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The Effect of Providing Nitrogen on The Growth of Kesum (*Persicaria minor* Huds.) in a Deep Water Culture Hydroponic System

Sandy Ramadani[1], Wan Arfiani Barus[1,*], Yaseer Suhaimi bin Mohd[2]

Abstract

Kesum (*Persicaria minor* Huds.), a plant rich in flavonoids such as quercetin and quercetin-3-glucuronide, holds significant value as a traditional medicine and distinctive culinary herb, particularly in West Kalimantan. This study evaluated the effects of five nitrogen concentrations (0, 50, 100, 150, and 200 mg L^{-1}) on the growth and phytochemical accumulation of kesum cultivated using a floating-raft deep water culture (DWC) hydroponic system. The experiment was conducted in a greenhouse at MARDI, Malaysia, employing a randomized block design with five replications. The results revealed highly significant effects of nitrogen ($p < 0.01$) on all measured growth and phytochemical parameters. Key findings include the highest plant height (80.33 cm) at 100 mg L^{-1} nitrogen, maximum biomass production (fresh weight 176.64 g and dry weight 43.99 g per 30 plants) at 150 mg L^{-1} nitrogen, and a substantial increase in phytochemical content at 50 mg L^{-1} nitrogen, with quercetin-3-glucuronide reaching 98 μg/mg and quercetin 67 μg/mg—2 to 3 times higher than the control. In contrast, 200 mg L^{-1} nitrogen caused toxicity, resulting in reduced biomass and phytochemical levels. Based on these findings, the optimal nutrient recommendations are 100-150 mg L^{-1} nitrogen (with phosphorus maintained at 150 mg L^{-1} and potassium at 200 mg L^{-1}) for commercial production aimed at maximizing fresh leaf yield and biomass, and 50 mg L^{-1} nitrogen for cultivation focused on maximizing bioactive compound content for phytochemical extraction and the phytopharmaceutical industry.

Keywords: Analysis of Nutrients, Flavonoid Accumulation, Macro, Micro, Nutrient Solutions

1. Introduction

Indonesia boasts rich biodiversity, particularly in its diverse flora, which is widely used as traditional medicinal plants. One interesting plant to study is kesum (*Persicaria minor* Huds) (Taek et al., 2019). Formerly known as Polygonum minus Huds., the kesum plant grows in tropical and subtropical regions. Indonesia has significant potential to produce over 20,000 types of medicinal plants traditionally used as medicinal ingredients (Marhaeni, 2020). This plant has long been used by communities as a food ingredient, especially in traditional dishes (Satriyati & Biroli, 2021). Research by S. Dewi et al. (2019) indicates that through the isolation and characterization of methanol extracts of kesum leaves, flavonoid compounds, including rutin and quercetin, have been identified.

Kesum (Polygonum minus Huds.), a member of the Polygonaceae family, is a climbing plant that can grow up to 1 meter in height in lowland areas and up to 1.5 meters in the highlands. Its leaves are pointed and arrow-shaped, measuring 5–7 cm long and 0.5–2 cm wide (Mohd et al., 2022). This plant is native to Southeast Asia, including Malaysia, Thailand, Vietnam, and Indonesia. In Indonesia, it is particularly found in West Kalimantan. In West Kalimantan, Kesum (Polygonum minus Huds.) is widely used as a cooking spice, especially in the preparation of the regional spicy porridge. The plant thrives best in warm, humid environments, making it a common ingredient in various traditional dishes (Syari et al., 2022). The high demand for raw materials used in health product processing has driven the adoption of hydroponic systems to produce large quantities of raw materials quickly (Mohd et al., 2022).

