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# Study on Parameters Related to Growth, Yield, and Quality of Strawberry Plants (*Fragaria vesca* L.) Grown Hydroponically and in Soil

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**Abstract:** This study evaluated the effects of soil and hydroponic cultivation on the growth, yield, and quality parameters of Hana strawberry plants (*Fragaria vesca* L.). In the hydroponics method, four nutrient solutions were used: an inorganic Hydro Umat F solution, two types of organic solutions (fish-based soluble fertilizer and Vermicompost soluble fertilizer), and a combination of organic and inorganic nutrients (Hydro Umat F solution and Banana soluble fertilizer in a 1:1 ratio). TN1 substrate was combined with additional fertilization of fish- based soluble fertilizer, which was used in the experiment of growing plants in soil. The results showed that hydroponic cultivation using the Hydro Umat F solution promoted better growth than the other three nutrient solutions, and soil. Specifically, strawberry plants grown in the Hydro Umat F solution had the highest number of leaves per plant, stolons per plant and the largest leaflet size in the experimental groups. Conversely, soil cultivation resulted in higher yield and quality of Hana strawberries, as indicated by parameters such as the number of flowers per plant (29.67) flowers, the number of fruits per plant (20.08) fruits, fruiting rate (67.69)%, fresh weight of fruit (16.25 g), vitamin C content (66.7) mg.100g$^{-1}$ fresh weigh, total organic acid content (159.31) mg.100g$^{-1}$ fresh weight and sweetness index (11.08) °Brix. The results also showed that hydroponic cultivation with organic solutions reduced the growth and yield of Hana strawberry plants compared to inorganic solutions.

**Keywords**: Crop productivity, Hydro Umat F, Nutrient solution, Organic fertilizer, Plant growth.

## Introduction

Strawberries are nutritious fruits containing high concentrations of antioxidant and health-promoting bioactive compounds. They are rich in vitamins (such as vitamin C, B6, B9, K, E, ...), fiber, and minerals (K, Mn, Fe, Cu, P, Mg, ...) (Newerli-Guz *et al*., 2023). The consumption of strawberries has several health benefits, including lowering cholesterol, improving vascular endothelial function, reducing anti-inflammatory biomarkers, and decreasing the risk of oxidative stress-mediated diseases such as cancer (Giampieri *et al*., 2012). In addition to their nutritional and medical significance, strawberries also have significat economic potential. Developing this type of plant can lead to higher economic efficiency compared to other crop-growing models (Liu *et al*., 2016). Strawberries can be propagated through both sexual and asexual methods.

Among these, asexual propagation by in vitro tissue culture is considered the most effective method for producing commercial disease-free seedlings, especially those free from viral diseases (Kadhim & Abdulhussein, 2021).

Growing plants without soil, or hydroponics is a farming technique applicable in high-tech plant-growing models, facilitating the production of safe vegetable crops due to no requirement of pesticides and less water requirement. A few are climate change, urbanization, increased use of fertilizers, and natural calamities that can't be prevented. The hydroponic farming system doesn't need to face factors such as climate change, urbanization, increased use of fertilizers and natural calamities that can't be prevented as this farming system can also be a multi-story farming system only by grounding the stands (Kannan *et al.*, 2022). Compared to soil cultivation, hydroponic system has several advantages such as water conservation, saving spaces, not depending much on climate, year-round production, and higher yields (Upendri & Karunarathna, 2021). Furthermore, this cultivation is becoming more and more well-liked worldwide, in both developed and developing nations, and it is economical, disease-free, and environmentally friendly (Jan *et al.*, 2020).

In hydroponics techniques, nutrient solution is an important factor that directly affects the yield and quality of hydroponic plants. Besides, the optimal nutrient solution depends on the plant species, growth stage, sensitivity to nutritional disorders, and other climatic factors... (Le *et al.*, 2021). Therefore, to successfully apply hydroponic techniques to any plant, it is extremely crucial to determine the appropriate nutrient solution for high yield and ensure plant quality. Currently, most nutrient solutions used in hydroponic systems are inorganic. However, the heavy use of chemical or inorganic fertilizers in agricultural fields, including hydroponics has raised concerns about environmental and human health issues (Upendri & Karunarathna, 2021). In reality, there are some different organic nutrient sources used in hydroponic systems including a wide range of materials derived from animals, plants, and algae. In addition, their effects on plant growth compared to conventional fertilizers are also a topic of research interest (Park & Williams, 2024). Specifically, vermicompost leachate and extract from animal wastes such as fish, chicken, and turkey manure have been used for the cultivation of stevia, lettuce, tomato, and kale in suitable hydroponic system (Bidabadi et al., 2016; Arancon *et al.*, 2019; Tikasz *et al.*, 2019; Ahmed *et al.*, 2021).

