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Effect of BIO-P60 and BIO-T10 Applications on the Growth and Yield of Water Spinach Using a Hydroponic System

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Abstract
Cultivating water spinach using a hydroponic system and applying biofertilizers is a modern, environmentally friendly agricultural solution. This research aimed to determine the effect of Bio P60 and Bio T10 applications on the growth and yield of water spinach in a hydroponic system. The research was conducted in Banyumas Regency, Central Java, from February to May 2025. A Completely Randomized Design was employed with 2 factors. The first factor is hydroponic systems: wick and NFT systems, and the second factor is biofertilizer: Bio P60, Bio T10, and without biofertilizer. Data were analyzed using Analysis of Variance and Tukey's test at α = 5%. The research results showed that the wick and NFT (Nutrient Film Technique) hydroponic systems produced no significant differences in plant height, number of leaves, leaf area, biological fresh weight, and economic fresh weight of water spinach. Seed treatment by soaking with Bio P60 and Bio T10 biofertilizers significantly increased the biological fresh weight and economic fresh weight of water spinach compared to without biofertilizer application. In this study, biological fresh weight is an important variable determining the high production of water spinach per plant, with correlation coefficient and path coefficient analysis values of $r = 0.92$ (p-value ≤ 0.01) and $β = 0.94$ (p-value ≤ 0.05), respectively. To improve water spinach production and encourage sustainable farming methods, it is advised to use Bio P60 and Bio T10 in hydroponic water spinach cultivation.

Keyword: *Biofertilizer, Ipomoea aquatica, NFT, wick system.*

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INTRODUCTION

Water spinach (*Ipomoea aquatica* Forsk.) is one of the most popular leafy vegetables cultivated in Indonesia, due to its rapid growth phase and ease of cultivation, even in limited areas (Nitasari & Wahidah, 2020; Saleh & Bahri, 2023). Water spinach is a green vegetable rich in vitamins and minerals at an affordable price, and can be cultivated hydroponically (Fevria et al., 2021). Water spinach is rich in nutrients, bioactive compounds, vitamin A, protein, and antioxidants that are good for health (Hossain et al., 2021). The cultivation of vegetables such as water spinach in urban areas is greatly influenced by land availability, as it is known that land in cities is limited for agriculture (Santoso & Suhardjono, 2020). Water spinach cultivation using hydroponic systems is increasingly popular because it can improve the efficiency of water and fertilizer use and provide better environmental control compared to conventional cultivation (Manek et al., 2025). The application of the hydroponic system allows for more optimal nutrient management because the nutrients directly reach the plant root system, thereby providing higher and better quality yields (Fevria et al., 2021; Xiang et al., 2020).

The determining factors for successful plant cultivation using the hydroponic system are management, such as preparation of media, nutrient solutions, maintenance, harvesting, and post-harvesting (Hidayati et al., 2017). Measuring the EC (Electrical Conductivity) value is important and must be done regularly because it is the main indicator for determining the concentration of dissolved salts or nutrients in the nutrient solution. The optimal EC value for a plant can ensure that the plant's production is

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optimal (Shawon et al., 2023). In hydroponic systems, there are two commonly used methods, namely the Wick System and NFT (Nutrient Film Technique). The wick system is one of the simplest hydroponic methods and is widely used by beginners. It relies on the principle of capillarity, where a wick or string, usually made of flannel, cotton, or raffia, is used to deliver the nutrient solution from the reservoir to the plant roots through growing media such as rockwool, cocopeat, and vermiculite (Harahap et al., 2020). The wick system has the advantage of being cost-effective because it does not require electricity or pumps to deliver nutrients to the root area and is easy to maintain (Nurwahyudi & Hatta, 2021). This system is very suitable for leafy vegetables such as water spinach, which do not require a lot of water (Al Toriq et al., 2025).

