

UTILIZATION OF ARDUINO MICROCONTROLLER FOR PRECISE WATER SUPPLY MANAGEMENT TO ENHANCE WATER SPINACH (*Ipomoea reptans* Poir) GROWTH

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ABSTRACT

*In Indonesia, agricultural practices remain largely dependent on traditional methods, particularly in plant care and irrigation management. Such reliance often results in inefficient water use and inconsistent crop yields, underscoring the urgent need for technological innovation in precision agriculture. The integration of affordable microcontroller-based systems offers a practical solution for smallholder farmers to enhance crop productivity and resource efficiency. This study investigates the application of an Arduino UNO microcontroller integrated with a soil moisture sensor for the cultivation of water spinach (*Ipomoea reptans* Poir) under controlled irrigation conditions. Four soil moisture ranges were tested: 80–100%, 60–80%, 40–60%, and 20–40% of field capacity. The research objectives were to: (i) optimize the operation of the Arduino microcontroller for automated irrigation, (ii) evaluate the effects of different soil moisture levels on water spinach growth, and (iii) determine the optimal moisture range for maximizing growth and yield. The results demonstrate that the Arduino-based system reliably regulated soil moisture according to programmed parameters, enabling precise, automated irrigation aligned with crop water requirements. Growth performance varied significantly across treatments, with plants maintained at 80–100% of field capacity showing the highest growth rate and yield. Notably, water spinach cultivated at 40–60% of field capacity still produced marketable crops, indicating potential water-saving benefits. This research highlights the contribution of low-cost microcontroller technology in advancing precision agriculture for leafy vegetables. It provides practical insights for sustainable irrigation management, offering farmers a feasible pathway to improve productivity while conserving water resources.*

KATA KUNCI:

Arduino, pertumbuhan, manajemen air, kangkung

ABSTRAK

Di Indonesia, metode tradisional masih mendominasi praktik pertanian, terutama dalam perawatan dan pemeliharaan tanaman. Integrasi mikrokontroler Arduino UNO dengan sensor kelembaban tanah memberikan kemajuan signifikan bagi petani dengan memfasilitasi manajemen kelembaban tanah yang lebih presisi. Studi ini mengeksplorasi penerapan mikrokontroler Arduino UNO dalam budidaya kangkung (*Ipomoea reptans* Poir) di bawah berbagai tingkat kelembaban: 80-100%, 60-80%, 40-60%, dan 20-40% dari kapasitas lapang. Tujuan penelitian ini adalah untuk: (i) mengoptimalkan penggunaan mikrokontroler Arduino untuk meningkatkan pertumbuhan kangkung, (ii) mengevaluasi dampak berbagai tingkat kelembaban tanah terhadap pertumbuhan kangkung yang diatur secara presisi oleh mikrokontroler Arduino, dan (iii) mengidentifikasi tingkat kelembaban optimal untuk pertumbuhan kangkung. Temuan menunjukkan bahwa mikrokontroler Arduino, bersama dengan sensor kelembaban tanah, beroperasi secara efektif sesuai dengan parameter yang diprogram, memastikan irigasi otomatis yang memenuhi kebutuhan air tanaman kangkung. Hasil penelitian lebih lanjut menunjukkan bahwa variasi tingkat kelembaban secara signifikan mempengaruhi hasil pertumbuhan kangkung, dengan kandungan kelembaban 80-100% dari kapasitas lapang memberikan pertumbuhan dan produksi yang paling menguntungkan. Selain itu, tanaman kangkung yang dipelihara pada tingkat kelembaban 40-60% dari kapasitas lapang menghasilkan tanaman yang layak dipasarkan.