Strawberry plants generally thrive in mild temperature and low humidity. According to Nishizawa (2021), strawberry production in East and Southeast Asian countries is quite difficult due to rainy climate. This difficulty has been resolved, and high-quality strawberry fruit has been grown utilizing greenhouse techniques and cultivars that are appropriate for production even in such humid climates. In Vietnam, strawberries are often grown in areas such as Moc Chau (Son La province), Da Lat (Lam Dong province). Ha Noi the capital of Vietnam, has a humid subtropical climate so it is not easy to grow strawberry plants here. However, selecting suitable strawberry varieties and cultivation condition may provide a good solution to this problem.

Strawberry plants often require quite specific growing conditions, such as growing on clean substrates, using little chemical fertilizer to ensure the quality and food safety of fresh fruit (Nguyen Thuy Quy Tu *et al.*, 2016).

Strawberry plants can be grown both in soil and hydroponically (Treftz & Omaye, 2015).

In addition to the environmental benefits, due to the market demand for organic products, the desirable taste of some organic products as well as other health benefits, the interest in organic hydroponics is increasing (Park & Williams, 2024). We hypothesize that organic solutions can be used as a nutrient solution in hydroponic strawberry cultivation or as a soil fertilizer.

Therefore, this study was conducted with the aim of comparing the efficiency of hydroponic strawberry cultivation and soil-grown method based on the use of organic nutrient solutions and inorganic solutions.

## Materials & Methods

### Study area

The experiments were carried out from September 2023 to April 2024 in the greenhouse of the Experimental Garden, Faculty of Biology, Hanoi National University of Education, Hanoi, Vietnam.

The parameters of strawberry plants were determined in the laboratory of the Department of Plant Physiology and Applications within same faculty.

### Materials

This study used the plant materials, *in vitro* three-week-old Hana strawberry plants, provided by Thai Thinh Binh trading company limited, Vietnam.

Four nutrient solution formulas were used in the hydroponic experiment including: Hydro Umat F inorganic nutrient solution; two types of organic nutrient solutions (fish-based soluble fertilizer and Vermicompost solution); one type of organic and inorganic mixed solution (Hydro Umat F and Banana soluble fertilizer at 1:1 ratio). The specific ingredients of the nutrient solutions are as follows:

- Hydro Umat F inorganic nutrient solution

(MTV Gia Vien Hydroponics Co., Ltd, Vietnam) includes 2 parts. Part A: $NO_3^-$ (21.17 $g.L^{-1}$), Ca (32.13 $g.L^{-1}$), $K_2O$ (43.98 $g.L^{-1}$), Fe (EDTA – 0.6 $g.L^{-1}$). Part B: $P_2O_5$ (15.10 $g.L^{-1}$), $K_2O$ (21.99 $g.L^{-1}$), $NO_3^-$ (13.09 $g.L^{-1}$), S (13.31 $g.L^{-1}$), Mg (10.00 $g.L^{-1}$), Mn (190 ppm), B (90 ppm), Zn (29 ppm), Cu (21 ppm), Mo (18 ppm).

- Fish-based soluble fertilizer (APC Co., Ltd, Vietnam) contains organic compounds (20%), total nitrogen (2%), $P_2O_5$ (1%), $K_2O$ (1%), Bo (60 ppm), Cu (50 ppm), Zn (60 ppm), Mn (50 ppm).

- Vermicompost solution (Hiryo Co., Ltd, Vietnam) contains cellulolytic microorganisms (*Bacillus* sp., *Streptomyces* sp., *Trichoderma* spp., *Azotobater* spp.), natural organic, amino acids, essential macro and micro elements for plants.

- Banana soluble fertilizer (OEM company, Vietnam) contains banana juice (80%), soybeans (20%), chicken eggs, Humic and microorganisms (*Bacillus* sp., *Trichoderma* spp., *Saccharomyces* sp.).

All growing solutions were prepared according to the manufacturer's instructions based on dilution from stock solutions.

The study used a static hydroponic system, with nutrient solution stored in styrofoam containers (40 liter capacity), and coconut fiber the growing medium. While in the soil growing experiment, TN1 substrate (Minh Duc Co., Ltd, Vietnam) and nursery pots to grow strawberry plants were used.

**Methods**

**Experimental layout method**

Experiment of growing plant in soil Each *in vitro* three-week-old Hana strawberry plant was grown in a plastic pot containing two kilograms of TN1 substrate (Fig. 1A). The substrate was kept moist by watering daily, with the addition Fish-based soluble fertilizer once a week (30 mL $time^{-1}$). This method made use of sixteen plants. Three times the experiment was conducted.

