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The effect of Nano-NPK, fulvic acid and their interaction on some physical properties of two cherry tomato varieties *Solanum lycopersicum*

var. cerasiforme.

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Abstract

The experiment was carried out in one of the unheated plastic houses at the station affiliated with the College of Agriculture and Marshlands / University of Thi Qar, Al-Muhiyah area, during the winter season 2024-2025, using a split-split plot design, the averages of the treatments were compared according to the least significant difference (LSD) test at the probability level of 0.05. The experiment included three factors: the first factor: two varieties of cherry tomatoes, Wadi Star and Cherry, the second factor, three concentrations of Nano NPK (0, 2.5 and 5) g L^{-1} sprayed on the plant, and the third factor, three concentrations of fulvic acid (0, 2 and 4) g L^{-1} as a soil addition to the plant, with three replicates for each treatment. The aim was to determine the variety of cherry tomatoes that can be successfully grown in the conditions of Thi Qar Governorate and that has high productivity, as well as to determine the optimal concentration of both Nano NPK and fulvic acid in the physical characteristics of cherry tomato plants. The results showed superiority the cherry variety was superior to the Wadi star variety in the number of fruits per plant, length, weight and diameter of the fruit at averages of (272.9 fruits. plant^{-1}, 17.800 mm, 6.178 g and 17.450 mm) respectively, and the Nano NPK concentration of 5 g. L^{-1} was significantly superior in the number of fruits, length, weight and diameter of the fruit at averages of (294.8 fruits plant^{-1}, 18.280 mm, 6.356 g and 17.930 mm) respectively, while fulvic acid was significantly superior to the concentration of 4 g L^{-1} with the number of fruits, length, weight and diameter of the fruit (346.0 fruits.plant^{-1} , 20.425 mm , 7.150 g and 20.075 mm) respectively, and the results of the statistical analysis showed that the two-way and three-way interactions between the study factors were also significant in the studied traits.

I. Introduction

Cherry tomato is a horticultural crop that has gained increasing attention in recent years, its superior marketing and nutritional qualities have made it popular in many countries around the world, its small fruit size and diverse shapes and colors make it a popular crop in many countries, it also contains high concentrations of bioactive compounds such as carotenoids, lycopene, and vitamins, furthermore, it is rich in essential minerals, which give it a high nutritional value and link its consumption to the prevention of some chronic diseases (Kalogeropoulos, 2012; Aggarwal and Reo, 2000; Filgueira and Reo, 2013). Despite this global interest, cherry tomato cultivation in Iraq remains limited, as it is considered an unconventional crop in local markets and is not as widely distributed as conventional tomatoes (Hassan, 2004; Al-Tayyar, 2024).

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National agricultural statistics indicate that tomato production in Iraq in 2023 amounted to approximately (534.821) tons, at an average of (6.15 tons per dunum^{-1}) from a cultivated area of (86.942) dunums (Statistics and Geographic Information Systems Authority, 2024). The average daily consumption of tomatoes per Iraqi individual is approximately (23.9 g), which is lower than the average recorded in developed countries, which reaches (72.7 g) II(Jones, 2008), indicating the need to adopt modern agricultural practices that contribute to increasing productivity and improving quality, fertilization is among the most important agricultural processes affecting tomato growth and productivity, as it provides the major NPK elements necessary for the continuation of plant vital processes and achieving a balance between vegetative growth, flowering, and fruiting (Hawkes ford, 2012). However, the excessive use of conventional fertilizers has in many cases led to environmental and agricultural problems, hence, the trend towards the use of Nano-fertilizers, which are characterized by their high penetration and absorption capacity, reducing the amount of additions, and increasing the efficiency of use (Singh *et al*., 2017; Naderi and Shahraki, 2011).

In addition, the importance of introducing humic compounds, especially fulvic acid, into modern fertilization programs is highlighted, due to their physiological role in enhancing nutrient availability, stimulating photosynthesis, and increasing the formation of chlorophyll and proteins, which positively impacts vegetative growth and productivity (Pettit, 2003; El-Tahlawy and Ali, 2022).

