EFFECT OF FERTILIZATION TREATMENT ON GROWTH, YIELD, FRUIT QUALITY, AND NUTRITION ACCUMULATION OF CHERRY TOMATO

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Abstract. The application of nutrients has a significant impact on cherry tomato fruit yield and quality. In a greenhouse experiment, a popular local cherry tomato cultivar (*Lycopersicon esculentum* var. *cerasiforme* Alef), namely 'Yuekeda 101' was grown under various fertilization conditions. In this study, the yield, agronomic traits, and fruit quality of cherry tomatoes were determined to evaluate the effect of fertilization treatment on cherry tomato growth. Results showed that the fertilization treatment significantly affected the growth, yield, fruit quality, and nutrition accumulation in the cherry tomato plants. The T1 treatment (without reduction of the chemical + application of humic acid fertilizer) harvested the highest fruit yield per plant (1195.0 g). Additional applications of humic acid fertilizer might benefit cherry tomatoes to achieve a balance between fruit yield and quality. Variations in cherry tomato yield and fruit quality are correlated with the nutrient content of the plant's various tissues. The treatment without reduction of the chemical with the application of the humic acid could balance the yield and fruit quality of cherry tomatoes. The results of this study suggested that the administration of a combination of fertilizers could regulate the growth and nutrient accumulation of cherry tomato plants, thereby influencing their yield and fruit quality.
Keywords: *cherry tomato, fertilization, yield, fruit quality, agronomic traits*

Introduction

The tomato is recognized as an important crop globally for its nutritional and economic value. The tomato is not only a fresh vegetable in the industrialized world but is also important for the food industry as a raw material for ketchup production. It is well known that tomatoes are essential for the health of humans (Chapagain and Orr, 2009). The cherry tomato *(Lycopersicon esculentum* var. *cerasiforme* Alef) as fresh fruit is highly popular due to its high mineral nutrients and good taste. It is becoming popular for cultivation under protected agriculture, including greenhouses (Hita et al., 2007). The planting area of cherry tomato cultivation in China is about 150,000 ha, and nearly 53.3% of cherry tomato cultivation is produced in greenhouses (Du et al., 2022). However, the yield and nutrients of cherry tomatoes, which are widely grown in greenhouses, are limited by fertilization factors. The quality and safety requirements for fresh cherry tomatoes are more stringent than those for tomatoes. However, the yield and nutrients of cherry tomatoes, which are widely grown in greenhouses, are limited by fertilization factors (Maboko et al., 2017). The quality and safety requirements for fresh cherry tomatoes are more stringent than those for tomatoes. Therefore, improving the yield and fruit quality of cherry tomatoes is important to increase the profitability of cultivation and to improve a healthy human diet.

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With the growing prevalence of cherry tomato cultivation, sustainable production of cherry tomatoes should be a top priority, especially in terms of fertilization management (Zheng et al., 2020; Nie et al., 2022). In contrast to chemical fertilizer, organic fertilization increased cherry tomato yield and fruit quality, according to a previous study (Matos et al., 2021). Tomatoes' yield, fruit count, and nutrient content were all affected by organic fertilization (Stoleru et al., 2020). Maia et al. (2013) found that bovine manure affected the development of cherry tomatoes and that plants grown with cattle manure were superior to those grown with chemical fertilizer. Fink et al. (2020) observed a study for specific recommendations for P and K fertilization to increase the yield of cherry tomatoes. The result indicated that higher yields were obtained with a lower chemical input than what is recommended for tomatoes in general and that P is crucial for tomato cherry production. The relative chlorophyll index may have predicted quantities of nitrogen fertilizer for cherry tomato cultivation, as suggested by Vieira et al. (2016). Fras-Moreno et al. (2020) found that nitrogen application influences the fruit quality and antioxidant status of cherry tomatoes grown in greenhouses. In addition, cherry tomato growth, yield, and fruit quality were substantially affected by the organic-inorganic fertilizer treatments (Shi et al., 2008). In addition, Castro et al. (2006) provided evidence of the viability of using fish effluent to irrigate cherry tomatoes grown with various types of organic fertilizers, which results in increased yields.