Experiment of growing plant in hydroponic systems

Three-week-old *in vitro* strawberry plants were planted in net pots (Fig. 1B) in a static hydroponic system using four different solution formulations: Hydro Umat F solution, a mixture of Hydro Umat F solution and banana soluble fertilizer (1:1 ratio), Fish-based soluble fertilizer, and Vermicompost solution.


**Fig. (1): (A) The in vitro three-week-old Hana strawberry plant was grown in a plastic pot containing TN1 substrate and (B) in net pots, (C) Four plants were placed in a box containing nutrient solution.**

Each experiment formulation was designed in four boxes, there were four plants in each box (Fig. 1C). The experiment was repeated three times. The pH level of all nutrient solutions was maintained in the range of 6.0 to 6.5.

## Research methods

**Analytical methods of physiological and growth parameters**

Number of leaves per plant, number of stolons per plant: Count the number of leaves and

**stolons on each plant**

Leaflet size: Use a ruler (with accuracy to 0.1cm) to measure the leaflets. The length was measured from the base of the petiole to the top of the leaflet, and the width was measured at the widest point.

Chlorophyll content: Use the handheld chlorophyll meter SPAD – 502 (Konica Minolta, Japan).

The total chlorophyll content is converted from SPAD units to $mg.dm^{-2}$ according to Richardson A.D.

Total chlorophyll content is calculated according to the formula:

$$Y\ (mg.dm^{-2}) = (5.52\times10^{-4} + 4.04\times10^{-4} + 1.25\times 10^{-5} \times x^2)\times100$$

Where:

Y is the Chlorophyll content ($mg.dm^{-2}$)

x is the SPAD value

All growth parameters were determined 45 days after growing Hana strawberry plants in soil and hydroponic systems.

**Analytical methods for yield parameters**

Number of flowers per plant: Count the number of flowers per plant within 2 months after the first flower appeared.

Number of fruits per plant: Count the number of fruits per plant within 2 months after the first fruit appeared.

Fresh weight of fruit (g): Weight each fruit on an analytical scale with a precision of $10^{-4}$ g. This parameter was determined at the harvested stage.

Fruit size (cm): Use a ruler (with accuracy to 0.1cm) to measure the distance between two fruit edges in length and width. This parameter was also determined when the fruit was ripe, and harvested with at least ¾ of the surface showing a red color.

**Analytical methods for quality parameters**

Sweetness index (Brix): use the Brix meter (DeltaTrak, China) to determine the sweetness index of fruit.

Vitamin C content ($mg.100g^{-1}$ fresh weight): determine by the iodine titration method as described by (Thuy *et al*., 2021).

Total organic acid content ($mg.100g^{-1}$ fresh weight): use Ermacov method described by (Thuy *et al*., 2021).

Nitrate content ($mg.kg^{-1}$ fresh weight): determine by the spectrophotometric method using salicylic acid reagent mentioned in (Nguyen Thi Thu Phuong *et al*., 2020).

**Statistical analysis**

The data were statistically processed using Microsoft Excel and SPSS 16.0 software. The data were processed using one-way ANOVA analysis (Turkey's HSD test) at a significance level of $\alpha = 0.05$.

## Results & Discussion

### Effect of cultivation conditions on some physiological and growth parameters of strawberry plant

The findings in Table 1 demonstrated that strawberry plants produced in hydroponic systems grew more effectively than those grown in soil systems when the effects of several experimental formulations were compared on three growth-related parameters. Strawberry plants grew least in Vermicompost solution and most in Hydro Umat F solution in hydroponic systems.

Specifically, the number of leaves per plant was highest in the hydroponic groups using Hydro Umat F solution and Hydro Umat F solution mixed with Banana soluble fertilizer, with results ranging from 12.92 to 12.58 leaves. This result was higher than the soil growing group (12.33 leaves) and the hydroponic growing using Fish-based soluble fertilizer solution (12.17 leaves). The lowest average number of leaves was measured on strawberry plants grown in Vermicompost solution with an average result of 11.67 leaves, 1.25 leaves lower than the formula using Hydro Umat F solution.

Similar to the number of leaves, the statistical results in Table 1 showed that the number of stolons per plant was divided into 3 groups, the group with the highest number of stolons was still the hydroponic growing formula using Hydro Umat F solution mixed Banana soluble fertilizer and Hydro Umat F solution, with the result ranging from 6.92 to 7.08 stolons. This data was higher than the second group, the formula groups using Fish-based soluble fertilizer and Vermicompost solution, about 4.75 to 4.17 stolons. The number of stolons per plant was lowest in the soil growing formula, with 2.75 stolons. This result was 4.33 stolons lower than formula using Hydro Umat F solution.

Base on analyzing the results of two parameters including the number of leaves and stolons per plant, using inorganic hydroponic solution helped strawberry plants grow significantly better than using organic hydroponic solution such as Fish-based soluble fertilizer and Vermicompost solution. Particularly for the number of stolons, hydroponic growing strongly promoted the breeding process in strawberry plants, creating 2.5 times more stolons than strawberry plants grown in soil. This result suggests suitable cultivation conditions for the purpose of propagating strawberry plant from stolons.