1. INTRODUCTION

Agriculture plays a crucial role in meeting the food demands of Indonesia. As the population continues to grow annually, the demand for food, particularly vegetables, also increases (Aminah, 2020). To address this rising demand, the adoption of modern technology is essential, especially technology that can assist farmers in their agricultural practices. One such technological innovation is the Arduino microcontroller, an open-source microcontroller board that integrates hardware, programming languages, and an Integrated Development Environment (IDE) (Nandhini, 2017). This microcontroller is programmable and can be tailored to meet specific agricultural needs. Moreover, microcontrollers have been extensively utilized as automation tools in various sectors, including industry and robotics (Hakim, 2020; Louis, 2016). Water Spinach is one of the most widely cultivated vegetables in Indonesia. According to the Central Statistics Agency (BPS), the total water Spinach production in 2020 was 579,748 tons. In the same year, Lampung Province ranked ninth nationally in water Spinach production, contributing 12,051 tons. The continuous population growth is expected to further increase the demand for water spinach, necessitating enhanced production (Roidah, 2014). However, one of the challenges in water spinach cultivation is prolonged drought, which increases transpiration rates (Emebu, 2011), particularly in regions where conventional farming practices prevail (Al-Obaidi, 2020; Vagulabranan, 2016). To address these challenges, the implementation of an advanced irrigation system that can automate the watering process is essential. Such a system would help maintain optimal soil moisture levels, thus meeting the water requirements of the water spinach. The Arduino microcontroller, when integrated with a soil moisture sensor, can automate water flow based on real-time soil moisture levels, thereby enhancing the efficiency of irrigation (Laia, 2020).

2. MATERIALS AND METHODS

2.1 Materials and Tools

This research was conducted at the Integrated Field Laboratory, Faculty of Agriculture, University of Lampung. The materials used include water, planting media (soil, husk charcoal, manure, NPK fertilizer, and dolomite), Water Spinach seeds, a data logger, duct tape, glue gun, nails, wooden boards, pesticides, and clear plastic sheeting. The tools employed in this research include an adapter, seedling containers, a sprayer, stationery, a soil moisture meter, Arduino UNO, breadboard, hoe, bucket, grinder, fiber spot cable, jumper cables, tool protection box, laptop, micro SD, ruler, tray, test pen, mini screwdriver, oven, thin knife/cutter, pump, real-time clock (RTC Ds3231), relay, shovel, water hose, soldering iron, marker, ¼-inch hose, raffia, digital scale, and plug terminal.

2.2 Research Methodology

The research was conducted using a Randomized Block Design (RBD) to assess the impact of different treatments across replications. The study focused on a single factor: soil moisture at varying levels of field capacity, specifically 80-100%, 60-80%, 40-60%, and 20-40%, with each treatment replicated four times across the experimental units.

2.3 Research Processes

2.3.1 Layout Determination

The study employed four experimental plots to represent the treatments, each subdivided into four replications. Each plot measured 1.4 m² x 1 m², with treatment plots measuring 35 cm² x 100 cm².

2.3.2 Hardware Design

The hardware setup for the research involved the Arduino UNO microcontroller, equipped with a V1.2 soil moisture sensor, battery, relay, water pump, male-to-female jumper cables, and a circuit box (Padyal, 2018; Mauddiya, 2020). The hardware design process included: (a) Installing components on the Arduino UNO; (b) Programming using the Ds3231 RTC module; (c) Application and testing of the final assembled tool.

2.3.3 Plot Creation

Replication plots were constructed using wooden planks with dimensions of 1 m² in width and 1.4 m² in length. The completed plots were lined with plastic sheeting to maintain consistent water levels within each plot, ensuring controlled water stress.

2.3.4 Drainage Assembly

The drainage system utilized a ¾-inch hose, 1.4 m² in length. The hose was perforated using a soldering iron to create uniform holes, spaced approximately 10 cm apart (Bolu, 2019).

2.3.5 Planting Media Preparation

Each replication contained approximately 40 kg of soil, with each plot holding around 120 kg. Soil pH was measured, and if it deviated from recommended levels, dolomite was added to adjust it. To increase soil pH by one level, 200 tons/ha of dolomite was required. Husk charcoal was also incorporated at a 1:4 ratio.

2.3.6 Tool Calibration and Soil Moisture Determination

Several steps were undertaken in this stage: (a) Soil sterilization in an oven at 105°C for approximately 10 minutes per replication to obtain sensor values at different soil moisture levels; (b) Weighing the soil before and after the oven process to compare weights; (c) Determining 0% soil moisture by drying the soil in an oven for 24 hours (Barapatre, 2019); (d) Determining 100% soil moisture by saturating the soil with water until it dripped, followed by moisture measurement. The calibration process resulted in a graph showing the relationship between gravimetric soil moisture and sensor readings.

