VOLUME 11 Issue 1
JULY 2026

E-ISSN: 2622-3384
P-ISSN: 2527-9939

JURNAL MEdu Mangifera Edu

Influence of different growing media on growth performance and essential mineral accumulation in *Brassica juncea* L.

Ghina Imannisa*, Yayu Sri Rahayu, Winda Rianti
Department of Agrotechnology, Faculty of Agriculture, Universitas Singaperbangsa Karawang, Jalan HS. Ronggo Waluyo, Puseurjaya, Telukjambe Timur, Karawang, West Java, Indonesia
*Corresponding author: imannisaghina@gmail.com

ABSTRACT

Microgreens are nutrient-dense vegetables widely cultivated in urban agriculture because of their short production cycle and high nutritional value. Although previous studies have demonstrated that growing media influence microgreen growth and nutritional quality, limited information is available on whether a single growing medium can simultaneously optimize biomass production and the accumulation of specific essential minerals. Therefore, this study compared five commonly used growing media to determine their effects on growth performance and the accumulation of manganese (Mn), phosphorus (P), and chloride (Cl) in green mustard microgreens (Brassica juncea L.). The study used a single-factor Randomized Block Design with five treatments and five replications: M0 (soil), M1 (cocopeat), M2 (vermiculite), M3 (rockwool), and M4 (perlite). Data were analyzed using analysis of variance followed by a 5% Least Significant Difference test. Growing media significantly affected all measured growth parameters and mineral concentrations. Soil produced the greatest plant height (6.602 cm), leaf area (1.013 cm^2), net assimilation rate (0.818 g cm^{-2} day^{-1}), and crop growth rate (2.398 g m^{-2} day^{-1}). Perlite formed the highest statistical group for phosphorus accumulation (756.0 mg/100g), vermiculite produced the highest manganese concentration (65.8 mg/100g), whereas cocopeat accumulated the greatest chloride concentration (4617.8 mg/100g). The findings demonstrate that no single growing medium simultaneously optimized both biomass production and mineral accumulation. Soil is recommended when biomass production is prioritized, whereas vermiculite, cocopeat, and perlite may be selected according to specific mineral enrichment objectives. These findings provide practical guidance for urban agriculture and functional-food production by supporting goal-oriented growing-medium selection.

ARTICLE INFO

Keywords
Chloride (Cl), Growing media, Manganese (Mn), Microgreens, Phosphorus (P).

Received
April 20, 2026

Revised
July 25, 2026

Accepted
July 26, 2026

Published
July 31, 2026

How to cite
Imannisa, G., Rahayu, Y. S., & Rianti, W. (2026). Influence of different growing media on growth performance and essential mineral accumulation in *Brassica juncea* L. *Jurnal Mangifera Edu*, *11*(1), 88-100. https://doi.org/10.31943/mangiferaedu.v11i1.271

INTRODUCTION

Population growth and rapid urbanization continue to increase the demand for fresh, nutritious, and sustainably produced food while simultaneously reducing the availability of agricultural land (Sonyinderawan, 2020). This situation has encouraged the development of urban agriculture as an alternative approach to food production in limited spaces. Urban farming enables communities to cultivate vegetables efficiently in residential and metropolitan areas while improving access to fresh produce and supporting local food security. Among various urban farming commodities, microgreens have attracted increasing attention because they require minimal cultivation space, have a short production cycle, and possess high nutritional value (Pratio et al., 2024; Sarjani et al., 2024).

Microgreens are immature vegetable seedlings harvested after the cotyledons are fully expanded and the first true leaves begin to emerge, generally within 7–14 days after germination (Kingsley et al., 2020; Thirumalaisrinivasan et al., 2023). Compared with mature vegetables, many microgreen species contain higher concentrations of vitamins, minerals, antioxidants, and other bioactive compounds, making them attractive functional foods (Bhaswant et al., 2023). Among these nutrients, phosphorus (P), manganese (Mn), and chloride (Cl) play essential physiological roles in plant growth and are also important for human nutrition. Phosphorus is required for energy metabolism and biomass production, manganese functions in photosynthesis and enzyme activation, whereas chloride contributes to osmotic regulation and ionic balance (Mardalena, 2021; Raut et al., 2024).

Green mustard (*Brassica juncea* L.) is considered one of the most promising microgreen species because of its rapid growth, high germination rate, and rich nutritional composition (Alloggia et al., 2023). Previous studies have shown that mustard microgreens contain considerable amounts of vitamins, antioxidants, minerals, and phytochemicals that may contribute to a healthier diet (Bashariah et al., 2024). However, the nutritional quality of microgreens is strongly influenced not only by plant species but also by cultivation practices, particularly the selection of growing media.

Growing media play an important role in regulating water availability, aeration, root development, and nutrient uptake, thereby directly affecting plant growth and mineral accumulation. According to Ramli et al. (2023), soil generally provides natural nutrients and relatively stable moisture conditions, whereas cocopeat possesses high water-holding capacity and cation retention (Gunjal et al., 2024). Vermiculite is characterized by high cation-exchange capacity, perlite improves root aeration through its porous structure, and rockwool provides a favorable physical environment but contains little or no available nutrients unless nutrient solutions are supplied (Balik et al., 2024; Gruda, 2019; Khairunnisa et al., 2023). These contrasting physical and chemical properties suggest that different growing media may produce different growth responses and mineral accumulation patterns.