Regarding leaflets size, strawberry plants

grown hydroponically had longer leaflets size than strawberry plants grown in soil. In hydroponic systems, strawberry plants grown in Hydro Umat F solution had the longest leaflets, with an average of 12.33 cm length and 7.08 cm width. The shortest size was strawberry plants grown in soil, with an average of leaflets of 9.58 cm in length and 6.53 cm in width. Strawberry plants grown in the mixed solution showed no significant difference in results compared to strawberry plants grown in Hydro Umat F solution. Strawberry plants grown in Vermicompost solution and Fish-based soluble fertilizer had nearly results, with leaflet lengths ranging from 10.11 to 10.33 cm and widths from 6.81 to 7.35 cm.

Besides the three growth parameters mentioned above, this study also evaluated the influence of cultivation conditions on the total chlorophyll content of strawberry leaves.

Table 1 pointed out that the chlorophyll content of strawberry plants grown in soil was

higher results than plants grown in the four experimental formulas of hydroponic systems. In hydroponic systems, the chlorophyll content of strawberry plants grown in Fish-based soluble fertilizer was the highest, with an average result of 2.72 $mg.dm^{-2}$. This result was 0.5 $mg.dm^{-2}$ lower than the result of strawberry plants grown in soil. While the leaves' chlorophyll content of strawberry plants grown in Hydro Umat F solution had the lowest result (2.05 $mg.dm^{-2}$). Compared to the results obtained by Fernandez-Cabanas *et al*., (2022), the chlorophyll content of strawberry leaves in this study is between the measured value of new and old leaves in converted from the SPAD value.

According to the statistical results, strawberry plants grown in inorganic solutions have longer leaves than those produced in organic solutions, but the color of their leaves is paler than that of plants grown in soil or in organic solutions.

**Table (1): Effect of cultivation conditions on the number of leaves, number of stolons, leaflet size and chlorophyll content in strawberry plants.**

| System | Nutrient | Number of leaves. $plant^{-1}$ | Number of stolons. $plant^{-1}$ | Leaflet size (cm) | | Chlorophyll content ($mg.dm^{-2}$) |
|---|---|---|---|---|---|---|
| | | | | Length | Width | |
| Hydroponic system | Hydro Umat F solution | 12.92 ± 1.68[a] | 7.08 ± 0.79[a] | 12.33 ± 0.59[a] | 7.80 ± 0.49[a] | 2.05 ± 0.26[c] |
| | Hydro Umat F solution + Banana soluble fertilizer | 12.58 ± 1.51[a] | 6.92 ± 0.90[a] | 11.31 ± 0.45[a] | 7.71 ± 0.36[a] | 2.17 ± 0.24[c] |
| | Fish-based soluble fertilizer | 12.17 ± 1.80[b] | 4.75 ± 0.87[b] | 10.33 ± 0.49[b] | 7.35 ± 0.33[b] | 2.72 ± 0.19[a] |
| | Vermicompost solution | 11.67 ± 1.92[c] | 4.17 ± 0.94[b] | 10.11 ± 0.57[b] | 6.81 ± 0.34[c] | 2.67 ± 0.21[b] |
| Soil system | Adding Fish-based soluble fertilizer | 12.33 ± 2.19[b] | 2.75 ± 1.14[c] | 9.58 ± 0.56[b] | 6.53 ± 0.31[c] | 2.76 ± 0.20[a] |

(Values with the same letter in the same column are not statistically significantly different ($\alpha$ = 0.05))

## Effect of cultivation conditions on some yield parameters of strawberry plants

### Number of flowers and fruits of strawberry plant

The results shown in Table 2 demonstrated that strawberry plants grown in soil had more flowers and fruits than those grown hydroponically. In hydroponic systems, strawberry plants grown in Hydro Umat F solution had the most number of flowers and fruits, approximately 25.2 flowers and 17.08 fruits, respectively. In contrast, plants grown in Vermicompost solution had the fewest flowers and fruits, with about 6.2 flowers, 3.17 fruits, respectively. This result was 1/6 of the result of strawberry plants grown in Hydro Umat F solution and is significantly lower than the 51.08 fruits.plant$^{-1}$ results obtained in the study by (Satin *et al*., 2020).

The statistics in Table 2 has showed that the fruiting rate of strawberry plant grown in soil and Hydro Umat F solution were the highest, reaching 67.69%, and 67.21%, respectively. Strawberry plants grown in Vermicompost had the lowest fruiting rate, about 49.35%.

