Journal for Research in Applied Sciences and Biotechnology

www.jrasb.com

ISSN: 2583-4053

Volume-1 Issue-4 || October 2022 || PP. 139-150

https://doi.org/10.55544/jrasb.1.4.19

The Effect of Fertilization by Humic Acid and Foliar Spraying with Nano-Micro-Nutrients on the Productive Traits of *Solanum melongena* L.

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www.jrasb.com || Vol. 1 No. 4 (2022): October Issue

Received: 16-09-2022	**Revised:** 07-10-2022	**Accepted:** 17-10-2022

ABSTRACT

A factorial experiment was carried out according to the design of the completely randomized sector (R.C.B.D.) in the greenhouse of one of the nurseries in Al-Khalis district, located in the north of Diyala governorate, about 55 km from the capital Baghdad, investigate the effect of humic acid, nano-zinc oxide and nano-iron oxide on vegetative growth characteristics for eggplant, the planting experiment was carried out in the autumn season, on 9/10/2021. The experiment included treating the eggplants with 50 kg. ha^{-1} of humic acid and 50 to 100 mg. ^{1} liter of zinc oxide nanoparticles ZnO and iron oxide nanoparticles Fe3O4. The study results showed significant differences at the probability level of 5% between the averages of all the studied traits due to treating plants with humic acid. The study's results also showed that the highest averages were obtained from the treatment with zinc oxide nanoparticles at a concentration of 50 mg. L^{-1}. Significant differences were also obtained in the length of the fruit (cm), the yield of a plot of fruits (kg. plot^{-1}), and the total yield (kg. hectare^{-1}) as a result of treating the eggplant plant with nano iron oxide at a concentration of 50 mg. L^{-1}.

Keywords- Humic acid, nano zinc oxide, nano iron oxide, eggplant, productivity characteristics.

I. INTRODUCTION

Humic acid (H.A.) is one of the decomposition products of humic substances and the most important organic acid because it is safe, has a high solubility in water, is easy to add, very efficient, and does not leave any harmful effects on humans and animals. Furthermore, its presence is not limited to the soil as it is also found in rivers, oceans, and coal. (Nikbakht et al., 2011). Humic acid plays an essential, indirect role in improving plant growth through its influence on various physical, chemical, and biological properties of soil (Usharani et al., 2019; Chen et al., 2017; Suman et al., 2017). Its direct role is represented by its effect of increasing cell membrane permeability, water and nutrient absorption, respiration, photosynthesis, growth and elongation of root cells, seed germination rate, protein synthesis, and stimulating enzyme activity. (Russo and Berly, 1990; Chen et al., 2004; Fahraman et al., 2014). Humic acid also acts as a biological catalyst that stimulates the plant's hormonal activities and the activity of antioxidants (Duan et al., 2020).

Micronutrients are the elements needed by plants in smaller quantities than macronutrients. The role of micronutrients in the growth and reproduction of plants, animals, and humans has been sufficiently documented. The availability of micronutrients greatly affects the ability of plants to adapt to conditions that are unsuitable for growth, and they have direct roles in plant metabolism. Because they have two or more oxidation states, they play an important role in redox reactions through electron transfer. These elements form mineral enzymes, act as catalysts, and are vital in the regulation of osmosis and protection from abiotic stress in plants. Micronutrients protect plants by acting as components and activators of several enzymes in their defense system, such as catalase,

ISSN: 2583-4053
Volume-1 Issue-4 || October 2022 || PP. 139-150
https://doi.org/10.55544/jrasb.1.4.19

ascorbate peroxidase, and superoxide dismutase, which are involved in the detoxification of highly reactive oxygen species (R.O.S.) produced during abiotic stress (Pandey, 2018).

Iron, one of the essential micronutrients for plant growth and development, is the fourth most important nutrient, but its quantity is low or insufficient for plant requirements (Askary et al., 2017). Iron plays an important role in various physiological activities of plants, for example, electron transfer in photosynthesis and respiration (Gao and Dubos, 2021), absorption of sulfur and nitrogen, synthesis of plant hormones and enzymes, D.N.A. repair, as well as biosynthesis of amino acids (Lill, 2009; Balk and Pilon, 2011). In addition, Iron contributes to the formation of chlorophyll and protects it from strong sunlight and harmful wavelengths. Hence, its deficiency and an increase in its concentration above the ideal is a serious problem that can significantly affect the quality and productivity of crops (SADRARHAMI et al., 2021).

Zinc is considered one of the essential micronutrients for humans, animals, and plants. Plants absorb Zinc as a binary cation (Zn^{+2}) (Howladar, 2022). It forms various enzymes that catalyze many metabolic reactions in plants. Zinc also plays an important role in photosynthesis, cell membrane safety, protein synthesis, pollen formation, building chlorophyll, and enhancing the level of antioxidant enzymes within plant tissues and plant resistance to diseases (Hussain et al., 2015) as well as biosynthesis of plant growth hormones. Nano-science is one of the sciences interested in studying matter based on nanoscale 9-10 meters, i.e., ranging from 1-100 nanometers. The reason for this interest is that nanomaterials appear to have chemical and physical properties different from the properties they show when they are in their traditional dimensions, that is, more than 100 nanometers, as a high surface area characterizes nanoparticles to volume ratio, as well as optical, electrical and thermal properties that give them outstanding physical, chemical and biological characteristics in terms of absorption and activity (Rastogi et al., 2017).