II. Materials and methods:

The field experiment was conducted in an unheated greenhouse at the College of Agriculture and Marshlands Station, Thi Qar University, located at coordinates (46.22°E, 31.05°N), during the winter season of 2024–2025. The aim was to evaluate the effect of nano-NPK fertilizer, fulvic acid, and their interaction on some physical growth traits of two cherry tomato varietys (Wadi Star and Cherry). A randomized complete block design (RCBD) was used, based on a split-plot design with three replicates, the primary factor was assigned to the varietys, while the secondary factor was fulvic acid at three concentrations (0, 2, and 4 g L^{-1}) added to the soil with irrigation water, the third factor was Nano-NPK fertilizer (20:20:20) at three concentrations (0, 2.5, and 5 g L^{-1}), applied by foliar spray.

Seeds of the two study varieties were planted in cork trays filled with peat moss, when they reached the stage of developing two to three true leaves, the seedlings were transferred and planted in a greenhouse on December 2, 2024. The total number of experimental units was 54 units (10 plants per experimental unit), totaling 540 plants. The first spraying and application treatment was carried out one month after planting, and was repeated regularly every 15 days until the end of the experiment on May 30, 2025.

The results were statistically analyzed using the Genstat 2012 program using the analysis of variance method, and significance between means was tested using the least significant difference (LSD) test, at a probability level of 0.05 (Al-Rawi and Abdul Aziz, 2000).

Studied Characteristics:

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

The cumulative number of fruits was calculated from the beginning of harvest until the end and divided by the number of experimental units, the average was then calculated.

2. Fruit length (mm):

Fruits were taken from six plants, and the length was measured using a Vernier scale, the average was then calculated.

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3. Fruit weight per plant (g):

The fruit weight was calculated using a gram balance for six plants from each experimental unit, the cumulative fruit yield was then calculated, dividing the total weight by the cumulative number of fruits.

4. Fruit diameter (mm):

Six fruits were taken from each plant, and the fruit diameter was measured from the mid-point of the fruit using a Vernier scale, the average was then calculated for each experimental unit.

5. Yield per plant (kg):

The yield per plant was calculated by calculating the cumulative yield per plant and dividing by the number of plants.

Statistical analysis:

The results were statistically analyzed using the Genstat 2012 program, and the significance of the differences between the means was tested using the least significant difference (LSD) test at a probability level of 0.05 (Al-Rawi and Abdul Aziz, 2000).

III. Results and Discussion:

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

The results of table (1) show the significant superiority of the Cherry variety in fruit number, achieving the highest average of 272.9 fruits plant^{-1}, compared to the Wadi Star variety, which recorded the lowest average of 264.4 fruits plant^{-1}.

Spraying Nano-NPK at a concentration of 5 g L^{-1} achieved the highest average fruit number of 294.8 fruits plant^{-1}, compared to the control treatment, which recorded the lowest average of 241.1 fruits plant^{-1}.

The results of the same table show that adding fulvic acid at a concentration of 4 g L^{-1} achieved the highest average of 346.0 fruits plant^{-1}, compared to the control treatment, which recorded the lowest average of 184.3 fruits plant^{-1}.

The interaction between the variety and Nano-NPK spraying was significant. The Cherry variety, at a concentration of 5 g L^{1} Nano-NPK, recorded the highest average of 300.7 fruits plant^{1}, while the Wadi Star variety, in the control treatment, recorded the lowest average, at 232.0 fruits plant^{1}.

The results show that the interaction between the Wadi Star variety and fulvic acid at a concentration of 4 g L^{1} significantly outperformed, achieving the highest average of 348.3 fruits plant^{1}, compared to the control treatment of the same variety, which recorded the lowest average fruit number, at 178.2 fruits plant^{1}. As for the interaction between spraying with Nano-NPK and fulvic acid, the interaction between Nano-NPK at a concentration of 5 g L^{-1} and fulvic acid at a concentration of 4 g L^{-1} was significantly superior, achieving the highest average of 367.5 fruits plant^{-1}, compared to the control treatment, which produced the lowest average fruit number of 168.7 fruits plant^{-1}.

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As for the triple interaction between the variety, spraying with Nano-NPK, and adding fulvic acid, the interaction between the Cherry variety and Nano-NPK at a concentration of 5 g L^{-1} and fulvic acid at a concentration of 4 g L^{-1} was significantly superior, achieving the highest average of 366.0 fruits $plant^{-1}$, while the control treatment for the Wadi Star variety recorded the lowest average of 170.0 fruits $plant^{-1}$.

