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Growth and Yield of Three Mustard Green (*Brassica juncea* L.) Varieties in Different Growing Media Using the Nutrient Film Technique (NFT) Hydroponic System

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ABSTRACT

The increasing demand for fresh vegetables amid limited agricultural land has driven the adoption of hydroponic systems as an efficient cultivation solution. This study aimed to evaluate the effects of combining three mustard green (*Brassica juncea* L.) varieties Kumala, Shinta, and Tosakan with three types of growing media rockwool, cocopeat, and sponge under the Nutrient Film Technique (NFT) hydroponic system. A split-plot design was used in an experiment involving 108 plants to assess growth parameters and yield. Results indicated that the growing media had a highly significant effect on all observed variables, while the plant variety significantly affected plant height and leaf number. The Shinta sponge combination produced the tallest plants, whereas Kumala rockwool resulted in the highest fresh weight and root length. Cocopeat consistently yielded the poorest growth and productivity across all varieties. These findings highlight the importance of selecting growing media that support optimal aeration and water retention in NFT systems, as well as the adaptability of plant varieties to specific cultivation conditions. The interaction between variety and medium showed diverse physiological responses that can be leveraged to enhance production efficiency. This study recommends the use of rockwool and sponge media, alongside responsive variety selection, as strategic approaches to optimize mustard green cultivation in hydroponic systems, particularly within the framework of sustainable urban agriculture.

INTRODUCTION

The increasing demand for fresh vegetables, including mustard greens (*Brassica juncea* L.), highlights the need for efficient agricultural practices amidst urbanization and limited arable land. Mustard greens are known for their high nutritional content, including vitamins A, C, and K, as well as various antioxidant compounds, making them a popular choice among consumers (Bidara et al., 2024). The cultivation of mustard greens faces challenges due to land conversion for residential and industrial purposes; therefore, innovative agricultural methods such as hydroponics have gained significant attention as a viable alternative (Kailashkumar et al., 2023).

Hydroponics, particularly the Nutrient Film Technique (NFT) system, enables plant cultivation without soil by using nutrient solutions as a source of essential elements for plant growth. This method maximizes resource efficiency by enabling cultivation in smaller spaces. The NFT system operates by continuously flowing a thin film of nutrient solution over plant roots, allowing optimal absorption of nutrients and oxygen. However, the success of hydroponic cultivation greatly depends on the selection of appropriate growing media, which provide mechanical support and serve as reservoirs for water and air needed for root development. Commonly used media such as rockwool, rice husk charcoal, and cocopeat each have their own strengths and weaknesses, affecting plant growth and overall yield (Khozin et al., 2023).

In addition, plant genetic factors play an important role in the success of hydroponic cultivation. Different varieties of mustard greens exhibit different responses to environmental conditions and growing media (Gustiar et al., 2022) The interaction between varietal characteristics and specific types of media has not been thoroughly studied, as most previous research tends to examine these factors in isolation (Nafiah et al., 2023).

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Therefore, this study proposes an integrated approach to evaluate the combination of three mustard green varieties and three types of growing media within the NFT hydroponic system. This approach aims to identify the most optimal variety–media combinations that can significantly enhance growth and production efficiency (Ramsari & Hidayat, 2022).

This research aims to determine the effects of various growing media on the growth and yield of mustard greens in the NFT system, assess the performance of each variety under different media conditions, and ultimately identify the most advantageous combinations to improve hydroponic productivity (Himawan et al., 2024). The findings of this study are expected to provide practical applications for urban farmers, promote sustainability, and support the wider adoption of hydroponic systems in areas facing land scarcity for traditional farming (Pamuji et al., 2024).

MATERIALS AND METHODS

This research was conducted at Samata Green House, Samata, Somba Opu District, Gowa Regency, South Sulawesi, at an altitude of 10 meters above sea level with an average temperature of 28°C. The study was carried out from May to July 2024. The materials used in this study included mustard green seeds of the Kumala, Shinta, and Tosakan varieties, AB Mix nutrients, water, sponges, rockwool, and cocopeat. The equipment used consisted of an NFT hydroponic system installation, seedling trays, water tanks, cutter/knife, rulers, net pots, TDS meter, measuring cups, labels, pH meter, and digital scales.