Although numerous studies have investigated the effects of growing media on microgreen growth and nutritional quality, most have focused primarily on biomass production, yield, or overall nutritional composition. Only limited studies have simultaneously evaluated vegetative growth and the accumulation of specific essential minerals under identical cultivation conditions (Al-barry et al., 2025; Sukewijaya et al., 2025). Moreover, comparisons among soil, cocopeat, vermiculite, rockwool, and perlite using the same plant species and experimental conditions remain scarce. Consequently, it remains unclear whether a single growing medium can optimize both plant growth and essential mineral accumulation simultaneously.

The selection of phosphorus (P), manganese (Mn), and chloride (Cl) was based on their essential roles in both plant physiology and human nutrition. Phosphorus represents an essential macronutrient involved in energy transfer and biomass formation, whereas manganese and chloride are essential micronutrients required for photosynthesis, enzymatic activity, and osmotic regulation. (Bhat et al., 2024; Pessoa et al., 2026; Seeda et al., 2021). These minerals were therefore selected as representative indicators to evaluate how different growing media influence nutrient accumulation in green mustard microgreens.

Therefore, this study evaluated the effects of five commonly used growing media on plant height, leaf area, net assimilation rate, crop growth rate, and the accumulation of phosphorus (P), manganese (Mn), and chloride (Cl) in green mustard microgreens (*Brassica juncea* L.). Unlike previous studies that mainly emphasized growth performance or general nutritional quality, this study integrates biomass-related growth parameters with the accumulation of three essential minerals within a single comparative experiment. The findings are expected to provide scientific evidence for selecting growing media according to specific production objectives, either maximizing biomass production or enhancing targeted mineral composition, thereby contributing to the development of sustainable urban agriculture and functional-food production.

METHOD

This study was conducted from December 2025 to January 2026 at Building A, Faculty of Agriculture, Universitas Singaperbangsa Karawang, Karawang, West Java, Indonesia. The experiment was performed under ambient environmental conditions with an average temperature of 30.2°C, relative humidity of 76.9%, and a natural light intensity of 7.300 lux throughout the cultivation period.

Green mustard (*Brassica juncea* L.) seeds were obtained from Cap Panah Merah. The growing media evaluated were soil, cocopeat, vermiculite, rockwool, and perlite. Cocopeat, vermiculite, rockwool, and perlite were commercial horticultural substrates (Jirifarm®, Indonesia), whereas soil was collected from the topsoil layer of agricultural land. Water for irrigation was also used. The main equipment consisted of plastic containers (16.5 × 12.5 × 6 cm), an X-ray fluorescence spectrometer (XRF), and supporting laboratory instruments.

The experiment was arranged in a single-factor Randomized Block Design (RBD) with five growing media treatments: M0 (soil), M1 (cocopeat), M2 (vermiculite), M3 (rockwool), and M4 (perlite). Each treatment was replicated five times, resulting in 25 experimental units. Each experimental unit consisted of seven planting containers, for a total of 175 containers.

The study consisted of several stages, including seed preparation, growing media preparation, planting, maintenance, harvesting, and mineral analysis. Before sowing, seeds were soaked in clean water for one hour to improve germination, and only fully submerged seeds were selected. Soil was air-dried, cleaned from plant debris, and sieved before use. Cocopeat was soaked in water for 24 h to reduce soluble salts, whereas vermiculite, rockwool, and perlite were moistened with distilled water before sowing. No fertilizers or nutrient solutions were applied throughout the experiment to ensure that plant responses reflected the intrinsic properties of each growing medium.

Approximately 400 seeds were uniformly distributed in each plastic tray. Trays were irrigated once daily using clean water to maintain adequate moisture throughout the experiment. No additional fertilizers or nutrient solutions were applied during cultivation. Pest and disease occurrence was monitored daily, although no serious infestation was observed during the experiment. Microgreens were harvested 14 days after planting (DAP).

Table 1. Characteristics of growing media used in the study

Medium	Characteristics
Soil	Natural growing medium containing macro- and micronutrients, with a relatively high water-holding capacity and favorable drainage and aeration properties that support plant growth (Hassan, 2023; Hidayat et al., 2022).
Cocopeat	Organic growing medium derived from processed coconut husk fibers. It has high water-holding capacity, good aeration, and supports root growth. However, cocopeat contains limited nutrients and may require washing before use to reduce tannin and salt contents (Kamaluddin et al., 2022; Saputra et al., 2025).
Vermiculite	Expanded silicate mineral with a lightweight, highly porous structure, high water-holding capacity, and strong capillarity. It has a neutral pH, low electrical conductivity (EC), and a relatively high cation exchange capacity (15–21 cmol kg^{-1}), enabling efficient retention of water and nutrients (Bar-Tal et al., 2019).
Rockwool	Inert fibrous substrate produced by melting natural rocks at high temperatures. It provides excellent water retention and aeration, maintains high moisture levels and is widely used in horticultural cultivation (Yafuso et al., 2024).
Perlite	Expanded volcanic glass characterized by high porosity, low bulk density, and the ability to retain water while providing excellent aeration and drainage. It is chemically inert, has a neutral pH, contains negligible mineral nutrients and is sterile due to high-temperature processing (Bar-Tal et al., 2019).