**Table (2): Effect of cultivation conditions on the number of flowers and fruits of strawberry plants.**

| System | Nutrient | Number of flowers. plant$^{-1}$ | Number of fruits. plant$^{-1}$ | Fruiting rate (%) |
|---|---|---|---|---|
| Hydroponic system | Hydro Umat F solution | $25.42 \pm 1.51^{b}$ | $17.08 \pm 1.92^{b}$ | 67.21 |
| | Hydro Umat F solution + Banana soluble fertilizer | $25.08 \pm 1.92^{b}$ | $16.17 \pm 1.36^{b}$ | 64.45 |
| | Fish-based soluble fertilizer | $17.42 \pm 1.85^{c}$ | $11.92 \pm 1.93^{c}$ | 68.42 |
| | Vermicompost solution | $6.42 \pm 0.82^{d}$ | $3.17 \pm 0.69^{d}$ | 49.35 |
| Soil system | Adding Fish-based soluble fertilizer | $29.67 \pm 1.67^{a}$ | $20.08 \pm 1.90^{a}$ | 67.69 |

(Values with the same letter in the same column are not statistically significantly different ($\alpha = 0.05$))

### Fresh weight of fruit

According to the statistical data in Table 3, strawberry plants grown in soil had the heaviest average fresh weight of fruits, with 16.25 g. In contrast, strawberry plants grown

in hydroponic systems using Vermicompost solution had the lowest fresh weight of fruits, with 5.14 g and nearly one-third of those grown in soil. Furthermore, in hydroponic systems, strawberry plants grown in Hydro Umat F solution had the heaviest fresh weight of fruits, about 13.08 g and approximately 2,5 g time as heavy as those grown in Vermicompost solution.

In the study of (Mohammad *et al*., 2016), the

fresh weight of strawberries sold at local markets in Indonesia was divided into three groups, type A had a weight ranging from (12-20) g, type B had a weight of (7-11) g and type C was from (4-7) g. According to the result mentioned in (Satin *et al*., 2020), when growing strawberries on soil using plastic cover, the average fresh weight of fruit was

14.10 g. Compared to the results of this study, it was found that strawberries obtained from soil growing formulas and hydroponic formulas using Hydro Umat F solution and Hydro Umat F mixed with Banana soluble fertilizer reached average to good weight. However, this result is lower than the average weight of strawberries grown in soil (18.20 $g.fruit^{-1}$) using mulching and drip irrigation systems (Antunes *et al*., 2010).

**Fruits size of strawberry plants**

The result presented in Table 3 showed that strawberry plants grown in soil had the highest fruit length and fruit width, measuring 4.12 cm and 3.82 cm, respectively. This result was higher than all experimental solution formulas in hydroponic systems. In hydroponic systems, similar to number of fruits and fresh weight of fruit, the fruit size of strawberry plants grown in Vermicompost solution was still the lowest, with the length and width of 2.67 cm and 2.23 cm, respectively. While the fruits of plants grown in Hydro Umat F solution were the highest in the hydroponic formula group and there was no statistical difference compared to the fruit size of plants grown in soil. Comparing the fruit size of three strawberry varieties, Praratchatan 60, 72 and 80, (Boonyakia *et al*., 2016) found that the length of the fruit ranged from 3.95 to 4.40 cm, while fruit width ranges from 3.43 to 3.51 cm. Thus, it can be seen that the size of Hana strawberries grown in soil in our study is equivalent to the results of this study, while the size of hydroponic strawberries is lower.

**Table (3): Effect of cultivation conditions on fruit size and fresh weight at harvest stage.**

| System | Nutrient | Fruit size (cm) | | Fresh weight of fruit (g) |
|---|---|---|---|---|
| | | Fruit length | Fruit width | |
| Hydroponic system | Hydro Umat F solution | $3.93 \pm 0.62^a$ | $3.05 \pm 0.39^b$ | $13.08 \pm 1.07^b$ |
| | Hydro Umat F solution + Banana soluble fertilizer | $3.64 \pm 0.49^b$ | $3.18 \pm 0.37^b$ | $12.39 \pm 0.96^b$ |
| | Fish-based soluble fertilizer | $3.52 \pm 0.30^b$ | $3.02 \pm 0.46^b$ | $10.21 \pm 1.0^c$ |
| | Vermicompost solution | $2.67 \pm 0.37^c$ | $2.23 \pm 0.31^c$ | $5.14 \pm 0.75^d$ |
| Soil system | Adding Fish-based soluble fertilizer | $4.12 \pm 0.35^a$ | $3.82 \pm 0.23^a$ | $16.25 \pm 1.09^a$ |

(Values with the same letter in the same column are not statistically significantly different ($\alpha = 0.05$))

**Effect of cultivation conditions on some quality parameters of strawberry plants**

In this study, we conducted an assessment of some of the basic parameters related to the quality of strawberry plants, including vitamin C content, total organic acid content, sweetness index and nitrate content. The results are presented in Figure 2 and Table 4.

