PREPRINT

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Optimizing Growth of Melon (*Cucumis melo* L. cv. Madesta) in Nutrient Film Technique and Drip Irrigation Hydroponics with Varied Substrates

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ARTICLE INFO

Article history:
Received: 16 March 2024
Accepted: 05 April 2024
Published: 25 October 2024

DOI: https://doi.org/10.47836/pjtas.47.4.09

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ABSTRACT

Hydroponic systems offer a promising solution for urban farming and the utilization of unproductive land. Successful implementation, however, requires careful optimization to select the most effective hydroponic system tailored to specific plants and environmental conditions. This study aims to compare the growth and physiological responses of Madesta melons (*Cucumis melo* L. cv. Madesta) cultivated using the nutrient film technique (NFT) and drip irrigation system (DIS) with variations in growth media. The Madesta melon seeds underwent a two-week germination phase in coco peat media, followed by transplanting

ISSN: 1511-3701
e-ISSN: 2231-8542

into NFT and DIS setups utilizing diverse growth media, including rice husk, rice husk mixed with compost, and compost only. Over four weeks post-cultivation, assessments were conducted on key growth metrics such as leaf count, leaf diameter, plant height, and stem diameter. Plant physiological responses were also analyzed, encompassing chlorophyll and nitrogen levels, along with the mineral composition within leaves and fruits. Results revealed that the DIS cultivation outperformed the NFT in terms of growth outcomes. Among the varied media combinations, the rice husk and compost blend supported growth most effectively. Notably, no significant differences were observed in leaf and fruit nitrogen content between the DIS and NFT systems, and the overall mineral content of the media remained relatively stable before and after the cultivation period. Mineral content analysis revealed calcium as the predominant element in the leaves, while potassium emerged as the most abundant mineral in the fruits. This research sheds light on the potential of hydroponic systems, specifically the DIS method, for enhancing melon cultivation, emphasizing the importance of selecting appropriate growth media to maximize plant growth.

Keywords: Agricultural innovation, drip irrigation system, hydroponic, melon, nutrient film technique

INTRODUCTION

Rapid industrialization caused the reduction of cultivable land and the degradation of farming land due to water pollution from industrial waste and excessive fertilization. A hydroponic system is an excellent solution to address both water conservation and over-fertilization issues. Hydroponics is a method of growing plants without soil, using a nutrient-rich water solution to deliver essential minerals directly to the plant roots. This system offers several benefits, including water efficiency, precise nutrient delivery, space efficiency, faster growth, and higher yields compared to traditional methods (Velazquez-Gonzalez et al., 2022). Several hydroponic farming methods include drip irrigation system (DIS) and nutrient film technique (NFT). Drip irrigation systems involve fertigation systems; in this process, fertilizer and nutrients are dissolved and distributed along with water in drip irrigation (P. Yang et al., 2023). In a hydroponic NFT system, nutrients are supplied to plants by a steady stream of water that forms a 2–3 mm thin film of a nutrient-rich layer. The nutrient supplied to plants is composed of inorganic compounds that produce nutritional ions when dissolved in water (Sharma et al., 2018; Syarifudin et al., 2023).

Various fruits and vegetables have been cultivated using the hydroponic system. For tomatoes, comparisons among NFT, DIS, and the floating raft system revealed superior performance in DIS (Schmautz et al., 2016). Deep water culture produced the highest yield in a lettuce comparative study, while NFT showcased superior water efficiency over conventional soil-based cultivation methods (Majid et al., 2021). Both hydroponic systems produced significantly higher yield and nutritional content than soil-based cultivation. Deep water culture was also reported to produce tomatoes with higher beta-carotene and lycopene contents compared to DIS and soil-based cultivation (Verdoliva et al., 2021). Collectively, these findings indicate that adopting a hydroponic cultivation system has the potential to enhance crop productivity. Moreover, selecting the appropriate hydroponic system is crucial in achieving optimal results.

