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Effect of foliar application of Humic acid and Nano Iron on Physical Characteristics of Eggplant (*Solanum melongena* L.)

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Abstract

This experiment was conducted at the open-air researches station of the College of Agriculture and Marshlands, University of Thi Qar, Thi Qar Governorate, Iraq, during 2024-2025. The purpose of the study was to investigate the effect of foliar spraying with humic acid at three concentrations (0, 2, and 4) g/L and foliar spraying with nano-iron at five concentrations (0, 20, 40, 60, and 100) mg/L on the physical characteristics of eggplant (*Solanum melongena* L. Var. Barcelona). Results showed that (4) g/L Humic acid concentration was superior in terms: Plant height (73.89) cm/plant, leaves number(57.78) leaf), stem diameter(2.67) cm/plant, branches number(3.99) branch/plant, fruits number(19.69) fruit/plant and fruit weight (118.14) g/fruit. Also, Results showed that (60) mg/L nano-iron concentration was superior in terms (Plant height(73.40)cm/plant, leaves number(53.92) leaf/plant, stem diameter(2.72)cm/plant, branches number(3.74) branches/plant, fruits number(19.31) fruit/plant and fruit weight (117.69) g/fruit.

Keywords: Agriculture, Marshlands, Thi Qar, Fruit, leaves.

I. Introduction

Eggplant Eggplant (*Solanum melongena* L.) is cultivated for its edible fruits (Gürbüz et al., 2018), is grown in large areas of the world, especially in subtropical and tropical regions of the globe(Rotino et al., 2014 and Mwinuka et al., 2021). Eggplant fruits contain many nutrients and vitamins that contribute to enhancing the health of the human body(Braga et al., 2016 ; Blando et al., 2018) Eggplant is one of the most consumed vegetables due to its antioxidant and antimicrobial properties. (Sharma, and Kaushik, 2021) It has a good nutritional value, as it contains low levels of fat and carbohydrates, and is characterized by the presence of important substances (organic acids, free sugars, unsaturated fatty acids, and phenolic acids). It is an important source of natural compounds and pigments.(Silva, et al., 2021). Amino acids and humic acids are considered biostimulants for plant growth. (Mohammed Amin and Kanimarani, 2020). Humic acid is a substance produced by the metabolic activity of microorganisms, the decomposition of microbes and plant and animal remains in the soil, (Amador et al., 2018; Amiri Foroutaghi et al., 2022; Najarian et al., 2022). It is successfully used to reduce the use of chemicals that contribute to environmental pollution and also increases nutrient uptake in the soil, thus increasing growth and yield. It works to increase root and leaf growth activity, increase the efficiency of nutrient uptake, and activate enzyme activity in plants (Zandonadi et al., 2014; Monda et al., 2021). One of the effective methods farmers use is foliar feeding to supply plants with important nutrients. Leaves and vegetative branches are a major center for nutrient absorption like the root system.(Hasan et al ., 2019; Hasan et al., 2022). Foliar application of nano-elements has been used in global agricultural crop systems to achieve increased production. Nano-fertilizers are active materials in agriculture that provide essential nutrients to plants, due to their great ability to penetrate and reach anywhere in plant tissues due to their

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small surface area (Al-Juthari and Saadoun, 2018;Hayyawi et al., 2020). Nanotechnology is based on the principle of reverse engineering known in nature, which allows the manufacture of materials within nanoscale sizes such as atoms and particles(Al ghasheem, 2023). Therefore, the study aims to know the effect of humic acid biostimulants and nano iron fertilizer on the growth and productivity of eggplant plants.