The observed parameters included plant height, leaf area, net assimilation rate (NAR), crop growth rate (CGR), and mineral content. Plant height was recorded at 4, 8, and 12 DAP using a ruler from the medium surface to the highest leaf tip. Leaf area was measured at 14 DAP using digital image analysis. Images of cotyledon leaves were taken on a white background with a ruler as a scale reference and analyzed using ImageJ.

The net assimilation rate (NAR) was calculated based on the increase in plant dry weight relative to leaf area over time as follows:

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\ln A_2 - \ln A_1}{A_2 - A_1} \quad (1)$$

where $W_1$and W_2represent plant dry weight at the first and second observations (g), $A_1$and A_2represent leaf area at the first and second observations (cm^2), $t_1$and $t_2$represent the time interval between observations (days), and $\ln$denotes the natural logarithm. The crop growth rate (CGR) was calculated using the following formula:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{Ga} \quad (2)$$

where $W_1$and W_2represent plant dry weight (g), $t_1$and $t_2$represent the observation time interval (days), and $G_a$represents the planting area (m^2).

Mineral content analysis was conducted using the PANalytical Epsilon 1 X-Ray Fluorescence Spectrometer manufactured by Malvern Panalytical. Plant samples were oven-dried at 75°C for 12 h, ground into a fine powder, and placed in plastic sample cups sealed with a 3.6 µm Mylar film. The instrument was calibrated using the Omnian standardless method with gain calibration prior to analysis. Samples were analyzed at 8 and 12 kV, and the concentrations of phosphorus (P), manganese (Mn), and chloride (Cl) were quantified using Epsilon Dashboard software (Panalytical, 2018).

Data were subjected to analysis of variance (ANOVA) at the 5% significance level using IBM SPSS Statistics software. Prior to ANOVA, data were examined for normality and homogeneity of variance. When significant differences among treatments were detected, means were separated using the Least Significant Difference (LSD) test at $P < 0.05$.

RESULTS AND DISCUSSION

Plant Height

Analysis of variance showed that growing media significantly affected plant height at 4, 8, and 12 DAP. The LSD test ($P < 0.05$) indicated significant differences among treatments at each observation period (Table 2). Soil (M0) consistently produced the tallest plants throughout the experiment, reaching 6.602 cm at 12 DAP, whereas perlite (M4) produced the lowest plant height.

Table 2. Mean plant height of green mustard microgreens (*Brassica juncea* L.) at 4, 8, and 12 DAP

Treatments	Plant Height (cm)		
	4 DAP	8 DAP	12 DAP
M0 (Soil)	3.780 ± 0.11 a	4.804 ± 0.13 a	6.602 ± 0.13 a
M1 (Cocopeat)	3.000 ± 0.18 b	4.384 ± 0.28 c	5.554 ± 0.28 b
M2 (Vermiculite)	3.084 ± 0.10 b	4.146 ± 0.12 c	5.024 ± 0.11 c
M3 (Rockwool)	3.640 ± 0.08 a	4.746 ± 0.06 b	5.716 ± 0.10 b
M4 (Perlite)	1.872 ± 0.14 c	2.762 ± 0.12 d	3.712 ± 0.11 d

The superior plant height observed in soil indicates that this medium provided a more favorable root environment for early seedling development than the soilless substrates evaluated. Soil naturally contains essential macro- and micronutrients while maintaining a balanced combination of water retention, aeration, and nutrient availability, thereby supporting continuous cell division and elongation during early vegetative growth. These conditions are particularly important for microgreens because their short growth cycle requires rapid nutrient acquisition immediately after germination (Chen et al., 2024; Efendi et al., 2020)

Similar results were reported by Putra et al. (2025), who observed improved growth of mustard microgreens cultivated in nutrient-supportive media. Likewise, Ramli et al. (2023) demonstrated that soil-based media promoted greater vegetative growth owing to their balanced physical and chemical properties. However, these findings differ from those reported by Nishanth et al. (2025), who found that hydroponic substrates such as rockwool produced growth comparable to soil when supplemented with complete nutrient solutions. The discrepancy is likely attributable to differences in nutrient management because no additional nutrient solution was supplied in the present study.

The poor performance of perlite may be associated with its highly porous structure and limited capacity to retain nutrients. Although high porosity improves root aeration, excessive drainage may reduce water and nutrient availability during early seedling establishment, thereby restricting cell expansion and shoot elongation (Sisriana et al., 2021). This finding suggests that physical aeration alone is insufficient to support optimal microgreen growth without adequate nutrient availability.

Leaf Area

The growing medium also significantly affected leaf area at 14 DAP. The 5% LSD test separated the treatment means into four statistical groups, with soil (M0) producing the largest leaf area (1.013 cm^2) and perlite (M4) the smallest (Table 3).