Cherry tomato yield and quality are significantly enhanced by the administration of multiple fertilizers simultaneously. Lira-Saldivar et al. (2014) discovered a significant response in yield and biomass of cherry tomatoes to biofertilization with beneficial microorganisms under shade house conditions. According to Du et al. (2022), biofertilization with photosynthetic microbes is a novel method for promoting the growth of cherry tomatoes. According to Nie et al. (2022), an inorganic nutrient solution containing bacterial manure can increase the yield, quality, and antioxidant response of hydroponic cherry tomatoes grown in a 100% inorganic nutrient solution without the use of microbial fertilizer. Li et al. (2017), Liu et al. (2020), and Wang et al. (2021) reported that the application of microbial fertilizer can increase cherry tomato production, soluble minerals, soluble protein content, and soluble sugar content in tomato fruits. In addition, Bautista et al. (2020) suggested that the nutrients provided by tomatoes to various plant tissues are crucial. Therefore, the growth status of the plant could be determined by analyzing the nutrient content of the leaves, blooms, and fruits.

Overall, fertilization is essential for cherry tomato production in order to gain a comprehensive understanding of productivity and produce quality under the combined administration of various fertilizers. This study aimed to determine the effect of fertilization treatments on the growth, yield, fruit quality, and nutrient accumulation of cherry tomatoes, as well as the relationship between yield and fruit quality, finally determine the strategies of various fertilizer combinations applicable to the greenhouse cultivation of cherry tomatoes in order to increase their commercial value and cultivation profitability.

Materials and methods

Experimental description

The greenhouse experiment was conducted at the Baiyun Experimental Base of the Guangdong Academy of Agricultural Sciences from August 2021 to January 2022. The cherry tomato plants were grown under floating capillary hydroponic cultivation

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(FCH). The test cherry tomato variety was 'Yuekeda 101', which is a popular cultivated variety in Guangdong province and is bred by the Institute of Facilities Agriculture of Guangdong Academy of Agricultural Sciences. This cultivar is suitable for planting throughout the year in Guangdong province. This variety has characteristics of high taste quality, yellow fruit, crack-resistant peel, and good fruit shape. The test fertilizer used was 'Nongyishi' (Guangzhou Brlong Agricultural Materials Co., Ltd, Guangzhou, China), 'microbial activation of mineral pordic acid' which contains 4% of humic acid.

The seeds of the cherry tomato for this experiment were sown on August 10, 2021, and were transplanted on September 17, 2021, the cherry tomato fruit was first harvested on December 7, 2021. The experimental area was 11 meters long, which the planting of 55 cherry tomato plants, with 3 repeats for each treatment. A completely randomly arranged design was used for this study in the greenhouse. The planting density was 30 cm × 180 cm. Irrigation and pest management were performed based on conventional management practices in the local provinces.

Experimental design

Four different fertilization treatments were applied to the cherry tomato plants. The experimental treatments with a different nutrient solution are shown in *Table 1*. The amount of trace elements is consistent, and the specific formula can be seen in *Table 1*.

Table 1. *fertilization treatments with different nutrient solution (mg L^{-1})*

Treatment	Calcium nitrate	Potassium nitrate	Potassium dihydrogen phosphate	Ammonium dihydrogen phosphate	Magnesium sulfate	'Nongyishi	Microbial activation of mineral poric acid
CK	900	500	150	50	500	0	0
T1	900	500	150	50	500	1000	0
T2	810	450	135	45	450	1000	0
T3	900	500	150	50	500	0	1000
T4	810	450	135	45	450	0	1000

Sampling and measurement

Yield, fruit weight, and fruit shape measurement

The cherry tomato yield per plant was measured by harvesting the fruit yield of the cherry tomato plant which began on 7th December. After harvest, the weight of the cherry tomato fruit was recorded with an electronic balance (accurate to 0.01 g) for the measure of fruit weight. The fruit length and fruit width were measured for recording the fruit shape (accurate to 0.01 cm).

Fruit quality measurement

At the fruit ripening stage, 20 mature fruits with uniform size were selected from the second and third ear fruits of each treatment for the determination of the cherry tomato fruit quality. To determine the fruit quality of tomatoes, fructose, glucose, VC, soluble solid, titratable acid, sucrose, and total soluble sugar content were measured. The above produce quality parameters were determined using Wang et al.'s (2023) method.

