}	73.4^{a}	168.7^{bcde}	132.4^{bcde}	268.8^{abc}	205.8^{ab}
	50 Gr	98.0^{abcde}	94.3^{bc}	66.8^{fgh}	55.3^{bcde}	158.9^{cde}	127.2^{cdef}	225.7^{ef}	182.5^{bcde}
	50 Np	95.3^{bcde}	85.0^{defg}	82.7^{cdef}	45.8^{efgh}	188.6^{b}	143.8^{abc}	271.3^{abc}	189.6^{bcd}

* 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.

Numbers leaves and leaf area plant^{-1}

Results in Table 4 illustrated that, the main effect of soil humic acid rate at 75 kg fed^{-1} on leaves number and leaves area plant^{-1}, intrinsically, the best value, in both seasons except the main effect of humic acid at any rate used on leaves number plant^{-1} was at par, in 2015 season. The main effect foliar of zinc oxide and nanoparticles at different applications beside control was not significantly respond, in both seasons.

Table 5 shows the interaction effect of two studied factors under study showed that, interaction between soil humic acid at rates at control and/or 75 kg fed^{-1}× foliar zinc oxide concretion at 100 ppm on leaves number plant^{-1}, significantly, was the superior mean value while, soil humic acid rates at 0 and/or 50 kg fed^{-1} × foliar nanoparticles and/or zinc oxide concentration at 100 ppm on leaf area plant^{-1}, intrinsically, the pioneer mean value, in both seasons

Our results showed that, the main effect of soil humic acid at rate 75 kg fed^{-1} on leaves area plant^{-1} was the pioneer, in both seasons while, soil humic acid at rate 75 kg fed^{-1} on leaves number, leaves and canopy dry weightplant^{-1} was the best mean value, in 2nd season. The beneficial impact of soil humic acid at rate 75 kg fed^{-1} can be explained, soil humic acid contained some regulating growth as cytokines **(Zhang and Ervin, 2004)** and auxins **(Osman and Ewees, 2008)** and thus a positive effect on leaves area, leaves number, leaves, and canopy dry weightplant^{-1}. Similar conclusions by **Adani *et al*. (1998), Turkmen *et al*. (2004), Yigit and Dikilitas (2008) and Feleafel and Mirdad (2014)** on tomato. The main effect of foliar application zinc oxide and nanoparticles zinc oxide, irrespective of the concentration used, beside control on all morphological traits measured did not significantly respond, i n both seasons. The interaction effect of two studied factors under study on all morphological measured, intrinsically, in both seasons. The interaction difference between maximum and control mean value on plant height, shoots, leaves and canopy dry weight, leaves number and leaves area plant^{-1}, as an averaged of the two seasons, increased by 18.40, 81.88, 77.59, 56.08, 93.82 and 131.88 %, respectively.

Fruits yield and its components

Fruits early yield fed^{-1}, number and weight plot^{-1}

Data listed in Table 6 showed that, soil humic acid rates at 0 or 25 and/or 50kg fed^{-1} on fruits early yield fed^{-1}, significantly, higher magnitude mean value than 75 kg fed^{-1}whilst, humic acid at any rate used on fruits number and weight plot did not significantly respond, in both seasons. The analysis of variance for foliar zinc oxide and nanoparticles zinc oxide at different concentrations used on fruits early yield fed^{-1}, number and weight plot^{-1} did not intrinsically respond, in both seasons.

Table 7 shows the interaction effect of two studied factors showed that, interaction between soil humic acid rate at 50 kg fed^{-1} × foliar zinc oxide concentration at 50 ppm on furits early yield fed^{-1} , significantly, the heaviest, through two seasons. The combined treatment of soil humic acid rate at 0 and/or 25 kg fed^{-1} togther with foliar zinc ocide and/or nanoparticles zinc oxide concentration at 100 ppm on fruits number and weight plot^{-1}, intrinsically, the highest and heaviest mean value, orderly, through the two seasons.