The Deep Water Culture (DWC) hydroponic system replaces soil as a root-support medium by directly supplying nutrients, water, and oxygen through a solution in which the plant roots are continuously submerged (Yulia

*Correspondence: wanarfianibarus@umsu.ac.id
1) Universitas Muhammadiyah Sumatera Utara - Jl. Kapten Muchtar Basri No.3, Glugur Darat II, Kec. Medan Timur, Kota Medan, Sumatera Utara 20238, Indonesia
2) Malaysian Agricultural Research and Development Institute (MARDI) -MARDI, Persiaran MARDI-UPM, 43400 Serdang, Selangor, Malaysia

Rahmi et al., 2020). Limited land availability is a major constraint in conventional crop cultivation; However, hydroponics offers an effective solution for areas with restricted agricultural land because it requires minimal space and can be implemented in home yards, balconies, rooftops, or other open spaces. Consequently, the Deep Water Culture hydroponic system represents a highly effective approach for agricultural development in urban areas or regions with severe land limitations. Nearly all types of horticultural crops can be successfully cultivated using the DWC system, including kesum

Hydroponics is a plant cultivation system that uses nutrient-rich water solutions without soil. One hydroponic method that can be implemented is the floating hydroponic system (Ainina & Aini, 2018). This floating raft hydroponic system involves growing plants in holes in a tub or Styrofoam container floating above a nutrient solution in a reservoir, allowing the plant roots to come into direct contact with the nutrient solution (Ullah et al., 2019). Floating raft hydroponic cultivation has other advantages, including year-round availability and a shorter, more efficient cultivation cycle (Siregar & Novita, 2021)

A crucial factor determining the success of hydroponic cultivation is the nutrient solution. Meeting the plant's nutritional needs can lead to optimal growth (Valdhini & Aini, 2017). In general, hydroponics requires a complete nutrient mix containing essential macro and micronutrients.

Many complex fertilizers are available today, including AB Mix, which is specially formulated for hydroponics. Stock solution A contains macronutrients: Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sulfur (S), while stock solution B contains micronutrients: Iron (Fe), Manganese (Mn), Boron (B), Copper (Cu), Zinc (Zn), and Molybdenum (Mo). A crucial aspect in hydroponics is the precise formulation of nutrient solutions. S. Dewi et al., 2019) . researched optimizing nutrient composition for hydroponically grown cherry tomatoes and found that the optimal N:P: K ratio can increase yield by up to 30 %.

This study aims to evaluate the application of nutrient solutions in the Deep Water Culture (DWC) hydroponic system, with a particular focus on nitrogen, as a Solution to overcome land limitations at the Malaysian Agricultural Research and Development Institute (MARDI). In addition, this research also seeks to increase agricultural productivity, improve crop quality, and produce higher-quality plants. The results of this study are expected to advance agricultural science regarding the Deep Water Culture hydroponic system and to provide appropriate nutrient recommendations for farmers and the government to support sustainable agriculture in areas with limited land availability.

Nitrogen plays a crucial role in cultivating Kesum (Polygonum minus Huds.) using a Deep Water Culture (DWC) floating hydroponic system, where optimal nitrogen concentrations can enhance vegetative growth, biomass yield, and phytochemical content (Marbun, 2020). Each plant type requires different nutrient processes; this study aims to determine the optimal nutrient solution composition for Kesum plants. One challenge in preparing nutrient solutions is the lack of an ideal nutrient dosage to support optimal plant growth. Therefore, the AB mix dosage for kesum plants requires further research to identify the optimal dosage (Tiljuir et al., 2023). Therefore, this study was conducted to determine the effect of nitrogen concentration on the growth of Kesum (*Persicaria minor* Huds.) plants in a hydroponic system.

2. Material and Methods

2.1. Research Location

This research was conducted at the Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Selangor, Malaysia, at coordinates 2.9911° N, 101.7016° E, in a greenhouse. The study was conducted from September 22 to November 10, 2025 over two months. Furthermore, it is at an altitude of ±36 meters above sea level. This activity was conducted at the MARDI PTJ IC Plant Industry (Industrial Plantation Institute).

2.2. Planting Material

The Kesum plant can be propagated through stem cuttings. Top cuttings 15 cm long and containing 7–9 nodes are used as planting material. Leaves and lateral shoots are removed from the cuttings, leaving only the leaves on the main shoot. The stem cuttings, clamped with a damp sponge as a germination medium, are placed into planting holes on polystyrene. The 5 cm of the Kesum cuttings are submerged in the nutrient solution, while the remaining 7.5 cm are kept above the polystyrene in hydroponic systems. Generally, Kesum cuttings are planted in hydroponic systems in the afternoon to reduce stress on the planting material. The Kesum cuttings will begin to root after three days.

