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FONi's Performances in the Hydroponic Cultivation of Various Vegetables

Eka Erfiana[1*], Budi Indra Setiawan[1], Satyanto Krido Saptomo[1]

[1]Department of Civil and Environmental Engineering, Faculty of Agricultural Engineering and Technology, IPB University, Ulin Street, Kampus IPB Dramaga, Babakan, Kec. Dramaga, Kabupaten Bogor, Jawa Barat 16680, Indonesia.

*Corresponding author, email: erfiana1990eka@apps.ipb.ac.id

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Abstract

Land conversion, a phenomenon being encountered today, has led to a decline in the availability of agricultural land. On the other hand, population growth requires more food, which means more farmland is needed. Hydroponics is a method to grow crops intensively in any form of space without using soil, but only nutritious water as the growing medium. Hydroponics can produce high-quality crops and is easy to implement, making it popular in urban areas. However, it requires a continuous flow of water using electric pumps, which ultimately increases investment and operating costs. In this study, FONi (An Unpowered Automatic Fertigator) was tested to maintain water levels and flow rates as required by the plants. FONi is designed to replace the water lost by plant evapotranspiration, utilizing an automatic water valve. Here, FONi demonstrated good performance in growing three types of vegetables, namely water spinach (kangkung), choy sum (caisim), and spinach (bayam). The water productivity of each was 47.51 kg/m³, 43.80 kg/m³, and 21.25 kg/m³, respectively, and the land productivity was 1.35 kg/m², 0.97 kg/m², and 0.57 kg/m², respectively. The overall water efficiency was above 80%. By applying FONi, hydroponic cultivation activities at the research site, which had been suspended, can resume without incurring electricity costs.

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1. Introduction

The conversion of agricultural land to non-agricultural use is one of the most common types of land conversion, particularly in Indonesia. According to research Abimayu & Kurniati., (2024), the conversion of agricultural land to industrial land has a negative impact on food crop production. Additionally, economic hubs are targets for land conversion into residential areas (Monsaputra, 2023). Land conversion is also defined as a change in the intended use of land caused by various factors, primarily to meet the growing needs of an increasing population (Casanova Noviyanti & Sutrisno, 2021).

Indonesia currently ranks fourth among countries with the largest populations in the world. An estimated 66.6% of Indonesia's population is expected to live in urban areas by 2035 (BPS, 2020). This will undoubtedly lead to an increase in the demand for residential, industrial, and infrastructure land and pose challenges to food security due to the reduction in agricultural land. These challenges are further exacerbated by unpredictable climate change, which future generations will have to confront and adapt to. Hydroponic farming systems offer an efficient use of available space to support sustainable agriculture (Rajaseger et al., 2023).

Although there is a fairly large hydroponic cultivation area, it is not operating productively because of these issues. Hydroponic cultivation, which uses water as a growing medium, can be performed in small home gardens, garages, rooftops, and other unproductive areas. In addition to power dependency, the costs of equipment preparation and the need for monitoring and maintenance are also drawbacks of hydroponic systems (Rajaseger et al., 2023). However, this will undoubtedly be challenging to implement because of the significant costs involved. Hydroponic cultivation, which uses water as a growing medium, can be performed in small home gardens, garages, rooftops, and other unproductive spaces. Another advantage of this hydroponic system is that it can be carried out year-round, enabling continuous production and higher yields compared to conventional farming (Roidah, 2014). Small home gardens, garages, rooftops, and other unproductive spaces can be utilized for hydroponic cultivation.Hydroponics is a plant cultivation system that uses water as a growing medium. Small home gardens, garages, rooftops, or other unproductive spaces can be utilized for hydroponic cultivation. Another advantage of this hydroponic system is that it can be carried out year-round, enabling continuous production and yielding higher yields compared to conventional farming (Roidah, 2014). The DFT (Deep Flow Technique) hydroponic system is a type of hydroponic system in which plants are cultivated by placing their roots directly in a layer of water 4 to 6 cm deep. In principle, this system relies on a continuous 24 hour electricity supply to pump and circulate nutrient-rich water continuously (Yuniarti et al., 2023). Innovations in the application of solar panels as an electricity source for hydroponic system irrigation have also been implemented (Rumambi et al., 2023). However, this will undoubtedly be challenging to implement due to the significant costs involved. In addition to power dependency, the costs of equipment preparation and the need for monitoring and maintenance are also part of the drawbacks of hydroponic systems (Rajaseger et al., 2023). Based on these issues, the same situation occurs at the Irrigation Engineering Office. There is a fairly large hydroponic cultivation area, but it is not operating productively due to these issues.