2.3.7 Planting and Embroidery

Water Spinach was planted with spacing of 15 cm² x 10 cm². The planting medium was perforated to a depth of approximately 5 cm², and each planting hole was filled with 3-5 seeds.

2.3.8 Fertilization

The first fertilization was conducted two weeks before planting, using NPK fertilizer at a rate of 200 tons/ha and goat manure at 30 tons/ha (Ermansyah, 2022).

2.3.9 Harvesting

Harvesting was performed 35 days after planting (DAP) by uprooting the entire Water Spinach plants. The harvested plants were washed and drained for 15 minutes before observations were conducted.

3. RESULTS AND DISCUSSION

3.1 Performance of the Arduino-Based Automatic Watering System

The results indicate that the Arduino-based microcontroller serves as an effective automatic watering tool. It operates by measuring soil moisture levels using a soil moisture sensor, which transmits an electrical current through the soil to detect resistance and determine moisture content (Husdi, 2018). The gathered soil moisture data is used to control the water pump, automatically activating or deactivating it based on preset conditions. Variations in soil moisture levels significantly affected the growth parameters of water spinach, including plant height, leaf number, leaf length, fresh weight, root weight, root length, and leaf greenness (Mariem, 2020).

3.2 Arduino System Operation

Prior to use, the sensors connected to the Arduino system must undergo calibration to correlate sensor readings with actual soil moisture levels (Mardika, 2019). The system is programmed to maintain soil moisture within specific ranges: 80-100%, 60-80%, 40-60%, and 20-40% of field capacity.

3.3 Arduino Assembly

The automatic watering system is centered on the Arduino microcontroller, supported by a soil moisture sensor and a water pump (Pamungkas, 2020). A schematic of the Arduino microcontroller and its associated sensors, used as an automatic watering tool, is illustrated in Figure 1.

Figure 1 illustrates the operational mechanism of the soil moisture sensor, which measures the moisture content in the soil. When the soil moisture level falls below the predefined threshold, the relay is activated automatically, triggering the water pump to irrigate the soil, thereby maintaining adequate moisture levels (Aziz, 2020). All data generated by the Arduino system, including sensor readings and operational logs, are stored on a micro SD card. To ensure accurate timekeeping for measurements, the Ds3231 RTC (Real-Time Clock) module is employed, providing precise tracking of seconds, minutes, hours, days, dates, months, and years.