Nanotechnology works to achieve many goals of the agricultural sector which serve the agricultural development strategy by finding nano-technological solutions to the problems facing agriculture, as the continuous addition of traditional chemical fertilizers and their overuse to compensate for the deficiency in these micronutrients exacerbates the problem of environmental pollution. As well as decreasing crop production, deteriorating quality, soil failure, and low content of nutrients (Al-Juthery et al., 2018). Therefore, nanotechnology contributes to solving the problem of agricultural fertilizers by producing environmentally friendly, economically reasonable, and highly efficient nanometer fertilizers, which are considered an effective alternative to traditional fertilizers.

The eggplant (*Solanum melongena*) is an annual herbaceous plant in temperate regions and perennials in the tropics. It is a healthy, low-calorie food that contains carbohydrates, sugars, fats, dietary fibers, proteins, antioxidants, a variety of vitamins A, B, E, and C, as well as many minerals such as Iron, calcium, potassium, magnesium, Zinc, phosphorous and manganese (Naeem and Ugur, 2019). The eggplant fruit contains phenolic compounds such as anthocyanins and phenolic acids with antioxidant properties and alkaloids with many beneficial biological and pharmaceutical properties (Gürbüz et al.,2018).

Eggplant plays an important role in regulating blood pressure. This effect may be due to eggplant containing a good amount of acetylcholine, which lowers blood pressure by inhibiting the activity of the sympathetic nervous system (YAMAGUCHI et al., 2019).

Eggplant is also eaten for dietary purposes, as anthocyanins play an effective role in lowering the level of triglycerides and cholesterol in the blood, increasing high-density lipoprotein (HDL) (Seeram et al., 2001), as well as its importance in treating ulcer diseases (Yousuf et al., 2016) and improving vision. (Ghosh and Konishi, 2007).

Eggplant skin also contains the phenolic compound chlorogenic acid (Prohens et al., 2013), which has shown anti-cancer functions, such as leukemia, lung cancer, and stomach and colon cancer (Tajik et al., 2017; Frank, 2016).

Furthermore, eggplant showed a practical effect against various bacteria such as Escherichia coli, Staphylococcus aureus, Bacillus subtilis, Vibrio cholera and Pseudomonas sp. and B. cereus (Ahmed et al., 2016). Current studies aim to investigate the effect of individual and joint addition of humic acid, nano zinc oxide, and nano iron oxide on the vegetative traits of eggplant, as well as investigate the optimal concentration of nanomaterials used, which gives the best averages for the traits under study.

II. MATERIALS AND METHODS

2.1. Experimental Field Preparation

The study was conducted in the greenhouse belonging to one of the nurseries in the Al-Khalis district, located in the north of Diyala governorate, on the Barcelona variety of Spanish origin. To prepare a suitable seedbed, the field's soil, whose area measured 277.5 m^2, was plowed with a moldboard plow and then smoothed and leveled. To study some of the physical and chemical properties of the field soil, samples were taken from it before planting at a depth of 0-30 cm, mixed well, and sent to the laboratories of the Soil Department / Directorate of Agriculture in Diyala Governorate. Table (1) shows the results of the analysis conducted on the field soil. The cultivation was done in terraces, with 54 experimental units, 2 meters long and 1.5 meters wide for each experimental unit, leaving a distance of 50 cm between one unit and another. The cultivation was done

Journal for Research in Applied Sciences and Biotechnology

ISSN: 2583-4053
Volume-1 Issue-4 || October 2022 || PP. 139-150

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https://doi.org/10.55544/jrasb.1.4.19

with three replications which were randomly distributed. Eggplant seedlings bearing 3 leaves, which were obtained from one of the private nurseries in Tarmiyah district, were planted by eight seedlings in one experimental unit, leaving a distance of 50 cm between one seedling and another. N.P.K. 20:20:20 fertilizer was added at 300 kg per 1 ha in two batches, the first one a week after planting the seedlings and the second two weeks after the first batch. The field's service operations of irrigation, weeding, disease, and pest control were carried out uniformly for all experimental units when necessary. The fungicide Proxanil was added to the field's soil before planting at a rate of 2 kg. When infected with whiteflies, the plants were controlled by the insecticide Decis. This was sprayed all over the plants to kill the insect, and after a month, a second control was conducted to eliminate the larvae and eggs once and for all.

