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Optimization of Dutch Bucket Method in Melon (*Cucumis melo* L.) Plant Culture with Variations of Nutrition, Bucket, and Pruning

Anif Yuni Muallifah[1]*, Muhammad Ikhwan Ardiansyah[1], Budurul Fadhilah[2]

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ABSTRACT

This study aimed to evaluate the effects of nutrient concentration, bucket size, and pruning on the growth and yield of melon plants (Cucumis melo L.). The experiment was arranged using a completely randomized design (CRD) with a factorial design consisting of three factors: nutrient concentration (1500 and 2000 ppm), bucket size (large and small), and pruning (pruned and unpruned). The research stages included greenhouse sterilization, installation of a modified Dutch bucket system with four nutrient outlet holes, seedling, planting, maintenance, and harvesting. Data were analyzed using analysis of variance (ANOVA), followed by Tukey's post hoc test at a 95% confidence level. The results showed that the modified Dutch bucket system functioned effectively, with efficient nutrient circulation. The environmental conditions in the greenhouse ranged from 31.3°C to 39.7°C, relative humidity from 30% to 59.3%, and light intensity from 2445.7 to 23651.7 lux. Nutrient concentration significantly affected plant height, leaf width, root fresh weight, fruit weight, fruit diameter, and fruit sweetness, whereas bucket size significantly influenced fruit weight, fruit diameter, and fruit sweetness. Pruning significantly affected only the plant height. The best treatment was 1500 ppm nutrient concentration using a large bucket without pruning, producing the highest values for leaf width (27.2 cm), root fresh weight (112.44 g), fruit weight (1517 g), fruit diameter (47 cm), and fruit sweetness (10.67 °Brix). These findings indicate that optimal nutrient concentration and bucket size are key factors for improving melon productivity under hydroponic conditions.

Keywords: ***Cucumis melo*** **L, Dutch bucket, greenhouse, hydroponics, nutrients**

INTRODUCTION

Hydroponic melon cultivation is becoming increasingly popular as an alternative method for boosting production on limited land. Hydroponic systems allow for precise control of growth factors, such as nutrients, pH, temperature, and the environment, thereby potentially increasing productivity and crop quality (Velazquez-Gonzalez *et al.* 2022; Savvas *et al.* 2023). One widely used method is the Dutch bucket system, which is efficient in terms of water and nutrient use and is suitable for intensive horticultural cultivation (Bhat *et al.* 2023; Yang *et al.* 2023).

However, implementation at the farmer level still faces various technical challenges that prevent productivity from reaching its full potential. In the field, hydroponic farmers generally use buckets of inconsistent sizes (for example, 8–20 L) and apply varying nutrient concentrations without clear guidelines. These conditions result in uneven plant growth, limited root development and fluctuating crop yields. Several reports indicate that limitations in root medium volume can hinder nutrient and water uptake, thereby reducing growth efficiency and crop yield (Lee *et al.* 2023). Furthermore, improper nutrient management can lead to nutrient imbalances, which in turn affect productivity (Chairudin *et al.* 2024).

Physiologically, plant growth in hydroponic systems is strongly influenced by the interaction between nutrient concentration and root zone capacity. Nutrients play a vital role in supporting the development of plant organs, such as roots, stems, leaves, flowers, and fruits (Abdul Rahim *et al.* 2024; Malviya *et al.* 2020). The size of the bucket, as a representation of the root zone volume, determines the availability of growing space, aeration, and water retention capacity, which directly influences nutrient uptake (Raviteja *et al.* 2021; Yang *et al.* 2023). Therefore, the size of the bucket serves not only as a container but also as a key factor that can determine the efficiency of the hydroponic system.

In contrast, pruning techniques are used to regulate the distribution of photosynthates and improve fruit quality. Several studies have reported that pruning can increase crop yield (Nilakandi *et al.* 2024), yet conflicting results have also been found, where pruning

[1] Integrated Laboratory Sunan Kalijaga State Islamic University Yogyakarta, Special Region of Yogyakarta 55281, Indonesia
[2] Biology Study Program, Faculty of Science and Technology, Sunan Kalijaga State Islamic University Yogyakarta, Special Region of Yogyakarta 55281, Indonesia
* Corresponding Author:
Email: anif.muallifah@uin-suka.ac.id

had no significant effect on melon growth (Siregar *et al.* 2020). This indicates that the effectiveness of pruning is highly dependent on cultivation conditions and their interaction with other factors.