Table 4. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato leaves number and leaves area plant^{-1} at 90 days after transplanting during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Leaves number plant^{-1}		Leaves area plant^{-1} (cm^2)	
		1st	2nd	1st	2nd
0		155.0^{A} *	244.0^{B}	355.40^{AB}	243.96^{B}
25		145.5^{A}	241.2^{B}	281.35^{B}	241.23^{B}
50		136.6^{A}	313.7^{AB}	338.13^{AB}	313.74^{AB}
75		158.3^{A}	377.0^{A}	366.25^{A}	377.02^{A}
	0	136.6^{A}	255.7^{A}	312.62^{A}	255.68^{A}
	100 Gr	160.8^{A}	314.1^{A}	328.14^{A}	314.08^{A}
	100 Np	145.2^{A}	273.2^{A}	347.06^{A}	273.17^{A}
	50 Gr	143.3^{A}	333.1^{A}	322.49^{A}	333.07^{A}
	50 Np	158.3^{A}	294.0^{A}	366.11^{A}	293.95^{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 5. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato leaves number and leaves area plant^{-1} at 90 days after transplanting during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Leaves number plant^{-1}		Leaf area plant^{-1} (cm^2)	
		1st	2nd	1st	2nd
0	0	146.3^{defghij}	71.0^{kl}	282.94^{f}	152.43^{j}
	100Gr	185.3^{a}*	115.3^{ghi}	296.75^{ef}	235.84^{ghi}
	100Np	137.3^{efghij}	110.7^{hi}	488.00^{a}	195.45^{ij}
	50 Gr	157.7^{bcdef}	88.7^{ijk}	330.33^{cdef}	298.05^{defg}
	50 Np	148.3^{defghhij}	117.7^{efghi}	378.98^{bc}	338.04^{cde}
25	0	127.3^{ij}	108.0^{hij}	294.30^{f}	232.08^{ghi}
	100Gr	167.3^{abcd}	159.3^{abc}	324.27^{cdef}	260.78^{fghi}
	100Np	123.7^{j}	116.3^{fghi}	196.36^{g}	261.13^{fghi}
	50 Gr	153.7^{cdefgh}	81.3^{jk}	286.78^{f}	217.08^{hij}
	50 Np	155.3^{bcdefg}	107.7^{hij}	305.06^{ef}	235.08^{ghi}
50	0	130.0^{ghij}	125.0^{defgh}	338.59^{cdef}	250.52^{fghi}
	100Gr	129.0^{ghij}	150.3^{bcd}	322.40^{cdef}	444.01^{a}
	100Np	138.0^{efghij}	145.7^{bcde}	304.88^{ef}	273.37^{efgh}
	50 Gr	134.3^{fghij}	141.3^{cdefg}	358.14^{bcde}	384.78^{abc}
	50 Np	151.7^{cdefghi}	48.3^{l}	366.65^{bcd}	216.01^{hij}
75	0	142.7^{defghij}	162.0^{abc}	334.66^{cdef}	387.69^{abc}
	100Gr	161.7^{abcde}	185.3^{a}	369.15^{bcd}	315.69^{cdef}
	100Np	181.7^{ab}	173.0^{ab}	398.99^{bc}	362.73^{bcd}
	50 Gr	127.7^{hij}	145.0^{cdef}	314.71^{def}	432.36^{ab}
	50 Np	178.0^{abc}	120.7^{efgh}	413.75^{b}	386.65^{abc}