Table 3. Mean leaf area of green mustard microgreens (*Brassica juncea* L.) at 14 DAP

Treatments	Leaf Area (cm^2)
M0 (Soil)	1.013 ± 0.03 a
M1 (Cocopeat)	0.675 ± 0.01 b
M2 (Vermiculite)	0.542 ± 0.02 c
M3 (Rockwool)	0.624 ± 0.03 b
M4 (Perlite)	0.460 ± 0.02 d

Leaf area is an important determinant of photosynthetic capacity because it directly influences light interception and assimilate production. The significantly larger leaf area observed in soil is consistent with its superior plant height, indicating that adequate nutrient availability and favorable water status promoted sustained leaf expansion throughout the cultivation period (Sobhy & Anandhi, 2025). Larger leaves generally increase the photosynthetically active surface, thereby enhancing biomass accumulation. Nitrogen, in particular, is required for chlorophyll, proteins, and photosynthetic enzymes, so adequate availability can increase assimilate production and promote leaf development (Fathi, 2022).

Similar observations were reported by Wang et al. (2025), who found that nutrient-rich growing media significantly promoted leaf expansion in leafy vegetables. Conversely, perlite produced relatively small leaves despite its favorable aeration. This result suggests that nutrient availability rather than aeration alone became the dominant limiting factor for leaf development under the cultivation conditions used in this study. These findings further support the importance of balancing physical and chemical properties of growing media to maximize vegetative growth in microgreens.

Net Assimilation Rate

Analysis of variance indicated a significant effect of growing medium on the net assimilation rate of green mustard microgreens (Table 4). Soil (M0) produced the highest NAR (0.818 g cm^{-2} day^{-1}). Cocopeat, vermiculite, rockwool, and perlite showed intermediate values and did not differ significantly from soil or rockwool.

Table 4. Mean *n*et *a*ssimilation *r*ate of *g*reen *m*ustard *m*icrogreens (Brassica juncea L.)

Treatments	Net Assimilation Rate (g cm^{-2} day^{-1})
M0 (Soil)	0.818 ± 0.012 a
M1 (Cocopeat)	0.778 ± 0.024 b
M2 (Vermiculite)	0.758 ± 0.028 b
M3 (Rockwool)	0.728 ± 0.005 b
M4 (Perlite)	0.771 ± 0.009 b

Net assimilation rate reflects the efficiency with which plants convert intercepted light into dry matter per unit leaf area. The significantly higher NAR observed in soil indicates that this medium provided a favorable balance of water availability, nutrient supply, and root-zone aeration, supporting efficient photosynthesis and carbon assimilation. Adequate nutrient availability, particularly nitrogen and phosphorus, promotes chlorophyll synthesis, enzyme activity, stomatal function, and carbon fixation, thereby enhancing dry matter accumulation (Dıaz-Lopez et al., 2020).

These results are consistent with Yuliana et al. (2025), who reported that improved leaf development enhances photosynthetic efficiency and biomass accumulation. Similarly, Nishanth et al. (2025) demonstrated that substrate properties influence photosynthetic performance by affecting root function and nutrient uptake. In contrast, although rockwool maintains good water retention and aeration, its inert nature limits nutrient availability unless supplemented, which may restrict leaf development and photosynthetic performance (Khairunnisa et al., 2023; Putra et al., 2025)

The statistically intermediate NAR values for cocopeat, vermiculite, and perlite indicate similar assimilation efficiency despite differences in plant growth. Notably, perlite maintained a relatively high NAR despite producing the lowest plant height and leaf area, indicating that photosynthetic efficiency per unit leaf area does not necessarily translate into greater biomass production. Therefore, NAR should be interpreted alongside crop growth rate to provide a more comprehensive assessment of plant productivity.

Crop Growth Rate

Growing medium significantly affected crop growth rate. The 5% LSD test showed that soil produced the highest CGR (2.398 g m^{-2} day^{-1}), whereas rockwool produced the lowest value (1.117 g m^{-2} day^{-1}). Cocopeat, vermiculite, and perlite produced in intermediate growth rates.

Table 5. Mean crop growth rate of green mustard microgreens (*Brassica juncea L.*)

Treatments	Crop Growth Rate (g m^{-2} day^{-1})
M0 (Soil)	2.398 ± 0.14 a
M1 (Cocopeat)	1.781 ± 0.27 b
M2 (Vermiculite)	1.376 ± 0.26 c
M3 (Rockwool)	1.117 ± 0.09 c
M4 (Perlite)	1.523 ± 0.09 c

Crop growth rate (CGR) reflects the overall increase in plant biomass over time and therefore integrates the combined effects of leaf development, photosynthetic efficiency, and nutrient uptake. The superior CGR observed in soil confirms that its favorable physical and chemical properties consistently supported plant growth throughout the cultivation period (Gruda, 2019). Unlike NAR, which measures assimilation efficiency per unit leaf area, CGR is strongly influenced by the total photosynthetically active surface. Consequently, the larger leaf area produced in soil resulted in greater carbon assimilation and dry matter accumulation.