Variety	**Fulvic acid concentrations g L^{-1}**	**Nano NPK concentrations g L^{-1}**			**Interaction of variety and fulvic acid**
		0	**2.5**	**5**	
Wadi star	**0**	170.0	178.0	186.7	178.2
	2	195.3	293.0	311.3	266.6
	4	330.7	345.3	369.0	348.3
Cherry	**0**	167.3	176.0	228.0	190.4
	2	258.0	288.0	308.0	284.7
	4	325.0	340.0	366.0	343.7
Nano NPK Average		241.1	270.1	294.8	
Interaction of variety and Nano NPK		**0**	**2.5**	**5**	Variety Average
Wadi star		232.0	272.1	289.0	264.4
cherry		250.1	268.0	300.7	272.9
Interaction of Nano NPK and fulvic acid		**0**	**2.5**	**5**	Fulvic acid Average
0		168.7	177.0	207.3	184.3
2		226.7	290.5	309.7	275.6
4		327.8	342.7	367.5	346.0
L.S.D$\geq_{0.05}$					
Variety	Fulvic acid	Nano NPK	Variety + Fulvic acid	Variety + Nano NPK	Nano NPK + Fulvic acid	Variety + Nano NPK + Fulvic acid
6.87	4.05	5.34	5.92	7.06	8.27	11.78

Table (1) The effect of Nano NPK, fulvic acid, two varieties of cherry tomatoes, and the interaction between them on the number of fruits per plant (fruit $plant^{-1}$).

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2. Fruit length (mm)

The results of table (2) show that the Cherry variety significantly outperformed, achieving the highest fruit length average of 17.800 mm, compared to the Wadi Star variety, which recorded the lowest average of 16.380 mm.

Spraying Nano-NPK at a concentration of 5 g L^{-1} achieved the highest average, with a significant difference of 18.280 mm compared to the control treatment, which recorded the lowest average of 15.790 mm.

The results of the table also show that the treatment adding fulvic acid at a concentration of 4 g L^{-1} significantly outperformed the other two varieties, achieving the highest average of 20.425 mm, compared to the control treatment, which recorded the lowest average of 14.590 mm. The interaction between the Cherry variety and spraying with NPK at a concentration of 5 g L^{-1} was significantly superior, achieving the highest average of 19.030 mm, while the control treatment for the Wadi Star variety recorded the lowest average of 15.430 mm. Meanwhile, the interaction between the Cherry variety and the addition of fulvic acid at a concentration of 4 g L^{-1} had a significant effect, achieving the highest

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average of 21.760 mm, compared to the control treatment for the Wadi Star variety, which recorded the lowest average of 14.170 mm. The results of the same table show that the interaction between spraying with Nano-NPK and fulvic acid

was significant, the interaction treatment Nano-NPK at a concentration of 5 g L^{-1} and fulvic acid at a concentration of 4 g L^{-1} achieved the highest average fruit length of 22.900 mm, compared to the control treatment, which produced the lowest average fruit length of 14.035 mm. From Table (2), it is noted that the triple interaction between the variety, spraying with Nano-NPK, and adding fulvic acid was significant, the interaction treatment between the Cherry variety, Nano-NPK at a concentration of 5 g L^{-1}, and fulvic acid at a concentration of 4 g L^{-1} achieved the highest average fruit length of 24.430 mm, while the control treatment for the Wadi Star variety recorded the lowest average of 13.630 mm

Table (2) The effect of Nano NPK, fulvic acid, two varieties of cherry tomatoes, and the interaction between them on the Fruit length (mm).

Variety	Fulvic acid concentrations g L^{-1}	Nano NPK concentrations g L^{-1}			Interaction of variety and fulvic acid
		0	2.5	5	
Wadi star	0	13.630	14.080	14.800	14.170
	2	15.340	15.880	16.420	15.880
	4	17.320	18.580	21.370	19.090
Cherry	0	14.440	15.070	15.520	15.010
	2	16.150	16.600	17.140	16.630
	4	17.860	22.990	24.430	21.760
Nano NPK Average		15.790	17.200	18.280	
Interaction of variety and Nano NPK		0	2.5	5	Variety Average
Wadi star		15.430	16.180	17.530	16.380
cherry		16.150	18.220	19.030	17.800
Interaction of Nano NPK and fulvic acid		0	2.5	5	Fulvic acid Average
0		14.035	14.575	15.160	14.590
2		15.745	16.240	16.780	16.255
4		17.590	20.785	22.900	20.425
L.S.D≥ 0.05					
Variety	Fulvic acid	Nano NPK	Variety + Fulvic acid	Variety + Nano NPK	Nano NPK + Fulvic acid	Variety + Nano NPK + Fulvic acid
0.6762	0.3401	0.2547	0.5475	0.5134	0.4681	0.6999