Table 1: Chemical and physical properties of field soil

No	Characteristics		Size	Unit
1	Ec		4.4	$Ds.m^{-1}$
2	Ph		7.2	———
3	Organic matter		1	%
	Soil separators	sand	10	%
		clay	30	%
		silt	60	%
	Soil texture		silty clay loam	
	Total Nitrogen		88.3	$Mg.kg^{-1}$
	available phosphorus		3.6	$Mg.kg^{-1}$
	available potassium		93	$Mg.kg^{-1}$

2.2. Experimental design and experimental treatments

A factorial experiment was carried out according to a completely randomized block design (R.C.B.D.), and the experiment included two concentrations of humic acid (Agro Humic Acid Granule 99%), 0 and 50 $kg.Hictar^{-1}$, and three concentrations of nano iron oxide Fe3O4 and zinc oxide nanoparticles ZnO, 0, 50, and 100 $mg.Liter^{-1}$. The number of transactions was 18, repeated thrice, so the total number of experimental units was 54. Humic acid was added to the ground, while nano iron oxide and nano zinc oxide, with the concentrations mentioned previously, were added as a foliar addition with a three-day difference between the ground addition of humic acid and the foliar addition of the nano nutrients, where the plant reached a stage of 4-5 leaves.

A plastic barrier was used to separate the experimental unit from the other during spraying to prevent the spray fluid from transferring between the experimental units. The plants were sprayed with nano iron oxide first, and after three days, they were sprayed with nano zinc oxide. The spraying process was carried out in the early morning using a 1-liter hand-held sprayer until completely wet. Before that, 2-3 drops of liquid soap were added as a diffuser.

2.3. The source of the nanomaterial and its characteristics:

Iron oxide Fe3O4 and zinc oxide ZnO nanoparticles were obtained from the Kashan University of Iran, as well as a set of physical and chemical tests for each material, which included X-ray Diffraction (X-RD), Energy Dispersive X-ray Spectroscopy (E.D.X.), and Scanning Electron Microscopy (S.E.M.).

2.4. Studied Characteristics:

A total of three plants were randomly selected from the two median lines of each experimental unit and marked with colored tape to study their productive characteristics, which included: the number of fruits (fruit. plant-1), fruit length (cm), fruit weight ($gm.plant^{-1}$), the yield of a plot of fruits ($kg.\ plot^{-1}$), and the total yield ($kg.\ hectare^{-1}$).

III. RESULTS AND DISCUSSION

3.1. Results of physical and chemical tests for nanomaterials

Figure 1 illustrates the results of the XRD examination of the crystal structure and phase purity of the ZnO nanoparticles prepared by the precipitation method. Figure 2 shows the crystal structure and phase purity of Fe3O4 nanoparticles, which were also prepared by precipitation.

It is also clear from Figure 3 that the results of the E.D.X. examination determine the components of nano-zinc oxide. The energy-dispersive X-ray spectrum contains Zinc, carbon, and oxygen, with rates of 70.9%, 16.9%, and 12.1%, respectively. Figure 4 shows the results of the E.D.X. examination to determine the components of iron oxide nanoparticles. The energy-dispersive X-ray spectrum contains Iron and oxygen at rates of 66.8% and 33.2% for Iron and oxygen, respectively.

Figure (5) shows zinc oxide nanoparticles' phenotypic and structural characteristics prepared by deposition using scanning electron microscopy (S.E.M.). Agglomerated, and the reason is due to the electrostatic effects and the effect of the aqueous suspension.

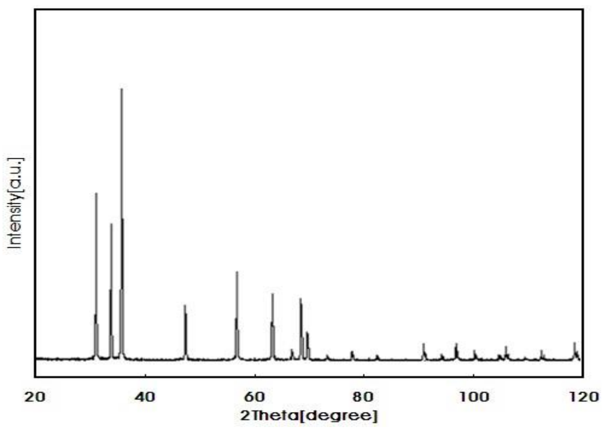

Figure 1: XRD of Zinc

ISSN: 2583-4053
Volume-1 Issue-4 || October 2022 || PP. 139-150
https://doi.org/10.55544/jrasb.1.4.19