Although various studies have examined the effects of nutrition, container size, and pruning, most have been conducted in isolation or in limited combinations. However, these approaches have not been able to explain the complex interactions between factors, nor have they produced practical recommendations for field conditions. Consequently, research findings are often applicable only under specific experimental conditions, and it is difficult for farmers to implement them on a wider scale.

The novelty of this study lies in its integrative approach, which evaluates the interactions between nutrient concentration, container size, and pruning techniques within a single experimental design, while positioning container size as the primary factor directly determining root zone capacity and fertigation system efficiency. Furthermore, this study not only identifies the statistically best treatment but also considers practical field applications through the interpretation of the results based on growth efficiency and potential for practical implementation. Thus, this study is expected to bridge the gap between experimental results and technical cultivation needs at the farmer level.

This study aimed to analyze the effects and interactions of nutrient concentration, bucket size, and pruning techniques on the growth and yield of melon plants in a Dutch bucket hydroponic system and to determine the most optimal treatment combination with the greatest potential for practical application in the field.

METHODS

Study Site and Materials

This study was conducted in a greenhouse from May to September 2024 at the Integrated Laboratory of UIN Sunan Kalijaga, Yogyakarta. The materials used included melon (Cucumis melo L.) seeds of the Golden New Kinanti variety (PT Tunas Agro; Ministerial Decree No. 503/Kpts/SR.120/9/2007), AB mix nutrient solution, cocopeat seedling medium, and clean water were used. The equipment used included a Dutch bucket hydroponic system, buckets of two sizes, pH meter, EC meter, thermometer, hygrometer, lux meter, digital scales, and plant growth measurement tools.

Experimental Design and Treatments

The experimental design employed a Completely Randomised Design (CRD) with three factors: nutrient concentration, bucket size, and pruning technique. This resulted in 8 treatment combinations (2 × 2 × 2), each repeated three times, giving a total of 24 experimental units (plants). The nutrient solution concentrations were 1500 and 2000 ppm. The nutrient solution was prepared using AB mix (Baraponik), which contained macro-nutrients (N, P, K, Ca, Mg, S) and micro-nutrients (Fe, Mn, B, Zn, Cu, Mo). These nutrients were formulated into stocks A and B to prevent precipitate formation. The AB mix nutrient solution was prepared by mixing stock A and stock B in a ratio of 5 ml stock A: 5 ml stock B: 1 L of water to achieve a nutrient solution concentration of 1000 ppm. Furthermore, the buckets used in this study were of large and small sizes. The large bucket measured 43.5 × 32.5 × 14.5 cm (L × W × H) with a nutrient solution capacity of 20 litres, whereas the small bucket measured 36 × 29 × 12.5 cm (L × W × H) with a nutrient solution capacity of 13 L. Four output holes were made in each bucket for nutrient solution circulation (Figure 1). Another treatment involved pruning and non-pruning of plant tips and lateral branches.

Experimental Procedures

The research began with cleaning the greenhouse using a disinfectant. Next, Dutch bucket systems were installed, each measuring 3.5 m × 1 m × 2 m, comprising two units. This was followed by sowing the seeds in cocopeat until they were approximately 10–14 days old or had 2–3 true leaves. The AB mix nutrient

(a) (b) (c) (d)

Figure 1 (a) bucket design on hydroponic system (b) installation of dutch bucket hydroponic system (c) melon plant growth on dutch bucket hydroponic system (d) melon fruit cultivated using dutch bucket hydroponic system.

solution was prepared according to the treatment concentrations of 1500 and 2000 ppm. Next, melon seedlings were planted in a Dutch bucket hydroponic system. Subsequently, plant maintenance is carried out, including pest and disease control, staking, and pruning in accordance with the treatment, namely, pruning of lateral branches and the plant's apical portion above the 25th leaf node, and pollination. The final stage involves harvesting, which is carried out based on maturity indicators: the fruit is a perfect yellow color, a characteristic melon aroma is present, the nearest leaves begin to dry out, and the fruit stalk turns yellowish.

Observation Parameters

The observation parameters in this study included environmental parameters (temperature (°C), humidity (%), and light intensity), nutrient solution (solution pH and solution temperature), plant growth (plant height (cm), leaf width (cm), root length (cm), root weight (g)), and crop yield (fruit weight (g), fruit diameter (cm), and sugar content (°Brix)). Observations of environmental and nutrient solution parameters were performed every two days.