3. Fruit weight (g):

The results of table (3) show that the Cherry variety significantly outperformed the other two varieties in fruit weight, achieving the highest average of 6.178 g, while the Wadi Star variety recorded the lowest average of 5.652 g.

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As for the Nano-NPK fertilizer, the 5 g L^{-1} concentration significantly outperformed, recording the highest average of 6.356 g, compared to the control treatment, which recorded the lowest average of 5.433 g.

The results of the table show that the addition of fulvic acid at a concentration of 4 g L^{-1} achieved the highest fruit weight with a significant difference, reaching an average of 7.150 g, compared to the control treatment, which recorded the lowest average of 4.989 g. The interaction between the Cherry variety and Nano-NPK at a concentration of 5 g L^{-1} significantly outperformed, achieving the highest average of 6.633 g, while the control treatment for the Wadi Star variety recorded the lowest average of 5.300 g.

Meanwhile, the interaction between the Cherry variety and fulvic acid at a concentration of 4 g L^{-1} significantly outperformed, achieving the highest average of 7.644 g, compared to the control treatment for the Wadi Star variety, which recorded the lowest average fruit weight of 4.833 g.

The interaction between Nano-NPK at a concentration of 5 g L^{-1} and fulvic acid at a concentration of 4 g L^{-1} significantly outperformed, achieving the highest average of 8.067 g, compared to the control treatment, which recorded the lowest average fruit weight of 4.783 g. From the results of the same table, it is noted that the triple interaction treatment between the Cherry variety and spraying with Nano NPK at a concentration of 5 g L^{-1} and adding fulvic acid at a concentration of 4 g L^{-1} had a significant effect, and achieved the highest average fruit weight of 8.633 g, while the control treatment for the Wadi Star variety recorded the lowest average of 4.633 g.

Table (3) The effect of Nano NPK, fulvic acid, two varieties of cherry tomatoes, and the interaction between them on the Fruit weight (g).

Variety	Fulvic acid concentrations g L^{-1}	Nano NPK concentrations g L^{-1}			Interaction of variety and fulvic acid
		0	2.5	5	
Wadi star	**0**	4.633	4.800	5.067	4.833
	2	5.267	5.467	5.667	5.467
	4	6.000	6.467	7.500	6.656
Cherry	**0**	4.933	5.167	5.333	5.144
	2	5.567	5.733	5.933	5.744
	4	6.200	8.100	8.633	7.644
Nano NPK Average		5.433	5.956	6.356	
Interaction of variety and Nano NPK		**0**	**2.5**	**5**	Variety Average
Wadi star		5.300	5.578	6.078	5.652
cherry		5.567	6.333	6.633	6.178
Interaction of Nano NPK and fulvic acid		**0**	**2.5**	**5**	Fulvic acid Average
0		4.783	4.983	5.200	4.989
2		5.417	5.600	5.800	5.606
4		6.100	7.283	8.067	7.150

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L.S.D≥ 0.05						
Variety	Fulvic acid	Nano NPK	Variety + Fulvic acid	Variety + Nano NPK	Nano NPK + Fulvic acid	Variety + Nano NPK + Fulvic acid
0.2504	0.1260	0.0943	0.2028	0.1902	0.1734	0.2592

4. Fruit Diameter (mm)

The results of table (4) show the effect of Nano-NPK, fulvic acid, and the two cherry tomato varieties, as well as their interaction on fruit diameter (mm). The Cherry variety significantly outperformed, achieving the highest average of 17.450 mm, compared to the Wadi Star variety, which recorded the lowest average of 16.030 mm.

The results of the same table show that spraying with a Nano-NPK concentration of 5 g L^{-1} recorded the highest average fruit diameter of 17.930 mm, compared to the control treatment, which recorded the lowest average of 15.440 mm.