An analysis was conducted to determine the water requirements of plants, productivity of water and land, irrigation efficiency, and performance of FONi with indicators of plant growth and yield using the DFT hydroponic system. Based on the background described above, it is necessary to apply FONi to DFT hydroponic systems.Currently, FONi technology is being developed and applied in horticultural crop cultivation, including flowers, fruit plants, and vegetables. Therefore, efforts are needed to modify hydroponic systems by applying FONi technology to address electricity dependency and reduce the labor requirements. This irrigation system is referred to as automatic irrigation, in which the water supply is controlled by a floating valve to maintain soil moisture levels. FONi (An Unpowered Automatic Fertigator) is an irrigation technology for crop cultivation that is a

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solution for ensuring the availability of irrigation water, independent of electrical power, and minimizing operator involvement (Muharomah et al., 2023). This irrigation system is referred to as automatic irrigation, where the water supply is controlled by a floating valve to maintain soil moisture levels. Additionally, this irrigation model is easy to maintain and operate (Syafriyandi et al., 2023). Therefore, efforts are needed to modify hydroponic systems by applying FONi technology to address electricity dependency and reduce labor requirements. Currently, FONi technology is beginning to develop and be applied in horticultural crop cultivation, including flowers, fruit plants, and vegetables. Based on the background described above, it is necessary to apply FONi to the DFT hydroponic system. An analysis was conducted to determine the water requirements of plants, to find out the productivity of water and land, as well as irrigation efficiency, and to figure out the performance of FONi with indicators of plant growth and yield with the DFT hydroponic system.

2. Material and Methods

2.1 Time and Location

The Irrigation Engineering Center is located in the East Bekasi District of Bekasi City, West Java, and the research was conducted from December 2024 to February 2025. The research location was carried out in one of the greenhouses owned by the Irrigation Engineering Center. The Irrigation Engineering Center is located in East Bekasi District, Bekasi City, West Java. Geographically, the research location is at 6°15'20" South Latitude and 107°00'5" East Longitude.

2.2 Research Instrument

Other equipment used included a water meter to measure the volume of water entering the plant system, a stop valve, and an automatic valve as a water level regulator in the tank and reservoir. The equipment used in this study included an automatic weather station (AWS) located inside the greenhouse, an Ezviz CCTV camera used to monitor vegetable growth, smartphones, and a laptop required for research data preparation and processing. Other equipment used includes a water meter to measure the volume of water entering the plant system, a stop valve, and an automatic valve as a water level regulator in the tank and reservoir. The materials used included vegetable seeds (water spinach, choy sum, and spinach), rockwool, net pots, AB mix fertilizer, and components from the FONi hydroponic system, including ½ inch and 2 ½ inch PVC pipes, 3 × 3 angle iron, lightweight steel, buckets, seed trays, and a 90 L water tank.

2.3 Research Prosedure

The research consisted of several stages, including a literature review, preparation and design of the FONi hydroponic system, implementation of the research (installation of the FONi system and vegetable cultivation), data collection, analysis of the data obtained, and preparation of the final report.

2.3.1 Preparation and design of FONi-hydoponics

The DFT hydroponic system with FONi technology had 905 planting holes and was assembled using 3 inch PVC pipes and consisted of six seedling trays. The hydroponic pipes were arranged in parallel to ensure even water flow distribution. As shown in Figure 1.

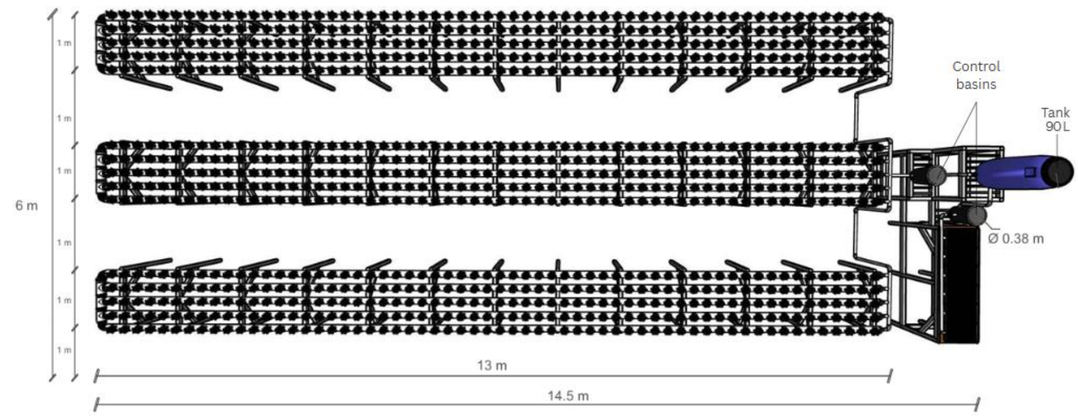

Figure 1. Top view of the FONi design in the DFT hydroponic system.

There were three groups of hydroponic plant pipes, each containing five pipes and 61 planting holes. The diameter of the planting holes in the hydroponic system was 5 cm, with a spacing of 15 cm between holes. The irrigation water distribution from the source to the hydroponic system and seedling tray was connected using ½ inch PVC pipes. The dimensions of the seedling and tank tables from the side view are shown in Figure 2.