This research was conducted using a Split-Plot Design (RPT). The main plot factor was the mustard green varieties, consisting of 3 treatment types Kumala, Shinta, and Tosakan. The sub-plot factor was the growing media, consisting of 3 types: cocopeat, rockwool, and sponge. From these two factors, 9 treatment combinations were obtained, and each combination was repeated 3 times, resulting in a total of 27 experimental units. Each experimental unit consisted of 4 plants, resulting in a total of 108 plants.

RESULTS AND DISCUSSION

1. Plant Height

The observations of plant height and analysis of variance (ANOVA) are presented in Table 1. The ANOVA indicates that the mustard variety treatments have a significant effect, while the growing medium treatments have a highly significant effect on plant height. However, the interaction between both factors showed no significant effect.

Table 1. Average plant height (cm) of three mustard varieties and types of growing media in the NFT hydroponic system.

Variety	Growing Media			Average	LSD 0.05
	Cocopeat	Rockwool	Sponge		
Kumala	8.08	38.13	38.84	27.35[b]	5.71
Shinta	16.38	40.30	42.63	33.10[a]	
Tosakan	16.92	40.75	40.67	32.78[a]	
Average	13.79[b]	39.73[a]	40.71[a]		
LSD 0.05	3.97				

Note: Mean values followed by different letters (a, b) indicate significant differences according to the LSD test at the 0.05 level.

Based on Table 1, the best treatment for the growth of mustard plant height in the NFT hydroponic system was the combination of the Shinta variety with sponge growing medium, which recorded the highest average plant height of 42.63 cm. Conversely, the lowest growth was observed in the combination of the Kumala variety with cocopeat growing medium, with an average plant height of only 8.08 cm. The comparison between these two extreme results shows a very significant difference, where the best treatment produced plant height more than five times greater than the lowest one. This indicates that selecting the appropriate plant variety and growing medium plays a crucial role in the growth of mustard plants in the NFT hydroponic system.

The influence of cultivar selection on plant performance in soilless systems has been highlighted by (Mutua et al., 2021). Conversely, the very low plant height observed in the Kumala variety, at only 8.08 cm,

reinforces the notion that not all varieties respond equally under hydroponic conditions. This may be due to the variety's limited ability to absorb nutrients or to develop roots effectively in the cocopeat medium (Jagtap et al., 2023).

The choice of growing medium also plays a significant role in plant growth. The sponge medium used for the Shinta variety likely offers better aeration and moisture retention compared to cocopeat, thereby supporting root development and overall plant health (Bafort et al., 2022). This aligns with findings that optimal substrate selection can enhance nutrient uptake and growth parameters in hydroponic systems (Baiyin et al., 2021). Furthermore, research shows that substrates providing sufficient moisture and oxygen levels contribute to greater plant vigor and survivability in hydroponic setups (Kailashkumar et al., 2023)

Moreover, the fivefold increase in plant height observed in the Shinta variety compared to the Kumala variety underscores the importance of integrating both variety and growing medium selection to maximize productivity in hydroponic environments. This is consistent with previous studies indicating that the success of hydroponic farming depends heavily on balancing varietal selection with environmental factors such as nutrient availability and substrate characteristics (Meselmani, 2023). Therefore, a more strategic approach in selecting both mustard variety and appropriate growing medium could optimize growth outcomes and yield, ultimately leading to more efficient hydroponic farming practices.

2. Number of Leaves

The observed average number of mustard green leaves at harvest under various treatments of plant varieties and growing media, along with the analysis of variance, is presented in Table 2. The analysis of variance indicates that the individual effects of plant variety and growing media, as well as their interaction, had a highly significant effect on the number of leaves.

Table 2. Average number of leaves of three mustard green varieties and growing media types in an NFT hydroponic system.

Variety	Growing Media			Average	LSD 0.05
	Cocopeat	Rockwool	Sponge		
Kumala	$7.08^{b}{}_{x}$	$13.67^{a}{}_{x}$	$13.17^{a}{}_{x}$	11.31	1.62
Shinta	$6.00^{b}{}_{x}$	$7.83^{a}{}_{y}$	$8.17^{a}{}_{y}$	7.33	
Tosakan	$5.58^{a}{}_{x}$	$7.17^{a}{}_{y}$	$7.08^{a}{}_{y}$	6.61	
Average	6.22	9.56	9.47		

Note: Mean values followed by different letters (a, b) indicate significant differences according to the LSD test at the 0.05 level.