Figure 1. Planting materials used

2.3. Hydroponic Planting Systems

Hydroponic cultivation of Kesum using the Deep Water Culture (DWC) or floating raft technique is the easiest and most cost-effective method to implement and manage. The container dimensions for this hydroponic system were 1 m wide, 3 m long, and 0.3 m high. The container used in the hydroponic system was made of fiberglass. Plants suitable for growing using this technique are those with a short life cycle, such as leafy vegetables like mustard greens, water spinach, kale, and Kesum. The advantages of this system include ease of construction, no electricity required, low water consumption, and readily available materials and equipment**.**

Figure 2. Sponge as a germination medium

Figure 3. Kesum plants are ready to be planted in hydroponic containers

2.4. Research Methods

This study used a randomized block design (RBD) with five replications. Each treatment plot consists of 30 plants. The experiment involved four levels of nitrogen (N) concentration. The fertilizers used were formulated by the Malaysian Agricultural Research and Development Institute (MARDI) to meet the needs of the Kesum plant, with nitrogen concentrations varying according to the treatments. Treatments (T0-T4) had varying levels of nitrogen (N) mixed into the nutrient solution (0-50-100-150-200 mg L^{-1}), while phosphorus (P) and potassium (K) levels were kept constant at 150 mg L^{-1} and 200 mg L^{-1}, respectively. $NH4NO_3$ was used as the nitrogen source in the experiment. The NH4NO3 content was calculated and added to the nutrient solution. The nutrient solution was prepared as a 5 L stock solution. In total, five nutrient solutions were prepared as stock solutions for each treatment. All fertilizers used were water-soluble. The nutrient solution concentration was maintained at 2.0-2.5 EC and measured with an EC meter. The pH of the nutrient solution is adjusted to 5.5–6.5 before being applied to the plants. The diagram for implementing this research is as follows:

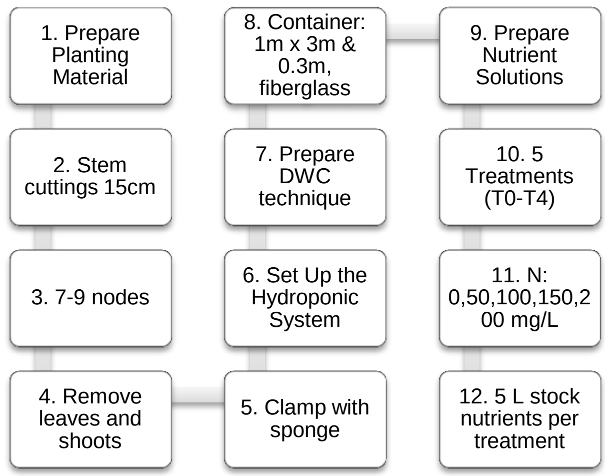

Figure 4. Research flow diagram

2.5. Observation Parameters

The growth of each Kesum plant was measured using Plant Height, Stem Diameter, SPAD, Wet Weight, Dry Weight, and Canopy Area. Thirty Kesum plants per treatment were collected to determine growth after 2 months of planting. The diagram for implementing this research is as follows:

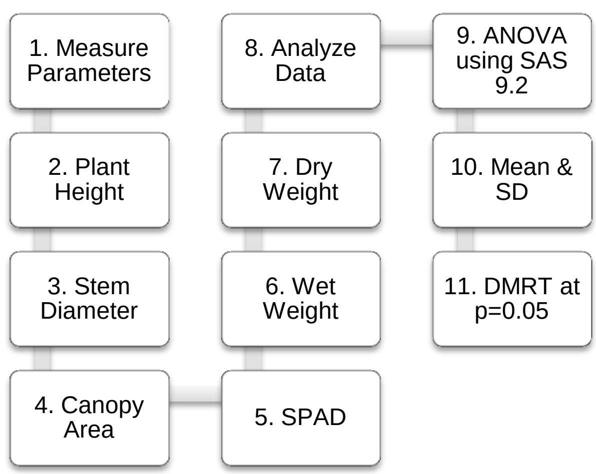

Figure 5. Observation parameters

2.6. Data Analysis

The data were analyzed statistically using analysis of variance (ANOVA) procedures to test the significance of all variables studied in SAS (version 9.2; SAS Institute, Cary, NC, USA).