In addition to the choice of hydroponic system, the selection of growth media within the system can also substantially impact plant productivity. The choice of media substrate directly influences factors such as root development, nutrient availability, water retention, and aeration, which can collectively affect plant productivity. For example, a coco peat and perlite blend proved most effective when assessing hydroponic substrates for green pepper yield. Additionally, for cucumber cultivation, the pine substrate yielded the highest produce and enhanced the production of essential phytochemicals (Majid et al., 2021; T. Yang et al., 2023).

It is crucial to optimize the system by carefully selecting suitable systems and media substrates tailored to specific plants and environmental conditions to achieve optimal outcomes in hydroponic cultivation. Melon agriculture holds significant economic value globally due to its widespread consumption, market demand, and export potential. While hydroponic systems are widely studied for melon cultivation, research on optimizing the system and growth media remains limited. Additionally, there is a lack of work comparing the DIS and NFT for melon cultivation, especially with varying media in DIS. This study conducts a comprehensive comparison of DIS and NFT for melon cultivation, evaluating outcomes with environmentally friendly, cost-effective, and readily available growth media: rice husk (a rice farming by-product) and compost (from plant and animal waste decomposition) (Gruda, 2019).

MATERIALS AND METHODS

Materials

This research used the melon cultivar Madesta (*Cucumis melo* L. cv. Madesta), AB mix nutrients (Hidroponik Surabaya, Indonesia), rice husk and compost. The equipment used for the research includes a greenhouse, drip irrigation and nutrient film technique installation system, a UV-Vis spectrophotometer (Thermo Scientific, USA), and an X-ray fluorescent analyzer (Malvern Panalytical, United Kingdom).

Experiment Design

Melon was cultivated in a greenhouse using two hydroponic systems: drip irrigation (DIS) and nutrient film technique (NFT). The average temperature inside the greenhouse across the day is relatively stable, between 26–29°C, while humidity is between 67–93%. In DIS, three different growth media were used: rice husk, a mix of rice husk and compost (1:1), and compost only. The melon seed was first germinated in coco peat media for two weeks. The seedling was transferred to the NFT system and DIS using three different media. In the DIS, AB mix nutrient was supplied to the plant every 5 hr through drip irrigation for 10 min. The AB mix concentration provided to the plants was 750 mg/L in the first and second week of cultivation, 1,000 mg/L in the third week, 1250 mg/L in the fourth week, 1,500 mg/L in the fifth week, and 2,000 mg/L in the sixth week of cultivation. In the NFT system, the AB mix nutrient was supplied continuously to the plants, with the same concentration as used in the DIS. The melon plant was cultivated for a total of 70 days before harvesting. In the fourth week of cultivation, growth parameters were recorded, including leaf number, leaf diameter, plant height, stem diameter, and fruit fresh weight. Following the harvest, physiological parameters were measured, including leaf chlorophyll content, fruit sugar and nitrogen content, and nitrogen level and mineral content in the media before and after cultivation.

Measurement of Melon Growth Rate

Melon growth parameters were measured every week, from the first week of cultivation in the DIS and NFT system to the fourth week. The growth parameters measured include plant height, leaf number, leaf diameter, and stem diameter.

Measurement of Leaf Chlorophyll Content

For each treatment, as much as 0.2 g of leaves were collected from three plants. Next, the leaf samples were homogenized, and 10 ml of cold acetone was added. The processed samples were filtered and centrifuged at 4,500 x *g* for 5 min to separate the supernatant. The resulting supernatant was then pipetted into a glass cuvette, and the absorbance was measured at 645 and 662 nm using a UV-Vis spectrophotometer (Thermo Scientific, USA). The chlorophyll content was then calculated using the following equation (Aremu et al., 2012):

$$\text{Chlorophyll } \alpha = (11.24 \times A662) - (2.04 \times A645) \quad (1)$$

$$\text{Chlorophyll } b = (20.13 \times A645) - (4.19 \times A662) \quad (2)$$

$$\text{Total chlorophyll} = (7.05 \times A662) + (18.09 \times A645) \quad (3)$$