The NFT (Nutrient Film Technique) system is one of the most widely used modern hydroponic techniques due to its efficiency and productivity. In this system, plant roots are placed in a thin layer of nutrient solution that flows continuously along a channel or sloped pipe with the help of a pump for 24 hours. Nutrients are constantly circulating, so that plant roots receive an optimal supply of water, oxygen, and nutrients (Nurza, 2022). The main components of NFT include a reservoir, a pump, a channel (usually a PVC pipe), and a nutrient solution return channel (Rozilan et al., 2023). The advantages of NFT include faster plant growth and efficient use of water and nutrients. However, this system is highly dependent on electricity; if the power goes out and the pump stops, the plants can dry out in a short time. NFT is particularly suitable for small-rooted plants such as water spinach, lettuce, and spinach (Payumi et al., 2022). Compared to the wick system, NFT is superior in producing growth, yield, and quality of cultivated plants (Dhumal et al., 2025).

Despite using a hydroponic system, plant growth and yield may potentially decline, mainly due to attacks by plant pests. One effort to overcome this problem is the use of biofertilizers containing beneficial microorganisms, such as *Pseudomonas fluorescens* in Bio P60 and *Trichoderma harzianum* in Bio T10 (Carsidi et al., 2023). Bio P60 is also known as a rhizosphere bacteria-based biofertilizer that can produce plant growth hormones, including IAA, which plays a role in stimulating root growth and increasing the efficiency of plant nutrient absorption (Wulansari et al., 2023). Bio T10 contains secondary metabolites from the *Trichoderma harzianum* fungus, which act as biological agents, increasing plant resistance to disease while also helping plant growth by improving substrate quality and nutrient availability (Soesanto et al., 2024; Widarawati et al., 2022).

Various studies examining the effects of frequency and dosage of Bio P60 and Bio T10 biofertilizers have shown positive results on plant growth and yield, such as plant height, number of leaves, and leaf area in various commodities such as sugar palm (Widarawati et al., 2022), cherry tomatoes (Wulansari et al., 2023), and melons (Soesanto et al., 2024), but research specifically exploring the effect of Bio P60 and Bio T10 on water spinach hydroponic systems has not been found. Therefore, this study is necessary to determine the extent of the effect of Bio P60 and Bio T10 application on the growth and yield of water spinach in a hydroponic system to obtain optimal results, as well as to serve as a reference in the development of sustainable agricultural technology, particularly for leafy vegetable commodities.

MATERIALS AND METHODS

Place and Time

The research was conducted at the Greenhouse and Agronomy and Horticulture Laboratory, Faculty of Agriculture, Universitas Jenderal Soedirman, North Purwokerto District, Banyumas Regency, from February to May 2025, at an altitude of 159 meters above sea level (m asl).

Materials and Tools

The materials used in this study were water spinach seeds, 20% salt solution, clean water, rockwool, trays, water, Bio P60 (*Pseudomonas fluorescens* P60, 10^8 cells mL^{-1}), Bio T10 (*Trichoderma harzianum* T10, 10^8 conidia mL^{-1}) (Mugiastuti et al., 2025), AB-mix nutrients, and filter paper. Materials for assembling the hydroponic installation included plastic trays, styrofoam, net pots, gutters, lightweight steel frames, PVC pipes, hydroponic hoses, and electrical cables. Tools used include a nutrient tank/container for storing nutrient solution, a pH meter, a TDS meter, a stirrer, a glass beaker, tweezers, a water pump, an aerator, a hacksaw, an electric drill, a wrench, a spirit level, scales, a ruler, plastic packaging, and stationery.

Research Methods

The research was designed using a Completely Randomized Design (CRD) consisting of two factors. The first factor was the hydroponic system: the wick system and NFT (Nutrient Film Technique) system. The second factor was biofertilizer: Bio-P60, Bio-T10, and without biofertilizer (control).

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From these two factors, six treatment combinations were obtained, with three replicates, resulting in 18 experimental units. Each experimental unit contained six plants, resulting in a total of 108 water spinach plants.