**Table (4): Effect of cultivation conditions on sweetness index and nitrate content of fruit at the harvest stage.**

| System | Nutrient | Sweetness index (°Brix) | Nitrate content ($mg.kg^{-1}$ FW ) |
|---|---|---|---|
| Hydroponic system | Hydro Umat F solution | 9.92 ± 0.89$^{b}$ | 65.39 ± 2.59$^{b}$ |
| | Hydro Umat F solution + Banana soluble fertilizer | 10.08 ± 0.90$^{b}$ | 62.13 ± 3.62$^{c}$ |
| | Fish-based soluble fertilizer | 10.17 ± 0.72$^{b}$ | 66.62 ± 2.96$^{b}$ |
| | Vermicompost solution | 9.25 ± 0.97$^{c}$ | 55.98 ± 1.05$^{d}$ |
| Soil system | Adding Fish-based soluble fertilizer | 11.08 ± 0.51$^{a}$ | 67.86 ± 1.29$^{a}$ |

(Values with the same letter in the same column are not statistically significantly different (α = 0.05))

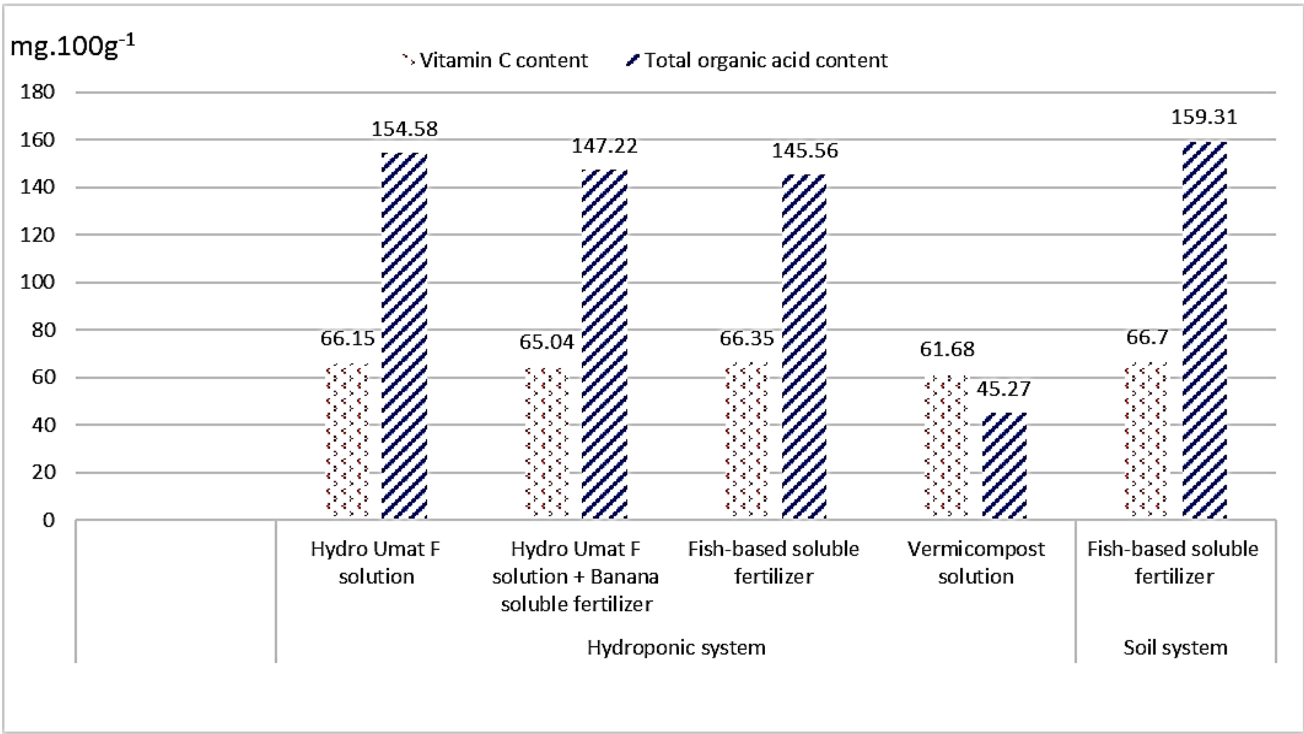


**Fig. (2): Effect of cultivation conditions on vitamin C content and total organic acid content of ripe strawberries.**

### Vitamin C content

The vitamins found in the largest amount in strawberry fruits include vitamin C. The vitamin C content in strawberries ranges widely from 23.16 to 112.34 $mg.100g^{-1}$ fresh weight influenced by many factors, such as climatic and soil factors, fertilizers, strawberry varieties, cultivation methods and post-harvest storage conditions (Newerli-Guz *et al*., 2023). Based on the data in Figure 2, the vitamin C content of strawberries grown in three formulas, including growing in soil, growing hydroponically using Hydro Umat F solution and Fished-based soluble fertilizer was all equivalent, ranging from 66.15 to 66.70 mg.100g$^{-1}$. This result was not significantly higher than the result measured in the formula using Hydro Umat F solution mixed with Banana soluble fertilizer (nearly 65.04 mg.100g$^{-1}$). The vitamin C content of strawberries harvested from strawberry plants grown in Vermicompost solution also reached 61.68, and 5.02 mg.100g$^{-1}$ lower than those grown in soil. This vitamin C content of strawberries grown in soil was higher than vitamin C content of strawberries (supermarket and farmers' market) in the study of (Sabolová & Kouřimská, 2020).

**Total organic acid content**

The results in Figure 2 showed that strawberry plants grown in soil had the highest total organic acid content of fruits among the five experimental formulas, with an average of 159.31 mg.100g$^{-1}$. In hydroponic systems, similar to the sweetness index and vitamin C content of strawberries, strawberry plants grown in Vermicompost solution had the lowest total organic acid content of fruits, nearly 45.27 mg.100g$^{-1}$. While strawberry plants grown in Hydro Umat F solution had the highest total organic acid content of strawberries, with the an average of 154.58 mg.100g$^{-1}$, and three times higher than that of strawberry plants grown in Vermicompost solution.

**Sweetness index of strawberry**

The data in Table 4 illustrated that strawberry plants grown in soil had the highest sweetness index of fruits among the five experimental formulas, with an average value of 11.08 Brix. In hydroponic systems, strawberry plants grown in Fish-based soluble fertilizer had the highest sweetness index of strawberries, nearly 10.17 °Brix and 0.91 °Brix less than those grown in soil. While strawberry plants grown in Vermicompost solution had the lowest sweetness index of fruits, 9.25 Brix. This result is higher than those described in the report of (Fernandez-Cabanas *et al*., 2022), when analyzed the sweetness of strawberries grown in an aquaponic system (with an average sweetness of 8.4 Brix).