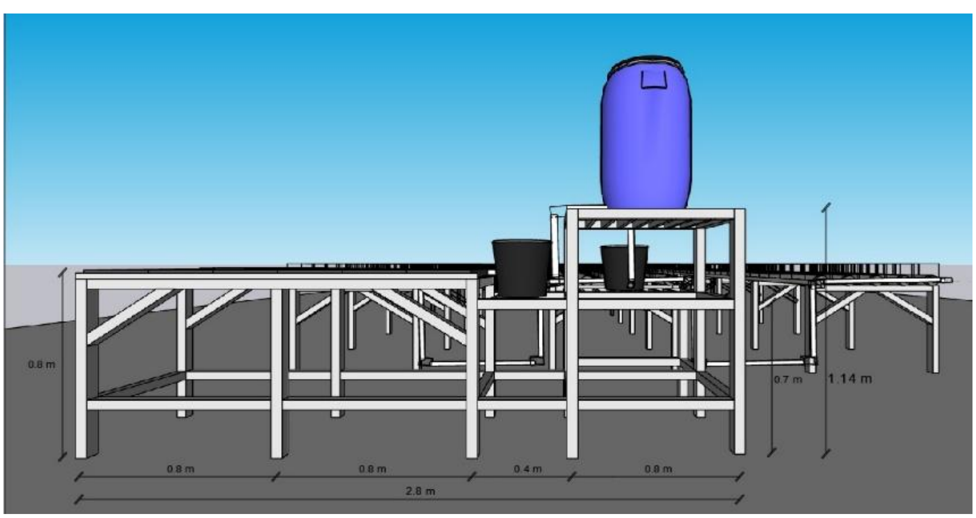

Figure 2. Side view of the FONi design in the DFT hydroponic system.

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The irrigation water was obtained from a tank equipped with an automatic water valve to maintain a constant water supply. The tank had a storage capacity of 90 L. There were also two control basins equipped with automatic water valves that functioned to regulate the water level, and the water that flowed was water from the tank. These control basins were located before the hydroponic planting table system and before the seedling table. At each pipe connection in the series, whether to the seedling table or planting table, there are several stop valves that function as drainage channels and irrigation barriers.

2.3.2 Vegetable Cultivation

The stages of vegetable cultivation (water spinach, choy sum, and spinach) consisted of seed preparation, sowing, transplanting, maintenance, and harvesting. The first step is to select high-quality seeds. This is done by soaking the vegetable seeds, waiting for a while, and selecting the seeds that sink to the bottom of the container.

Next, sowing was performed using rockwool pieces measuring 2 × 2 cm. The selected seeds were then placed on a sowing tray with rockwool as the growing medium. The seed germination process is allowed to proceed for 24 hours under moist and dark conditions. Therefore, after sowing, the sowing tray was covered with plastic/a tarp to protect it from sunlight. Sowing was carried out for approximately 10–14 days or until the seedlings grew and had 3 to 4 true leaves. After approximately 14 days, the second step was the transplantation process. In this process, the seedlings are transferred from the sowing tray to net pots, which are then placed on the hydroponic pipes.

The third step that needs to be taken is maintenance, which includes cleaning the plant environment if there are pests, checking nutrients and pH levels, and providing nutrients periodically according to the age of the plant. Based on the ppm and pH values for hydroponic plants, water spinach and choy sum require a nutrient solution with a concentration of 1,050 – 1,400 ppm and a pH of 5.5 – 6.5. Meanwhile, spinach requires 1,260 – 1,610 ppm and a pH of 6.0 – 7.0 (Nugroho, 2016). Since there are three different types of plants from one tank source, nutrients and pH are administered according to the age of the plant and do not exceed the upper limits of 1,610 ppm and 7.0 pH. Nutrient application is performed by dissolving liquid fertilizer in the form of an AB mix directly into the tank so that not only water is distributed but also plant nutrients. The growing period lasted until 66 DAP, with the first harvest of water spinach occurring on day 24 DAP, while choy sum and spinach were harvested on days 34 to 36 DAP. Harvesting is conducted 4 to 5 times per growing period, with the process involving cutting the portion of the plant ready for harvest.

2.4 Data Retrieval and Alaysis

Several observations were made during the study, including plant growth, crop yield (harvest), irrigation water consumption, and environmental conditions. Observations of plant growth yielded data on plant height, number of leaves, and leaf widths. Harvest yield data were recorded in kilograms

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and obtained from 4 to 5 harvests. The harvesting process involved cutting the plants, leaving a height of approximately 5 cm for water and spinach. For choy sum, the outer leaves were cut, leaving the smaller ones intact. Water consumption data were obtained from a meter installed from the water source to the tank. Environmental condition data, such as temperature, relative humidity, and solar radiation, were obtained from AWS sensors installed at the research site at 30 min intervals.

