



Capillary Flow in a Smart Watering System

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ABSTRACT

The use of water in the agricultural sector continues to be carried out to increase demand and availability in an economical and efficient manner. Irrigation is a way to meet plant needs. There are several irrigation systems, including the smart watering system. This system provides water flow from the main reservoir to the plant reservoir through outlet holes and hose channels. Then the water from the plant reservoir is absorbed through the capillary axis. On a household scale, capillary irrigation can be developed. This research was carried out on spinach plants using a treatment design method using two capillary axes by adjusting the water opening and closing system from the main reservoir. The research parameters consisted of water use, water loss and root fresh weight. The research results showed that evaporation occurred every day under normal conditions on days 1 to 10. There was an increase in evaporation on the 12th day until harvest. The main reservoir measures 46 cm long and 31 cm wide. The upper limit of the water level is 13 cm and the lower limit of the water level is 9 cm from the bottom of the main reservoir. The water level condition from day 1 until harvest time decreased by up to 9.8 cm. The fresh weight condition obtained on day 1 was 0 grams, day 13 was 21.23 grams and day 28 (harvest) was 37.12 grams.

INTRODUCTION

A common problem in urban areas in farming is limited land and water. Conservation of water resources is currently required by the use of efficient technology. One of the technologies used is a smart watering system. This technology can be used in small-scale water-saving irrigation systems, namely hydroponics. Water flow from open irrigation canals often cannot reach downstream due to leaks and waste (Arbina Satria Afiatan, Cholauna Meilia Sumarantini 1, 2022). Based on the type of media, there are two types of hydroponic systems, namely water culture and substrate hydroponics. Water culture hydroponics uses water as a growing medium, while in the substrate hydroponics system, plants are grown in an inert medium which can be sand, rockwool, gravel and so on. In the substrate hydroponic system, the irrigation system used is open, that is, water together with the nutrient solution is channeled to the plants in a certain amount, so that it can be directly absorbed by the plant roots (Tri Indriyati, 2018). A hydroponic Smart Watering System that uses an autopot allows plants to get water and nutrients automatically because the autopot is equipped with an automatic valve (smart valve). The autopot fertigation system is a technology that provides nutrient solution according to plant water needs without using electricity to circulate the nutrient solution. Based on (Bafdal et al., 2018) states that the valve (smart valve) on the autopot functions to regulate the height of the water entering the autopot, where the water will come out when the water level in the autopot is at the minimum level and the valve will close when the water is at the maximum level. so that the water provided is directly absorbed by the plant roots for growth. The advantage of this system is that it does not use electricity to circulate the nutrient solution. Using an autopot can save labor because it works on the principle of a self-watering system. Because it is equipped with a cover, this system can minimize water loss due to evaporation. The hydraulic flow in the smart watering system is self-drain circulation. This flow must be maintained and keep flowing constantly, there must be no blockages or obstructions to this flow. If there is an obstacle to the flow, water circulation will not function and plants will be hampered in receiving nutrients. The mechanism for providing water is by controlling a float valve which opens if there is a decrease in water due to evapotranspiration in the land (Ardiansyah et al., 2023). Efficient use of water in crop cultivation can be implemented in an irrigation system that is able to reduce water loss through evaporation, percolation and surface flow without reducing productivity (Kahfiani, 2017). Providing irrigation water to agricultural land or distributing water in a smart watering system aims to optimally meet the water needs of plants during their growth period.

LITERATURE REVIEW

1. (Arbina et al., 2022) : This study aims to determine the number of axes and the right type of planting media on the growth and yield of tomato plants. The experimental design used was a randomized block design with 2 factors repeated 3 times. The results showed that the number of axes was very significantly different in fruit diameter, significantly different in leaf area, other variables were not significantly different.

2. (Fujimaki, H., & Mamedov, A. I. 2018) : To automatically meet crop water requirement and regulate drought stress to enhance sugar content, a capillary-driven automatic irrigation system (new sand ponics, NSP) was invented. Results showed that NSP can still be more profitable than SP even when frequent leaching is required.
3. (Rustan and Andi Kahfiani. 2017) : The capillary irrigation system works by starting with a piece of flannel cloth placed inside the pipe and then absorbing water from the PVC pipe which functions as a water reservoir.
4. (Wang, P. et al. 2024) : In this study, explore the capillary dynamics within root-like networks under the influence of gravity and derive the most rapid capillary flow via structural optimization. These results affirm that root-like networks can enhance capillary flow, providing critical insights for numerous capillary-flow-dependent engineering applications.