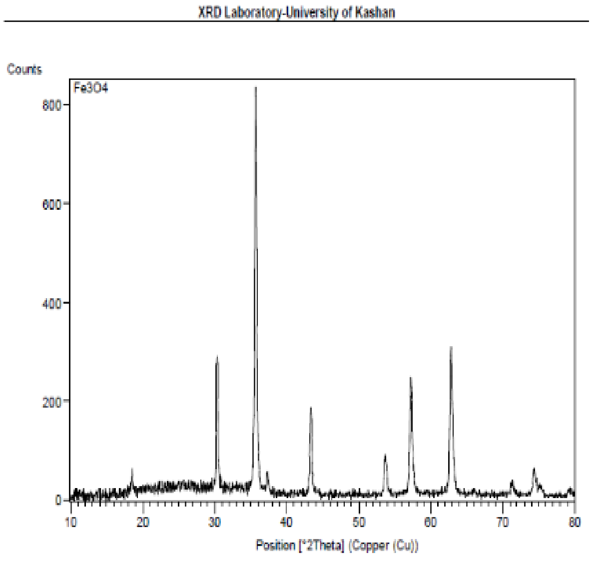

Figure 2: XRD of Fe3O4

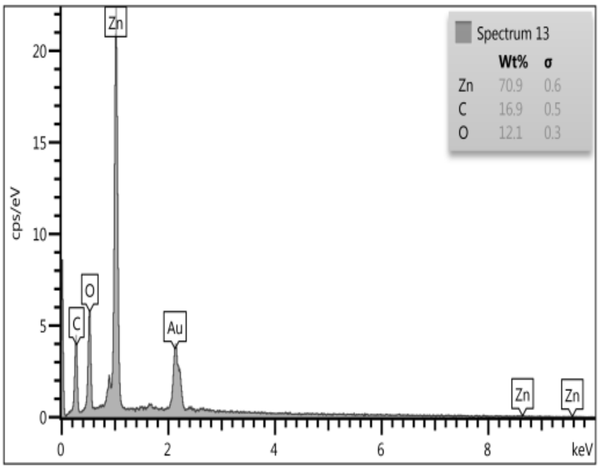

Figure 3: E.D.X. of Zinc

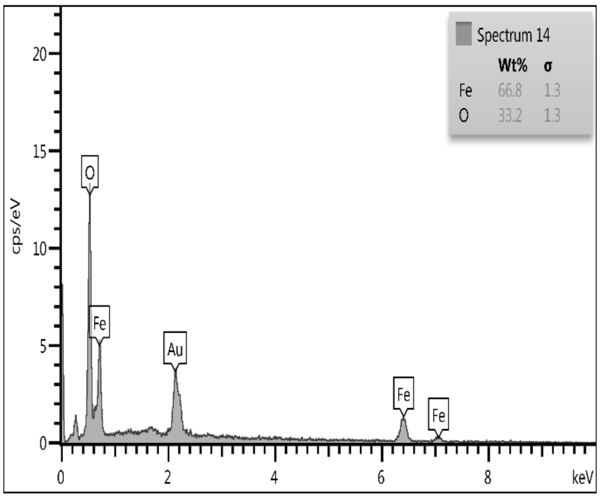

Figure 4: E.D.X. of Fe3O4

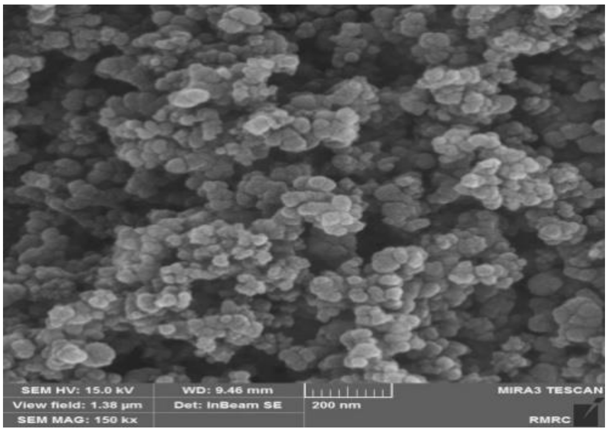

Figure 4: S.E.M. of Zinc

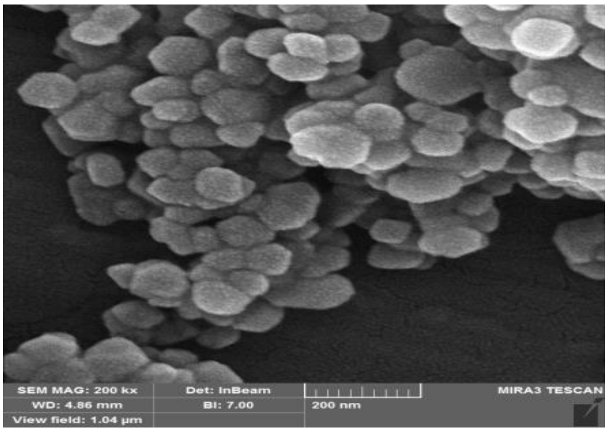

Figure 5: S.E.M. of Fe3O4

3.2. Effect of Humic acid, Zinc nanoparticles, and Fe3O4 nanoparticles on productivity characteristics

3.2.1. Number of fruits (fruit. plant^{-1})

The results in Table 2 showed significant differences at the 5% probability level between the means of the number of fruits due to treating the eggplant plant with humic acid at a concentration of 50 kg.ha^{-1}, recording an average of 3.081 fruits with an increase of 25.2% compared to the control treatment, which recorded the lowest average, Which amounted to 2,459 fruits.

The reason for the resulting increased number of fruits may be attributed to the addition of humic acid to its role in increasing the plant's absorption of nutrients and water, as well as its role in stimulating cell division through its role in regulating the levels of plant growth hormones and thus plays an important role in improving plant growth and increasing its productivity (Kanimarani, 2020) and these research results agree with what was found (Jaafar and Abbass, 2020; Moursy and et al., 2021)

The results of Table 2 did not show any significant differences in the averages.

This trait resulted from spraying the eggplant plant with nano-zinc oxide and nano-iron oxide.