II. Materials and Methods

Experiment was conducted at the open-air researches station of the College of Agriculture and Marshlands, University of Thi Qar, Thi Qar Governorate, Iraq, during 2024-2025. The purpose of the study was to investigate the effect of foliar spraying with humic acid at three concentrations (0, 2, and 4) g/L and foliar spraying with nano-iron at five concentrations (0, 20, 40, 60, and 100) mg/L on the physical characteristics of eggplant (*Solanum melongena* L. Var. Barcelona).including: plant height, leaf count, stem diameter, number of branches, fruit count, and fruit weight. Four plants were randomly selected from each experimental unit to perform the required measurements.The plants were sprayed throughout the growth period at a rate of three sprays, with a time interval of 15 days between each spray, in the morning using hand sprayers, until the plant was completely wet. Experiment was based on 15 treatments with three replicates in the form of 45 experimental units within the RCBD design. The experiment was analyzed using analysis of variance(ANOVA) for the studied traits using Genstat statistical program, the averages were tested according to the least significant difference test LSD at 5%.

III. Results and Discussion

1. Plant Height:

Results in Table 1 confirmed the presence of statistically significant differences in the effect of foliar spray concentrations of humic acid and nano-iron on eggplant plant height. Humic acid at (4) g/L concentration was superior on the rest of the treatmenys with an average plant height (73.89) cm, while (0) g/L concentration recorded an average height (71.91) cm. Also, nano-iron at (60) mg/L concentration was superior on the rest of the treatmenys with an average plant height (73.40) cm, compared to (0) g/L concentration (control treatment) recorded an average height (72.18) cm. Also, results were showed the effect of the interaction between humic acid and nano iron, as the results showed that the (4) g/L, humic acid concentration and (60) mg/L nano-iron concentration was superior on the rest of the treatmens, with an average plant height (74.43) cm compared to (0) g/L concentration (control treatment) recorded an average height (70.75) cm.

Table (1): Effect of Humic Acid and Nano Iron Concentrations and Their Interaction on Eggplant Plant Height (cm/plant)

Humic Acid Con. (g/L)	**Nano Iron Con. (mg/L)**					
	0	20	40	60	100	**Mean (Humic Acid)**
0	70.75	71.61	72.34	72.36	72.32	71.91
2	72.63	73.01	73.10	73.40	73.33	73.03
4	73.18	73.44	74.17	74.43	74.22	73.89
Mean (Nano Iron)	72.18	72.69	73.20	73.40	73.22	
L.S.D	Nano Iron		Humic Acid		Interaction	

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0.05%	0.40	0.31	0.69

2. Leaves number:

Results in Table 2 confirmed the presence of statistically significant differences in the effect of foliar spray concentrations of humic acid and nano-iron on eggplant leaves number. Humic acid at (4) g/L concentration was superior on the rest of the treatmenys with an average leaves number (57.78) leaf/plant, while (0) g/L concentration recorded an average leaves number (42.02) leaf/plant. Also, nano-iron at (60) mg/L concentration was superior on the rest of the treatmenys with an average leaves number (53.92) leaf/plant, compared to (0) g/L concentration (control treatment) recorded an average leaves number (45.83) leaf/plant. Also, results were showed the effect of the interaction between humic acid and nano iron, as the results showed that the (4) g/L Humic acid concentration and(60) mg/L nano-iron concentration was superior on the rest of the treatmens, with an average leaves number (59.28) leaf/plant compared to (0) g/L concentration (control treatment) recorded to leaves number (32.40) leaf/plant.

Table (2): Effect of Humic Acid and Nano Iron Concentrations and Their Interaction on Eggplant leaf num. (leaf/plant).

Humic Acid Con. (g/L)	Nano Iron Con. (mg/L)					
	0	20	40	60	100	Mean (Humic Acid)
0	32.40	41.24	43.03	47.53	45.93	42.02
2	48.76	50.59	53.66	54.95	54.62	52.51
4	56.34	57.26	57.70	59.28	58.32	57.78
Mean (Nano Iron)	45.83	49.70	51.46	53.92	52.95	
L.S.D	Nano Iron		Humic Acid		Interaction	
0.05%	1.126		0.872		1.950	

3. Stem diameter:

Results in Table 3 confirmed the presence of statistically significant differences in the effect of foliar spray concentrations of humic acid and nano-iron on eggplant stem diameter. Humic acid at (4) g/L concentration was superior on the rest of the treatmenys with an average stem diameter (2.67) cm/plant, while (0) g/L concentration recorded an average stem diameter (2.11) cm/plant. Also, nano-iron at (60) mg/L concentration was superior on the rest of the treatmenys with an average stem diameter (2.72) cm/plant, compared to (0) g/L concentration (control treatment) recorded an average stem diameter (2.13) cm/plant. Also, results were showed the effect of the interaction between humic acid and nano iron, as the results showed that the (4) g/L Humic acid concentration and(60) mg/L nano-iron concentration was superior on the rest of the treatmens, with an average stem diameter (2.96) cm/plant compared to (0) g/L concentration (control treatment) recorded to stem diameter (1.72) cm/plant.