Measurement of Total Nitrogen Content

As much as 0.1 g of dried samples were mixed with 1 g of copper sulfate and 2.5 ml of sulfuric acid. The mixture was then heated for 1 hr using a water bath. The processed samples were then transferred to a distillation flask, and 10 ml of 40% sodium hydroxide (Merck, USA) and 50 ml of distilled water were added; the mixture was then distilled until the volume reached 40 ml. Next, 10 of 0.02 M chloric acid (Merck, USA) was added with 4 drops of red and blue methylene indicators (Merck, USA). The mixture was then titrated by adding 0.02 M sodium hydroxide (Merck, USA) until the solution turned bright green.

Mineral Content Measurement

As much as 1 g of dried extract was analyzed using an X-ray fluorescent analyzer (Malvern Panalytical, United Kingdom) at 24.7°C and 67% humidity. Two replicates were used to measure the mineral content in each sample.

Data Analysis

Except for the measurement of mineral content, all measurements were conducted using five to ten independent replicates. The analysis output was presented as mean value ± SD and statistical analysis was performed using two-way analysis of variance (ANOVA) with Duncan's new multiple range test by Statistical Product and Service Solutions (SPSS) software (version 20.0). A probability (*p*-value) of less than 0.05 was considered statistically significant.

RESULTS

Melon Cultivation within A Drip Irrigation System, Utilizing A Blend of Rice Husk and Compost, Resulted in Optimal Growth

Overall, the growth measurement data showed that the DIS system has a better effect on melon growth than the NFT system. In the fourth week of the cultivation, melons that were grown using DIS showed higher plant height, number of leaves, leaf diameter, and stem diameter (Figure 1). In the first to fourth week of cultivation, leaf numbers in melons cultivated in NFT are lower than in melons cultivated in DIS using various media (Figure 1A). Similar results were observed for leaf diameter, plant height, and stem diameter in the first three weeks of cultivation (Figures 1B and 1C). On the other hand, in the fourth week of cultivation, stem diameter in the NFT system is not significantly different from that of DIS using compost only and compost mixed with rice husk. However, it is significantly higher than DIS using rice husk only (Figure 1D).

Our data showed that the best media for melon cultivation is DIS, using rice husk mixed with compost (Figure 1), which showed significantly higher leaf diameter and plant height (Figures 1B and 1C) following four weeks of cultivation. However, no significant difference was observed in leaf numbers among different media (Figure 1A).

The Hydroponic System and Growth Media Influenced Leaf Chlorophyll Content and Fruit Weight

The highest leaf chlorophyll content was observed in melon leaf cultivated using the NFT system, while there is no significant difference in leaf chlorophyll content among different media in DIS (Figure 2A). Although chlorophyll content was highest in plants cultivated using NFT, there is no significant difference in leaf and fruit nitrogen content between plants cultivated in NFT and DIS (Figure 2B). Plants cultivated through NFT, DIS with compost media, and DIS with rice husk mixed with compost displayed comparable fresh fruit weight. However, the fruit weight was notably reduced in plants cultivated using DIS with rice husk media (Figure 2C).