METHODOLOGY

This research was carried out within three months, from June to August 2024, in Cirebon City, West Java Province with topographic conditions at an altitude of 32 meters above sea level. The design in this research is a smart watering system used for spinach plants. The number of planting holes in this system is 60 holes. The treatment design uses two capillary axes in each hole by adjusting the water opening and closing system from the main reservoir. The main reservoir is given a full volume of water until the flowing flow fills the 60 holes. The flow of water flows from the reservoir to the water hose until it flows into the flannel cloth. Flanel fabric is made in 2 axes as a capillary system. Monitoring and controlling the water supply is carried out appropriately to the capillary interface is reached (Fujimaki & Mamedov, 2018). At this stage, the 60 pot holes are ready to be filled with planting media and spinach seeds. The planting medium was chosen using rockwool with a thickness of 1.5 cm. The planting period for spinach from sowing to harvest is 28 days. At the start of system operation, the water flow conditions are not released until the liquid fertilizer as a nutrient is mixed in the main reservoir.

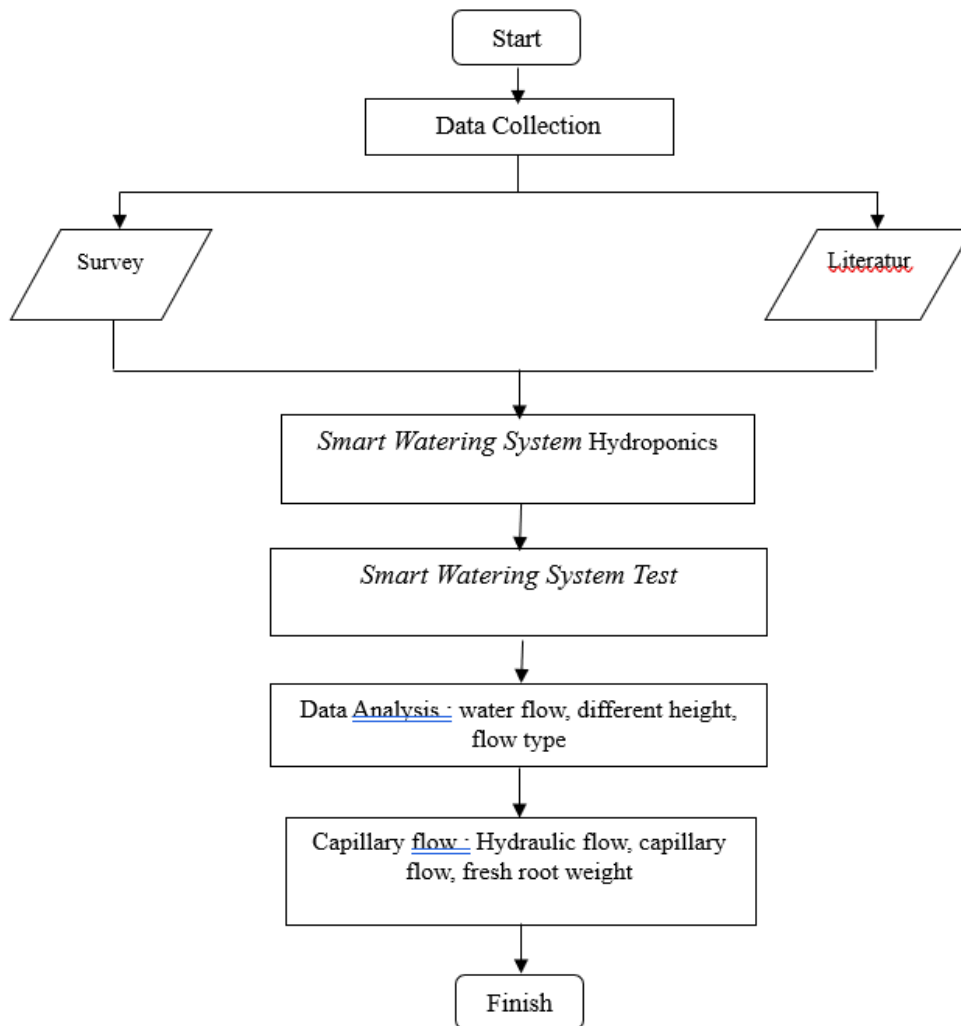


Figure 1. Research Flowchart

RESEARCH RESULTS AND DISCUSSION

Table 1 shows the condition of the hydraulic flow before it is distributed to the hose lines and system network. When the reservoir volume is completely filled with water, the water flow flows through the outlet hole when the regulator hole is opened. The height of the outlet hole from the bottom of the reservoir is 5 cm. When the outlet hole is opened, a flow velocity of 0.0016 m/s occurs with a flow length of 0.22 m. The water in the tank will continue to decrease and become straighter with a shorter flow length. The water flow will stop when the water level in the reservoir is 3 cm below the outlet hole from the bottom of the reservoir.