Temperature and humidity measurements were taken using a thermohygrometer placed at the study site. Every two days, the temperature and humidity readings displayed on the thermohygrometer were recorded. The light intensity was measured using a lux meter. The solution temperature was measured using a thermometer, and the solution pH was measured using a pH meter.

Data Analysis

All observational data were analyzed using Analysis of Variance (ANOVA), followed by Tukey's post hoc test at 95% confidence levels using GraphPad Prism 10.4.0 software.

RESULTS AND DISCUSSION

Hydroponic cultivation systems for horticultural crops have been widely recognized for their ability to enhance productivity and improve crop quality. However, the success of such systems is strongly influenced by the interaction between environmental conditions, nutrient solution management, and the cultivation method applied (Anand *et al.* 2020; Savvas *et al.* 2023). In this study, these factors were evaluated in an integrated manner to determine their influence on the growth and yield of melon plants cultivated using a modified Dutch bucket system.

Environmental Parameters

The greenhouse environment showed daily fluctuations in temperature, relative humidity, and light intensity, which are critical factors that influence plant growth and fruit development (Figure 2). The recorded temperature ranged from 31.3°C to 39.7°C, with an average of 35.3°C (Table 1). This range exceeds the optimal temperature requirement for melon cultivation, which is between 29.86°C and 32.42°C (Aulia *et al.* 2022). Elevated temperatures can increase plant respiration rates, leading to a reduction in net photosynthate accumulation, which is essential for growth and fruit development (Heo *et al.* 2024). Furthermore, high temperatures increase the transpiration rate, potentially causing water stress and reducing plant physiological efficiency.

The relative humidity in the greenhouse ranged from 30% to 47.4%, which is significantly lower than the optimal range of approximately 68–76% for melon cultivation (Aulia *et al.* 2022). Low humidity accelerates

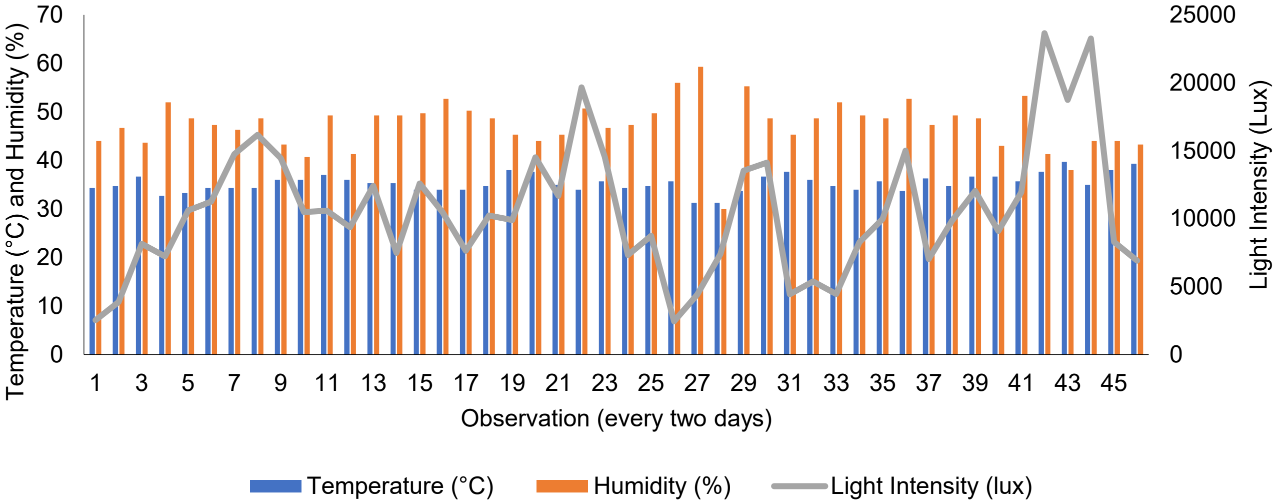

Figure 2 Environmental profile of the integrated laboratory greenhouse at UIN Sunan Kalijaga Yogyakarta.

Table 1 Observation results of environmental parameters in the greenhouse at UIN Sunan Kalijaga Yogyakarta

Measurement result	Temperature (°C)	Humidity (%)	Light intensity (lux)
Lowest score	31.3	30.0	2445.7
Highest score	39.7	59.3	23651.7
Average	35.3	47.4	10585.1

transpiration, leading to an imbalance between water uptake and water loss. This condition may reduce stomatal efficiency and limit photosynthesis, ultimately affecting the biomass accumulation and fruit quality. Conversely, higher relative humidity has been associated with increased accumulation of sugars and amino acids, contributing to improved fruit quality (Diao *et al.* 2022). Therefore, the relatively low humidity observed in this study likely limited optimal plant performance.