The mean and standard deviation (SD) of the replicates were determined using analysis of variance (ANOVA), and Duncan's Multiple Range Test (DMRT) was used to determine significant differences between treatments. The statistical significance level was set at 0.05 for all tests.

3. Results and Discussion

Nitrogen fertilizer application affects plant height, stem diameter, chlorophyll volume, wet weight, and dry weight of Kesum plants (Table 1).

Table 1. Anova Analysis of Kesum Plant Growth

Parameter	Repeated	Treatment	Average ± SE	CV %
Plant Height	47.32	50741.38	68.53 ± 3.25 **	8.21
Stem diameter	0.17	44.97	6.50 ± 0.29 **	7.71
Canopy	15.85	9400.17	51.12 ± 2.62 **	8.87
SPAD	39.13	12726.35	45.12 ± 2.20 **	8.43
Wet Weight	61.68	275715.44	144.62 ± 7.24 **	8.67
Dry weight	33.62	6869.39	35.92 ± 1.61 **	7.79

Information: Analysis of variance (ANOVA) to test significant differences between treatments. The statistical significance level was set at 0.01** and 0.05* for all tests. This study used a randomized block design (RBD) with five replications and n = 30 plants/treatment/block.

Based on the variance analysis (ANOVA) used, it is found that Nitrogen fertilizer application can increase plant height, leaf number, and leaf surface area, which play a role in light absorption efficiency (Pameling & Suprihati, 2025). In food crops such as rice and corn, the addition of nitrogen at appropriate rates has been shown to increase the number of tillers and seed weight significantly (Anastasia et al., 2014). However, excessive nitrogen fertilization can have negative effects, such as excessive vegetative growth, delayed flowering, and decreased generative yields (Haq et al., 2024). Excess nitrogen also increases plant susceptibility to pests and diseases and can cause environmental pollution by leaching nitrate into groundwater.

Figure 6. Kesum plants aged 60 DAP in a hydroponic system

Based on table 1, observations of the results of the analysis of variance show that nitrogen concentration (Treatment) has a very significant effect ($p < 0.01$) on all growth parameters of the kesum plant, including plant height 50741.38, stem diameter (F = 44.97), canopy area (F = 9400.17), SPAD value (F = 12726.35), fresh weight (F = 275715.44), and dry optimal dose adjustments are needed to avoid negative effects such as overgrowth or nutritional imbalance, which can be further studied through specific dose analysis plants to nitrogen, with a low coefficient of variation (CV) value (7.71–8.87%) indicating relatively small data variability and consistent results. Nitrogen plays an important role in increasing vegetative growth (Barus *et al., 2018), chlorophyll (*0.05), indicating data consistency between replications. The overall average (Grand mean) reflects a positive response of weight (F = 6869.39). The replication factor did not show a significant effect (p > formation (SPAD value), and biomass accumulation (wet and dry weight), but 9400.17), SPAD value (F = 12726.35), fresh weight (F = 275715.44), and dry optimal dose adjustments are needed to avoid negative effects such as overgrowth or nutritional imbalance, which can be.

Based on Table 2, the average plant heights for the 50 mg/L, 150 mg/L, and 200 mg/L treatments showed similar average growth rates. However, field observations indicated that the 100 mg/L treatment produced the highest plant height, averaging 80.33 cm. Based on these results, it can be concluded that increasing the AB Mix nutrient dosage for kesum plants tends to improve plant growth.

These research findings support the statement (Frasetya et al., 2018) that the higher the nutrient solution concentration, the more nutrients it contains, thereby ensuring sufficient plant growth during the vegetative phase.