The findings presented in Table 2 indicate that the Kumala variety produced the highest average number of leaves, reaching 13.67, which was significantly higher compared to the Tosakan variety, which recorded the lowest average of 5.58 leaves. This improved growth performance can be attributed to several factors associated with the use of rockwool as a growing medium compared to cocopeat.

Rockwool possesses unique physical and chemical properties that support optimal plant growth. It has excellent aeration characteristics and strong water retention capacity, allowing for optimal oxygen availability in the root zone while maintaining adequate moisture. These conditions are crucial for the development of a healthy root system, ultimately promoting greater leaf production and overall plant vigor (Suharjo & Suaib, 2022). Additionally, the inert nature of rockwool prevents it from harboring pathogens that may harm plant health, making it a preferred medium in hydroponic systems (Thomas et al., 2023).

In contrast, cocopeat, while offering advantages such as water retention and being a renewable resource, may not provide the same level of aeration as rockwool. This can hinder root development, particularly under compact or oxygen-deficient conditions (Nerlich et al., 2022). Therefore, the physiological limitations posed by cocopeat on the Tosakan variety may explain its lower leaf production. Research confirms that substrate selection significantly influences plant growth outcomes, with rockwool supporting better nutrient absorption and retention, thereby enhancing leaf development compared to cocopeat (Qaryouti et al., 2023).

Furthermore, the specific characteristics of each variety must also be considered. The Kumala variety is known for its vigorous growth and high yield potential, which is further enhanced by the suitability of

rockwool in meeting its requirements for moisture, aeration, and stability (Harahap, 2024). On the other hand, the poor performance of the Tosakan variety in cocopeat suggests a potential mismatch between varietal traits and the growing conditions provided by the medium. This emphasizes the importance of selecting both the appropriate variety and growing medium to optimize yield in hydroponic systems (Batubara et al., 2023). The superior aeration and water retention properties of rockwool, combined with the strong growth traits of the Kumala variety, result in a highly promising hydroponic cultivation scenario.

3. Root Length

The observed average root length of mustard plants under various treatments of mustard varieties and growing media, along with the analysis of variance, is presented in Table 3. The analysis of variance shows that the growing media had a highly significant effect on root length, and there was a significant interaction between mustard variety and growing media. However, the variety treatments alone did not have a significant effect.

Table 3. Average root length (cm) of three mustard green varieties and growing media types in an NFT hydroponic system.

Variety	Growing Media			Average	LSD 0.05
	Cocopeat	Rockwool	Sponge		
Kumala	3.25^{b}_{y}	16.58^{a}_{x}	16.08^{a}_{x}	11.97	2.51
Shinta	8.33^{b}_{x}	11.71^{a}_{y}	13.75^{a}_{xy}	11.26	
Tosakan	9.33^{b}_{x}	14.25^{a}_{x}	11.83^{a}_{y}	11.81	
Average	6.97	14.18	13.89		

Note: Mean values followed by different letters (a, b) indicate significant differences according to the LSD test at the 0.05 level.

The results presented in Table 3 show that the combination of the Kumala variety with rockwool growing medium produced the longest average root length, reaching 16.58 cm, while the Kumala variety grown in cocopeat resulted in significantly shorter roots, only 3.25 cm in length. This striking difference highlights the important role played by both variety and growing medium in the hydroponic cultivation of mustard plants and aligns with previous studies indicating that substrate selection can significantly influence root morphology and growth (Bertoldo et al., 2023).

The superior root length observed with rockwool can be attributed to its beneficial physical properties, such as excellent aeration, strong water retention capacity, and inertness to pathogens. Rockwool provides a well-structured environment that ensures optimal oxygen availability to the roots, which is essential for respiration and nutrient uptake. This increased aeration can stimulate root elongation and branching, resulting in a more developed root architecture compared to cocopeat, which has lower aeration capacity and can potentially lead to anaerobic conditions under certain watering practices (Robin et al., 2021).