Sowing was carried out 7 days before transplanting the seedlings. Sort the seeds before sowing by selecting seeds that were intact/undamaged, plump, bright in color, and not wrinkled. The selected seeds were soaked in a 20% salt solution for 30 minutes. Seeds that sank were rinsed with clean water and drained, while seeds that floated were not used. The seeds were then soaked in Bio-P60 and Bio-T10 solutions according to each treatment at a concentration of 0.02% (2 $ml.l^{-1}$ of clean water) for 15 minutes. The seeds are sown on 2 cm x 2 cm x 2 cm rockwool that has been sufficiently moistened (not flooded) with Bio-P60 and Bio-T10 solutions according to each treatment and placed in a tray. The trays were placed in a shaded area for 2–3 days. Once germination occurred, they could gradually be moved to a sunny location. Seedling transplantation to the hydroponic system was carried out 7 days after sowing.

The hydroponic system assembly for the wick system used plastic trays to hold the nutrient solution. Styrofoam was used as a container for the growing medium and to support the plants. It was cut to fit the size of the tray, and planting holes were made in the styrofoam to fit the net pots (4.5 cm in diameter). Assembly of a hydroponic system for an NFT system involves using a lightweight steel installation frame in the shape of a table with four supporting legs, where one side is made higher than the others (installation slope of 1–3% or 1–3 cm per meter of pipe length). The gutter was cut according to the length of the installation frame, and holes were made with a planting distance of 15 cm and a hole diameter of 4.5 cm. The reservoir and lid were placed on top of the installation frame, and a drainage channel for the nutrient solution from the water gutter to the nutrient reservoir was made using PVC pipes. The hydroponic hose was connected to the pump, which was connected to the nutrient reservoir. The end of the hydroponic hose was connected to the gutter.

In each of the hydroponic systems, AB-mix nutrients were prepared. A total of 179.96 g of nutrient A was dissolved in 1 liter of water, and 128.02 g of nutrient B in 1 liter of water. Each of them was placed in separate bottles and stirred evenly to become concentrate A and concentrate B. A total of 500 ml of concentrate A and concentrate B were dissolved in 40 liters of water and stirred. The 40 liters of AB-mix nutrient solution were then made into 150 liters of solution (equivalent to 5 ml of concentrate A + 5 ml of concentrate B in 1.5 liters of water). The nutrient solution was adjusted to the hydroponic system used. The water spinach seedlings were transplanted by transferring the rockwool to net pots in both the wick system and the NFT system. The seedlings are transplanted 1 week after sowing (WAS). The water spinach was harvested when the plants were 3 weeks old (28 days including sowing).

The variables observed were microclimate conditions; air temperature and relative humidity using a thermohygrometer, light intensity using a lux meter, pH of the nutrient solution measured using a pH meter, Total Dissolved Solids (TDS) (ppm) and EC (Electrical Conductivity) ($mS.cm^{-1}$) measured using TDS and EC meters, which were conducted when the plants were 1, 2, and 3 weeks after transplanting (WAT). The plant growth variables observed included plant height (cm) at 2 and 3 WAT, number of leaves at 2 and 3 WAT, and the variables of water spinach yield components observed at harvest (3 WAT) included leaf area (cm^2) using the gravimetric method, biological fresh weight ($g.plant^{-1}$) which included the crown and roots of water spinach plants, yield variables in the form of economic weight ($g.plant^{-1}$) which included the weight of the crown (stems and leaves) of water spinach plants.

Data Analysis

The observation data were analyzed using analysis of variance (ANOVA) at a level of α 5% to determine the effect of treatment, followed by a post hoc test, Tukey's HSD (Honestly Significant Difference) at a level of α 5% if there were significant differences between treatment factors. Pearson's correlation analysis was used to measure the strength of the linear relationship between two variables. The results of this analysis were correlation coefficients ranging from -1 to +1. Coefficients close to +1 indicate a strong positive relationship, while coefficients close to -1 indicate a strong negative relationship, and coefficients close to 0 indicate a weak or no linear relationship. Path coefficient analysis is a technique used to divide correlation coefficients into direct and indirect effects. The variables studied are classified as dependent variables and independent variables. In path analysis, economic weight is used as the dependent variable, biological harvest weight is used as the mediator variable, and other variables are used as independent variables. Statistical analysis was performed using the RStudio 3.6.0 program.