Table 2. Observations on the growth of Kesum plants 60 HST in the hydroponic system

Treatment	Plant Height	Stem Diameter	Canopy	SPAD	Wet Weight	Dry Weight
0 mg/L	31.88 ± 1.28 c	5.51 ± 0.22 b	36.04 ± 1.44 b	27.73 ± 1.11 a	60.33 ± 3.02 b	24.25 ± 1.21 a
50 mg/L	75.63 ± 3.03 a	7.15 ± 0.29 c	51.12 ± 2.04 c	44.89 ± 1.80 b	157.45 ± 7.87 a	37.48 ± 1.87 b
100 mg/L	80.33 ± 3.21 d	6.80 ± 0.27 d	54.29 ± 2.17 a	47.68 ± 1.91 c	172.06 ± 8.60 c	40.33 ± 2.02 c
150 mg/L	78.32 ± 3.13 b	6.48 ± 0.26 a	55.45 ± 2.22 a	51.46 ± 2.06 d	176.64 ± 8.83 d	43.99 ± 2.20 d
200 mg/L	76.46 ± 3.06 ab	6.55 ± 0.26 a	58.67 ± 2.35 d	53.79 ± 2.15 e	156.59 ± 7.83 a	33.50 ± 1.68 e

Information: Analysis of variance (ANOVA) with Duncan's Multiple Range Test (DMRT) to test significant differences between treatments. This study used a randomized block design (RBD) with five replications and n = 30 plants/treatment/block.

3.1. Average Stem Diameter (mm)

Based on Table 2, the best stem diameter was observed at the 50 mg/L dose (7.15 mm), then decreased at higher doses to the lowest at the 150 mg/L and 200 mg/L treatments. Plant stem diameter showed a significant response to variations in treatment concentration. This result indicates a significant difference based on Duncan's Multiple Range Test (DMRT) at the 5% significance level. Research by Ayu et al. (2017) showed that the main effect of NPK Mutiara fertilizer application significantly influenced melon plant stem diameter. The largest stem diameter was achieved with a dose of 5 g per plant (K1), measuring 11.86 mm, although this value was not significantly different from the untreated control (K0) at 10.45 mm, nor from the higher dose of 10 g per plant (K2) at 11.55 mm and 15 g per plant (K3) at 11.41 mm. These findings are consistent with Surya et al.'s (2021) assertion that a strong correlation exists between stem diameter and plant height, with plants exhibiting below-average height typically developing above-average stem diameters.

3.2. Canopy Area

Based on Table 2, the canopy area parameter continued to increase linearly from 36.04 cm² at 0 mg/L to 58.67 cm² at 200 mg/L, indicating that the high-dose treatment significantly promoted plant canopy expansion and was associated with increased photosynthesis. These research findings support those of Fakhrusy Zakariyya (. statement that in the early developmental stages, the growth and width of the plant's leaf canopy will continue to increase along with plant growth. Similarly, the leaf area in the canopy and the area of ground protected by the canopy will also increase.

3.3. Number of Chlorophyll (SPAD)

Based on Table 2, the SPAD value, an indicator of chlorophyll content, also increased consistently from 27.73 for the 0 mg/L treatment to 53.79 for the 200 mg/L treatment, indicating that higher doses effectively increase photosynthetic efficiency and leaf health. However, it is necessary to be aware of the potential for overdosing, as seen in decreases in other parameters such as height and diameter, so that the optimal overall dose appears to be in the range of 100-150 mg/L for balanced plant growth. Measurements were carried out on the uppermost part of the leaf, namely the top leaf before the flag leaf appears and the flag leaf after it appears, because this part is generally used in the practice of collecting data on the level of greenness of plant leaves. The results of this study are supported by Nurcahyani et al. (2020), who reported that chlorophyll b content tends to be lower than chlorophyll a and total chlorophyll, because chlorophyll a plays a more efficient role in photosynthesis and light capture. In short, chlorophyll b supports chlorophyll a, helping transfer light energy to it and allowing plants to adapt to changes in light intensity and environmental conditions.