Figure 2. Reservoir With Outlet Hole

Table 1. Hydraulics Flow In Reservoir Before Distribution

No	Discharge Length (m)	Flow Velocity (ms ⁻¹)
1	0.22	0.00160
2	0.20	0.00155
3	0.15	0.00058
4	0.10	0.00050
5	0.07	0.00009
6	0.00	0.00000

Source: Results of Research 2024

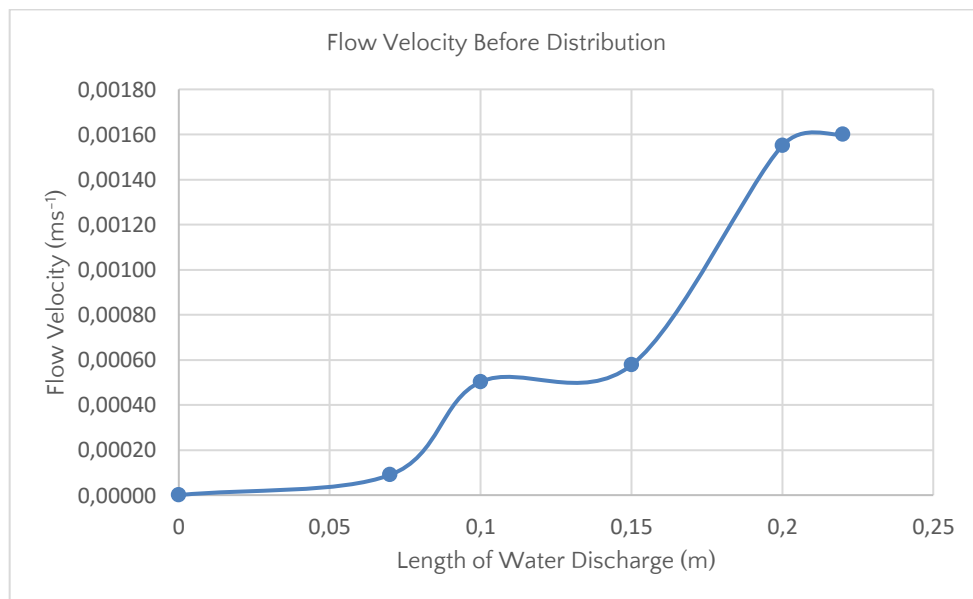


Figure 3. Graphic Hydraulics Flow In Reservoir Before Distribution

For capillary flow, it can be seen in table 2. Capillary flow occurs when the reservoir hole regulator is opened. Water flows through a hose that has a diameter of 0.008 m. Spinach plants that have been sown are stored in a smart watering system netpot, where the storage tank is filled with water with a volume of 0.0185 m³. The water balance that occurs between the reservoir water volume and the water volume under the netpot occurs due to the influence of the capillary flannel fabric and the capillary valve. The flannel used consists of two axes. After an interval of 14 days, plant growth was evaluated to measure plant performance such as height, stems and leaves (Semananda et al., 2016).

Table 2. Capillary Flow

No	Day (m ³)	Volume
1	1	0.0185
2	10	0.0171
3	13	0.0143
4	20	0.0128
5	25	0.0071
6	28	0.0043