This result align with Zhang et al. (2021), who emphasized that adequate water retention and aeration promote root activity and biomass production. Similar responses have also been reported in leafy vegetables grown in nutrient-supportive substrates (Rahmadani et al., 2023). The contrasting responses between NAR and CGR demonstrate that photosynthetic efficiency alone is insufficient to predict overall biomass production. Instead, successful microgreen cultivation requires an appropriate balance between assimilation efficiency and canopy development. This finding represents one of the key contributions of the present study because it highlights that different growing media influence plant productivity through different physiological mechanisms.

Analysis of Phosphorus (P) Mineral Content

Growing medium significantly affected phosphorus (P) content. Perlite (M4) produced the numerically highest value (756.0 mg/100g), but it did not differ significantly from cocopeat (754.2 mg/100g). Vermiculite (M2) was statistically intermediate, whereas soil (M0) contained the lowest P concentration (Table 6).

Table 6. Mean phosphorus content of green mustard microgreens (*Brassica juncea* L.)

Treatments	Phosphorus (mg/100g)
M0 (Soil)	451.8 ± 7.7 c
M1 (Cocopeat)	754.2 ± 23.7 a
M2 (Vermiculite)	706.8 ± 31.3 b
M3 (Rockwool)	671.2 ± 25.7 b
M4 (Perlite)	756.0 ± 33.0 a

Unlike the growth parameters, phosphorus concentration was highest in perlite and cocopeat rather than soil. This result indicates that the medium promoting the greatest biomass does not necessarily produce the highest mineral concentration. Such differences may reflect variations in nutrient retention, phosphorus availability, and biomass dilution among growing media (Gbollie et al., 2021). The relatively low phosphorus concentration observed in soil may be explained by the dilution effect, whereby rapid biomass accumulation distributes absorbed phosphorus over a larger amount of plant tissue, thereby reducing tissue concentration despite potentially greater total phosphorus uptake (Balik et al., 2024).

A similar phenomenon has been reported in leafy vegetables where vigorous growth reduces mineral concentration without decreasing total nutrient accumulation (Gruda, 2019). However, because the physicochemical properties of the growing media were not analyzed in the present study, this explanation should be interpreted cautiously. Future studies should evaluate substrate pH, electrical conductivity, nutrient availability, and phosphorus dynamics before and after cultivation.

Analysis of Manganese (Mn) Mineral Content

Growing medium significantly affected manganese (Mn) content. Vermiculite (M2) produced the highest concentration (65.8 mg/100g) and differed significantly from all other treatments, while soil (M0) ranked second at 59.4 mg/100g (Table 7).

Table 7. Mean manganese content of green mustard microgreens (*Brassica juncea* L.)

Treatments	Manganese (mg/100g)
M0 (Soil)	59.4 ± 3.7 b
M1 (Cocopeat)	31.2 ± 0.5 c
M2 (Vermiculite)	65.8 ± 2.2 a
M3 (Rockwool)	35.6 ± 1.2 c
M4 (Perlite)	34.4 0.7 c

Vermiculite produced the highest manganese concentration among all growing media, which is consistent with its high cation-exchange capacity and mineral composition. Vermiculite is capable of retaining divalent cations such as Mn^{2+}, thereby maintaining greater manganese availability in the root zone throughout plant growth. Manganese plays essential roles in photosystem II, enzyme activation, and antioxidant metabolism (Chatzistathis et al., 2020). Saurabh et al. (2025) similarly reported substrate-dependent differences in the mineral composition of microgreens. Importantly, vermiculite did not produce the greatest plant height, leaf area, or crop growth rate, indicating that increased Mn concentration alone could not compensate for limitations in other nutrients, water–air balance, or total photosynthetic surface. Vermiculite may therefore be considered when Mn enrichment is a production objective. However, consistency across substrate batches and the relationship between tissue concentration, bioavailability, and fresh yield should be evaluated before practical recommendations are generalized.

These findings reinforce the concept that nutrient enrichment and biomass production should not be considered equivalent production targets. Growing media selected to maximize specific mineral concentrations may not necessarily produce the highest plant growth.

Analysis of Chloride (Cl) Mineral Content

Growing medium significantly affected chloride (Cl) content. Cocopeat (M1) produced the highest concentration (4617.8 mg/100g), followed by soil (3465.0 mg/100g), while vermiculite, rockwool, and perlite formed a substantially lower statistical group (Table 8).

Table 8. Mean chloride content of green mustard microgreens (*Brassica juncea* L.)

Treatments	Chloride (mg/100g)
M0 (Soil)	3465.0 ± 152.6 b
M1 (Cocopeat)	4617.8 ± 183.2 a
M2 (Vermiculite)	562.2 ± 48.3 c
M3 (Rockwool)	607.8 ± 17.3 c
M4 (Perlite)	612.8 ± 41.7 c

The high Cl concentration under cocopeat may originate from soluble salt residues in coconut husk and from incomplete washing or buffering, which can increase chloride availability in the medium (Gbollie et al., 2021). The high water-retention capacity and large surface area of cocopeat may further promote the retention and movement of dissolved ions to plant roots (Gohardoust et al., 2020). This interpretation is also compatible with evidence that coconut fiber can accumulate elements associated with saline growing environments (Verasoundarapandian et al., 2021). Chloride is essential for ionic and osmotic balance at appropriate levels, but excessive accumulation may become undesirable for plant performance and nutritional quality (Raut et al., 2024). Because the present study did not establish a beneficial or excessive threshold for the observed 4.618% concentration, the result should not automatically be interpreted as a nutritional advantage. It is more appropriately viewed as evidence that cocopeat strongly influences chloride accumulation and therefore requires careful washing, buffering, and monitoring when used for microgreen production. This distinction is relevant to plant health, human consumption, and substrate quality control.