Journal for Research in Applied Sciences and Biotechnology
www.jrasb.com

ISSN: 2583-4053
Volume-1 Issue-4 || October 2022 || PP. 139-150
https://doi.org/10.55544/jrasb.1.4.19

Table 2: The effect of fertilization by humic acid and foliar spraying with nano zinc oxide ZnO and nano iron oxide Fe3O4 on the number of fruits (fruit. Plant^{-1}).

Concentrations of humic acid Kg.hac^{-1})(	Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO mg.l^{-1})(			Double interaction of humic acid and Fe3O4
		0	50	100	
0	0	2.333	2.400	2.267	2.333
	50	2.567	2.533	2.667	2.589
	100	2.267	3.000	2.100	2.456
50	0	3.233	3.367	2.967	3.189
	50	3.000	3.333	2.900	3.078
	100	3.233	3.067	2.633	2.978
Average of zinc effect		2.772	2.950	2.589	2.770
LSD 0.05		n.s			n.s
Triple interaction LSD 0.05		n.s			
Double interaction of humic acid and ZnO					
Concentrations of humic acid Kg.hac^{-1})(	Concentrations of ZnO (mg.l^{-1})				Average of Humic acid effect
	0		50	100	
0	2.389		2.644	2.344	2.459
50	3.156		3.256	2.833	3.081
Double interaction LSD 0.05	n.s				0.263
Double interaction of ZnO and Fe3O4					
Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO (mg.l^{-1})				Average of Fe3O4 effect
	0		50	100	
0	2.783		2.883	2.617	2.761
50	2.783		2.933	2.783	2.833
100	2.750		3.033	2.367	2.717
Double interaction LSD 0.05	n.s				n.s

3.2.2. Fruit Length (cm)

The results of Table 3 showed significant differences at the probability level of 5% between the averages of the characteristic of fruit length as a result of treating the eggplant plant with humic acid at a concentration of 50 kg.ha^{-1}, recording an average of 15.759 cm and an increase of 7.07% compared to the controlled treatment, which recorded the lowest average, amounted to 14 .718 cm.

The reason for the resulting increase in the length of the fruit as a result of treatment with humic acid may be attributed to its vital role in various vital activities such as respiration, photosynthesis, and D.N.A. metabolism, as well as the hormonal activity that was shown by this acid (Farahi and et al., 2013). These search results are consistent with the same results of (Bhuvaneshwari et al., 2020; Akladious and Mohamed, 2018)

The results of Table 3 also indicated that there were significant differences at the 5% probability level between the averages of this trait as a result of treating eggplant plants with nano zinc oxide ZnO at concentrations 0, 50, and 100 mg.l^{-1}, and the results showed that the best fruit length obtained was as a result of treating plants With Zinc at a concentration of 50 mg.l^{-1}, this addition recorded the highest average of 15,905 cm, with an increase of 4.72% and 8.77% compared to the concentration of 100 mg.l^{-1} and the control treatment 0 mg.l^{-1}, respectively. Likewise, the results in the table indicate a clear decrease in the fruit length characteristic

ISSN: 2583-4053
Volume-1 Issue-4 || October 2022 || PP. 139-150
https://doi.org/10.55544/jrasb.1.4.19

due to treating plants with nano zinc oxide at a high concentration of 100 $mg.L^{-1}$, and the decrease was 3.62 % compared to the control treatment.

The reason for the increase in the length of the fruit due to adding nano-zinc oxide may be its role in activating the endogenous auxin and some other growth stimuli. (RAJKUMAR and Lal, 2014). These research results agree with what was found by (Semida et al., 2021).

The results of the same table show significant increases in the fruit length as a result of treating plants with nano iron oxide Fe3O4 and that the highest average of this trait was due to treating plants at a concentration of 50 mg. 100 $mg.L^{-1}$ and the control treatment, respectively, while a significant decrease in this trait was obtained as a result of treating the eggplant plant with a high concentration of nano iron oxide, as the concentration of 100 $mg.L^{-1}$ recorded the lowest average and reached 14,794 cm with a decrease rate of 1.47% compared to the control treatment.

During the stage of reproductive growth, the fruits act as an estuary, drawing more materials from the photosynthesis process than other plant parts; because Iron is one of the important nutrients that play an important role in increasing the process of photosynthesis, so, the external addition of Iron will lead to an increase in the products of photosynthesis and thus increasing the size of the fruits (Davarpanah et al., 2017).

The binary and triple interactions resulting from the joint addition of humic acid, nano zinc oxide and nano iron oxide did not record any significant differences between the average fruit length traits. Table (3) shows the effect of ground addition of humic acid and foliar spraying with nano zinc oxide ZnO and nano iron oxide Fe3O4 on fruit length (cm).

Table 3: The effect of fertilization by humic acid and foliar spraying with nano zinc oxide ZnO and nano iron oxide Fe3O4 on fruit length (cm).