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

Table 6. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato fruits early yield fed^{-1}, number and weight yield plot^{-1} during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruits early yield fed^{-1} (tone)		Fruits number Plot^{-1}		Fruits weight Plot^{-1} (kg)	
		1st	2nd	1st	2nd	1st	2nd
0		16.336^{A}*	16.668^{A}	587.1^{A}	629.3^{A}	72.37^{A}	72.73^{A}
25		14.538^{A}	14.538^{A}	584.4^{A}	637.5^{A}	71.46^{A}	72.37^{A}
50		13.279^{AB}	13.279^{AB}	555.1^{A}	615.6^{A}	70.25^{A}	70.25^{A}
75		9.083^{B}	9.083^{B}	549.1^{A}	611.5^{A}	64.85^{A}	64.85^{A}
	0	11.444^{A}	11.860^{A}	574.8^{A}	635.8^{A}	69.7 ^{A}	71.3^{A}
	100 Gr	11.859^{A}	11.859^{A}	536.5^{A}	605.2^{A}	64.1 ^{A}	64.1^{A}
	100 Np	13.800^{A}	13.800^{A}	609.8^{A}	663.5^{A}	75.3 ^{A}	75.3^{A}
	50 Gr	15.834^{A}	15.834^{A}	559.2^{A}	603.8^{A}	68.3 ^{A}	68.3^{A}
	50 Np	13.607^{A}	13.607^{A}	564.2^{A}	608.9^{A}	71.2 ^{A}	71.2^{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=nanopaticles zinc oxide.

Table 7. The interaction effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato fruits early yield fed^{-1}, number, and weight yield plot^{-1} during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruits early yield fed^{-1} (tone)		Fruits number Plot^{-1}		Fruits weight Plot^{-1} (kg)	
		1st	2nd	1st	2nd	1st	2nd
0	0	14.399^{defg}	16.062^{bcd}	589.3^{abc}	629.3^{abc}	72.8^{ab}	79.2^{abc}
	100Gr	13.619^{efg}	13.618^{cdef}	552.0^{abc}	596.0^{bc}	63.1^{bcd}	63.1^{def}
	100Np	18.739^{ab}	18.739^{ab}	669.3^{a}	709.3^{a}	81.5^{a}	81.5^{a}
	50 Gr	18.557^{bc}	18.557^{ab}	549.0^{abc}	595.7^{bc}	68.2^{abcd}	68.2^{cde}
	50 Np	16.366^{bcde}	16.366^{bc}	576.0^{abc}	616.0^{abc}	71.7^{abc}	71.7^{abcde}
25	0	15.811^{cdef}	15.811^{bcde}	600.0^{ab}	630.7^{abc}	78.5^{a}	78.5^{abc}
	100Gr	13.921^{defg}	13.921^{cdef}	628.7^{a}	708.7^{a}	74.4^{ab}	74.4^{abcd}
	100Np	14.250^{defg}	14.250^{cdef}	614.7^{a}	697.3^{ab}	77.9^{a}	77.9^{abc}
	50 Gr	16.576^{bcd}	16.576^{bc}	580.7^{abc}	$620.7^{ab\quad c}$	69.1^{abcd}	69.1^{bcde}
	50 Np	12.129^{gh}	12.129^{fg}	498.0^{bcd}	530.0^{cd}	62.0^{bcd}	62.0^{def}
50	0	8.766^{i}	8.766^{h}	576.7^{abc}	683.3^{ab}	69.4^{abc}	69.4^{abcde}
	100Gr	11.853^{gh}	11.853^{fg}	390.7^{d}	434.7^{d}	49.6^{d}	49.6^{f}
	100Np	12.835^{g}	12.835^{ef}	574.0^{abc}	619.3^{abc}	72.3^{ab}	72.3^{abcde}
	50 Gr	19.676^{a}*	19.676^{a}	626.0^{a}	666.0^{ab}	80.5^{a}	80.5^{ab}
	50 Np	13.265^{efg}	13.265^{def}	608.0^{ab}	674.7^{ab}	79.4^{a}	79.4^{abc}
75	0	6.801^{i}	6.801^{h}	533.3^{abc}	600.0^{abc}	58.3^{cd}	58.3^{ef}
	100Gr	8.044^{i}	8.044^{h}	574.7^{abc}	681.3^{ab}	69.3^{abc}	69.3^{abcde}
	100Np	9.377^{hi}	9.377^{gh}	581.3^{abc}	628.0^{abc}	69.7^{abc}	69.7^{abcde}
	50 Gr	8.525^{i}	8.525^{h}	481.0^{cd}	533.0^{cd}	55.3^{d}	55.3^{ef}
	50 Np	12.668^{g}	12.668^{f}	575.0^{abc}	615.0^{abc}	71.6^{abc}	71.6^{abcde}