Overall, the present study demonstrates that no single growing medium simultaneously optimized plant growth and essential mineral accumulation in green mustard microgreens. Soil consistently produced superior vegetative growth and biomass-related parameters, whereas vermiculite, cocopeat, and perlite were more effective for accumulating specific mineral elements. These findings indicate that growing-medium selection should be based on production objectives rather than assuming that one substrate is universally superior. This goal-oriented approach provides practical guidance for urban agriculture and commercial microgreen production while contributing to a better understanding of the physiological trade-offs between biomass production and nutrient enrichment.

CONCLUSION

Different growing media significantly influenced vegetative growth and mineral accumulation in green mustard microgreens (*Brassica juncea* L.). Soil (M0) consistently produced the greatest plant height, leaf area, net assimilation rate, and crop growth rate, indicating its superior ability to support biomass production. In contrast, mineral accumulation varied among substrates, with vermiculite promoting the highest Mn concentration, perlite and cocopeat producing the highest P concentration, and cocopeat resulting in the greatest Cl accumulation. These results demonstrate that no single growing medium simultaneously maximized vegetative performance and all mineral contents.

Soil is recommended when the production objective is to maximize growth and biomass, while vermiculite, perlite, or cocopeat may be selected to enhance specific mineral profiles. Overall, this study demonstrates that growing media play an important role in determining both productivity and nutritional quality of microgreens, providing a scientific basis for goal-oriented substrate selection in sustainable urban agriculture. Future research should evaluate media combinations and nutrient management strategies to optimize microgreen production further.

REFERENCES

Al-barry, U. F., Syarifah, S. M., & Nugraheni, I. A. (2025). Pengaruh jenis media tanam terhadap pertumbuhan dan potensi aktivitas antioksidan microgreens pakcoy. *Prosiding Seminar Nasional Penelitian Dan Pengabdian Kepada Masyarakat*, *3*, 145–154. https://proceeding.unisayogya.ac.id/index.php/prosemnaslppm/article/view/993

Alloggia, F. P., Bafumo, R. F., Ramirez, D. A., Maza, M. A., & Camargo, A. B. (2023). Brassicaceae microgreens: A novel and promissory source of sustainable bioactive compounds. *Food Science*, *6*, 100480. https://doi.org/10.1016/j.crfs.2023.100480

Balik, S., Dasgan, H. Y., Ikiz, B., & Gruda, N. S. (2024). The performance of growing-media-shaped microgreens: The growth, yield, and nutrient profiles of broccoli, red beet, and black radish. *Horticulturae*, *10*(12), 0–20. https://doi.org/10.3390/horticulturae10121289

Bar-Tal, A., Saha, U. K., Raviv, M., & Tuller, M. (2019). Inorganic and synthetic organic components of soilless culture and potting mixtures. In *Soilless culture* (pp. 259-301). Elsevier. https://doi.org/10.1016/B978-044452975-6.50014-9

Bashariah, B., Mbusango, A., Ningsi, R., & Tola, K. S. K. (2024). Microgreens dan senyawa yang terkandung didalamnya: Literatur review. *Indonesia Berdaya*, *5*(2), 695–704. https://doi.org/10.47679/ib.2024792

Bhaswant, M., Shanmugam, D. K., Miyazawa, T., Abe, C., & Miyazawa, T. (2023). Microgreens—a comprehensive review of bioactive molecules and health benefits. *Molecules*, 1–24. https://doi.org/10.3390/molecules28020867

Bhat, M. A., Mishra, A. K., Shah, S. N., Bhat, M. A., Jan, S., Rahman, S., Baek, K. H., & Jan, A. T.

(2024). Soil and mineral nutrients in plant health: a prospective study of iron and phosphorus in the growth and development of plants. *Current Issues in Molecular Biology*, *46*(6), 5194–5222. https://doi.org/10.3390/cimb46060312

Chatzistathis, T., Tzanakakis, V., Giannakoula, A., & Psoma, P. (2020). Sustainability inorganic and organic amendments affect soil fertility, nutrition, photosystem ii activity, and fruit weight and may enhance the sustainability of Solanum lycopersicon L. (cv. 'Mountain Fresh') Crop. *Sustainability*, *12*(9028), 1–20. https://doi.org/10.3390/su12219028

Chen, Q., Song, Y., An, Y., Lu, Y., & Zhong, G. (2024). Soil microorganisms: Their role in enhancing crop nutrition and health. *Diversity*, *16*(12), 1–26. https://doi.org/10.3390/d16120734

Dıaz-Lopez, E., Aguilar-Luna, J. M. E., & Loeza-Corte, J. M. (2020). Net assimilation rate and agronomic efficiency of nitrogen in tartago (Ricinus communis l.) (Euphorbiaceae) in dry climate. *Scientifica*. https://doi.org/10.1155/2020/7064745