Concentrations of humic acid $Kg.hac^{-1}$)(	Concentrations of Fe3O4 ($mg.l^{-1}$)	Concentrations of ZnO $mg.l^{-1}$)(			Double interaction of humic acid and Fe3O4
		0	50	100	
0	0	14.466	15.300	13.500	14.422
	50	15.366	15.666	16.166	15.733
	100	14.000	15.966	12.033	14.000
50	0	15.566	16.033	15.233	15.611
	50	15.800	16.300	16.133	16.077
	100	15.933	16.166	14.666	15.588
Average of zinc effect		15.188	15.905	14.622	15.238
LSD 0.05		0.886			n.s
Triple interaction LSD 0.05					
Double interaction of humic acid and ZnO					
Concentrations of humic acid $Kg.hac^{-1}$)(	Concentrations of ZnO ($mg.l^{-1}$)				Average of Humic acid effect
	0		50	100	
0	14.611		15.644	13.900	14.718
50	15.766		16.166	15.344	15.759
Double interaction LSD 0.05	n.s				0.723
Double interaction of ZnO and Fe3O4					
Concentrations of Fe3O4 ($mg.l^{-1}$)	Concentrations of ZnO ($mg.l^{-1}$)				Average of Fe3O4 effect
	0		50	100	
0	15.016		15.666	14.366	15.016
50	15.583		15.983	16.150	15.905
100	14.966		16.066	13.350	14.794
Double interaction LSD 0.05	n.s				0.886

Journal for Research in Applied Sciences and Biotechnology

ISSN: 2583-4053
Volume-1 Issue-4 || October 2022 || PP. 139-150

www.jrasb.com

https://doi.org/10.55544/jrasb.1.4.19

3.2.3. Fruits weight (gm.plant^{-1})

It is noticed from the results of Table 4 many significant differences at the 5% probability level between the mean of the fruit weight characteristic as a result of treating the eggplant plant with humic acid at a concentration of 50 kg. Its amount was 169,466 g. The reason for the resulting increase in the weight of the fruit as a result of the addition of humic acid may be attributed to the role of the acid in promoting root growth, which in turn leads to increased absorption of nutrients and water, as well as the content of this acid from micro-nutrients Fe, Zn, Cu and Mn, which thus cause an increase in the efficiency of photosynthesis followed by an increase in the carbohydrate synthesis and transport to be stored in the fruits to give the heaviest weight to the fruit (Jaafar and Abbass, 2020) (Alenazi and Khandaker, 2021) This research result is consistent with what was found (Jaafar and Abbass, 2020; Bhuvaneshwari et al., 2020).

The table's results also indicated significant differences at the 5% probability level between the average fruit weight characteristics due to the treatment of eggplant plants with nano zinc oxide ZnO at concentrations 0, 50, and 100 mg. Companies with Zinc at a concentration of 50 mg.l^{-1}, this addition recorded the highest average of 184.233 g, with an increase of 5.52% and 10.5% compared to the concentration of 100 mg.l^{-1} and the control treatment 0 mg.l^{-1}, respectively. Likewise, the results in the same table indicate a decrease in the fruit weight characteristic due to treating plants with nano zinc oxide at a high concentration of 100 mg.L^{-1}, and the decrease was 4.11 % compared to the control treatment.

The reason for the increase in this characteristic as a result of treatment with nano-zinc oxide may be due to the importance of Zinc in activating the work of many metabolic enzymes, and using it in a nano form has increased and accelerated the process of absorption by the leaves, as well as its role in regulating the metabolism of the plant hormones, Zinc modifies auxin levels through the synthesis of tryptophan, and auxin plays an important and effective role in increasing cell division and thus increasing fruit size and weight (Elsheery et al., 2020; Rivera-Gutiérrez et al., 2021). The results of the research agree with what was found by (Semida et al., 2021; Ahmed et al., 2021), while a significant decrease in the weight of the fruit was obtained as a result of treatment with a high concentration of nano-zinc oxide. This research result agreed with what was found by (Ahmed et al., 2021).

Table 4 did not show significant differences between the averages of the fruit weight trait due to treatment with nano iron oxide. The results did not show any significant differences between the mean of this trait due to the bilateral and triple interactions between humic acid, nano zinc oxide and nano iron oxide.

Table 4: Effect of fertilization by humic acid and foliar spraying with nano zinc oxide ZnO and nano iron oxide Fe3O4 on fruit weight (g. plant^{-1}).

Concentrations of humic acid Kg.hac^{-1})(	Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO mg.l^{-1})(			Double interaction of humic acid and Fe3O4
		0	50	100	
0	0	167.633	176.666	160.500	168.266
	50	172.966	185.166	174.833	177.655
	100	163.333	178.066	146.033	162.477
50	0	176.133	186.600	160.866	174.533
	50	176.500	191.166	183.333	183.666
	100	190.933	187.733	178.866	185.844
Average of zinc effect		174.583	184.233	167.405	175.407
LSD 0.05		12.157			n.s
Triple interaction LSD 0.05		n.s			
Double interaction of humic acid and ZnO					
Concentrations of humic acid Kg.hac^{-1})(	Concentrations of ZnO (mg.l^{-1})				Average of Humic acid effect
	0		50	100	
0	167.977		179.966	160.455	169.466
50	181.188		188.500	174.355	181.348
Double interaction LSD 0.05	n.s				9.926
Double interaction of ZnO and Fe3O4					
Concentrations of	Concentrations of ZnO (mg.l^{-1})				Average of

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Volume-1 Issue-4 || October 2022 || PP. 139-150
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Fe3O4 (mg.l^{-1})	0	50	100	Fe3O4 effect
0	171.883	181.633	160.683	
50	174.733	188.166	179.083	
100	177.133	182.900	162.450	
Double interaction LSD 0.05	n.s			n.s

3.2.4. Plot yield of frouts (kg. plot^{-1})

The results shown in Table 5 indicate significant differences at the 5% probability level between the mean of the fruit weight of the plank as a result of treating the eggplant plant with humic acid at a concentration of 50 kg.ha^{-1}, recording an average of 10.367 kg with an increase of 11.6% compared to the control treatment, which recorded the lowest average, Which amounted to 9,287 kg.