Determining the ETo value is done by processing weather data from AWS. Evapotranspiration calculations were performed using the Hargreaves method (Wu, 1997), as shown in Equation 1.

$$ET_o = 0{,}0135\ (T_{avg} + 17.8)\ R_s \left(\frac{238.8}{595.5 - 0.55\ Tavg}\right) \quad (1)$$

Where ETo is the potential evapotranspiration (mm/day), Tavg is the daily average temperature (^oC), and Rs is the solar radiation (MJ/m^2/hari). Based on the harvest results obtained, the amount of water required by the plants, and the amount of irrigation water provided during the growing season, an analysis of land and water productivity can be performed. Land productivity can be calculated by dividing the total harvest by the land area, as shown in Equation (2). For water productivity, there are two equations: physical water productivity and economic water productivity. The equations for physical and economic water productivity are presented in Equations (3) and (4) below (Muharomah et al., 2021; Muharomah et al., 2023).

$$LP = \frac{W}{A} \quad (2)$$

$$WP_a = \frac{W}{ETc} \quad (3)$$

$$WP_e = \frac{W}{V} \quad (4)$$

$$WUE = \frac{ETc}{V}\ x\ 100\% \quad (5)$$

Where LP is land productivity (kg/m^2), W is product weight (kg), A is land area (m^2), WPa is water productivity (kg/m^3), ETc is crop evapotranspiration (m^3), WPe is economic water productivity (kg/m^3), and V is irrigation water volume (m^3). WUE is the water-use efficiency (%), where the ET_c value is divided by the total volume of water input.

3. Results and Discussion

3.1 Microclimate of the Research Location

Research on the application of FONi in DFT hydroponic systems was conducted over 66 days, during which the growth of water spinach, choy sum, and spinach was observed. The greenhouse temperature ranged from 24.04°C to 36.89°C, with an average temperature of 28.62°C and relative humidity ranging from 62% to 87%. The maximum temperature occurred at 25 DAP, with a temperature of 36.89°C. The minimum temperature was recorded at 24.04°C at 57 DAP. When viewed carefully, the temperature and relative humidity graphs in Figure 3. shows a decrease in the temperature. This is because the early planting period coincided with the transition from the dry to the rainy season. Climate changes, such as temperature, showed a significant decrease from the early planting period to harvest, whereas relative humidity increased.

The results of environmental condition measurements during the study indicated that the temperature and relative humidity levels for the plants (water spinach, choy sum, and spinach) were significantly higher than the ideal environmental conditions for these plants. According to Zulfan et al. (2024), the ideal temperature range for water spinach is 25 – 30°C. The optimal relative humidity for water spinach is ≥60% (Putra et al., 2022). Based on the average temperature and relative humidity during the study, the microclimate conditions for water spinach met the growth requirements of the plant.

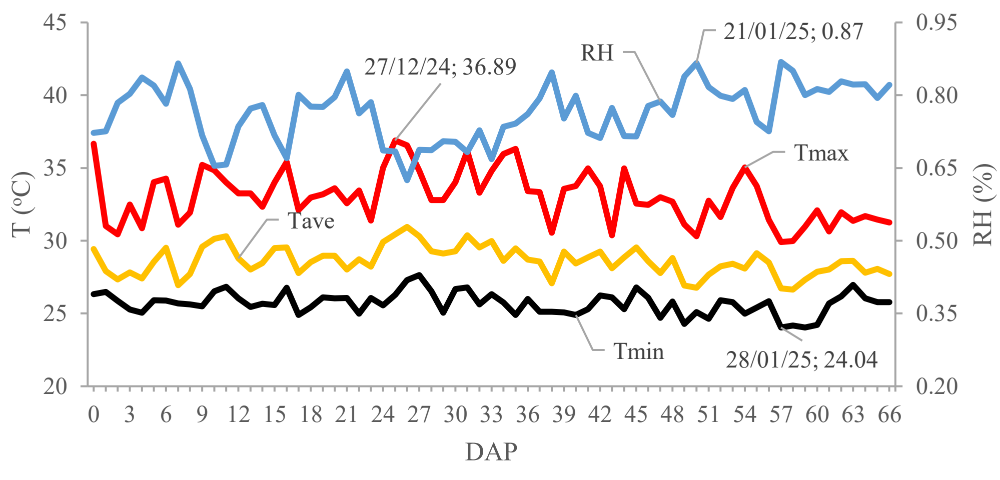

Figure 3. from Desember 02th 2024 to February 06th 2025.

Low temperatures can inhibit plant growth. Conversely, excessively high temperatures can lead to evapotranspiration exceeding the amount of water absorbed by plant roots, causing plants to wilt. Ramadhan & Ariffin (2022) state that some varieties of choy sum are heat tolerant and can grow well at temperatures of 27 – 32°C. Spinach plants can grow at temperatures of 20 – 30°C and relative humidity above 60% (Evinola, 2019). In a study conducted by Suarjana et al., (2020), it was found that

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spinach plants can still grow well at greenhouse temperatures and relative humidity levels of 27–35°C and 40–70%.

3.2 FONi Performance on DFT Hydroponic System

The implementation of FONi integrated into the DFT hydroponic system demonstrated that the water supply from the tank to the hydroponic pipes functioned effectively. At the onset of the growing period, the water level in the control basin was set to 8 cm, ensuring that all plant roots remained submerged. As plants grow, the water level must be raised to prevent water shortages. However, in this hydroponic system, the water level varies at several points on the pipe planting table because the soil surface is not even. This can certainly affect plant growth. Plants with excess water can trigger a lack of dissolved oxygen and even the emergence of fungi that can cause root rot.

The irrigation system consists of several pots connected to the lower part of the pot via water pipes, facilitating direct water distribution to the plants to meet their water needs (Muharomah et al., 2024). This means that the system is arranged like interconnected vessels, and the location of the water pipes at the bottom accelerates the delivery of water directly to the plant roots. Research conducted by (Dewi et al., 2020) indicates that this system can maintain the desired water level and allow water to flow continuously until the soil surface appears moist around the plant roots.