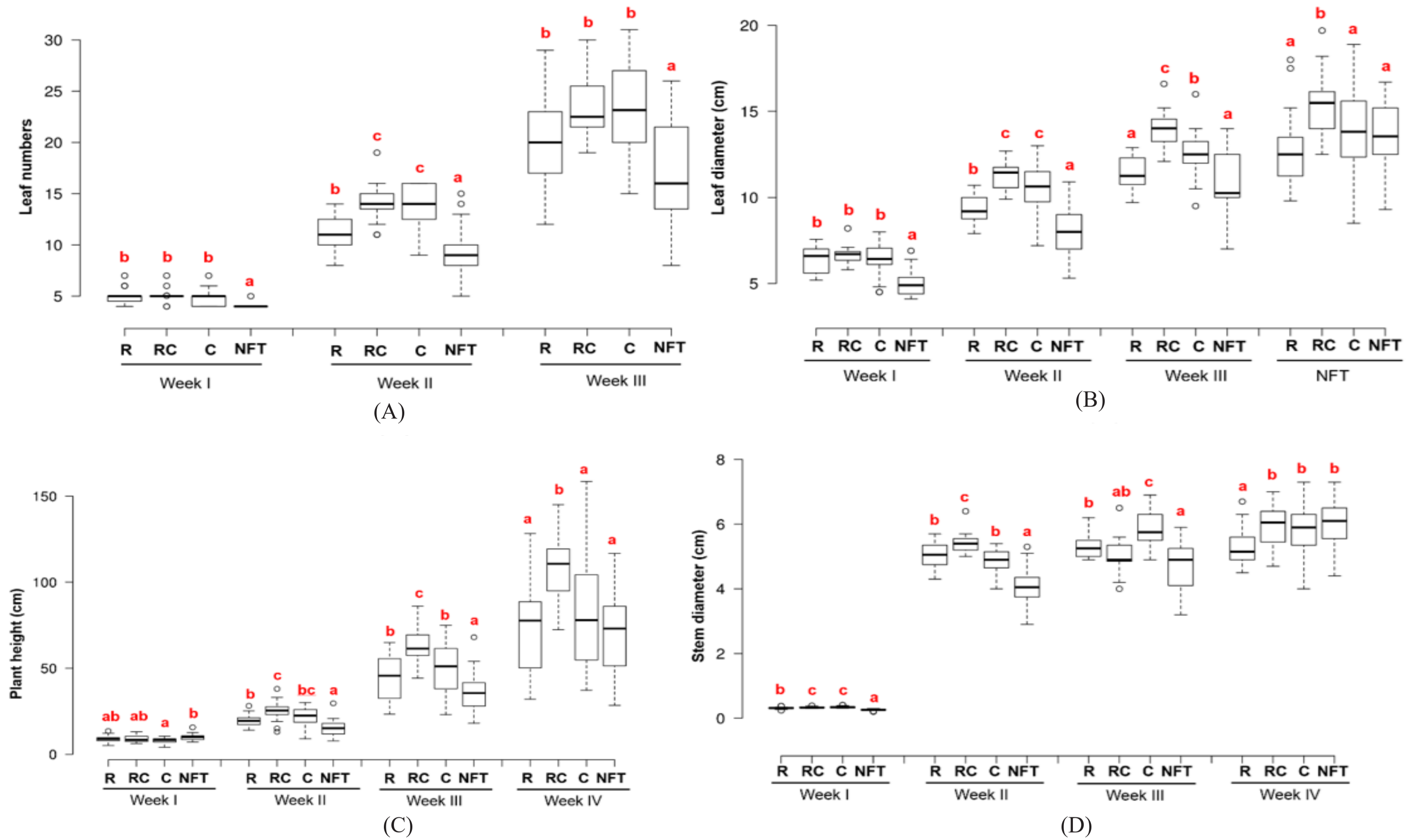

Figure 1. The growth parameters of melon following four weeks of cultivation in the nutrient film technique (NFT) system and drip irrigation system (DIS) with different media: (A) Measurement of leaf numbers, (B) Measurement of leaf diameter, (C) Measurement of plant height, and (D) Measurement of stem diameter

Note. R = DIS in rice husk, RC = DIS in rice husk + compost, C = DIS in compost only, and NFT = Nutrient film technique. Mean pairs with different letters are significantly different at the 5% probability level according to Duncan's new multiple range test