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RESULTS AND DISCUSSION

Microclimate Conditions of the Research Environment

Based on environmental observations in the cultivation greenhouse, the average air temperature during the study was 28.9–31.6 °C, with relative humidity of 73.3%–78.7% and light intensity of 2,275–4,303.7 lux. These environmental conditions are ideal for water spinach growth. The optimal air temperature for water spinach growth in greenhouses was 25–32 °C, with humidity of 40–75% (Nisa et al., 2023), and the optimal light intensity for water spinach was 4,305.56–8,611.13 lux (Fadhlillah et al., 2019).

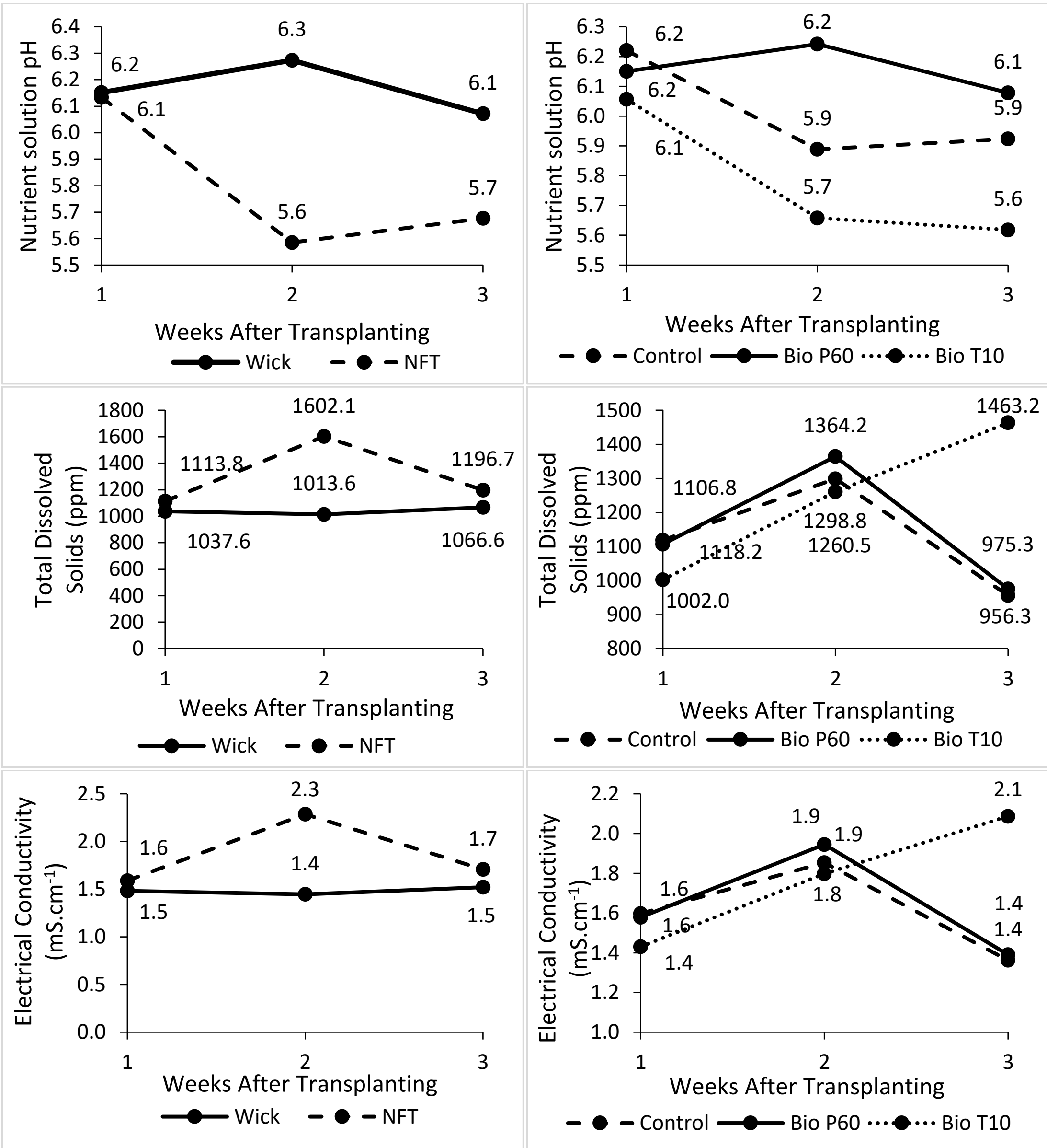

Figure 1. Nutrient pH, Total Dissolved Solids, and Electrical Conductivity for Each Treatment Factor

Observations of the nutrient solution pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC) were conducted every 1, 2, and 3 WAT. The data obtained were discussed for each of the factors because there were no significant differences between treatment factors. According to theory, the ideal nutrient solution pH for water spinach growth is 5.5–6.5 (Maulady et al., 2022). The nutrient solution pH in the wick and NFT hydroponic systems was still within the ideal pH range for water spinach, although the difference between the two systems was not significant. Similarly, the results of measurements for the nutrient solution pH with and without biofertilizer treatment were not significantly different. The Total Dissolved Solids (TDS) values for both factors tested were not significantly different, ranging from 1,013.6–

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1,066.6 ppm for wick system hydroponics and 1,113.8–1,602.1 ppm for NFT hydroponics, while the range for the used of biofertilizer and without biofertilizer was 956.3–1,463.2 ppm. The ideal TDS value for the growth of leafy vegetables such as water spinach was between 1,000–1,400 ppm. At a TDS level of 1,200 ppm, there was a balance of nutrients needed by plants, while a TDS of 1,400 ppm indicated a stagnant growth rate, so that a TDS exceeding 1,400 ppm did not benefit the growth and yield of water spinach and even reduced yields (Chander, 2023).