3.4. Wet Weight

Based on Table 2, the wet weight value increased significantly from 60.33 g at 0 mg/L (control) to a peak of 176.64 g in the 150 mg/L treatment. This result indicates that increasing the nitrogen dose to a specific concentration effectively increases the kesum plant biomass growth. However, in the 200 mg/L treatment, the wet weight decreased to 156.59 g, which was not significantly different from 157.45 g in the 50 mg/L treatment. This result indicates an optimal nitrogen administration limit around 150 mg/L. The 100 mg/L treatment with a wet weight of 172.06 g showed near-optimal performance. This phenomenon indicates that nitrogen supports protein and chlorophyll synthesis in photosynthesis, but excessive doses in the 200 mg/L treatment can cause toxicity or nutritional imbalance; therefore, nitrogen application in kesum plants should be optimized to 100-150 mg/L to maximize growth without risking reduced plant yields.

Research conducted by Hidayati et al. (2021). The findings indicated that nitrogen fertilization at 125 g m² (N4) resulted in the highest fresh weight of mustard greens (Brassica juncea L.), achieving 240.82 g per plant. By comparison, the lowest fresh weight was observed at the lowest application rate of 50 g m ⁻ ² (N1). Overall, nitrogen fertilization markedly enhanced the growth and development of mustard greens, with the 125 gm ⁻ ² dose emerging as the optimal treatment.

The results of this study support the statement of Anastasia et al. (2014), who stated that wet weight is the total weight of the plant that still contains water. Based on the statistical analysis, wet weight shows a difference in the effect of fertilizer type on the kesum plant.

3.5. Dry Weight

Based on Table 2, the dry weight of the oven plant can be weighed after the plant is 60 days old after planting. The plant is dried in an oven at 35-40 °C, then weighed until the oven-dry weight is constant. Increasing the nitrogen concentration from 0 mg/L to 150 mg/L resulted in an average dry biomass of 24.25 g and 43.99 g, respectively, with the highest value at 150 mg/L—research conducted by Nescaya Suhendri et al. (2020). The results showed that NPK 16:16:16 fertilizer application significantly increased the average dry weight of young fronds of vegetable fern (Diplazium esculentum). The highest dry weight was recorded in the 0.6 g per plant treatment (N2) at 1.34 g, while the lowest was obtained in the no-fertilizer control (N0) at 1.21 g. These findings demonstrate that NPK 16:16:16 fertilization significantly improves the dry weight of young fronds in Diplazium esculentum.

This increase reflects nitrogen's role in supporting protein synthesis and vegetative growth in plants (Barus & Khair, 2020). However, at 200 mg/L, the dry weight decreased to 33.50 g, lower than the 50 mg/L treatment (37.48 g) and the 100 mg/L treatment (40.33 g), indicating a toxic effect due to excess nitrogen. Therefore, the optimal nitrogen dose for cassava plants is 100-150 mg/L to maximize growth. This is supported by Widarawati et al. (2023). The addition of nitrogen nutrients to plants not only accelerates vegetative growth but also stimulates the conversion of carbohydrates into proteins, which is essential for cell division, elongation, and root enlargement.

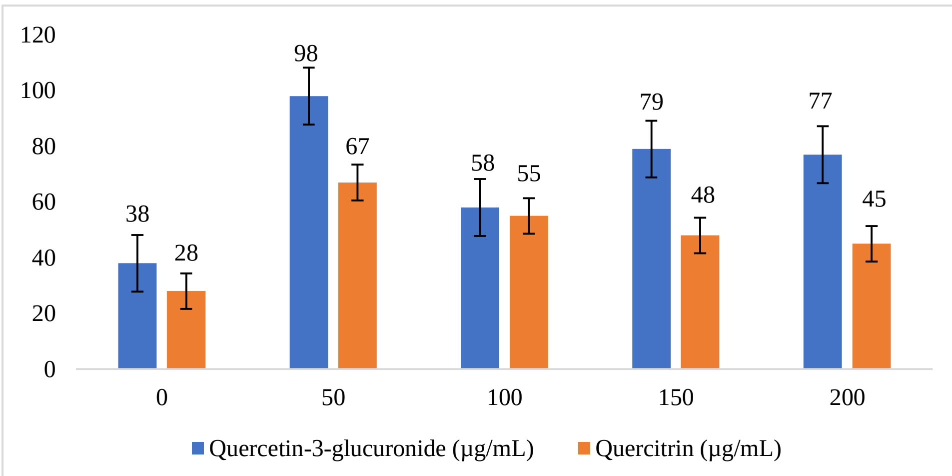

Figure 7. Diagram of the Phytochemical Content of Kesum Plants in Hydroponic Systems