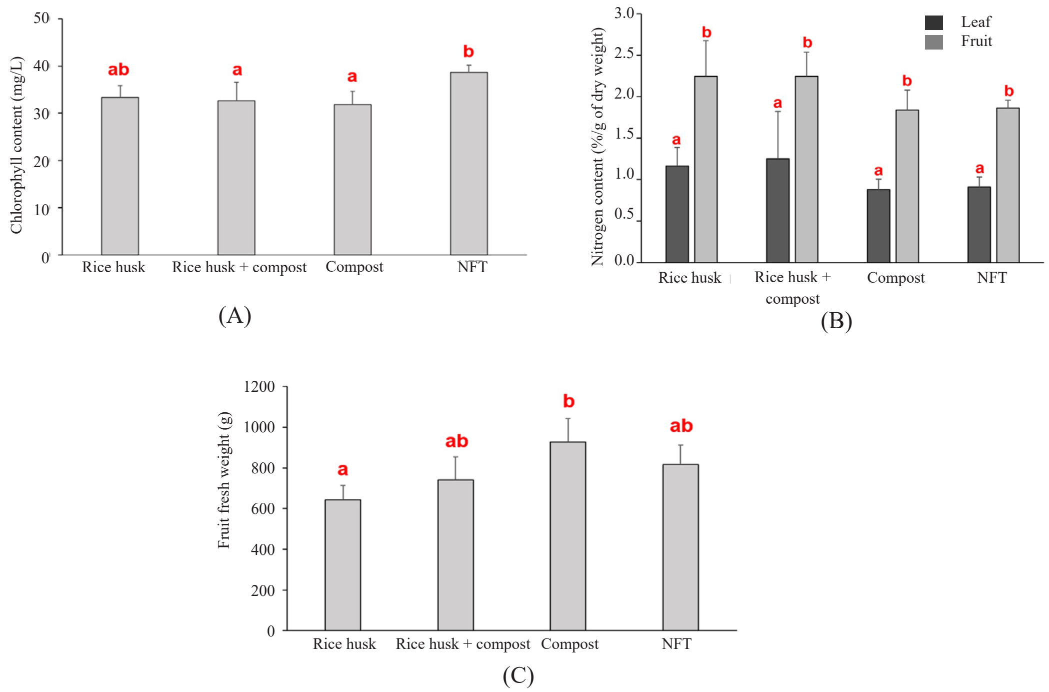

Figure 2. The effect of hydroponic system and growth media on (A) chlorophyll content, (B) leaf and fruit nitrogen content, and (C) fruit fresh weight

Note. Mean pairs with different letters are significantly different at the 5% probability level, according to Duncan's new multiple range test; NFT = Nutrient film technique

Melon Leaves and Fruits Exhibit Varying Mineral Compositions with Different Hydroponic Systems and Media Substrates

Across all hydroponic systems, aluminum and silicon were only detected in the leaf but not in the fruit (Table 1). The phosphorus concentration in the leaf is higher than in the fruit, and there is no significant difference in phosphorus concentration between plants cultivated in NFT and DIS; it is between 1.8–2.1% in the leaf and 3.8–4.4% in fruit (percent of weight). In all hydroponic systems, the most abundant mineral in melon leaves is calcium (65.9–69.1%), while the most abundant mineral in fruit is potassium (75.9–80%) (Table 1). The highest calcium (69.1%) and potassium (80.1%) concentrations were found in plants cultivated using DIS with rice husks mixed with compost media. These findings indicate that selecting hydroponic systems and media substrates can influence the mineral content in melon leaves and fruits.

Initial and Post-harvest Nitrogen and Mineral Content in the Growth Media

The initial nitrogen content in the media was similar between rice husk and rice husk mixed with compost, but it was significantly lower in media with compost only (Figure 3). Following cultivation and harvest, the

Table 1
Mineral content (% of dry weight) in the leaf and fruit of melon cultivated using NFT system and DIS with different media