Adding fulvic acid at a concentration of 4 g L^{-1} achieved the highest average, with a significant difference, in fruit diameter, reaching 20.075 mm, compared to the control treatment, which recorded the lowest average of 14.240 mm. The interaction between the variety and Nano-NPK spraying had a significant effect, the interaction between the Cherry variety and Nano-NPK at a concentration of 5 g L^{-1} achieved the highest average fruit diameter of 18.680 mm, while the control treatment for the Wadi Star variety recorded the lowest average of 15.080 mm. Meanwhile, the interaction between the Cherry variety and fulvic acid at a concentration of 4 g L^{-1} significantly outperformed, achieving the highest average of 21.410 mm, compared to the control treatment for the Wadi Star variety, which recorded the lowest average fruit diameter of 13.820 mm. The results show that the combination of spraying with Nano-NPK at a concentration of 5 g L^{-1} and fulvic acid at a concentration of 4 g L^{-1} significantly outperformed, achieving the highest fruit diameter of 22.550 mm, compared to the control treatment, which recorded the lowest average of 13.685 mm. The triple interaction treatment between the Cherry variety and spraying with Nano NPK at a concentration of 5 g L^{-1} and adding fulvic acid at a concentration of 4 g L^{-1} had a significant effect, and achieved the highest average fruit diameter of 24.080 mm, compared to the control treatment of the Wadi Star variety, which recorded the lowest average of 13.280 mm.

Table (4) The effect of Nano NPK, fulvic acid, two varieties of cherry tomatoes, and the interaction between them on the Fruit diameter (mm).

Variety	Fulvic acid concentrations g L^{-1}	Nano NPK concentrations g L^{-1}			Interaction of variety and fulvic acid
		0	2.5	5	
Wadi star	**0**	13.280	13.730	14.450	13.820
	2	14.990	15.530	16.070	15.530
	4	16.970	18.230	21.020	18.740
Cherry	**0**	14.090	14.720	15.170	14.660
	2	15.800	16.250	16.790	16.280
	4	17.510	22.640	24.080	21.410
Nano NPK Average		15.440	16.850	17.930	

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Interaction of variety and Nano NPK	**0**	**2.5**	**5**	Variety Average
Wadi star	15.080	15.830	17.180	16.030
cherry	15.800	17.870	18.680	17.450
Interaction of Nano NPK and fulvic acid	**0**	**2.5**	**5**	Fulvic acid Average
0	13.685	14.225	14.810	14.240
2	15.395	15.890	16.430	15.905
4	17.240	20.435	22.550	20.075

L.S.D≥ 0.05						
Variety	Fulvic acid	Nano NPK	Variety + Fulvic acid	Variety + Nano NPK	Nano NPK + Fulvic acid	Variety + Nano NPK + Fulvic acid
0.6762	0.3401	0.2547	0.5475	0.5134	0.4681	0.6999

5. Yield per plant (kg plant^{-1}):

The results of table (5) showed the significant superiority of the Wadi Star variety in yield per plant, achieving the highest average of 2.015 kg plant^{-1}, compared to the Cherry variety, which recorded the lowest average of 1.639 kg plant^{-1}.

The results of the same table show that spraying Nano-NPK at a concentration of 5 g L^{-1} achieved the highest average yield of 2.091 kg plant^{-1}, compared to the control treatment, which recorded the lowest average of 1.545 kg plant^{-1}.

As for the treatment adding fulvic acid at a concentration of 4 g L^{-1}, it significantly outperformed and achieved the highest average yield per plant of 2.907 kg plant^{-1}, compared to the control treatment, which recorded the lowest average of 0.851 kg plant^{-1}. The interaction treatment between the Wadi Star variety and spraying with Nano-NPK at a concentration of 5 g L^{-1} significantly outperformed, achieving the highest yield of 2.292 kg plant^{-1}, compared to the control treatment for the Cherry variety, which recorded the lowest yield of 1.328 kg plant^{-1}.