Figure 4. Water spinach, Choy sum, and Spinach.

Based on the research conducted, it can be seen in Figure 4 that the plants have good growth. Nutrient administration and checking were carried out periodically by measuring using a TDS meter to ensure that the plants' nutritional needs were met. In the first week, the concentration of the nutrient solution administered was 500 ppm, then in the second week it increased to 800 ppm. The

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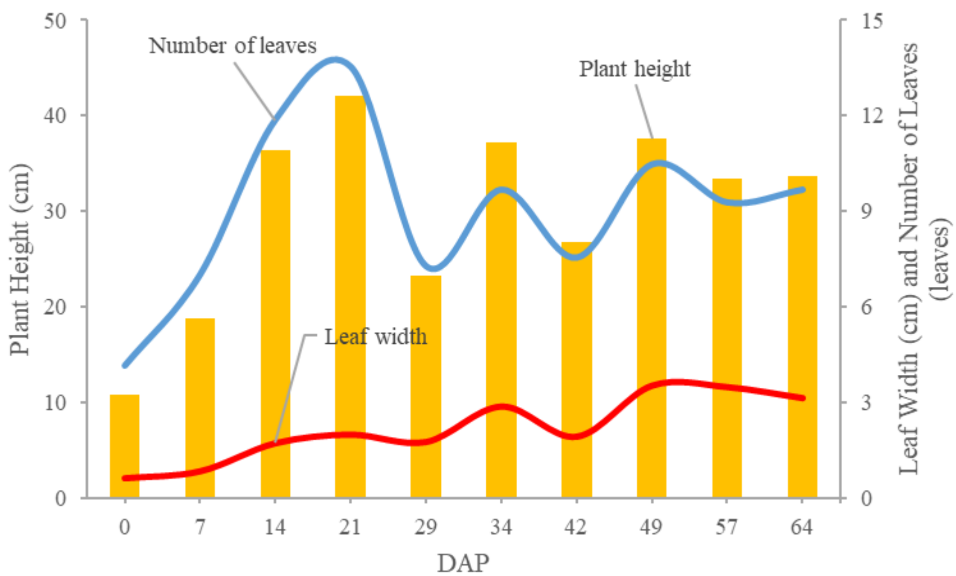
concentration of the nutrient solution is increased to 1,000 ppm to 1,500 ppm in the third, fourth, and subsequent weeks. The nutrient administration in this study does not exceed 1,500 ppm. Similarly, the pH level is maintained at no more than 7 pH.

One thing to note before building a FONi hydroponic system is to ensure that the contour or surface of the soil is flat. This is because it can cause differences in water levels in the plant pipes, especially in DFT hydroponic systems. Differences in water levels can affect the cultivation process, such as leaks caused by water overflow at certain points that are lower in elevation compared to others. Excessive water accumulation around the plants can lead to moist root areas, making them susceptible to bacteria or fungi that cause root rot. The stunted growth of plants due to root rot is generally caused by excessive water (Siswoyo & Sari, 2018).

3.3 Plant Growth

Measuring plant growth is very important because it serves as a benchmark for the success of this study. Several plant growth parameters were observed, namely plant height, leaf width, and number of leaves. Ezviz CCTV is used to monitor plant growth wherever we are. Meanwhile, smartphone is also used to document plant growth and all activites during the research. Figure 5 shows the plant growth during the planting period.



(a)

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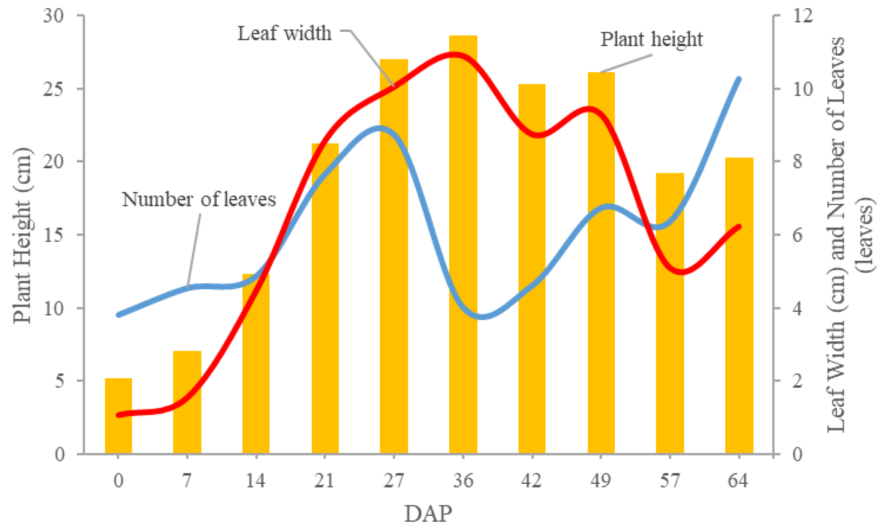