Mineral	Leaf (% of dry weight)				Fruit (% of dry weight)			
	R	RC	C	NFT	R	RC	C	NFT
Al	5.5 ± 0.7	5.5 ± 0.7	5.5 ± 0.7	5.5 ± 0.7	0	0	0	0
Si	4.5 ± 0.2	3.5 ± 0.6	4.2 ± 0.7	2.7 ± 0.0	0	0	0	0
P	1.9 ± 0.1	1.8 ± 0.6	2.1 ± 0.5	2.1 ± 0.0	3.9 ± 0.2	3.8 ± 0.0	4.4 ± 0.0	4.2 ± 0.4
S	3.7 ± 0.1	3.8 ± 0.2	3.8 ± 0.9	3.4 ± 0.4	1.6 ± 0.0	1.7 ± 0.1	1.7 ± 0.6	1.6 ± 0.2
K	15.6 ± 0.8	14.7 ± 0.2	17 ± 0.1	18.8 ± 0.2	75.9 ± 0.1	80.1 ± 0.4	77.3 ± 0.1	79.9 ± 0.2
Ca	67.3 ± 0.2	69.1 ± 0.2	65.9 ± 0.3	66.3 ± 0.8	16.4 ± 0.1	12.4 ± 0.2	14.3 ± 0.1	12.1 ± 0.1
Mn	0.1 ± 0.1	0.3 ± 0.1	0.1 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.1 ± 0.0
Fe	0.7 ± 0.0	0.6 ± 0.0	0.7 ± 0.0	0.7 ± 0.0	0.5 ± 0.0	0.4 ± 0.0	0.5 ± 0.0	0.5 ± 0.0
Cu	0.2 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.6 ± 0.0	0.6 ± 0.0	0.7 ± 0.0	0.7 ± 0.0
Zn	0	0	0	0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
Br	0	0	0	0	0	0	0	0
Rb	0	0	0	0	0.2 ± 0	0.2 ± 0	0	0
Sr	0.3 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.2 ± 0.0	0.1 ± 0.0	0.1 ± 0	0.1 ± 0.0	0.1 ± 0.0
Re	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.4 ± 0.0	0.5 ± 0	0.5 ± 0.0	4.3 ± 0.1

Note. R = DIS in rice husk; RC = DIS in rice husk + compost; C = DIS in compost only; NFT = Nutrient film technique; DIS = Drip irrigation system

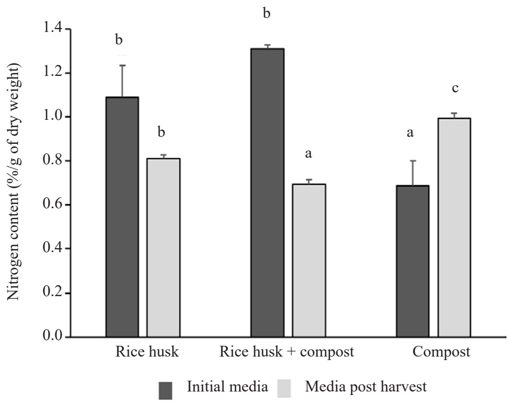

Figure 3. Initial and post-harvest nitrogen content in the growth media

Note. Mean pairs with different letters are significantly different at the 5% probability level, according to Duncan's new multiple range test

nitrogen content in media with compost is the highest, followed by rice husk and rice husk mixed with compost (Figure 3).

Silica was observed as the most abundant media in the initial media. Silica concentration is highest in rice husk in initial and post-harvest media. The concentration of silica, phosphorous, sulfur, and potassium is higher in post-harvest media compared to the initial media. On the other hand, the level of manganese is slightly decreasing in post-harvest media, while iron content is reduced significantly. The concentration of other minerals is very low across all media used, both in initial and post-harvest media (Table 2).

DISCUSSION

During the initial stages of melon growth, plants in the DIS exhibit better growth compared to the NFT system, evident in higher leaf numbers, leaf diameter, plant height, and stem diameter. These results indicate that solid growth media is required to support melon growth, especially to facilitate root development. The plants are growing slower in the NFT system because they need to adapt to the new environment since the plants are grown on liquid media, while melons naturally grow on soil. It aligns with prior studies that have indicated that media for hydroponic systems should have good water retention capacity, be rich in nutrients, have good aeration, and have a high ion exchange capacity.