Table (3): Effect of Humic Acid and Nano Iron Concentrations and Their Interaction on Eggplant stem diameter (cm/plant).

Humic Acid Con. (g/L)	**Nano Iron Con. (mg/L)**					
	0	20	40	60	100	**Mean (Humic Acid)**
0	1.72	1.90	2.15	2.47	2.31	2.11
2	2.27	2.35	2.51	2.73	2.43	2.45
4	2.42	2.67	2.80	2.96	2.52	2.67
Mean (Nano Iron)	2.13	2.30	2.48	2.72	2.43	

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L.S.D	Nano Iron	Humic Acid	Interaction
0.05%	0.136	0.105	0.236

4. Branches number:

Results in Table 4 confirmed the presence of statistically significant differences in the effect of foliar spray concentrations of humic acid and nano-iron on eggplant branches number. Humic acid at (4) g/L concentration was superior on the rest of the treatmenys with an average branches number (3.99) Branch/plant, while (0) g/L concentration recorded an average branches number (2.79) Branch/plant. Also, nano-iron at (60) mg/L concentration was superior on the rest of the treatmenys with an average branches number (3.74) Branch/plant, compared to (0) g/L concentration (control treatment) recorded an average branches number (3.13) Branch/plant. Also, results were showed the effect of the interaction between humic acid and nano iron, as the results showed that the (4) g/L Humic acid concentration and(60) mg/L nano-iron concentration was superior on the rest of the treatmens, with an average branches number (4.16) Branch/plant compared to (0) g/L concentration (control treatment) recorded to branches number (2.15) Branch/plant.

Table 4. Effect of Humic Acid and Nano Iron Concentrations and Their Interaction on Eggplant branches number (branch/plant).

Humic Acid Con. (g/L)	**Nano Iron Con. (mg/L)**					
	0	20	40	60	100	**Mean (Humic Acid)**
0	2.15	2.66	2.77	3.28	3.09	2.79
2	3.28	3.58	3.67	3.79	3.62	3.58
4	3.97	3.99	3.95	4.16	3.91	3.99
Mean (Nano Iron)	3.13	3.41	3.46	3.74	3.54	
L.S.D	Nano Iron		Humic Acid		Interaction	
0.05%	0.228		0.177		0.396	

5. Fruits number:

Results in Table 5 confirmed the presence of statistically significant differences in the effect of foliar spray concentrations of humic acid and nano-iron on eggplant fruits number. Humic acid at (4) g/L concentration was superior on the rest of the treatmenys with an average fruits number (19.69) fruit /plant, while (0) g/L concentration recorded an average fruits number (17.69) fruit /plant. Also, nano-iron at (60) mg/L concentration was superior on the rest of the treatmenys with an average fruits number (19.31) fruit /plant, compared to (0) g/L concentration (control treatment) recorded an average fruits number (18.02) fruit /plant. Also, results were showed the effect of the interaction between humic acid and nano iron, as the results showed that the (4) g/L Humic acid concentration and(60) mg/L nano-iron concentration was superior on the rest of the treatmens, with an average fruits number (19.85) fruit /plant compared to (0) g/L concentration (control treatment) recorded to fruits number (16.34) fruit /plant.

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Table 5. Effect of Humic Acid and Nano Iron Concentrations and Their Interaction on Eggplant fruit number (fruit/plant).