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SPAD value and plant dry biomass measurement

The SPAD value was measured by using a portable chlorophyll meter SPAD-502 (Japan) to measure the first fully mature leaf at 7d, 21d, 35d, 49d, and 63d after transplanting. The plant dry biomass was sampled at 7d, 21d, 35d, 49d, and 63d after transplanting. Three representative plants from each plot were selected and divided into stem, leaf, and fruit. The different plant tissue was oven- dried at 75℃ drying till constant weight for measurement of the dry biomass of the cherry tomato plant.

Determination of the total nitrogen, phosphorus, and potassium content and accumulation in plant

The dry biomass sample was used for the determination of the total nitrogen, phosphorus, and potassium content and accumulation in plants. The total nitrogen content was determined by using the sodium salicylate colorimetric method with the automatic flow injection analyzer determination (German Seal AA3). The total phosphorus content was measured by the ammonium molybdate color method with the automatic flow injection analyzer determination (German Seal AA3). The total potassium content was measured by using the flame photometer determination (model: FP6410, origin of Shanghai Electronic instrument analysis Co., LTD.). The total nitrogen, phosphorus, and potassium content and accumulation in the plant were then calculated by the nutrient content and the dry biomass.

Statistical analysis

The data were recorded and collated using Microsoft Excel 2019 and analyzed by Statistix version 8.0 for ANOVA. The means of each treatment were compared at the least significant difference LSD test at 5% probability.

Results

The fruit yield and fruit appearance traits

The highest yield per plant was detected at the T1 treatment (1195.0 g per plant). The T2 and T4 treatments resulted in a significant decrease yield compared with the CK treatment. Compared to the CK treatment, the T3 and T4 treatments lead to fruit weight, length, and fruit width decreased. The length/width of the fruit did not differ significantly between all fertilization treatments (*Table 2*).

The fruit quality traits

Compared with CK treatment, the T2, T3, and T4 fertilization treatments lead to a decrease in the fructose content by 22.76%, 5.53%, and 12.31%, respectively. The T1 treatment significantly increased the glucose content in fruit by 15.57% as compared with the CK treatment. All fertilization treatments resulted in a significant decrease in the content of VC (5.68-12.11%) but an increase in soluble solids (13.58-28.66%) compared with CK treatment. The T3 treatment significantly decreased the titratable acid content by 19.41% as compared to the CK treatment. No significant change was detected for sucrose content and total soluble sugar content at the fertilization treatment as compared with the CK treatment (*Fig. 1*).