Efendi, B., Supriyono, & Dewi, W. S. (2020). Microgreens in a combination of manure and biochar planting media growth and nitrogen uptake of kenikir (Cosmos caudatus Kunth.). *International Conference on Climate Smart Sustainable Agriculture*, *466*, 1–5. https://doi.org/10.1088/1755-1315/466/1/012018

Fathi, A. (2022). Role of nitrogen (n) in plant growth, photosynthesis pigments, and n use efficiency: A review. *Agrisost*, *28*, 1–8. https://doi.org/10.5281/zenodo.7143588

Gbollie, S. N., Mwonga, S. M., & Kibe, A. M. (2021). Effects of calcium nitrate levels and soaking durations on cocopeat nutrient content. *Journal of Agricultural Chemistry and Environment*, *10*, 372–388. https://doi.org/10.4236/jacen.2021.103024

Gohardoust, M. R., Bar-Tal, A., Effati, M., & Tuller, M. (2020). Characterization of physicochemical and hydraulic properties of organic and mineral soilless culture substrates and mixtures. *Agronomy*, *10*(9), 1403. https://doi.org/10.3390/agronomy10091403

Gruda, N. S. (2019). Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. *Agronomy*, *9*(298), 1–24. https://doi.org/10.3390/agronomy9060298

Gunjal, M., Singh, J., Kaur, J., Kaur, S., Nanda, V., Mehta, C. M., Bhadariya, V., & Rasane, P. (2024). Comparative analysis of morphological, nutritional, and bioactive properties of selected microgreens in alternative growing medium. *Journal of Botany*, *165*, 188–201. https://doi.org/10.1016/j.sajb.2023.12.038

Hassan, F. A. (2023). Assessing the impact of soil ph on horticultural crop yield and quality. *International Journal of Horticulture and Food Science*, *5*(1), 114–116. https://doi.org/10.33545/26631067.2023.v5.i1b.204

Hidayat, A., Adzima, A. F., & Khairisa, N. H. (2022). Analysis of soil fertility status on agricultural land in West Sinjai District. *Tunas Geografi*, *11*(1), 65–72. https://doi.org/10.24114/tgeo.v11i1.36577

Kamaluddin, N. N., Hindersah, R., Cahayaningrum, D. N., Purba2, P. S. J., Wibawa, D. I., & Setiawati, M. R. (2022). Karakterisasi media tanam dari kombinasi cocopeat dan pupuk kandang ayam. *Soilrens*, *20*(1), 16. https://doi.org/10.24198/soilrens.v20i1.41352

Khairunnisa, N., Warnita, & Hervani, D. (2023). Impact of growing media and nutrition on growth and yield of broccoli microgreens (Brassica oleracea). *International Journal of Environment, Agriculture and Biotechnology*, *8*(3), 30–34. https://doi.org/10.22161/ijeab

Kingsley, D., Mishra, T., & Subbalekshmi, V. (2020). Microgreens: A general review. *International Research Journal of Engineering and Technology*, *7*(11), 1336–1339. www.irjet.net

Mardalena, I. (2021). *Dasar-dasar ilmu gizi konsep dan penerapan pada asuhan keperawatan*. Pustaka Baru Press.

Nishanth, D., Nair, C. S., Manoharan, R., & Subramanian, R. (2025). Harnessing desert resources: a comparative study of microgreens growth, nutrient dynamics, and performance in desert sand and rockwool. *Plant Science*, 1–18. https://doi.org/10.3389/fpls.2025.1677009

Panalytical, M. (2018). *Epsilon 1: Small and powerful*. malvernpanatycal.com https://www.malvernpanalytical.com/en/products/product-range/epsilon-range/epsilon1

Pessoa, C. C., Daccak, D. F., Legoinha, P. A., Ramalho, J. C., Lidon, F. C., & Silva, M. M. (2026). Mn's key roles in plant ecophysiology: A comprehensive review for unstressed and stress conditions. *Agronomy*, *16*(709), 1–28. https://doi.org/10.3390/agronomy16070709

Pratio, G. A., Rohmah, S. N., Akbarsyah, M. A., & Supriyanto, A. E. (2024). Konsep urban farming pada kota tanpa lahan pertanian. *Jurnal Bengawan Solo Pusat Kajian Penelitian Dan Pengembangan Daerah Kota Surakarta*, *3*(2), 122–141. https://doi.org/10.58684/jbs.v3i2.78

Putra, S., Dalimunthe, B. A., Adam, D. H., & Sitanggang, K. D. (2025). The effect of various planting media on the growth and yield of microgreen mustard (Brassica juncea L). Jurnal Agro*nomi Tanaman Tropika*, *7*(1), 5–8. https://doi.org/10.36378/juatika.v7i1.4235

Rahmadani, D., Sasongko, P. E., & Wijaya, K. (2023). Prediksi kemampuan tanah dalam menahan air pada berbagai tipe penggunaan lahan di Desa Karangpatihan, Kecamatan Balong, Kabupaten Ponorogo menggunakan karakteristik tanah yang tersedia. *Jurnal Ilmu Pertanian Indonesia*, *25*(2), 66–73. https://doi.org/10.31186/jipi.25.2.66-73