Light intensity ranged from 2,445.7 to 23,651.7 lux, with an average of 10,585.1 lux (Table 1). This range falls within the optimal requirements for melon growth (1,000–30,000 lux), indicating that light availability was generally sufficient for photosynthesis (Utami *et al.* 2023). However, under high temperature and low humidity conditions, increased light intensity may exacerbate transpiration and reduce photosynthetic efficiency. This highlights the importance of maintaining a balanced microclimate, rather than optimizing a single environmental factor.

Nutrient Solution Parameters

The nutrient solution is a critical component of hydroponic systems, as it directly affects nutrient availability and plant uptake efficiency (Figure 3). In this study, the pH of the nutrient solution ranged from 5.0 to 6.8 (Table 2), which is close to the optimal pH level of approximately 6.0 for melon growth (Da Silva *et al.* 2019). This indicates that the nutrient availability was generally within a favorable range.

However, the temperature of the nutrient solution ranged from 24.70°C to 37.50°C, exceeding the recommended range of 18–25.2°C (Muchtar & Fitriati 2023). Elevated solution temperatures can significantly reduce the dissolved oxygen levels, thereby limiting root respiration and nutrient uptake efficiency (Bhat *et al.* 2023). This issue is further compounded by the high ambient temperatures within the greenhouse, which contribute to increased solution temperatures.

These findings suggest that although the chemical properties of the nutrient solution (pH) were within the optimal range, physical factors such as temperature played a limiting role in lettuce growth. Efficient nutrient uptake depends not only on nutrient availability but also on root health, which is highly influenced by oxygen availability and temperature.

Dutch Bucket System Performance

The Dutch bucket system used in this study was modified by incorporating four nutrient outlet holes (Figure 1) instead of the conventional single-outlet design. This modification improved nutrient circulation and aeration, ensuring the efficient reuse of excess nutrient solutions without wastage. Improved aeration is particularly important for maintaining adequate oxygen levels in the root zone, which supports root respiration and nutrient absorption (Al-Rawahy *et al.* 2019).

Bucket size was identified as a key factor influencing plant growth. The large bucket (20 L capacity) provided a greater root volume than the small bucket (13 L capacity), allowing for enhanced root development and improved nutrient uptake. Larger buckets also contributed to greater stability in the nutrient solution conditions, including temperature and nutrient concentration. This finding is consistent with previous studies, indicating that larger containers promote better root expansion and nutrient absorption (Lee *et al.* 2023; Yang *et al.* 2023).

Plant Growth and Yield

The results of this study indicate that nutrient concentration significantly affected most growth and yield parameters, including plant height, leaf width, root fresh weight, fruit weight, fruit diameter, and fruit sweetness. This confirms the critical role of nutrient availability in supporting plant growth and productivity (Abdul Rahim *et al.* 2024). In contrast, root length was not significantly affected, suggesting that root elongation may be less sensitive to nutrient concentration than other growth parameters.

Bucket size significantly influenced fruit-related parameters, including fruit weight, diameter, and sweetness. This indicates that the root environment plays an important role in determining photosynthate allocation to fruit development. Larger buckets likely provide more stable conditions for nutrient uptake, thereby supporting better fruit growth.

Pruning had a limited effect, significantly influencing only the plant height. This suggests that pruning may not be a dominant factor in the environmental conditions of this study. The effectiveness of pruning is often dependent on the balance between the source (leaf area) and sink (fruit), which may be disrupted under stress conditions, such as high temperature and low humidity (Siregar *et al.* 2020).

Tukey's post-hoc test identified the optimal treatment combination as a nutrient concentration of 1500 ppm, using a large bucket, and no pruning. This treatment resulted in the highest values for leaf width (27.2 cm), root fresh weight (112.44 g), fruit weight (1517 g), fruit diameter (47 cm), and fruit sweetness (10.67 °Brix) (Table 3). The fruit sweetness value