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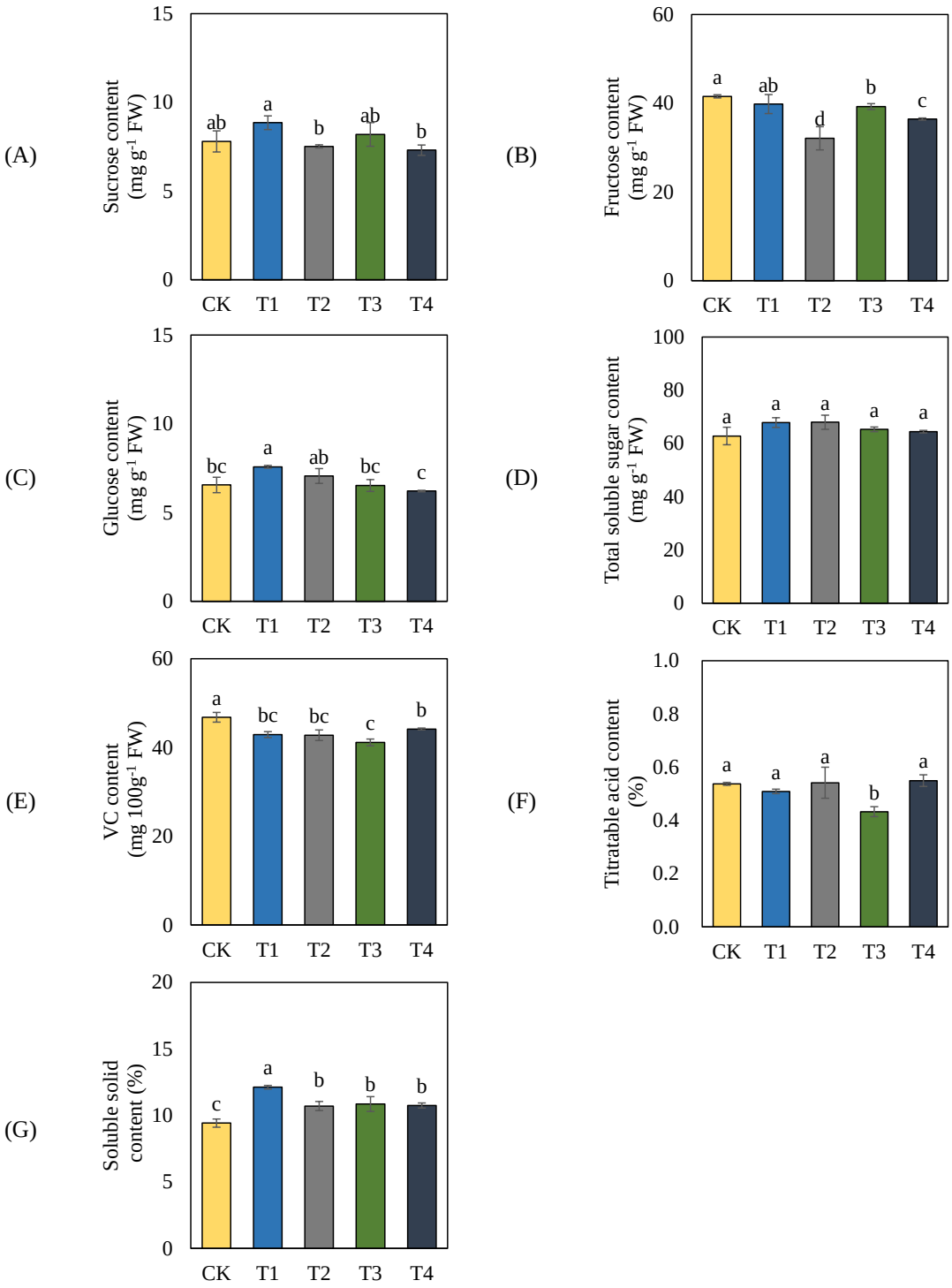

Figure 1. *The fruit quality traits under different fertilization treatments. Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)*

The SPAD value in leaf and dry biomass of plant

Compared with the CK treatment, the T2 and T3 treatment significantly increased the SPAD value in the leaf at 7d after transplanting. At 35d after transplanting, the T2, T3,

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and T4 treatments significantly increased the SPAD value in the leaf compared to the CK treatment. All the fertilization treatments compared to the CK treatment significantly increased the SPAD value in the leaf at 49d and 63d after transplanting (*Table 3*). The T1, T2, T3, and T4 treatment resulted dried biomass changes. At 63d after transplanting, the T1 treatment significantly increased whole plant dry biomass compared to the CK treatment (*Table 4*).

Table 2. *The fruit yield and fruit appearance traits under different fertilization treatments*

Treatment	Yield per plant (g)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Length/width
CK	1078.20ab	13.32a	3.14a	2.68a	1.17a
T1	1195.00a	12.90ab	2.98ab	2.62a	1.14a
T2	784.80cd	12.34abc	3.06a	2.65a	1.15a
T3	940.00bc	11.00c	2.80bc	2.46b	1.14a
T4	572.40d	11.40bc	2.69c	2.36b	1.14a

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

Table 3. *The SPAD value in leaf under different fertilization treatments*

Treatment	7 d	21 d	35 d	49 d	63 d
CK	45.53b	51.28ab	41.10b	40.95c	41.15c
T1	49.00ab	52.03a	41.9ab	45.53a	45.53a
T2	50.23a	50.28b	43.55a	42.78b	43.33b
T3	49.93a	52.18a	43.08a	46.33a	45.93a
T4	46.53ab	51.15ab	43.33a	45.10a	45.53a