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

Fruit weight, fruits yield plant^{-1} and total fruits yield fed^{-1}

Comparisons listed in Table 8 show that, the general effect of soil humic acid at various rates, foliar zinc oxide and nanoparticles zinc oxide at different concentrations on fruit weight, fruit yield plant^{-1} and total fruits yield fed^{-1}did not truly respond, during 1st and 2nd seasons.

Comparisons the interaction of twenty mean values (Table 9) indicated that, interaction between soil humic acid rates at control (soil distlled water) and/or 25 kg fed^{-1} × foliar at control (distlled water) on fruit weight, significantly, gave the heaviest averaged mean value, in both seasons. The combined treatment between soil humic acid rate at 50 kg fed^{-1} coplued with foliar nanoparticles zinc oxide concentration at 100 ppm on fruits yield plant^{-1}, intrinsically, produced the best mean value while, soil humic acid at control (soil distlled water) together with foliar nanoparticles zinc oxide concentration at 100 ppm on total fruits yield fed^{-1}, truly, the heaviest mean value, in both seasons.

The superiority of main effect of soil humic acid at rates 0, 25 and 50 kg fed^{-1} on fruits early yield fed^{-1}, probably due tocontain many micro and macro elements capable to increase availability, absorption, and uptake of nutrients which an eventual increase on fruits early yield fed^{-1}. Our results were in accordance with **Karakurt *et al.* (2009)** who reported that, soil or foliar humic acid, irrespective of the level used, on fruits pepper early yield ha^{-1}, significantly, the highest mean value. Oppositely, **Asri *et al*. (2015)** showed that, soil humic acid at levels 160 and 200 L ha^{-1} on tomato hybrid cv. Kero, significantly, recorded the highest fruit weight and fruits yield plant^{-1} compared to control and other levels.The promising of interaction between two studied factors under study on fruits total yield and its components, in both seasons.The interaction difference between maximum and control mean value on fruits early yield fed^{-1}, fruits number and weightplot^{-1}, fruit weight, fruits yield plant^{-1} and total fruits yield fed^{-1}, as an averaged of two investigated seasons, increased by 29.57, 9.70, 7.43, 0.10, 25.51 and 7.34 %, orderly.

Table 8. The main effect of soil humic acid, foliar zinc oxide and nanoparticles zinc oxide on tomato fruit weight, fruits yield plant^{-1} and total fruits yield fed^{-1}during 2017 and 2018 seasons

Humic acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruit weight (g)		Fruits yield plant^{-1} (kg)		Total fruits yield fed^{-1} (tones)	
		1st	2nd	1st	2nd	1st	2nd
0		121.6^{A}	115.7^{A}	5.347^{A}	4.8^{A}	37.51^{A}	38.51^{A}
25		124.1^{A}	112.8^{A}	5.347^{A}	5.5^{A}	37.99^{A}	37.99^{A}
50		126.4^{A}	113.5^{A}	5.267^{A}	6.2^{A}	36.88^{A}	36.88^{A}
75		117.3^{A}	105.6^{A}	4.813^{A}	5.0^{A}	34.04^{A}	34.04^{A}
	0	121.3^{A}	113.5^{A}	5.6^{A}	5.0^{A}	36.6^{A}	37.4^{A}
	100 Gr	119.4^{A}	104.7^{A}	4.7^{A}	4.6^{A}	33.6^{A}	33.6^{A}
	100 Np	124.0^{A}	113.2^{A}	5.8^{A}	6.0^{A}	39.6^{A}	39.6^{A}
	50 Gr	121.6^{A}	112.1^{A}	4.9^{A}	5.6^{A}	35.9^{A}	37.4^{A}
	50 Np	125.5^{A}	116.0^{A}	5.0^{A}	5.6^{A}	37.4^{A}	35.9^{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 weight, fruits yield plant^{-1} and total fruits yield fed^{-1} during 2017 and 2018 seasons