Electrical Conductivity (EC) values were directly proportional to TDS values, where EC for wick hydroponic systems was 1.4–1.5 $mS.cm^{-1}$ and NFT hydroponics was 1.6–2.3 $mS.cm^{-1}$, while the range for the used of organic fertilizers and without organic fertilizers was 1.4–2.1 $mS.cm^{-1}$. The optimal EC value for water spinach growth in hydroponics was in the range of 1.6–2.4 $mS.cm^{-1}$ (Efendi & Murdono, 2021), but some studies suggest that higher EC levels up to 2.8 $mS.cm^{-1}$ during the generative growth stage trigger higher crop yields, and exceeding this limit can cause nutrient toxicity, which can lead to osmotic stress, inhibit water and nutrient absorption, and damage plants (Shawon et al., 2023). The results of measuring the pH of the nutrient solution, TDS, and EC at 1–3 WAT indicated that the nutrient solution conditions were sufficiently suitable for water spinach cultivated using a hydroponic system, and the use of organic fertilizer did not inhibit the growth and yield of water spinach.

Plant Height and Number of Water Spinach Leaves

Plant growth can be described by the increase in plant size, which can be measured from the variables of plant height and number of leaves. Table 1 showed that the plant height and number of water spinach leaves observed at 2 and 3 WAT did not interact with the treatment factors and did not differ significantly between the hydroponic systems used with and without biofertilizer. Water spinach plant growth using the wick system ensured that plant roots received a simultaneous supply of water and nutrients (Nirmalasari & Fitriana, 2019), while in the NFT hydroponic system, plants received good air circulation in the plant root system due to the continuous flow of water and nutrients (Payumi et al., 2022). The main difference between the wick and NFT systems lies in the plant nutrient solution system. The wick system was classified as a passive nutrient solution system, where the plant roots remain in contact with the nutrient solution, while NFT was classified as an active nutrient solution system, which uses a reservoir and automatic pump to supply nutrients and water (Macwan et al., 2019).