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

Table 4. *The dry biomass of plant under different fertilization treatments*

Treatment	Leaf	Stem	Fruit	The whole plant
7 d				
CK	1.32b	0.96a	-	2.29a
T1	1.78a	0.72b	-	2.50a
T2	0.95c	0.68b	-	1.63c
T3	1.25b	0.97a	-	2.22ab
T4	1.16bc	0.77b	-	1.93bc
21 d				
CK	2.03bc	1.77ab	-	3.81b
T1	2.98a	2.03a	-	5.00a
T2	1.36d	1.27bc	-	2.63c
T3	2.33b	1.63ab	-	3.96b
T4	1.72cd	1.00c	-	2.72c

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35 d				
CK	7.33ab	4.30a	-	11.63ab
T1	8.21a	4.19a	-	12.39a
T2	5.59b	4.00a	-	9.60ab
T3	6.50ab	4.28a	-	10.77ab
T4	5.06b	3.80a	-	8.86b
49 d				
CK	14.23ab	14.51a	7.40a	36.14a
T1	16.85a	10.02b	4.97a	31.84a
T2	10.46bc	7.40c	4.33a	22.19b
T3	12.96bc	7.95bc	4.25a	25.16b
T4	9.82c	7.00c	4.30a	21.12b
63 d				
CK	20.48ab	22.71a	15.18a	58.36b
T1	23.09a	24.53a	20.01a	67.63a
T2	13.89b	13.89b	17.02a	44.80c
T3	16.08b	13.44b	15.33a	44.86c
T4	14.31b	13.14b	14.92a	42.37c

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

The total nitrogen, phosphorus, and potassium content of different plant tissue

At 7d after transplanting, all the fertilization treatment substantially increased the total nitrogen content of the leaf, and the T1 and T4 treatments substantially increased the total nitrogen content of the stem compared to the CK treatment. At 21d after transplanting, the T3 and T4 treatments substantially increased the total nitrogen content of the leaf and stem in comparison to the CK treatment. The T1 treatment substantially increased the total nitrogen content in the leaf and stem 35d after transplanting, compared to the CK treatment. The T1 treatment significantly increased the total nitrogen content in the stem and fruit 63d after transplanting, compared to the CK treatment, the T4 treatment increased the total nitrogen content in the fruit (*Table 5*). At 7d after transplanting, the T1 treatment significantly increased the total phosphate content of the stem in comparison to the CK treatment. At 7d and 21d after transplanting, the T3 and T4 treatments significantly increased the total phosphate content of the leaf and stem compared to the CK treatment. T1 substantially enhanced the total phosphate content in the leaf compared to the CK treatment 35d after transplanting. The T1 treatment increased the total phosphate content in the leaf and stem 49d after transplanting. Compared to the CK treatment, the T1 treatment significantly increased the total phosphate content in fruit at 63d after transplanting (*Table 6*). The T1 and T4 treatments significantly increased the total potassium content of the leaf 7d after transplantation and the stem 21 days after transplantation in comparison to the CK treatment. At 49d after transplanting, the T1, T3, and T4 treatments significantly increased the total potassium content of the leaf in comparison to the CK treatment. The T1 treatment increased the total potassium content in the leaf 63d after transplanting, whereas the T2 and T4 treatments increased the total potassium content in the fruit (*Table 7*).

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Table 5. *The nitrogen content in plant under different fertilization treatments (mg g^{-1})*

Treatment	Leaf	Stem	Fruit
7 d			
CK	37.22b	20.69b	-
T1	43.18a	23.52a	-
T2	42.02a	20.81b	-
T3	44.38a	22.13ab	-
T4	43.71a	22.82a	-
21 d			
CK	35.62b	16.75bc	-
T1	36.3ab	17.39b	-
T2	35.31b	15.38c	-
T3	39.81a	19.41a	-
T4	39.63a	19.87a	-
35 d			
CK	41.23b	17.71bc	-
T1	44.43a	21.92a	-
T2	35.04d	17.84bc	-
T3	41.01b	19.51b	-
T4	38.51c	17.42c	-
49 d			
CK	32.6ab	15.51a	18.41a
T1	34.67a	15.99a	20.94a
T2	32.11ab	14.83ab	20.17a
T3	34.34a	15.97a	22.10a
T4	30.24b	13.50b	18.85a
63 d			
CK	30.44ab	15.5b	20.86c
T1	33.03a	19.17a	23.07b
T2	28.11b	13.90c	20.80c
T3	28.93b	15.69b	20.96c
T4	29.92b	13.74c	24.45a