Humic Acid (kg fed^{-1})	Zinc oxide and nano zinc oxide (ppm)	Fruit weight (g)		Fruits yield plant^{-1} (kg)		Total fruits yield fed^{-1} (tones)	
		1st	2nd	1st	2nd	1st	2nd
0	0	126.1^{abcd}	131.1^{a}	6.3^{a}	4.9^{efgh}	38.2^{abc}	41.5^{a}
	100Gr	112.6^{ef}	104.0^{def}	4.9^{de}	4.0^{gh}	33.1^{bcde}	33.1^{bcdf}
	100Np	121.1^{bcde}	113.8^{bcde}	5.8^{abc}	5.4^{cdefg}	42.7^{a}	42.7^{a}
	50 Gr	122.7^{abcd}	113.2^{bcde}	4.8^{def}	3.8^{h}	35.8^{abcde}	35.8^{abcd}
	50 Np	125.5^{abcd}	116.6^{bcd}	4.9^{de}	5.8^{bcdef}	37.6^{abcd}	37.6^{abc}
25	0	131.9^{a}*	125.2^{a}	5.3^{bcd}	5.9^{abcdef}	41.2^{ab}	41.2^{a}
	100Gr	118.6^{de}	101.6^{ef}	5.0^{cde}	4.6^{fgh}	39.1^{abc}	39.1^{ab}
	100Np	129.6^{ab}	112.4^{bcde}	6.1^{ab}	6.5^{abcd}	40.9^{ab}	40.9^{a}
	50 Gr	117.7^{de}	110.0^{cde}	5.1^{cd}	6.8^{abc}	36.3^{abcde}	36.3^{abcd}
	50 Np	122.6^{abcd}	114.7^{bcd}	4.8^{def}	3.6^{h}	32.6^{cde}	32.6^{bcdf}
50	0	120.2^{bcde}	101.6^{ef}	5.8^{abc}	4.7^{fgh}	36.4^{abcd}	36.4^{abcd}
	100Gr	126.2^{abcd}	111.7^{cde}	4.0^{g}	5.1^{defgh}	26.0^{e}	26.0^{f}
	100Np	125.9^{abcd}	116.0^{bcd}	6.3^{a}	7.4^{a}	38.0^{abc}	38.0^{abc}
	50 Gr	128.6^{abc}	120.5^{abc}	5.5^{abcd}	7.3^{ab}	42.3^{ab}	42.3^{a}
	50 Np	131.2^{a}	117.9^{bc}	5.1^{cd}	6.6^{abcd}	41.7^{ab}	41.7^{a}
75	0	106.8^{f}	96.2^{f}	4.9^{de}	4.6^{fgh}	30.6^{de}	30.6^{cdf}
	100Gr	120.1^{bcde}	101.6^{ef}	4.7^{def}	4.8^{efgh}	36.4^{abcd}	36.4^{abcd}
	100Np	119.4^{cde}	110.6^{cde}	4.9^{de}	4.7^{fgh}	36.6^{abcd}	36.6^{abc}
	50 Gr	117.4^{de}	104.9^{def}	4.2^{ef}	4.5^{fgh}	29.1^{e}	29.1^{df}
	50 Np	122.9^{abcd}	114.8^{bcd}	5.3^{bcd}	6.3^{abcde}	37.6^{abcd}	37.6^{abc}

* 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, foliar zinc oxide and nanoparticles zinc oxide concentrations on vegetative growth and potential fruits productivity of a new tomato hybrid (*Solanum Lycopersicum* L.)

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