Across the three media used in DIS, the best growth was observed in melon cultivated using rice husk mixed with compost. When grown in this media, the plants showed the highest leaf diameter, plant height, and stem diameter because compost mixed with rice husk has a high water retention capacity, good aeration and drainage, and sufficient nutrition. Compost is an organic material produced through thermophilic and aerobic decomposition, rich with nutrients required by plants and an environmentally friendly fertilizer (Raviv, 2017). Media consisting of rice husks might have good aeration and drainage but have relatively low water retention capacity. Therefore, the supplied nutrient-rich water is not effectively retained in the media and absorbed by the root, thus limiting the melon growth. Media consisted only of compost, limiting the growth of melon because it has low aeration and drainage capacity. In previous work, it was reported that the best media for Inpari rice cultivation in a hydroponic system is rice husk charcoal and

Table 2
Mineral content (% of dry weight) in DIS initial and post-harvest media

Mineral	R	RC	C	R	RC	C
	Initial media			Post-harvest media		
Al	0.9 ± 0.1	5.2 ± 0.4	6.9 ± 0.3	0.8 ± 0.2	2.8 ± 0.3	4.9 ± 0.1
Si	57.3 ± 0.1	39.9 ± 0.1	35.7 ± 0.1	56.2 ± 0.3	55.6 ± 0.1	46.6 ± 0.1
P	3.1 ± 0.1	2.3 ± 0.1	2.1 ± 0.1	3.8 ± 0.2	2.7 ± 0.0	2.3 ± 0.0
S	1.6 ± 0.0	0.8 ± 0.0	0.6 ± 0.0	2.8 ± 0.0	1.4 ± 0.1	0.9 ± 0.0
K	11.4 ± 0.1	5 ± 0.0	4.1 ± 0.0	11.7 ± 01	5.4 ± 0.0	4.5 ± 0.0
Ca	13.1 ± 0.1	12.6 ± 0.1	13 ± 0.0	15.7 ± 0.1	10.2 ± 0.1	11.1 ± 0.1
Ti	0.4 ± 0.0	1.8 ± 0.0	2.1 ± 0.0	0.2 ± 0.0	1.2 ± 0.0	1.7 ± 0.0
V	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0	0	0.1 ± 0.0
Mn	2.9 ± 0.0	1.2 ± 0.0	0.9 ± 0.0	2.3 ± 0.0	0.9 ± 0.0	0.9 ± 0.0
Fe	7.7 ± 0.1	29.8 ± 0.3	33.1 ± 0.1	5.1 ± 0.0	18.5 ± 0.1	25.9 ± 0.1
Cu	0.6 ± 0.0	0.4 ± 0.0	0.3 ± 0.0	0.5 ± 0.0	0.3 ± 0.0	0.3 ± 0.0
Zn	0.9 ± 0.0	0.2 ± 0.0	0.2± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.1 ± 0.0
Sr	0.1 ± 0.0	0.4 ± 0.0	0.4± 0.0	0.1 ± 0.0	0.2 ± 0.0	0.3 ± 0.0
Zr	0	0.1 ± 0.0	0.1± 0.0	0	0.1 ± 0.0	0.1± 0.0
Ba	0.2 ± 0.0	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.0	0.2 ± 0.0	0.3 ± 0.0
Re	0.4 ± 0.0	0.1 ± 0	0.1 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.1 ± 0.0

Note. R = DIS in rice husk; RC = DIS in rice husk + compost; C = DIS in compost only; NFT = Nutrient film technique; DIS = Drip irrigation system cocopeat (Hidayat et al., 2021), while the media consisting of coconut husk is better for tomato compared to peat vermiculite and rock wool (Xiong et al., 2017). Collectively, these findings imply that each plant species required specific media for their optimal growth.