The interaction treatment between the Wadi Star variety and the addition of fulvic acid at a concentration of 4 g L^{-1} also significantly outperformed, achieving the highest yield of 3.193 kg plant^{-1}, compared to the control treatment for the Cherry variety, which recorded the lowest yield per plant of 0.8284 kg plant^{-1}. The results in the same table showed that the interaction between Nano-NPK at a concentration of 5 g L^{-1} and fulvic acid at a concentration of 4 g L^{-1} had a significant effect, achieving the highest average of 3.241 kg plant^{-1}, compared to the control treatment, which recorded the lowest average of 0.7892 kg plant^{-1}. As for the triple interaction treatments, the interaction between the Wadi Star variety and spraying with Nano-NPK at a concentration of 5 g L^{-1} and adding fulvic acid at a concentration of 4 g L^{-1} significantly outperformed, achieving the highest average of 3.483 kg plant^{-1}, while the control treatment for the Cherry variety recorded the lowest average of 0.7853 kg plant^{-1}.

Table (5) The effect of Nano NPK, fulvic acid, two varieties of cherry tomatoes, and the interaction between them on the Yield per plant (kg plant^{-1})

Variety		**Nano NPK concentrations g L^{-1}**	

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	Fulvic acid concentrations g L^{-1}	**0**	**2.5**	**5**	**Interaction of variety and fulvic acid**
Wadi star	**0**	0.7930	0.8400	0.9933	0.8754
	2	1.5667	1.9667	2.4000	1.9778
	4	2.9300	3.1667	3.4833	3.1933
Cherry	**0**	0.7853	0.8267	0.8733	0.8284
	2	1.1000	1.5000	1.8000	1.4667
	4	2.1000	2.7667	3.0000	2.6222
Nano NPK Average		1.5458	1.8444	2.0917	

Interaction of variety and Nano NPK	**0**	**2.5**	**5**	Variety Average
Wadi star	1.7632	1.9911	2.2922	2.0155
cherry	1.3284	1.6978	1.8911	1.6391

Interaction of Nano NPK and fulvic acid	**0**	**2.5**	**5**	Fulvic acid Average
0	0.7892	0.8333	0.9333	0.8519
2	1.3333	1.7333	2.1000	1.7222
4	2.5150	2.9667	3.2417	2.9078

L.S.D≥ 0.05

Variety	Fulvic acid	Nano NPK	Variety + Fulvic acid	Variety + Nano NPK	Nano NPK + Fulvic acid	Variety + Nano NPK + Fulvic acid
0.04384	0.08868	0.03841	0.10348	0.04927	0.09875	0.12235

The results of tables (1, 2, 3, 4, and 5) indicated significant differences between the two cherry tomato cultivars, this is attributed to genetic differences between the cultivars and their respective efficiency in absorbing nutrients and directing photosynthetic products to the floral and fruiting organs (Kole and Mishra, 2002). It was also found that Nano-NPK had a significant effect on all traits, as increasing its concentration to 5 g L^{-1} contributed to improving fruit number, increasing their dimensions and weight, and increasing plant yield, this is due to the vital role of macronutrients: nitrogen is involved in the formation of proteins and enzymes responsible for cell division, phosphorus is involved in producing the energy necessary for the differentiation of floral tissue, while potassium contributes to the transport of carbohydrates to the fruit formation sites (Hawkesford et al., 2012). (Singh *et al*., 2017 and Tripathi *et al*., 2017) indicated that Nano fertilizers increase the efficiency of plant absorption and metabolic processes, which positively impacts productivity and fruit quality. Fulvic acid, on the other hand, achieved significant increases in fruit number, weight, and plant yield with higher concentrations, this is attributed to its role as a bio stimulant that improves the availability of nutrients in the root zone and increases their uptake, in addition to stimulating photosynthesis and the formation of carbohydrates and proteins necessary for flower and fruit growth (Pettit, 2003). (El-Metwaly and Mansour, 2019) demonstrated that fulvic acid contributed to increasing productivity and improving fruit quality, (Abbawi and Al-Zubaidi, 2022) indicated that treating broccoli with fulvic acid led to a significant improvement in physical and chemical properties and increased yield, reinforcing the importance of fulvic acid in improving vegetable crop characteristics. (Fernandez, 2016) also indicated

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that foliar fertilization is an effective means of replacing elements, especially phosphorus, which contributes to improving fruit quality. (Yang, 2023) indicated that balanced fertilization with NPK contributes to enhancing the accumulation of lycopene and bioactive compounds in cherry tomato fruits, which is consistent with the results of this study.

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