The application of Bio P60 and Bio T10 biofertilizers during seed soaking did not show a significant difference compared to no biofertilizer application in terms of plant height and the number of water spinach leaves from 2 weeks of age until harvest (3 WAT). This may be due to the insufficient duration of seed soaking. Seed soaking using Bio P60 and Bio T10 ideally requires up to 30 minutes (Soesanto et al., 2024). The importance of proper soaking time was to prevent the sown seeds from experiencing cell damage and to reduce seed germination (Widarawati et al., 2022). Although not significantly different, the application of Bio P60 resulted in taller plants and more leaves. In addition to soaking time, low doses of biofertilizer had no effect or could reduce hormone activity, thus having no effect on the number of leaves (Mugiastuti et al., 2025).

Table 1. Plant Height and Number of Water Spinach Leaves at 2 and 3 WAT

Treatments	Plant Height 2 WAT (cm)	Plant Height 3 WAT (cm)	Number of Leaves 2 WAT	Number of Leaves 3 WAT
Hydroponic Systems				
Wick	24.13	34.38	11.69	19.17
NFT	27.34	40.89	11.54	17.49
Biofertilizer				
Bio P60	30.31	37.62	15.03	23.00
Bio T10	26.48	42.93	10.49	15.63
Without biofertilizer	20.40	32.35	9.33	16.35
Interaction	(-)	(-)	(-)	(-)
CV (%)	29.15	26.39	16.99	17.09

Remarks: Means followed by the different letters in the same column are significantly different at the 5% probability level by Tukey's test. The sign (-) indicates that there is no interaction between treatment factors. WAT = Weeks After Transplanting. CV = Coefficient of Variation.

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Yield Components and Water Spinach Yield

Water spinach plants were harvested at 3 weeks after transplanting, when the leaves were fresh green and fully open, before the plants flowered, with a plant height of 20–25 cm (Febriani et al., 2022). Plant leaves were important in the production of assimilates through photosynthesis, and they play a role in transpiration and respiration. Leaf area and leaf density were variables that could be measured to determine the growth and yield of water spinach plants (Ali et al., 2022).

Table 2 showed that the leaf area of water spinach observed at harvest (3 WAT) did not show any interaction between treatment factors and differed significantly both in the hydroponic system used and with and without biofertilizer. Biological fresh weight was the fresh biomass (biological material) of all parts of the plant, including roots, stems, leaves, and water contained in plant cells and tissues, expressed in units of mass per plant. Economic fresh weight was the fresh biomass of plants that had economic value or were sold, expressed in units of mass per plant. In this study, economic fresh weight refers to the fresh weight of water spinach leaves and stems without roots.

Table 2. Leaf Area of 3 WAT, Biological Fresh Weight, and Economic Fresh Weight of Water Spinach Plants

Treatments	Leaf Area of 3 WAT (cm^2)	Biological Fresh Weight ($g.plant^{-1}$)	Economic Fresh Weight ($g.plant^{-1}$)
Hydroponic Systems			
Wick	31.93	281.11	253.89
NFT	33.32	303.89	250.08
Biofertilizer			
Bio P60	35.36	349.72 a	293.06 a
Bio T10	35.27	360.56 a	343.00 a
Without biofertilizer	27.25	167.22 b	119.90 b
Interaction	(-)	(-)	(-)
CV (%)	37.66	19	19.86

Remarks: Means followed by the different letters in the same column are significantly different at the 5% probability level by Tukey's test. The sign (-) indicates that there is no interaction between treatment factors. WAT = Weeks After Transplanting. CV = Coefficient of Variation.