Although melon growth is slower in the NFT system, the chlorophyll content of NFT plants is higher than that of DIS. In the NFT system, AB mix nutrition is supplied continuously. Thus, nutrient availability for chlorophyll production is higher. In accordance with this, it is also reported that in lettuce, cultivation using NFT also resulted in higher leaf chlorophyll content compared to lettuce grown in soil and in aggregate media hydroponic system (Thomas et al., 2021). Total nitrogen measurement showed that the highest nitrogen level is found in med with rice husk mixed with compost (1.3%), while the lowest is found in compost media (0.7%). The high nitrogen content in mixed media is due to the high protein content in rice husk. Kuan et al. (2012) reported that dried rice husk contains 71.6% carbohydrate, 5.5% protein, 15.4% ash, and 0.9% fat. The application of rice husk biochar was also reported to improve nitrogen availability in soil (Oladele et al., 2019; Selvarajh et al., 2021). Low nitrogen content in compost media is probably due to incomplete decomposition of plant materials and animal waste in the compost. Therefore, the complex organic matter is not yet decomposed to simple nitrogen compounds.

Our data showed that the post-harvest media contained less nitrogen than the initial media, except for compost-only media, which showed higher nitrogen levels in post-harvest media. In rice husk media, we observed a 28% reduction in nitrogen content, while in rice husk mixed with compost, 38% nitrogen reduction was observed. On the other hand, a 30% increase in nitrogen content was detected in the compost post-harvest media (Figure 2C). The increasing nitrogen content in compost-only post-harvest media is probably due to low aeration and drainage; the supplied nitrogen-rich AB mix solution is trapped in the media and not effectively absorbed into the root. Our data indicates that AB mix solution can provide sufficient nitrogen for melon hydroponic cultivation, as shown by the consistently high nitrogen content in the fruit and leaf of melon cultivated using the NFT and DIS system. Although nitrogen content remains similar across all treatments, the significant differences in fruit weight were observed. The highest fruit weight was recorded in plants cultivated using DIS with compost-only media, while the lowest was observed in DIS with rice husk media. The volume and concentration of AB mix nutrients provided to the plants significantly affect the fruit's weight. Further optimization is required to evaluate the best volume, concentration, and period for the AB mix application.

The mineral content in the media is relatively stable, and there are no significant mineral content differences between initial and post-harvest media. This result indicates that melon is acquiring minerals mainly from the supplemented AB mix and not from the media. Some minerals are detected at higher concentrations in fruits compared to leaves; for example, phosphorus concentration in leaves (1.8-2.1%) is significantly lower than in fruits (3.8-4.4%). In general, phosphorus content is higher in fruits than in leaves, as observed in soybeans, almonds, and wheat (Siregar, 2020). Potassium concentration is also higher in melon fruits (76–80%) compared to leaf (14.70–18.85%). Potassium is required in protein synthesis (Koch & Mengel, 1974); the potassium level in leaves is lower than in fruits because proteins are synthesized at much higher levels since the development of seeds and fruits requires the activity of many different enzymes.

The micronutrient that is detected at different concentrations between leaf (0.59–0.73%) and fruits (0.10–0.19%) is iron. Although iron is not a direct part of chlorophyll structure, it is required to convert magnesium protoporphyrin to protochlorophyllide in chlorophyll. Therefore, iron is a pivotal component of chlorophyll synthesis (George et al., 1995). Due to iron's function in chlorophyll synthesis, iron is found in a much higher concentration in the leaf than in fruit.

CONCLUSION

This study identifies the DIS with a substrate of rice husk mixed with compost (1:1) as the optimal hydroponic system for enhancing melon growth and yield. While melon growth is relatively slower in the NFT system, the chlorophyll content in NFT plant leaves is higher. There are no significant differences in nitrogen content between NFT and DIS systems. However, potassium and calcium levels are higher in melons cultivated in DIS with a mix of rice husk and compost. A distinct variance in mineral content is observed between melon leaves and fruits, with Fe and calcium being predominant in leaves and potassium dominating in fruits.

ACKNOWLEDGEMENTS

This research is funded by "Riset Kolaborasi Indonesia-WCU (World Class University Tahun Anggaran 2023), number 967/UN3. LPPM/PT.01.03/2023

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