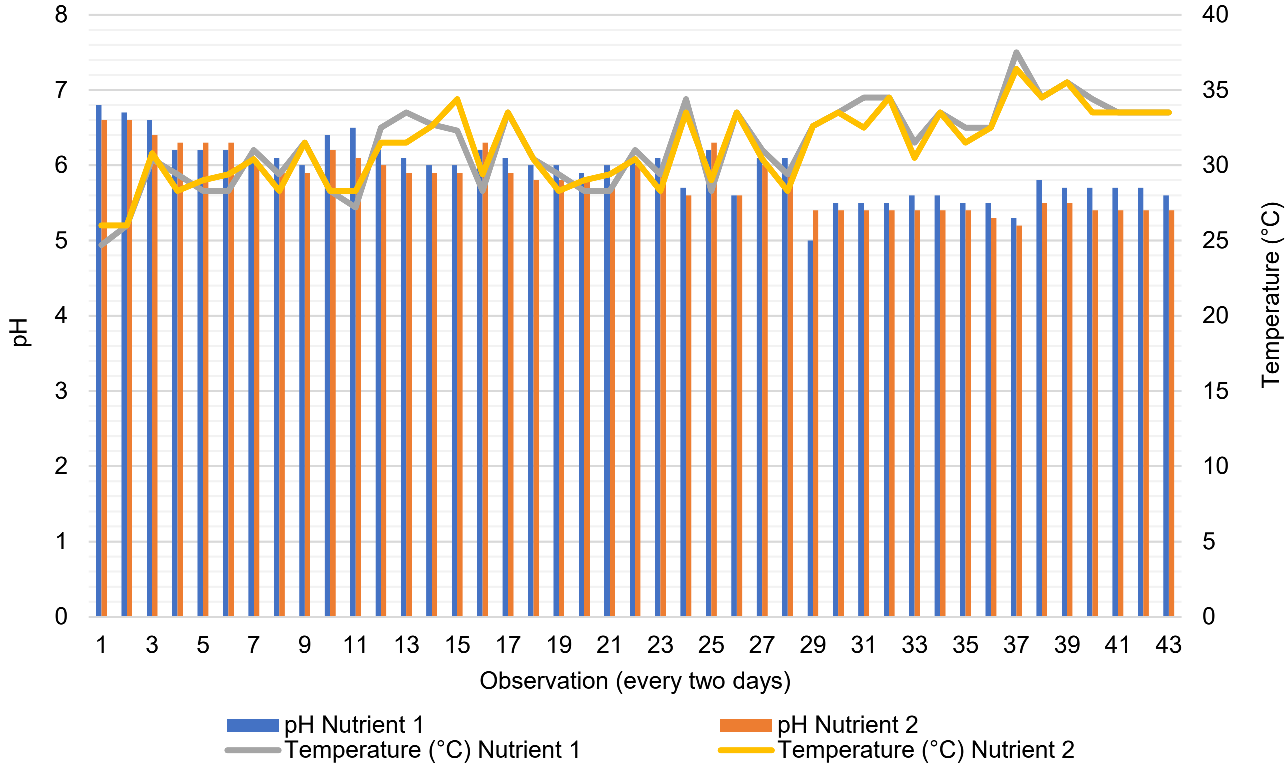

Figure 3 Observation profile of the dutch bucket system nutrient solution in the integrated laboratory greenhouse at UIN Sunan Kalijaga Yogyakarta.

Table 2 Results of pH and temperature measurements on AB mix nutrient solution in the dutch bucket system

Measurement result	pH		Temperature (°C)	
	Nutrisi 1	Nutrisi 2	Nutrisi 1	Nutrisi 2
Lowest score	5.00	5.20	24.70	26.00
Highest score	6.80	6.60	37.50	36.40
Average	5.94	5.81	31.35	31.19

Note: Nutrient 1: 1500 ppm and nutrient 2: 2000 ppm.

meets the general market standard of ≥10–14 °Brix, indicating acceptable to good quality fruit (Velazquez-Gonzalez *et al.* 2022; Savvas *et al.* 2023).

The superior performance of the 1500 ppm treatment suggests that moderate nutrient concentrations are more effective than higher concentrations (2000 ppm). Excessive nutrient concentrations can increase osmotic pressure, reduce water uptake, and potentially cause nutrient imbalances. Conversely, insufficient nutrient levels may limit plant growth owing to inadequate nutrient availability (Pratiwi *et al.* 2023; Rahmawati *et al.* 2024).

Interaction of Treatments

The interaction among nutrient concentration, bucket size, and pruning was not statistically significant, indicating that each factor acted independently to influence plant growth and yield. However, the effectiveness of each factor was influenced by environmental conditions and nutrient solution parameters.

High temperature and low humidity conditions increase plant transpiration rates, thereby increasing water and nutrient demand. Simultaneously, elevated nutrient solution temperatures reduced oxygen availability, limiting root function and nutrient uptake. Under these conditions, larger buckets played a crucial role in providing a more stable root environment, helping to mitigate the negative effects of environmental stress.