Table 2 showed that there was no interaction between treatment factors on biological fresh weight and economic fresh weight observed at harvest (3 WAT). Water spinach grown using the wick and NFT hydroponic systems showed no significant difference in biological and economic fresh weight, while the use of Bio P60 and Bio T10 biofertilizers resulted in significantly higher biological and economic fresh weight compared to without biofertilizer application. Bio P60 biofertilizer, which contains secondary metabolites from *Pseudomonas fluorescens* P60 bacteria, stimulated plant growth and acted as a PGPR that produced hormones for plants, including IAA, thereby increasing plant fresh weight compared to without Bio P60 application (Soesanto et al., 2019). Bio T10 biofertilizer contains *Trichoderma harzianum* T10, which, in addition to being an antagonistic fungus that plays an important role in the biological control of various plant diseases, also plays a role in stimulating plant growth by providing nutrients that are easily absorbed by plants (Dutta et al., 2024), thereby increasing plant fresh biomass (Soesanto et al., 2024). The application of Bio P60 and Bio T10, each of them or in combination, improved plant growth and yield, as well as plant resistance (Soesanto et al., 2019).

Correlation Coefficients and Path Analysis of Water Spinach Growth Components and Yield

Plant growth component variables were correlated with crop yield. Pearson's correlation coefficient (r) was used to indicate the strength of the relationship between two variables (Wamanrao et al., 2020). The closer the value was to +1 or -1, the stronger the linear relationship between the two variables. Correlation coefficients were stratified into several categories, namely insignificant (0.00–0.10), weak (0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89), and very strong (0.90–1.00) (Schober et al., 2018).

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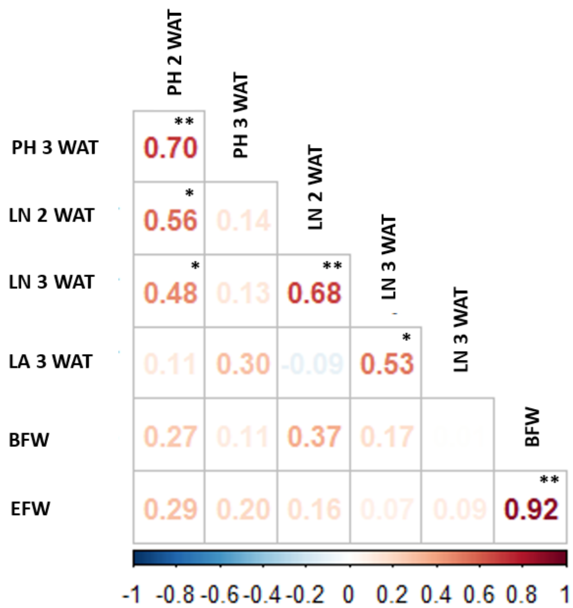

Figure 2. Correlogram of the relationship between growth variables and the economic fresh weight of water spinach

Remaks: WAT = Weeks After Transplanting. PH 2 WAT = Plant Height 2 WAT, PH 3 WAT = Plant Height 3 WAT, LN 2 WAT = Number of Leaves 2 WAT, LN 3 WAT = Number of Leaves 3 WAT, NA 3 WAT = Leaf Area 3 WAT, BFW = Biological Fresh Weight, EFW = Economic Fresh Weight. The numbers indicated a positive correlation, ** = significantly different at the 1% level, * = significantly different at the 5% level.

Figure 2 showed the correlogram of the relationship between growth components and yield, namely plant height, number of leaves, leaf area, biological fresh weight, and economic fresh weight. Plant height at 2 WAT was significantly and strongly positively correlated with plant height at 3 WAT and significantly and moderately positively correlated with the number of leaves at 2 and 3 WAT. The number of leaves at 3 WAT was significantly and moderately positively correlated with the number of leaves at 2 WAT and leaf area at 3 WAT. Biological fresh weight (r = 0.92**, p-value ≤ 0.01) was significantly correlated with economic fresh weight. High yield components influenced high yields (Rachana et al., 2021). Each one-unit increased in one component affects a one-unit increased in the other components (Syafrizal et al., 2024).