The study of Medeiros *et al*. (2015) also showed that the sweetness index of Oso Grande strawberry fruit was 8 Brix. This result is lower than the results for both strawberry plants grown hydroponically and grown in soil in our study. In another study, when evaluating the quality of 13 strawberry varieties grown in winter, Paparozzi *et al*. (2018) showed that the sweetness index of strawberries ranged from 4.16 to 12.94 Brix. Among them, there were 9 varieties with a sweetness index lower than 9.25 Brix, similar to the lowest sweetness index we measured in this study. Differences in climate (especially temperature and light) as well as soil and fertilizer conditions of the experimental area may be responsible for differences in yield and quality of strawberries (Satin *et al*., 2020).

**Nitrate content of strawberry**

The experimental results in Table 4 clearly demonstrated that strawberry plants grown in soil had the highest nitrate content of fruits among five experimental formulas, with an average content of 67.86 mg.kg$^{-1}$. In hydroponic systems, strawberry plants grown in Fish-based soluble fertilizer had the highest nitrate content of strawberries, nearly 66.62 mg.kg$^{-1}$. While strawberry plants grown in Vermicompost solution had the lowest nitrate content of fruits, with an average result of 55.98 mg.kg$^{-1}$, and 10.64 mg.kg$^{-1}$ less than the nitrate content of strawberry plants grown in Fish-based soluble fertilizer.

The nitrate concentration in our study is only around half of that Sabolová & Kouśimská (2020) measured in strawberries from supermarkets (122.39 mg.kg$^{-1}$) and farmer's market (116.63 mg.kg$^{-1}$). Reducing nitrate accumulation in leaf tissue, which is harmful to human health when consumed at high levels, is a potential advantage of using organic nutrients instead of conventional fertilizers high in nitrate (Karwowska & Kononiuk, 2020). Based on research findings, our study's nitrate concentration was at a low level. In light of the nitrate concentration signal, strawberries in our investigation are therefore safe to eat.

Among the nutrient solutions used in this study, the inorganic Hydro Umat F solution contains 12 macro and trace mineral elements in high concentrations, facilitating easy nutrient absorption by the plants. In contrast, the other organic solutions (including Vermicompost solution and Fish-based soluble fertilizer) have diverse nutritional composition, but the nutritional content of elements is low. Additionally, in solution form, they tend to create a scum layer on the surface that hinders oxygen dissolution of the solution. Beneficial microorganisms (including some fungi and bacteria as indicated in the material section above) that participate in decomposing organic matter in the original vermicompost solution may not have been effective in the growing solution. Supplementing this solution into the growing soil may be more effective than using it directly as a nutrient solution in the hydroponic system. This may explain the results obtained in this study, where strawberry plants grown in organic solutions grew slowly and had lower yields than those grown in inorganic solutions and soil.