Ramli, R., Nurcholis, J., & Ramadhani, A. (2023). Efektivitas pengaplikasian air kelapa dan berbagai jenis media tanam terhadap produksi microgreen tanaman sawi (Brassica juncea L.). *Jurnal Agrisistem*, *19*(1), 32–39. https://doi.org/10.52625/j-agr.v19i1.270

Raut, S. K., Singh, K., Sanghvi, S., Loyo-celis, V., Singh, E. R., Rao, S. G., Singh, H., & Varghese, L. (2024). Chloride ions in health and disease. *Bioscience Reports*, *44*(5), 4–6. https://doi.org/10.1042/bsr20240029

Saputra, A., Setyawati, E. R., & Wilisiani, F. (2025). Pengaruh cocopeat sebagai campuran media tanam pada beberapa kedalaman tanah (top soil, sub soil) terhadap pertumbuhan bibit kelapa sawit (Elaeis guinensis Jacq) di Main Nursery. *Agroforetech*, *3*(3), 1591–1598. https://jurnal.instiperjogja.ac.id/index.php/JOM/article/view/2202

Sarjani, A. S., Endrawati, T., & Puspitorini, P. (2024). Teknik budidaya microgreen berbasis varietas tanaman lokal. AJAD: Jurnal Penga*bdian Kepada Masyarakat*, *4*(3), 726–732. https://doi.org/10.59431/ajad.v4i3.421

Saurabh, K., Roy, H. S., Shubha, K., Sundaram, P. K., Prakash, V., Koley, T. K., ... & Singh, R. R. (2025). Transforming rice straw into eco-friendly growing medium for microgreens: a solution for agricultural waste management. *Frontiers in Sustainable Food Systems*, *9*, 1556396. https://doi.org/10.3389/fsufs.2025.1556396

Seeda, A., El-Nour, A., Hammad, & Yassen. (2021). Chloride ions as a beneficial and essential micronutrient multifunctional, role and regulation in plant physiology: A review. *Middle East Journal of Applied Sciences*, *11*(01), 76–125. https://doi.org/10.36632/mejas/2021.11.1.8

Sisriana, S., Suryani, S., & Sholihah, S. M. (2021). Pengaruh berbagai media tanam terhadap pertumbuhan dan kadar pigmen microgreens selada. *Jurnal Ilmiah Respati*, *12*(2), 163–176. https://doi.org/10.52643/jir.v12i2.1886

Sobhy, D. M., & Anandhi, A. (2025). Soil nutrient monitoring technologies for sustainable agriculture: A systematic review. *Sustainability*, *17*, 1–29. https://doi.org/10.3390/su17188477

Sonyinderawan, F. (2020). Dampak alih fungsi lahan sawah menjadi non pertanian mengakibatkan ancaman degradasi lingkungan. *JURNAL SWARNABHUMI: Jurnal Geografi Dan Pembelajaran Geografi*, *5*(2), 36. https://doi.org/10.31851/swarnabhumi.v5i2.4741

Sukewijaya, I. M., Dwiyani, R., & Bimantara, P. O. (2025). Optimization of growing media to support microgreens growth and nutritional profile. Agro Bali: Agricultural *Journal*, *8*(1), 102–113. https://doi.org/10.37637/ab.v8i1.2249

Thirumalaisrinivasan, R., Krishnamoorthi, K., Palanisamy, S., & Ganesan, B. (2023). A review on occurrence, properties and food supplemen of microgreens. *International Journal of Creative Research Thoughts*, *11*(5), 543–553. http://www.ijcrt.org/

Verasoundarapandian, G., Wong, C. Y., Shaharuddin, N. A., Gomez-Fuentes, C., Zulkharnain, A., & Ahmad, S. A. (2021). A review and bibliometric analysis on applications of microbial degradation of hydrocarbon contaminants in arctic marine environment at metagenomic and enzymatic levels. *International journal of environmental research and public health*, *18*(4),

1671. https://doi.org/10.3390/ijerph18041671

Wang, L., Hasnain, M., & Tang, Z. (2025). Soil water availability alters plant - soil feedback effects on invasive plant growth and foliar herbivory. *Journal of Plant Ecology*, *18*, 1–13. https://doi.org/10.1093/jpe/rtaf044

Yafuso, E. J., Fisher, P. R., Boh, A. C., & Altland, J. E. (2024). Water and air relations in propagation substrates. *Hortscience*, *54*(11), 2024–2030. https://doi.org/10.21273/HORTSCI14145-19

Yuliana, A. I., Kulsum, U., Qomariah, N., & Zuhria, S. A. (2025). Analisis pertumbuhan tanaman pakcoy akibat pemberian pupuk anorganik, pupuk organik cair dan pupuk hayati. *Exact Papers in Compilation*, *7*(4), 179–186. https://doi.org/10.32764/epic.v7i4.1597

Zhang, Y., Xiao, Z., Ager, E., Kong, L., & Tan, L. (2021). Nutritional quality and health benefits of microgreens, a crop of modern agriculture. *Journal of Future Foods*, *1*(1), 58–66. https://doi.org/10.1016/j.jfutfo.2021.07.001