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

Table 6. *The phosphate content in plant under different fertilization treatments (mg g^{-1})*

Treatment	Leaf	Stem	Fruit
7 d			
CK	3.16b	2.27b	-
T1	3.68ab	3.30a	-
T2	3.34ab	2.15b	-
T3	4.20a	3.05a	-
T4	4.18a	3.24a	-

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21 d			
CK	3.24b	2.51b	-
T1	3.34b	2.62b	-
T2	3.26b	2.49b	-
T3	4.03a	3.40a	-
T4	3.77a	3.12a	-
35 d			
CK	3.41b	2.97ab	-
T1	4.25a	3.45a	-
T2	3.31b	2.57b	-
T3	3.73ab	3.32a	-
T4	3.33b	2.79b	-
49 d			
CK	2.50bc	2.89bc	3.42ab
T1	3.28a	3.79a	3.47ab
T2	2.33c	2.37d	3.38ab
T3	2.84b	3.07b	3.71a
T4	2.39c	2.84c	3.09b
63 d			
CK	2.41ab	2.99a	3.87b
T1	2.81a	3.49a	4.27a
T2	2.36b	2.71a	3.37c
T3	2.39ab	3.21a	3.81b
T4	2.33b	2.55a	3.90b

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

Table 7. *The potassium content in plant under different fertilization treatments (mg g^{-1})*

Treatment	Leaf	Stem	Fruit
7 d			
CK	42.93b	58.78a	-
T1	45.92a	62.06a	-
T2	42.74b	52.95b	-
T3	43.02b	58.79a	-
T4	46.98a	61.70a	-
21 d			
CK	45.94a	45.17c	-
T1	46.33a	47.82b	-
T2	48.32a	41.78d	-
T3	46.43a	46.75bc	-
T4	48.33a	51.76a	-

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35 d			
CK	44.78a	42.00a	-
T1	44.96a	43.44a	-
T2	44.94a	42.32a	-
T3	45.32a	41.51a	-
T4	42.71a	39.93a	-
49 d			
CK	39.04c	33.93a	33.13a
T1	46.12a	34.19a	34.12a
T2	40.68bc	33.53a	36.71a
T3	46.96a	34.37a	36.10a
T4	42.13b	35.32a	33.91a
63 d			
CK	36.45bc	31.8ab	34.59b
T1	43.45a	34.59a	36.05ab
T2	34.44c	30.77b	38.91a
T3	37.53b	31.68ab	36.55ab
T4	36.83bc	29.63b	39.23a

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

The total nitrogen, phosphorus, and potassium accumulation in plant

The T1 treatment increased the total nitrogen accumulation in the leaf and the whole plant at 7d and 21d after transplanting. At 49d after transplanting, the T1 treatment increased the total nitrogen accumulation in the whole plant. At 49d after transplanting, all fertilization treatments significantly increased the total nitrogen accumulation in the fruit. At 63d after transplanting, the T1 treatment increased the total nitrogen accumulation in the stem, fruit, and whole plant as compared to the CK treatment (*Table 8*). Improvement in the total phosphate accumulation in the different plant tissues was detected varied from different treatments and sampling time (*Table 9*). The change in the potassium accumulation in plant tissues varied to the treatments and plant tissues. At 7d after transplanting, the T1 treatments significantly increased total potassium accumulation in the leaf compared to the CK treatment. Compared to the CK treatment, the T1 treatment significantly increased potassium accumulation in the leaf and entire plant 21d after transplanting. (*Table 10*).