Furthermore, research has shown that certain growing media, such as rockwool, can promote better root development by maintaining a stable moisture regime and reducing the risk of root diseases. For instance, studies on the effects of various hydroponic substrates have demonstrated that rockwool significantly enhances root development across different plant species by maintaining consistent moisture levels and facilitating proper nutrient delivery (Ribeiro et al., 2023). In contrast, cocopeat, while advantageous for specific plants due to its organic nature and water-holding capacity, has been found to result in suboptimal root growth in some species, especially when compared to more aerated substrates like rockwool (Meeboon et al., 2022).

Interestingly, the interaction between the Kumala variety and rockwool may also reflect a specific compatibility of this variety with the given growing conditions. Previous studies have shown that root responses can vary among plant varieties depending on the medium used, suggesting that the genetic traits of the Kumala variety may provide specific adaptability to the rockwool substrate, thereby further enhancing root development (Liu et al., 2023).

The performance of the Kumala variety when combined with rockwool not only resulted in better root growth compared to the cocopeat combination but also emphasizes the importance of selecting the appropriate substrate to ensure optimal plant health and productivity in hydroponic systems.

4. Fresh Plant Weight

Observations of fresh plant weight showed that both the interaction and the main effects of mustard green variety and growing media had a highly significant effect on the fresh weight of the plants.

Table 4. Average fresh weight (g) of three mustard green varieties and growing media types in an NFT hydroponic system.

Variety	Growing Media			Average	LSD 0.05
	Cocopeat	Rockwool	Sponge		
Kumala	4.00^{b}_{x}	117.25^{a}_{x}	111.92^{a}_{x}	77.72	22.53
Shinta	8.75^{b}_{x}	74.17^{a}_{y}	74.58^{a}_{y}	52.50	
Tosakan	9.58^{b}_{x}	66.58^{a}_{y}	61.58^{a}_{y}	45.92	
Average	7.44	86.00	82.69		

Note: Mean values followed by different letters (a, b, x, y) indicate significant differences according to the LSD test at the 0.05 level.

Table 4 presents the fresh weight results of different mustard green (Brassica juncea) varieties Kumala, Shinta and Tosakan cultivated using the Nutrient Film Technique (NFT) hydroponic system, showing significant variability influenced by genetic factors and the choice of growing media. In particular, the Kumala variety exhibited a strong response to the growing media, with average fresh weights of 117.25 g and 111.92 g when grown in rockwool and sponge, respectively, compared to only 4.00 g in cocopeat. This striking difference highlights the effectiveness of highly porous media such as rockwool and sponge, which enhance aeration and water retention, thereby optimizing root development and nutrient uptake (Chhetri et al., 2022).

Similar results were observed in the other varieties. For the Shinta variety, rockwool and sponge yielded average fresh weights of 74.17 g and 74.58 g, respectively, while cocopeat only produced 8.75 g. The Tosakan variety also showed better performance with rockwool and sponge, with average fresh weights of 66.58 g and 61.58 g, respectively, compared to 9.58 g in cocopeat. This consistent pattern indicates that rockwool and sponge provide a more favorable growing environment, likely enhancing vascular development and root architecture, which contributes to overall biomass accumulation (Pratiwi et al., 2023; Putra et al., 2023).

Overall, the data show that rockwool (86.00 g) and sponge (82.69 g) significantly outperformed cocopeat (7.44 g) in terms of average fresh weight across all varieties. These findings are consistent with literature suggesting that substrates with high porosity and good aeration properties, such as rockwool, are essential for maximizing the growth of hydroponically cultivated plants (Barus et al., 2021). In hydroponic systems, selecting the appropriate growing medium is crucial, as it directly influences water and nutrient absorption, demonstrating that the physical characteristics of the medium can greatly impact plant physiology and productivity (Rossi et al., 2024).

This comparative analysis shows that although all three mustard green varieties benefit from the NFT hydroponic system, their responses to different growing media vary significantly, with rockwool consistently resulting in the highest fresh weights. This emphasizes the importance of continued research to identify optimal growing conditions and media for each cultivar to enhance agricultural yields in hydroponic systems (Saputra et al., 2023).

5. Consumption Weight

Observation results of consumption weight after analysis showed that neither the interaction nor the main effect of mustard green variety had a significant influence on consumption weight. However, the type of growing media had a highly significant effect on the consumption weight of mustard plants.

Table 5. Average consumption weight (g) under treatments of mustard green varieties and growing media types.