Based on the diagram showing the concentrations of quercetin-3-glucuronide (blue) and quercetin (orange) in the leaves of the kesum plant at various nitrogen concentrations (0–200 µg/mg), it can be seen that optimal nitrogen application at a concentration of 50 µg/mg resulted in the highest phytochemical accumulation, with quercetin-3-glucuronide reaching 98 µg/mg and quercetin reaching 67 µg/mg, indicating a significant increase compared to the nitrogen-free controls (38 µg/mg and 28 µg/mg, respectively). However, further increases in nitrogen to 100–200 µg/mg actually decreased the levels of both compounds, with quercetin-3-glucuronide dropping to 58–77 µg/mg and quercetin even lower (45–55 µg/mg), indicating inhibition of flavonoid biosynthesis due to excess nitrogen, which may divert carbon assimilation to vegetative growth rather than secondary production. This is in line.

With the principle of plant nutrition, excess nitrogen can suppress the phenylpropanoid pathway. Therefore, the recommendation for cultivating kesum to maximize phytochemical content is a moderate nitrogen dose of around 50 µg/mg to support its pharmacological potential as a natural antioxidant—research conducted by Sukandiarsyah et al. (2025). The IC50 value of the ethanol extract of kesum (*Persicaria minor*) stem was 72.03 ppm. According to the classification of antioxidant activity based on IC50 values, very strong antioxidant activity is indicated by IC50 < 50 ppm, strong antioxidant activity by IC50 50–100 ppm, moderate activity by IC50 100–150 ppm, weak activity by IC50 150–200 ppm, and very weak activity by IC50 > 200 ppm. Therefore, the antioxidant activity of the kesum stem ethanol extract falls into the strong category. Furthermore, the principle that excess nitrogen suppresses the accumulation of phenolic compounds is supported by the research of Sutardi (2017), which explicitly discusses how nutrient stress conditions (such as deficiency) or appropriate N optimization trigger plant defense mechanisms to increase the production of secondary metabolites such as flavonoids.

The results of this study are supported by Kartikasari et al. (2022), who reported that kesum leaf extract was prepared by macerating dried simplicia for several days using various solvents, including 50% ethanol, 70% ethanol, 96% ethanol, and methanol. The aim of extracting kesum leaves with several types of solvents is to identify the chemical compounds contained in kesum leaves using different solvents.

4. Conclusion

This study demonstrates that nitrogen application in a floating raft hydroponic system (Deep Water Culture, DWC) has a highly significant effect on the growth and phytochemical content of kesum (*Persicaria minor* Huds.). Nitrogen concentrations of 100–150 mg L^{-1} proved optimal for vegetative growth and maximum biomass production, with the best performance observed at 150 mg L^{-1} (fresh weight 176.64 g, dry weight 43.99 g) and the greatest plant height at 100 mg L^{-1} (80.33 cm). In contrast, a low dose of 50 mg L^{-1} provided a clear advantage in phytochemical content, yielding the highest levels of quercetin-3-glucuronide and quercetin (98 µg/mg and 67 µg/mg, respectively), far exceeding those at higher doses. A dose of 200 mg L^{-1} caused a decline in performance due to nitrogen toxicity. Therefore, for kesum cultivation aimed at high-biomass vegetable production, nitrogen at 100–150 mg L^{-1} is recommended, whereas for producing herbal raw materials rich in antioxidants, the optimum nitrogen concentration is 50 mg L^{-1}. Precise nitrogen dose management enables hydroponic kesum cultivation to be accurately directed toward the intended production objective.

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