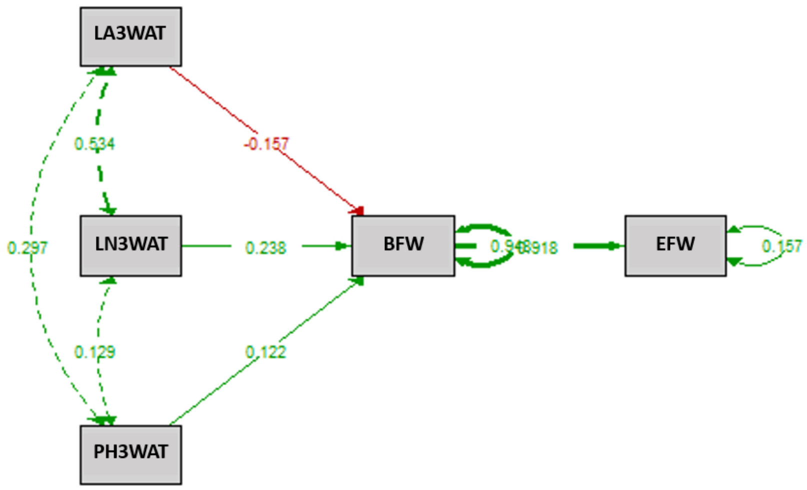

Figure 3. Path analysis diagram of growth variables on the economic yield of water spinach

Remaks: WAT = Weeks After Transplanting. PH3WAT = Plant Height 3 WAT, LN3WAT = Number of Leaves 3 WAT, NA3WAT = Leaf Area 3 WAT, BFW = Biological Fresh Weight, EFW = Economic Fresh Weight. R21 = 0.87 and R22 = 0.81. R^2_1 = 0.05 and R^2_2 = 0.88. Residual effect of path 1 (e1) = 0.97, residual effect of path 2 (e2) = 0.35.

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Path coefficient analysis (β) was conducted to examine the direct and indirect effects of independent variables on dependent variables (Wamanrao et al., 2020). Figure 3 showed a path analysis diagram of growth variables on the economic yield of water spinach. Plant height, number of leaves, and leaf area are independent variables, fresh economic weight were the dependent variables, and fresh biological weight was the mediator variable between the independent and dependent variables. Plant height 3 WAT (β = 0.238) and number of leaves 3 WAT (β = 0.122) had a positive direct effect on biological fresh weight. Leaf area 3 WAT (β = -0.157) had a negative direct effect on biological fresh weight.

The biological fresh weight had a direct positive effect on the economic fresh weight (β = 0.94, p-value ≤ 0.05). This result was consistent with the correlation coefficient results in Figure 2. Growth variables did not showed a strong effect on mediator variables, but mediator variables had a strong effect on dependent variables. Plants with high biological fresh weight generally also had high economic fresh weight, especially if the economically valuable parts grow optimally. Fresh weight was directly related to the productivity of leafy vegetables and can be used as an indicator to determine the production stage and growth rate (Moon et al., 2022). The results of the correlation coefficient and path coefficient analyzed indicated that the determination of growth variables needs to be considered in order to obtain important variables that determine high production.

CONCLUSION

The research demonstrated that the type of hydroponic system (wick and NFT) did not significantly affect the growth and yield of water spinach, as both systems produced comparable results in terms of plant height, number of leaves, leaf area, biological fresh weight, and economic fresh weight. However, the application of biofertilizers had a significant positive impact. Both Bio P60 and Bio T10 effectively increased the biological fresh weight and economic fresh weight of water spinach compared to cultivation without biofertilizers. Among the growth components, biological fresh weight was found to be the most important determinant of high yield, as it strongly influenced the economic fresh weight. Therefore, the use of Bio P60 and Bio T10 is recommended in hydroponic water spinach cultivation to enhance productivity and support sustainable agricultural practices.

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