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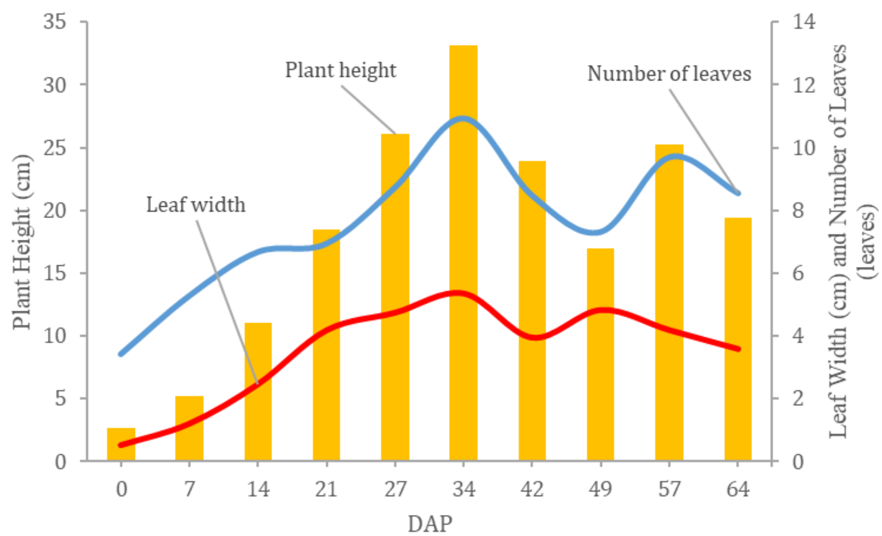

(c)

Figure 5. Plant growth on (a) Water spinach, (b) Choy sum, and (c) Spinach.

Eeach plant growth parameter experienced an upward and downward trend, including plant height, leaf width, and number of leaves. When viewed from the graph, a decline occurred after the first harvest. In water spinach plants, a decrease occurred after day 21 DAP, in choy sum plants after day 36 DAP, and in spinach plants after day 42 DAP. Harvesting by cutting the plant parts while leaving the stem or leaves allows the plants to regrow like in the initial phase. This is marked by the emergence of new leaf buds and the plant stem growing taller.

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Measurements of plant growth in this study were taken over a period of 66 DAP. For water spinach plants with a planting period of 64 DAP, the average plant height was 33.70 cm, with 9.67 leaves and a leaf width of 3.14 cm. The peak height for water spinach plants occurred at 21 DAP, with a plant height of 42.03 cm and 14 leaves. Putri et al., (2022) noted in their study that water spinach grown using a vertical hydroponic farming system in a greenhouse reached a plant height of ≤25 cm at 15 DAP, with 14 leaves.

For choy sum plants with a planting period of 64 DAP had an average plant height of 20.23 cm, 10.27 leaves, and a leaf width of 6.21 cm. At 36 DAP, choy sum plants grew to their maximum height of 28.65 cm, with the highest number of leaves at 64 DAP, which was 10 leaves. Choy sum cultivation using the NFT (Nutrient Film Technique) hydroponic system conducted at ATP Bogor had an average plant height of 28.4 cm at 3 weeks after planting (WAP) with 9 leaves (Syahidah et al., 2022). Spinach plants also had an average plant height of 19.38 cm, 8.54 leaves, and a leaf width of 3.57 cm with a planting period of 66 DAP.

3.4 Irrigation Water Consuption

The availability of water for plants is very important for their survival. Water not only serves as a source of energy in the process of photosynthesis, but also plays a role in transporting nutrients, helping to maintain plant temperature, and influencing plant growth. According to Zulfahmi & Suminarti, (2019) water deficiency in plants can disrupt morphological and physiological activities, thereby hindering plant growth and development. On the other hand, excessive water can lead to reduced oxygen supply, making it difficult for plants to thrive.

Daily irrigation water consumption during the study varied. Climatic factors can influence crop water consumption, such as temperature, solar radiation, precipitation, humidity, wind speed, and length of the growing season (Blaney & Criddle, 1962). In addition to crop age, which influences irrigation water consumption, the growth phase of the crop also affects the amount of irrigation water consumed. Irrigation water consumption continues to increase during the early stages of the growing season until day 21. After that, irrigation water consumption fluctuates until the end of the 66 day growing season. The average irrigation water consumption over 66 days was 56.06 L, with a total accumulated irrigation water consumption of 2,747.09 L.

3.5 Potential Evapotranspiration (ET_o) and Crop Coefficient (Kc)

Evapotranspiration is a phenomenon in which water moves from the earth's surface to the atmosphere, commonly referred to as evaporation. This evaporation process consists of evaporation from the soil and transpiration, evaporation from plants. Several climate variables, such as temperature and solar radiation, were processed to obtain the potential evapotranspiration value during the planting period. The potential evapotranspiration in this study was obtained as an accumulation of ETo totaling 59.02 mm over 66 DAP. The ETo values varied significantly, ranging

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from 0.28 mm/day to 1.22 mm/day. The average ETo value during the growing season was 0.77 mm/day. The FONi system is designed to replace water lost through evapotranspiration. If evapotranspiration reaches 0.27 mm in a day, the automatic water valve on the control basin will open and add water automatically.