The limited effect of pruning may be attributed to its dependence on the physiological balance of the plant, which is strongly influenced by environmental conditions. Under stress conditions, factors such as nutrient availability and root capacity may have a more dominant influence on plant performance than that of canopy management practices.

The results of this study demonstrate that the productivity of melon plants in a Dutch bucket hydroponic system is determined by the complex interaction between environmental conditions, nutrient solution characteristics, and cultivation practices. Suboptimal environmental conditions, particularly high

Table 3 Results of growth and production in melon plants using the dutch bucket system

Treatment	Plant height (cm)	Leaf width (cm)	Root length (cm)	Root wet weight (g)	Fruit weight (g)	Fruit diameter (cm)	Fruit sweetness (brix)
N1BP (Nutrient 1500 ppm; Big Bucket; Pruning)	278.3 ^{bc}	25.5 ^{ab}	64.67 ^{ab}	63.38 ^{a}	1025 ^{ab}	40.33 ^{ab}	8.4 ^{ab}
N1BTP (Nutrient 1500 ppm, Big Bucket, Non Pruning)	383.7 ^{a}	27.17 ^{a}	64.67 ^{ab}	112.44 ^{a}	1517 ^{a}	47 ^{a}	10.67 ^{a}
N1KP (Nutrient 1500 ppm; Small Bucket; Pruning)	235 ^{c}	25.8 ^{ab}	51.67 ^{b}	107.01 ^{a}	983 ^{ab}	40.5 ^{ab}	8.53 ^{ab}
N1KTP (Nutrient 1500 ppm; Small Bucket; Non Pruning)	409 ^{a}	22.33 ^{ab}	61 ^{ab}	59.12 ^{a}	683 ^{ab}	34 ^{ab}	6.93 ^{ac}
N2BP (Nutrient 2000 ppm; Big Bucket; Pruning)	244.7 ^{c}	23.17 ^{ab}	52.67 ^{ab}	29.80 ^{a}	608 ^{b}	31.73 ^{b}	4.77 ^{bc}
N2BTP (Nutrient 2000 ppm; Big Bucket; Non Pruning)	334.7 ^{ac}	22.83 ^{ab}	68.67 ^{ab}	46.06 ^{a}	1158 ^{ab}	39.5 ^{ab}	7.2 ^{ac}
N2KP (Nutrient 2000 ppm; Small Bucket; Pruning)	234.7 ^{c}	20.83 ^{b}	74.67 ^{a}	32.59 ^{a}	500 ^{b}	29.17 ^{b}	4.07 ^{c}
N2KTP (Nutrient 2000 ppm; Small Bucket; Non Pruning)	353.7 ^{ab}	22.5 ^{ab}	64 ^{ab}	44.59 ^{a}	817 ^{ab}	37.43 ^{ab}	5.83 ^{bc}

Note: Different letters indicate significant differences between means within columns at the 5% probability level according to Tukey test.

temperatures and low humidity, act as limiting factors that reduce the efficiency of photosynthesis and nutrient uptake.

Among the factors evaluated, nutrient concentration and bucket size were identified as the most important variables. The use of a moderate nutrient concentration (1500 ppm) combined with a larger bucket size provided the most favorable conditions for plant growth and fruit development in this study. These conditions helped optimize nutrient availability, root function, and fruit quality, even under suboptimal environmental conditions.

Therefore, achieving optimal results in hydroponic melon cultivation requires an integrated management approach that considers environmental control, nutrient solution management, and appropriate cultivation practices. This approach is essential for enhancing productivity and ensuring the production of high-quality fruits that meet market standards.

CONCLUSION

Based on the results of this study, we conclude that nutrient concentration, bucket size, and pruning treatment significantly influence melon plant growth and yield. Nutrient concentration affected plant height, leaf width, root fresh weight, fruit weight, fruit diameter, and fruit sweetness, whereas bucket size influenced fruit weight, fruit diameter, and fruit sweetness. In contrast, pruning treatment only had a significant effect on plant height. However, the interaction among the three factors (nutrient concentration, bucket size, and pruning) was not statistically significant, indicating that each factor contributed independently to plant response without synergistic effects under the experimental conditions used. The optimal treatment combination was achieved at 1500 ppm AB mix nutrient concentration using a large bucket without pruning, which consistently resulted in the best performance across most of the growth and yield parameters.

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