Variety	Growing Media			Average
	Cocopeat	Rockwool	Sponge	
Kumala	1.67	74.83	75.83	50.78
Shinta	4.92	44.58	50.83	33.44
Tosakan	5.75	42.92	57.25	35.31
Average	4.11[c]	54.11[b]	61.31[a]	
LSD 0.05	4.43			

Note: Mean values followed by different letters (a, b) indicate significant differences according to the LSD test at the 0.05 level.

Based on Table 5, the consumption weight data of three mustard green varieties Kumala, Shinta, and Tosakan cultivated using different growing media treatments, namely cocopeat, rockwool, and sponge, reveal significant differences in plant performance. Specifically, sponge media produced the highest average consumption weight at 61.31 g, followed by rockwool at 54.11 g, while cocopeat yielded the lowest value at only 4.11 g. These variations reflect the intrinsic characteristics of each growing medium and their influence on plant growth and nutrient uptake.

The Kumala variety exhibited the highest consumption weight when combined with sponge media, reaching 75.83 g. In contrast, cocopeat consistently resulted in the lowest consumption weights across all varieties, with Kumala in cocopeat recording the lowest value of 1.67 g. Similarly, the Shinta and Tosakan varieties grown in cocopeat only reached consumption weights of 4.92 g and 5.75 g, respectively. These findings emphasize the importance of choosing the right growing medium to optimize plant growth in hydroponic systems. Sponge media are known for their excellent water retention and aeration properties, which support root development and optimal nutrient absorption, ultimately enhancing plant performance and increasing consumption weight (Dutta et al., 2023).

In the context of hydroponics, the physical and chemical properties of growing media significantly affect plant health and productivity. For instance, cocopeat tends to have poor water retention capabilities in hydroponic systems, which require consistent moisture levels for optimal growth. Literature indicates that inorganic and organic substrates such as rockwool and sponge provide more favorable conditions for root systems by offering higher oxygen and nutrient availability compared to cocopeat, which may contain phytotoxic elements and lower nutrient availability (Dutta et al., 2023; Gustiar et al., 2022). The effectiveness of rockwool use is also supported by its structure, which allows for excellent drainagee essential for reducing the risk of root rot and supporting healthy plant growth (Latifah et al., 2023).

Furthermore, consumption weight outcomes can also be influenced by external factors such as nutrient solution composition and its interaction with the selected growing media. Nutrient uptake efficiency in hydroponics is often correlated with the medium's properties, such as pH stability and nutrient retention capacity, which are crucial for optimizing crop yields (Ali et al., 2021). Therefore, in the context of sustainable agricultural practices, integrating appropriate growing media such as sponge and rockwool into hydroponic systems can help address agricultural challenges related to nutrient distribution and land-use efficiency, particularly in urban farming settings (Indarwati et al., 2024).

The superior performance of sponge media, in particular, not only demonstrates the potential to increase plant biomass but also provides a pathway for developing more efficient and sustainable urban agricultural systems.

CONCLUSION

This study shows that the growing medium and plant variety have a significant impact on the growth and yield of green mustard in the NFT hydroponic system. The growing media of rockwool and sponge consistently provided better results compared to cocopeat. The highest average plant height was achieved by

sponge at 40.71 cm, followed by rockwool at 39.73 cm, and cocopeat at 13.79 cm. The highest number of leaves was found in plants grown in rockwool with an average of 9.56 leaves, followed by sponge at 9.47 leaves, and cocopeat at 6.22 leaves. The longest root length was also obtained from the rockwool medium with an average of 14.18 cm, sponge at 13.89 cm, and cocopeat at 6.97 cm. For fresh weight, rockwool produced an average of 86.00 g, sponge at 82.69 g, and cocopeat at 7.44 g. Meanwhile, the highest consumption weight was produced by sponge at 61.31 g, followed by rockwool at 54.11 g, and cocopeat at 4.11 g.

Plant variety also influenced growth, especially plant height and leaf number. The Shinta variety recorded the tallest plant height when grown in sponge medium, reaching 42.63 cm. On the other hand, the Kumala variety showed the best performance in several other parameters. Kumala grown in rockwool medium produced the highest number of leaves with an average of 13.67 leaves, the longest root length of 16.58 cm, and the highest fresh weight of 117.25 g. The highest consumption weight also came from the Kumala variety, which was 75.83 g when grown in sponge medium.

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