The weight of the fruits of one plate may be attributed to the increase in the number of fruits of one plant and the weight of the fruits of one plant as a result of adding humic acid at a concentration of 50 kg. hectare^{-1} was thus reflected on the weight of the fruits of one plate, which was similar to what he found (Akladious and Mohamed,2018; Bhuvaneshwari et al., 2020).

It is also evident from the results shown in Table 5 that there are significant differences at the 5% probability level between the averages of this trait as a result of treating eggplant plants with nano zinc oxide ZnO at concentrations 0, 50, and 100 mg.l^{-1}, and the results indicate that the best fruit weight per plate was obtained. It was a result of treating plants with nano zinc oxide at a concentration of 50 mg.l^{-1}, as this addition recorded the highest average and reached 10.419 kg with an increase of 7.82% and 10.82 percent compared to the concentration of 100 mg.l^{-1} and the control treatment 0 mg.l^{-1}, respectively. The results in the same table indicate a clear decrease in the characteristics of the fruit weight per plate as a result of treating plants with nano zinc oxide at a high concentration of 100 mg.L^{-1}, and the percentage of decrease was 2.71% compared to the control treatment.

The reason for the increase in the weight of the fruits of one plate as a result of the addition of nano-zinc oxide may be due to its role as a catalyst in the production of plant hormones that promote plant growth and increase its productivity (Uresti-Porras et al., 2021) and the results of the research agree with what he found (Ahmed et al., 2021). (García-López et al., 2019), at the same time, a significant decrease in the weight of the fruits of one plate was obtained as a result of treatment with a high concentration of nano-zinc oxide due to the plant's toxicity (García-López et al., 2019).

The results of the same table also show significant increases in the characteristics of the weight of the fruits of one plate as a result of treating plants with nano iron oxide Fe3O4, and that the highest average of this characteristic was as a result of treating plants with a concentration of 50 mg. % compared to the concentration of 100 mg.l-1 and the control treatment, respectively. At the same time, a significant decrease in this trait was obtained as a result of treating the eggplant plant with a high concentration of nano iron oxide, as the concentration of 100 mg.l^{-1} recorded the lowest average and reached 9.381 kg with a decrease of 3% compared to the control treatment.

The weight of the fruits of one plate comes from the addition of nano iron oxide to increase caused by the addition of this nanomaterial in weight. It leads to an increase in the efficiency of metabolic reactions and an increase in dry matter and yield because Iron acts as an electron carrier in the processes of respiration and photosynthesis and helps to remove toxins resulting from free radicals, as well as its role in oxygen transport and oxidation and reduction reactions (Nadi et al., 2013). Research with what it found (El-Desouky et al., 2021; Bozorgi, 2012).

These research results did not show any significant differences between this trait's averages due to the binary and triple interactions resulting from the joint addition of humic acid, nano-zinc oxide, and nano-iron oxide.

Table 5: The effect of fertilization by humic acid and foliar spraying with nano zinc oxide ZnO and nano iron oxide Fe3O4 on the yield of the plate (kg. plot^{-1}).

Concentrations of humic acid Kg.hac^{-1})(	Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO mg.l^{-1})(			Double interaction of humic acid and Fe3O4
		0	50	100	
0	0	9.048	9.751	8.171	8.990
	50	9.268	10.943	9.555	9.922
	100	8.852	9.418	8.581	8.950

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https://doi.org/10.55544/jrasb.1.4.19

50	0	10.428	10.513	10.120	10.353
	50	10.806	11.131	10.876	10.938
	100	9.575	10.756	9.103	9.811
Average of zinc effect		9.663	10.419	9.401	9.827
LSD 0.05		0.811			n.s
Triple interaction LSD 0.05		n.s			
Double interaction of humic acid and ZnO					
Concentrations of humic acid Kg.hac^{-1})(	Concentrations of ZnO (mg.l^{-1})				Average of Humic acid effect
	0		50	100	
0	9.056		10.037	8.769	9.287
50	10.270		10.800	10.033	10.367
Double interaction LSD 0.05	n.s				0.662
Double interaction of ZnO and Fe3O4					
Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO (mg.l^{-1})				Average of Fe3O4 effect
	0		50	100	
0	9.738		10.132	9.145	9.672
50	10.037		11.037	10.216	10.430
100	9.213		10.087	8.842	9.381
Double interaction LSD 0.05	n.s				0.811

3.2.5. Total yield (kg.ha^{-1})

The results of Table 6 indicate significant differences at the probability level of 5% between the averages of the characteristic of the total yield as a result of treating the eggplant plant with humic acid at a concentration of 50 kg.ha-^{1}, recording an average of 34.559 kg, with an increase of 11.6 % compared to the control treatment, which recorded the lowest average, A weight of 30,941 kg.