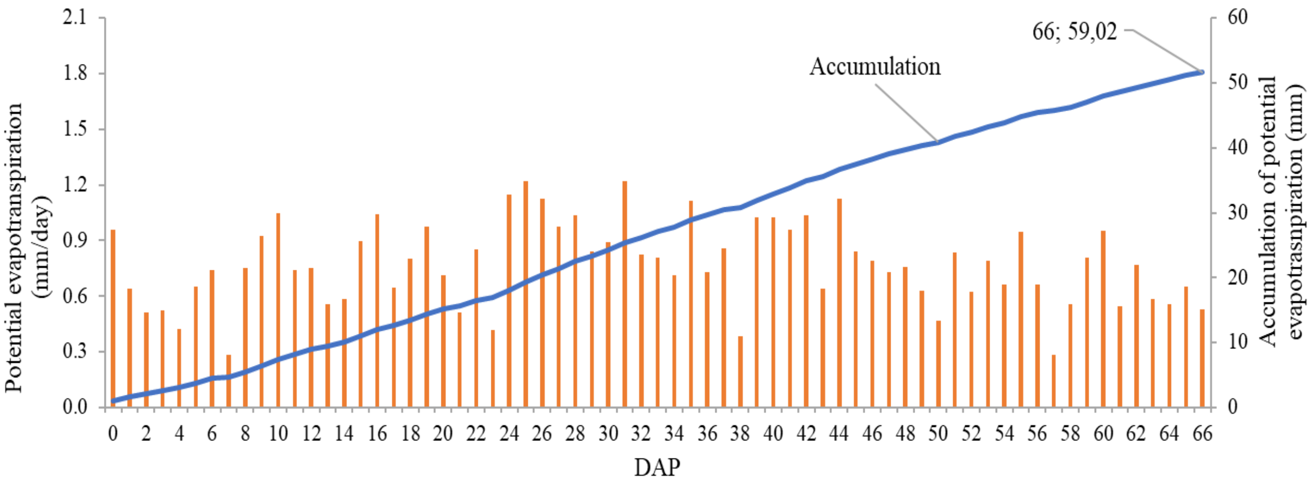

Figure 1. Daily Potential Evapotranspiration (ET_o) and Accumulation.

Based on Figure 6, day 25 DAP had the highest ETo value during the planting period at 1.22 mm. The high evapotranspiration value was caused by environmental factors such as temperature and solar radiation. This is supported by actual recorded data, which shows that on 25 DAP the temperature inside the greenhouse reached 36.89°C. The value of evapotranspiration increases when temperature, relative humidity, solar radiation, and wind speed increase. Climate parameters such as solar radiation, ambient temperature, air humidity, and wind speed generally influence potential evapotranspiration values (Fadhlillah et al., 2019). Each climate parameter has a different correlation with ETo values.

Solar radiation is one of three climate parameters that has the best linear relationship compared to temperature and relative humidity parameters. This is indicated by the coefficient of determination (R^2) value for the solar radiation parameter of 0.938 and the temperature parameter with an R^2 value of 0.5674, meaning they have a positive correlation with ETo. Meanwhile, the relative humidity parameter shows a negative correlation with ETo, with an R^2 value of 0.4984. A study on estimating ETo values in Wajo Regency conducted by Samsuar et al., (2022) concluded that weather factors such as temperature and solar radiation have a positive effect on ETo values. Meanwhile, other factors such as relative humidity have a negative effect on ETo values.

The crop coefficient, commonly abbreviated as Kc, is defined as the ratio of actual crop evapotranspiration to potential evapotranspiration. Kc values are influenced by changes in vegetation and land cover, so Kc varies during the crop growing season. In general, Kc will continue to increase

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during the early stages of planting, namely the initial to mid-season phases, and will decrease in the late-season phase. The initial phase typically occurs between 0 to 7 DAP, the crop development phase between 7 to 15 DAP, and the mid-season phase between 15 to 25/30 DAP. The late-season phase usually begins when the plant reaches over 30 DAP or is marked by signs such as yellowing leaves, slowed vegetative growth, and the appearance of flowers.

The Kc values for water spinach in this study, based on growth phases, namely initial phase, crop development phase, mid-season phase, and late-season phase, were 0.59, 0.92, 1.55, and 1.22, respectively. Meanwhile, choy sum and spinach plants had Kc values between 0.27 to 1.26 and 0.53 to 1.53, as shown in Figure 7. (Gupta et al., 2017) found that the Kc values for choy sum plants measured using the lysimeter method were 0.36 to 1.04. Based on the results of a study by (Syafriyandi et al., 2023), the Kc values for water spinach plants were 0.16 to 1.46, for choy sum plants 0.12 to 0.58, and for spinach plants 0.12 to 0.32. The trend in Kc values during the growing season can vary due to environmental factors. The subsurface irrigation system for water spinach using a series of funnel-shaped pots resulted in Kc values between 0.8 to 1.1 (Muharomah, Setiawan, & Watanabe, 2023).