Table 8. *The nitrogen accumulation in plant under different fertilization treatments (mg)*

Treatment	Leaf	Stem	Fruit	The whole plant
7 d				
CK	49.22bc	19.97ab	-	69.19b
T1	76.78a	17.00bc	-	93.78a
T2	39.88c	14.20c	-	54.09c
T3	55.17b	21.52a	-	76.69b
T4	50.71b	17.59bc	-	68.29b

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21 d				
CK	72.23bc	29.76a	-	101.99bc
T1	108.02a	35.35a	-	143.37a
T2	47.97d	19.37b	-	67.34d
T3	93.12ab	31.67a	-	124.79ab
T4	67.99cd	19.87b	-	87.87cd
35 d				
CK	302.03ab	76.18ab	-	378.21ab
T1	365.53a	91.81a	-	457.33a
T2	196.67b	71.28ab	-	267.94b
T3	267.30ab	83.13ab	-	350.43ab
T4	195.03b	66.02b	-	261.05b
49 d				
CK	464.96ab	224.90a	183.33d	873.20bc
T1	584.48a	161.3b	267.93c	1013.71a
T2	335.49bc	110.18c	320.79b	766.46c
T3	444.39ab	126.78bc	417.73a	988.89ab
T4	300.85c	94.82c	412.90a	808.57c
63 d				
CK	623.04ab	352.00b	316.78b	1291.81b
T1	769.86a	470.64a	462.36a	1702.86a
T2	390.09b	193.34c	353.74ab	937.16c
T3	465.31b	211.38c	320.89b	997.59c
T4	425.12b	179.94c	364.37ab	969.44c

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

Table 9. *The phosphate accumulation in plant under different fertilization treatments (mg)*

Treatment	Leaf	Stem	Fruit	The whole plant
7 d				
CK	4.21bc	2.19b	-	6.39b
T1	6.46a	2.39ab	-	8.85a
T2	3.16c	1.46c	-	4.63c
T3	5.22ab	2.97a	-	8.19a
T4	4.85b	2.5ab	-	7.34ab
21d				
CK	6.52b	4.46ab	-	10.97b
T1	9.95a	5.32a	-	15.27a
T2	4.42c	3.17b	-	7.59c
T3	9.40a	5.54a	-	14.94a
T4	6.47b	3.12b	-	9.59bc
35 d				
CK	24.97ab	12.79abc	-	37.75ab
T1	34.82a	14.47a	-	49.29a
T2	18.50b	10.09c	-	28.59b
T3	24.24b	14.27ab	-	38.50ab
T4	16.80b	10.61bc	-	27.40b

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49 d				
CK	35.02b	41.93a	34.15d	111.10b
T1	55.17a	37.87a	44.76c	137.79a
T2	24.35c	17.58c	53.75b	95.69c
T3	36.66b	24.37b	70.14a	131.16a
T4	23.56c	19.97bc	67.72a	111.25b
63 d				
CK	49.36ab	67.02a	58.78b	175.15b
T1	64.81a	85.28a	85.96a	236.05a
T2	32.66b	37.34b	57.22b	127.22c
T3	38.56b	43.26b	58.42b	140.25c
T4	33.21b	33.21b	58.16b	124.59c

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

Table 10. *The potassium accumulation in plant under different fertilization treatments (mg)*

Treatment	Leaf	Stem	Fruit	The whole plant
7 d				
CK	56.77b	56.80a	-	113.57ab
T1	81.70a	44.93bc	-	126.63a
T2	40.45c	36.12c	-	76.57c
T3	53.62b	57.07a	-	110.70b
T4	54.49b	47.55ab	-	102.04b
21 d				
CK	92.15bc	80.30a	-	172.45b
T1	137.99a	96.95a	-	234.94a
T2	65.60d	53.12b	-	118.73c
T3	108.26b	76.28a	-	184.53b
T4	82.99cd	51.78b	-	134.76c
35 d				
CK	328.08ab	180.65a	-	508.73ab
T1	368.82a	181.89a	-	550.71a
T2	252.60b	167.45ab	-	420.05ab
T3	295.14ab	178.24a	-	473.37ab
T4	216.88b	151.58b	-	368.46b
49 d				
CK	557.54bc	491.76a	328.99e	1378.29ab
T1	777.70a	342.68b	438.59d	1558.96a
T2	425.47c	248.08c	584.21c	1257.75b
T3	605.98ab	272.60bc	682.52b	1561.10a
T4	416.52c	249.01c	743.24a	1408.77ab
63 d				
CK	746.49ab	719.62a	523.57a	1989.68b
T1	1005.01a	846.83a	723.62a	2575.46a
T2	477.70b	427.44b	661.22a	1566.36c
T3	603.51b	426.02b	560.02a	1589.56c
T4	525.72b	387.61b	585.00a	1498.33c