Humic Acid Con. (g/L)	**Nano Iron Con. (mg/L)**					
	0	20	40	60	100	**Mean (Humic Acid)**
0	16.34	17.25	18.29	18.37	18.20	17.69
2	18.30	18.99	19.31	19.72	19.43	19.15
4	19.42	19.71	19.79	19.85	19.68	19.69
Mean (Nano Iron)	18.02	18.65	19.13	19.31	19.10	
L.S.D	Nano Iron		Humic Acid		Interaction	
0.05%	0.251		0.194		0.435	

6. Fruits weight:

Results in Table 6 confirmed the presence of statistically significant differences in the effect of foliar spray concentrations of humic acid and nano-iron on eggplant fruits weight. Humic acid at (4) g/L concentration was superior on the rest of the treatmenys with an average fruits weight (118.14) g/fruit, while (0) g/L concentration recorded an average fruits weight (116.38) g/fruit. Also, nano-iron at (60) mg/L concentration was superior on the rest of the treatmenys with an average fruits weight (117.69) g/fruit, compared to (0) g/L concentration (control treatment) recorded an average fruits number (116.99) g/fruit. Also, results were showed the effect of the interaction between humic acid and nano iron, as the results showed that the (4) g/L Humic acid concentration and(60) mg/L nano-iron concentration was superior on the rest of the treatmens, with an average fruits weight (118.28) g/fruit compared to (0) g/L concentration (control treatment) recorded to fruits weight (115.91) g/fruit.

Table 6. Effect of Humic Acid and Nano Iron Concentrations and Their Interaction on Eggplant fruit weight (g/fruit).

Humic Acid Con. (g/L)	**Nano Iron Con. (mg/L)**					
	0	20	40	60	100	**Mean (Humic Acid)**
0	115.91	115.96	116.62	116.73	116.68	116.38
2	117.06	117.27	117.30	118.08	117.75	117.49
4	118.01	118.09	118.19	118.28	118.13	118.14
Mean (Nano Iron)	116.99	117.10	117.37	117.69	117.52	
L.S.D	Nano Iron		Humic Acid		Interaction	
0.05%	0.266		0.206		0.460	

Results in Tables (1, 4, 3,4,5 and 6) indicate the effect of humic acid and nano-iron on to the increase (plant height, leaf glands, stem diameter, bud glands, fruit number, and fruit weight),this is attributed to the role of humic acid as a natural chelating agent for mineral elements in the soil, facilitating their absorption and stimulating cell division

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and elongation in plant tissues. In addition, it improves soil structure, water availability, and access to micronutrients, this effect was clearly reflected in plant growth and productivity (Canellas et al., 2020; Nardi, et al., 2021). On the other hand, nano-iron is essential for the formation of chlorophyll and enzymes involved in photosynthesis. When applied at appropriate concentrations, it enhances photosynthetic efficiency and increases the production of carbohydrates used in the formation of new tissues, including lateral branches (El-Gioushy et al., 2021). The increased growth characteristics and yield of eggplant when using humic acid and nano-iron together are also attributed to their synergistic effect in stimulating cell division, enhancing nutrient uptake, and activating physiological processes associated with vegetative growth. Humic acid acts as a natural biostimulant, increasing the availability of macro- and micronutrients in the soil and enhancing their uptake by the roots. This stimulates the formation of lateral buds and branch growth Additionally, humic acid plays a role similar to auxins in promoting cell division, which positively impacts branch proliferation (De Santiago et al., 2020). The increase in eggplant fruit number following foliar application of various concentrations of humic acid and nano iron is attributed to their direct role in enhancing physiological processes related to flowering, fruit set, and improved plant nutrition. These effects positively influence the biological mechanisms associated with fruit development and contribute to increased quantitative fruit production. These findings are consistent with the results reported by Raiesi-Ardali et al., (2022).

IV. Conclusion:

The results of this experiment confirmed that foliar spraying with humic acid and nano-iron had a significant effect on the physical properties of eggplant. The 4 g/L humic acid and 60 mg/L nano-iron concentrations achieved more pronounced improvements in all measured growth parameters. These results confirm the ability of these treatments to enhance eggplant growth and productivity under conditions in southern Iraq.

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