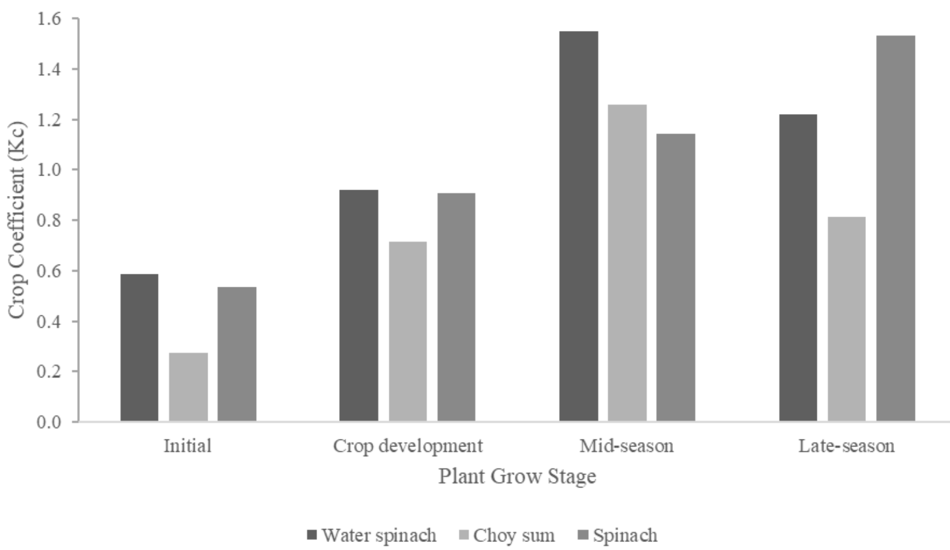

Figure 2. Crop Coefficient (Kc).

3.6 Land Productivity, Water Productivity, and Water Use Efficiency

Land and water productivity are related to the efficiency and effectiveness of irrigation systems. Land productivity is directly related to the amount of production (output) in relation to the production capacity (input). Meanwhile, water productivity is the ratio between crop production and the amount of water consumed by the crops. Land productivity varies in each planting period. Land productivity (LP) in this study was obtained for each crop, namely water spinach, choy sum, and spinach, at 1.35 kg/m², 0.97 kg/m², and 0.57 kg/m², respectively. Land productivity for conventional hydroponic choy sum crops using the DFT method is 1.37 kg/m² (Fauzan et al., 2022). On the other hand, the land productivity for water spinach and spinach are 0.83 kg/m² and 0.93 kg/m² (Indrayani et al., 2024).

Based on the above results, it can be seen that the total production of water spinach is almost three times that of spinach. Meanwhile, at 49 DAP, the choy sum plants showed early signs of declining productivity with the appearance of flowers and yellowing leaves. Then, at 61 DAP, 22% of the pots did not produce any yield due to stunted plants with brown leaves. This increased to 32% on 62 DAP and reached 65% on 66 DAP. Meanwhile, spinach plants experienced a decline in production due to fungus, causing some plants to suffer from root rot. This symptom was observed when the plants were 35 DAP old. A total of 24 spinach plant pots were eliminated at 43 DAP. Plants affected by root rot generally experience growth disorders, which can lead to leaf fall and plant death. The number of plant pots eliminated increased until the plants were 60 DAP old, with a total of 40 pots or 66% of spinach plants affected by root rot. The results of the study show that water spinach is very suitable for repeated harvesting. Choy sum showed a decline in productivity starting at 49 DAP, therefore the final harvest should be conducted between 40 to 45 DAP. Meanwhile, spinach plants are more suitable for a single harvest per growing period.

Water productivity (WPa) values were obtained for water spinach at 47.51 kg/m³, choy sum at 43.80 kg/m³, and spinach at 21.25 kg/m³. The economic water productivity (WPe) for water spinach, choy sum, and spinach was 14.27 kg/m³, 10.21 kg/m³, and 6.06 kg/m³, respectively. The water use efficiency (WUE) in this study was 82%. This value is significantly higher compared to previous research, which reported a water use efficiency of 54%. This study also utilized the FONi system, but with a specific minapadi concept tailored for urban agricultural areas (Julianto et al., 2025).

4. Conclusion

The implementation of the FONi system in DFT hydroponics results in excellent and effective plant growth. Water can automatically fill up to the end of the plant pipe when the water level inside is lower. Hydroponics combined with the FONi system creates electricity friendly cultivation, as it uses a water irrigation principle that does not require a pump and relies solely on gravity. The total irrigation water consumption during the 66 day growing period was 2,747.09 L. Plant growth was good, resulting in land productivity of 1.35 kg/m² for water spinach, 0.97 kg/m² for choy sum, and 0.57 kg/m² for spinach. Water productivity for water spinach was 47.51 kg/m³, choy sum 43.80 kg/m³, and spinach 21.25 kg/m³, with water use efficiency reaching 82%. Trials and development of the FONi-hydroponic system will continue to enhance irrigation efficiency toward 100%. Further research is recommended to improve the design of the circuit by adding a control basin for each type of plant. This is done to increase the uniformity of the water level caused by uneven contours or floors. It also takes into account the effect of nutrient solution concentration and pH on plant growth.

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