The reason for the resulting increase in the total yield may be attributed to the addition of humic acid to its role in increasing the various physiological processes in plants, as well as its role in providing micro and macronutrients, which thus improves the plant's content of proteins, vitamins and plant growth regulators, such as auxins and cytokinins (2007, Yildirim).

These research results are consistent with what was found by (Moursy et al., 2021; Jaafar and Abbass, 2020), and it is also evident from the results shown in the table that there are significant differences at the 5% probability level between the averages of this trait as a result of the treatment of eggplant plants with nano zinc oxide ZnO in concentrations. 0, 50 and 100 mg.l^{-1}, and the results show that the best total yield was obtained as a result of treating plants with Zinc at a concentration of 50 mg.l^{-1}, as this addition recorded the highest average of 34.730 kg with an increase of 7.91 and 10.82% compared to the concentration 100 mg.L-1 and control treatment 0 mg.L^{-1}, respectively.

The results shown in Table 6 also indicate a clear decrease in the characteristic of the total yield as a result of treating plants with nano zinc oxide at a high concentration of 100 mg.L^{-1}, and the percentage of decrease was 2.62% compared to the control treatment, and the reason for the increase in the characteristic of the total yield may be due to the addition of zinc oxide The nanoparticles indicated the role of Zinc in increasing the plant's internal content of plant hormones such as auxins, gibberellins, and melatonin, which are useful in improving growth and increasing productivity (Uresti-Porras et al., 2021)

As for the decrease in the total yield as a result of treatment with a high concentration of nano-zinc oxide, the reason for this may be due to the potential toxicity that may result from adding these nanomaterials with their high concentrations (Reed et al., 2011, Jurkow et al., 2020).

The results of the table also show significant increases in the trait of the total yield as a result of treating plants with nano iron oxide Fe3O4 and that the highest mean of this trait was due to treating plants at a concentration of 50 mg. 100 mg.L^{-1} and the control treatment, respectively, while a significant decrease in this trait was obtained as a result of treating the eggplant

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www.jrasb.com

ISSN: 2583-4053
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plant with a high concentration of nano iron oxide, as the concentration of 100 mg.L^{-1} recorded the lowest average and reached 31,243 kg with a decrease rate of 3.09% compared to the control treatment.

The increase in the total yield due to the addition of nano iron oxide may be attributed to the role of Iron in improving the efficiency of the photosynthesis process. Then the accumulation of the products of this process in the fruits thus increasing the total yield (Nadi et al., 2013). These research results agree with what he found (El - Desouky et al., 2021 Bozorgi, 2012); as for the decrease in the total yield as a result of treatment with a high concentration of nano iron oxide, the reason for this may be attributed to the decrease in the weight of the fruits of one plate, which was thus reflected on this characteristic.

These research results did not show significant differences between this trait's averages due to the binary and triple interactions resulting from the joint addition of humic acid, nano zinc oxide, and nano iron oxide.

Table 6: The Effect of fertilization by humic acid and foliar spraying with nano zinc oxide ZnO and nano iron oxide Fe3O4 on the total yield (kg. ha^{-1}).

Concentrations of humic acid Kg.hac^{-1})(	Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO mg.l^{-1})(			Double interaction of humic acid and Fe3O4
		0	50	100	
0	0	30.160	32.505	27.238	29.968
	50	30.894	36.477	31.852	33.074
	100	29.344	31.394	28.605	29.781
50	0	34.760	35.044	33.733	34.512
	50	36.021	37.105	36.255	36.460
	100	31.916	35.855	30.344	32.705
Average of zinc effect		32.182	34.730	31.337	32.750
LSD 0.05		2.716			n.s
Triple interaction LSD 0.05		n.s			
Double interaction of humic acid and ZnO					
Concentrations of humic acid Kg.hac^{-1})(	Concentrations of ZnO (mg.l^{-1})				Average of Humic acid effect
	0		50	100	
0	30.133		33458	29.231	30.941
50	34.232		36.001	33.444	34.559
Double interaction LSD 0.05	n.s				2.217
Double interaction of ZnO and Fe3O4					
Concentrations of Fe3O4 (mg.l^{-1})	Concentrations of ZnO (mg.l^{-1})				Average of Fe3O4 effect
	0		50	100	
0	32.460		33.774	30.485	32.240
50	33.457		36.791	34.053	34.767
100	30.630		33.624	29.474	31.243
Double interaction LSD 0.05	n.s				2.716

IV. CONCLUSIONS

It was found through the results of this research, the significant effect of the individual addition of each of humic acid, nano zinc oxide and nano iron oxide, while the results did not show any significant effect due to the joint addition of additives. The results also indicated the effective role of low concentrations of microelement nutrients when added in their nano form. However, those substances showed a toxic effect when added to plants in higher concentration.

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https://doi.org/10.55544/jrasb.1.4.19

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