Lowercase letters represent significant differences between treatments (LSD test, $p < 0.05$)

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Discussion

The study revealed that the fertilization treatment had a significant impact on the growth, yield, product quality, and nutrient accumulation of cherry tomato plants (*Fig. 1, Tables 2-10*). The T1 treatment (without reduction of the chemical fertilizer + application of the humic acid fertilizer) produced the highest fruit yield per plant (1,195.0 g) (*Table 2*). Additional application of the humic acid fertilizer was suggested as a means of balancing cherry tomato yield and product quality. Consistent with the findings of previous studies (Shi et al., 2008; Stoleru et al., 2020; Matos et al., 2021), the organic fertilization of cherry tomatoes increased yield and fruit quality (Shi et al., 2008; Stoleru et al., 2020; Matos et al., 2021). This study demonstrates that the yield and fruit quality of cherry tomatoes could change if the chemical nutrient content was decreased (*Fig. 1; Table 2*). According to Fink et al. (2020), the recommendation of P and K fertilization is essential for increasing cherry tomato yield. Zheng et al. (2020) and Nie et al. (2022) indicated that it is possible to achieve sustainable production of cherry tomatoes through proper fertilization management.

Cherry tomato yield and fruit quality are affected by the proper management of fertilizer (He et al., 2007; Irfanulden et al., 2020). In this study, the changes in yield and fruit quality are related to the nutrient content in the different plant tissues in the cherry tomato plant (*Fig. 1; Tables 2-10*). In general, the SPAD value, biomass, and nutrition accumulations in cherry tomatoes were highly related to the yield (Maria et al., 2017). The SPAD value of the leaf improved in the combination fertilization procedures compared to the CK treatment (*Table 3*). According to a previous study by Vieira et al. (2016), the relative chlorophyll index is significant for the growth status of cherry tomatoes and can be used to predict cherry tomato culture. These results suggested that the fertilization treatments provided suitable nutrient conditions for the cherry tomato plant growth, and ultimately improved the growth and nutrition accumulations in the plant of cherry tomato (*Tables 4-10*). As Bautista et al. (2020) suggested that the nutrients in tomato given to different plant tissue is important. Some studies have reported that the fertilizer application can increase cherry tomato production, and the content of soluble solids, soluble protein, and soluble sugar in tomato fruits (Li et al., 2017; Liu et al., 2020; Wang et al., 2021). Compared with CK, the total nitrogen, phosphorus, and potassium content in different plant tissue and the total nitrogen, phosphorus, and potassium accumulation in plants showed different changes regarding the sampling time and tissue under different fertilization treatments (*Tables 5-10*). The regulation effect due to the fertilization dose is obvious, and was similar to the results of those who reported the different regulation effects under different fertilization doses (Castro et al., 2006; Shi et al., 2008; Vieira et al., 2016; Fink et al., 2020; Frías-Moreno et al., 2020). The T1 treatment showed benefits in the total nitrogen, phosphorus, and potassium content in different plant tissue, and the total nitrogen, phosphorus, and potassium accumulation in plants resulted in higher yield production (*Tables 2* and *5-10*). Therefore, it is suggested that the optimization of fertilization treatment produced higher fruit yield in cherry tomatoes due to the regulation of leaf SPAD value, nutrient uptake, and accumulation.

This study examined the relationship between the yield and fruit quality of cherry tomatoes and their growth (SPAD value and biomass accumulation) as well as the nutrient content and accumulation of various tissues. Overall, the results of this study suggested that a combination of fertilizers could regulate the growth and nutrient accumulation of cherry tomato plants, thereby influencing their yield and produce quality.

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Conclusion

Significant fertilization treatment effects on the growth, yield, fruit quality, and nutrition accumulation of cherry tomatoes were observed in this study. The treatment without reduction of the chemical with the application of the humic acid could balance the yield and fruit quality of cherry tomatoes. The changes in yield and fruit quality are related to the nutrient accumulation of the different plant tissues in the cherry tomato plant.

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