Growing plants in soil and providing nutrients in an organic form tends to increase the quality of strawberry's fruits compared to using inorganic solutions alone. Ezziddine *et al*. (2020) used an organic solution from sludge treatment in aquaculture to grow lettuce. The results showed that the organic solutions reduced the average fresh weight of plants by 16% compared to the inorganic solution. However, foliar analysis revealed a similar or higher content of all nutrients, except for magnesium and molybdenum in the leaves of lettuce grown in the organic solution compared to those grown in the inorganic solution. This result is quite similar to the results in our study.

## Conclusion

Hydroponic growing using Hydro Umat F solution helped Hana strawberry plants grow better compared to three other nutrient solutions, Hydro Umat F solution mixed with Banana soluble fertilizer, Fish-based soluble fertilizer and Vermicompost solution, as well as compared to soil cultivation. Specifically, strawberry plant had an average of 19.92 leaves, 7.08 stolons and the largest leaf size (12.33 × 7.8 cm).

Growing Hana strawberry plants in soil increased the number of flowers and fruits per plant, as well as the fruiting rate compared to the hydroponic growing method. Strawberries harvested from plants grown in soil also had better quality and was shown by the following parameters: vitamin C content (66.70 mg.100g$^{-1}$), total organic acid content (159.31 mg.100g$^{-1}$), and sweetness index (11.08 Brix).

In hydroponic system, using solely organic solutions including Fish-based soluble fertilizer and Vermicompost solution made strawberry plants grow slowly and have low productivity (number of fruits per plant ranged from 3.1 to 11.9 fruits; fruit weight ranged from 5.14 g to 10.21 g). However, this did not significantly different impact fruit quality compared to using inorganic solutions or mixed organic and inorganic solutions.

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## Contributions of authors

**L.T.T:** Planned study design, advised on sample collection, designed methodology, laboratory analysis, reviewed and revised the manuscript.

**N.T.O**: Collected sample, conducted laboratory analysis, prepared draft manuscript.

**N.P.T:** Conducted laboratory analysis.

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## Conflicts of interest

The authors declare that they have no conflict of interests.

## Ethical approval

All ethical guidelines related to Fish and care issued by national and international organizations were implemented in this report.

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# دراسة المعايير المتعلقة بالنمو والانتاجية وجودة نباتات الفراولة (*Fragaria vesca* L.) المزروعة مائيًا وفي التربة

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**المستخلص:** اجريت الدراسة الحالية لمعرفة تأثير الزراعة في التربة والزراعة المائية على بعض صفات النمو لنبات الفراولة صنف هانا(*Fragaria vesca* L.) باستخدام طريقة الزراعة المائية، تم استخدام أربعة محاليل مغذية، محلول Hydro Umat Fغير العضوي، ونوعان من المحاليل العضوية (سماد قابل للذوبان من الأسماك وسماد قابل للذوبان من الدود، ومزيج من المغذيات العضوية وغير العضوية) محلول Hydro Umat F وسماد قابل للذوبان من الموز بنسبة (1:1 تم دمج ركيزة TN1 مع التسميد الإضافي من سماد الأسماك القابل للذوبان في تجربة زراعة النباتات في التربة .أظهرت النتائج أن الزراعة المائية باستخدام محلول Hydro Umat F حسنت النمو بشكل أفضل مقارنة بالمحاليل المغذية الثلاثة الأخرى والتربة سجلت نباتات الفراولة المزروعة في محلول Hydro Umat F اكبر عدد من الاوراق والسيقان لكل نبات ، وأكبر حجم للأوراق قياسا بالمعاملات الاخرى، كما أدت الزراعة في التربة إلى إنتاجية وجودة أعلى من فراولة صنف هانا، وحسب الصفات المدروسة مثل عدد الأزهار لكل نبات (29.67) زهرة، وعدد الثمار لكل نبات (20.08) ثمرة، ومعدل الإثمار(67.69 )%، والوزن الطازج للثمار (16.25)غم، ومحتوى فيتامين C (66.7 ملغم )100 غم$^{-1}$ وزن طازج، والحموضة الكلية القابلة للتعادل (159.31) ملغم 100 غم$^{-1}$ وزن طازج، ومؤشر الحلاوة (11.08) درجة بريكس .كما أظهرت النتائج أن الزراعة المائية باستخدام المحاليل العضوية قللت من نمو وإنتاجية نباتات الفراولة صنف هانا مقارنة باستخدام المحاليل غير العضوية.

**الكلمات المفتاحية** :إنتاجية المحاصيل،Hydro Umat F ، محلول المغذيات، سماد عضوي، نمو النبات.