Source: Results of Research 2024

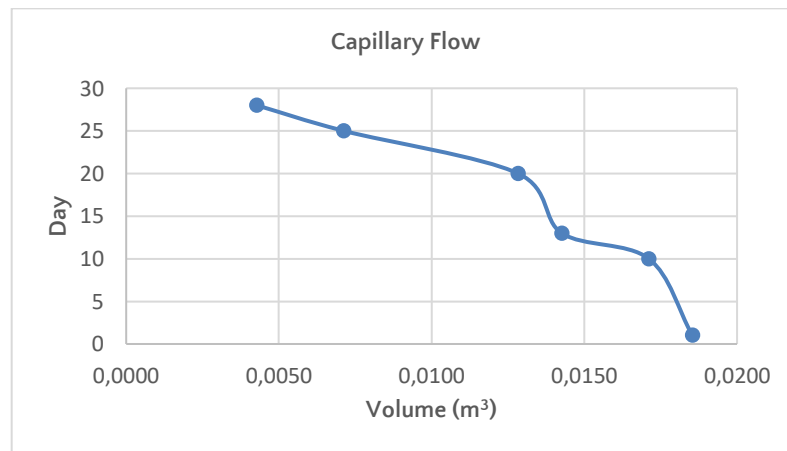


Figure 4. Graphic Capillary Flow

From the graph above, it can be seen that capillary flow with high water requirements occurs on days 20 to 25. In these conditions the growth of spinach plants is very significant. Capillary flow has garnered significant attention due to its unique dynamic characteristics that require no external force (Wang et al., 2024).



Figure 5. Capillary Flow in Netpot

The fresh root weight can be seen in table 3. The root system of spinach plants in the smart watering system grows on rockwool media and sticks together on capillary flanel fabric. Fresh root weight is the wet weight of the roots after harvest. One thing that influences root development is the planting medium. Rockwool planting media is used with a thickness of 1.5 cm according to the depth of the flannel capillary and the water level limits of the submerged netpot. Sufficient water and nutrients absorbed by spinach plants affect their growth (Nurdiyanto, 2022). The more roots there are in the planting medium, the higher the ability to obtain water and nutrients.

Table 3. Fresh Root Weight

No	Day	Weight
1	1	0.00
2	10	0.00
3	13	21.23
4	20	25.42
5	25	30.12
6	28	37.12

Source: Results of Research 2024

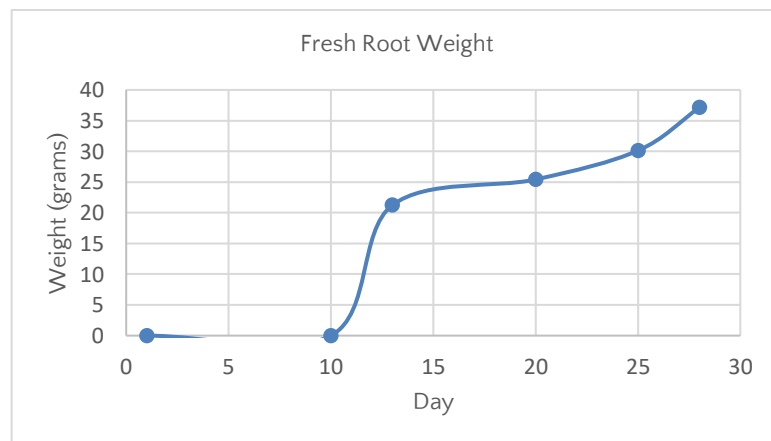


Figure 6. Graphic Fresh Root Weight

From the graph in Figure 6 above, it can be seen that the fresh weight of the roots on days 1 to 10 is 0 grams. This happens because on that day there was no significant root growth. The roots of spinach plants do not need much water and nutrients at this time. On the 13th day the root weight was 21.23 grams and on the 28th day (harvest) it was 37.12 grams. In this period, spinach plants need more water and nutrients so they grow and develop quickly.



Figure 7. Fresh Root Weight

CONCLUSIONS AND RECOMMENDATIONS

This research demonstrates that the application of a smart watering system with capillary flow has a significant positive impact on agriculture in urban areas where land availability is limited. The system provides an efficient solution for optimizing water use, maintaining soil moisture, and supporting plant growth, particularly under conditions of water scarcity. However, the study also highlights certain limitations, including the dependence on water volume and the duration of the crop harvest period. Since the experiment was conducted during the dry season, the findings primarily reflect the performance of the system under limited rainfall conditions. Despite these constraints, the research contributes valuable insights into sustainable agricultural practices that can enhance food security and urban greening. The smart watering system with capillary flow is recommended for use in urban agriculture, especially in limited spaces such as home gardens, rooftop farming, and vertical agriculture. Proper water management should be applied to ensure efficiency without reducing crop productivity. Local governments and institutions are also encouraged to provide training and support to promote wider adoption of this technology for sustainable urban farming.

ADVANCED RESEARCH

Future research is recommended to examine the effectiveness of the smart watering system using capillary flow during the rainy season, as this study was

conducted in the dry season. Investigating how varying weather conditions and moisture levels affect system performance will provide a more comprehensive understanding of its applicability throughout the year. Additionally, further studies could explore optimizing water volume control and evaluating long-term crop yield under different climate scenarios in urban farming environments.

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