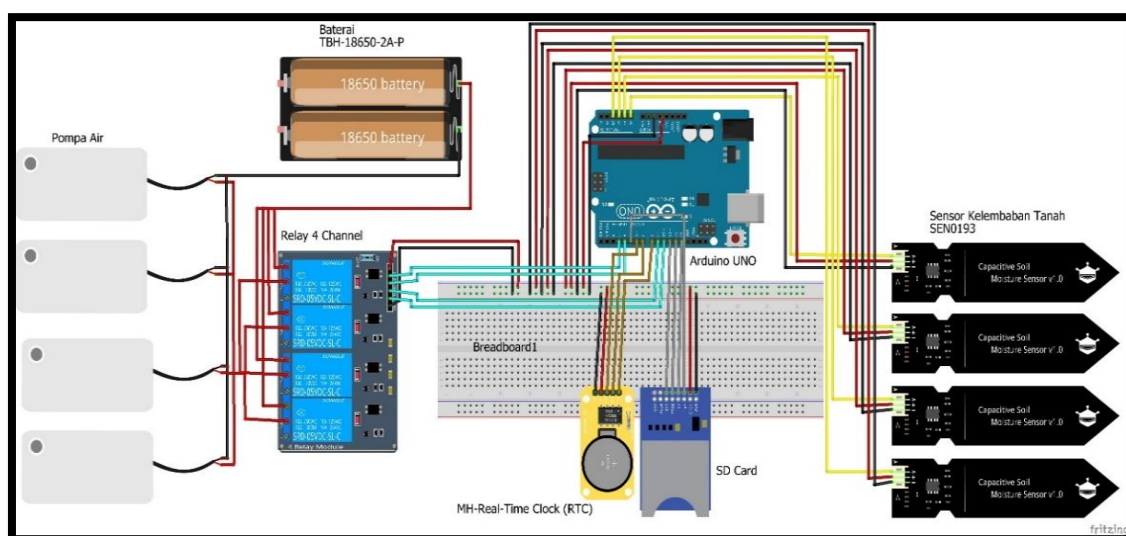


Figure 1. The sketch of Arduino made by using *fritzing* application

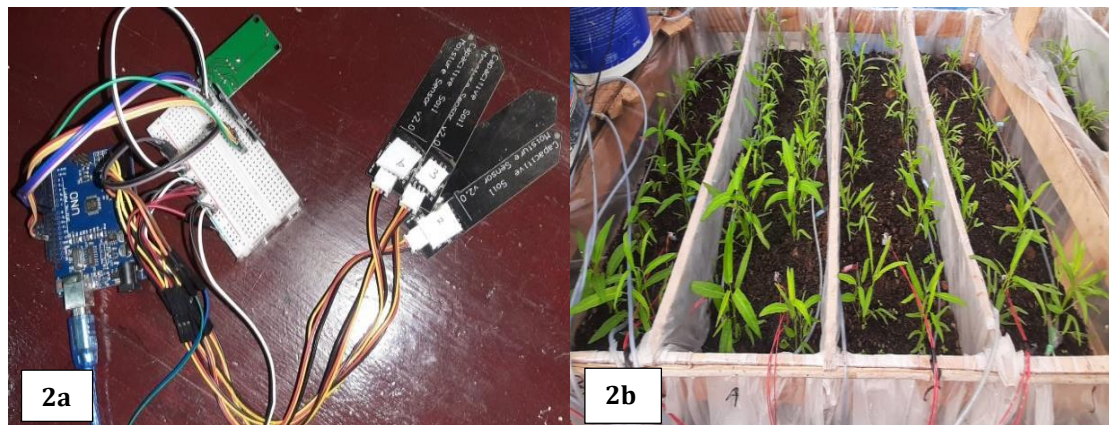


Figure 2a. Arduino microcontroller equipment, Figure 2b. Sensor location in the field

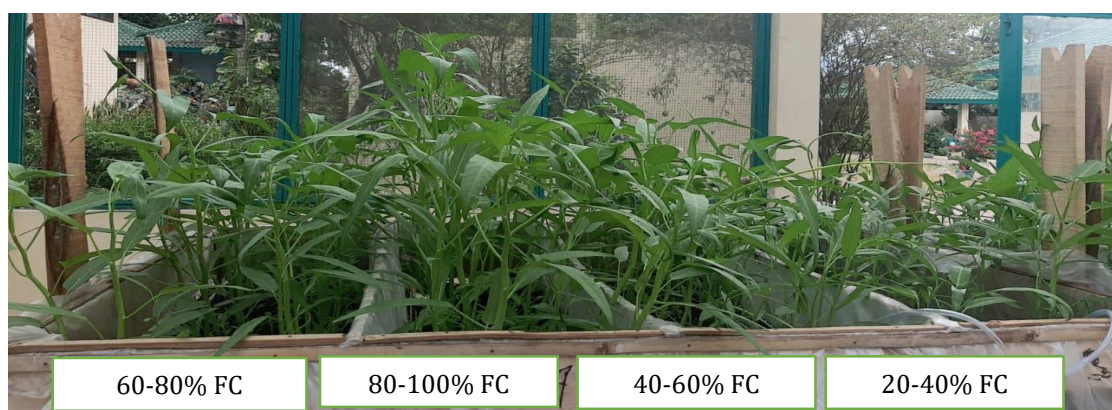


Figure 3. Water spinach growth in the field

The results of the research demonstrate that the Arduino microcontroller effectively regulates the growth conditions for water spinach. As illustrated in Figure 3, Water Spinach plants subjected to an 80-100% field capacity treatment exhibit significantly greater growth, producing taller plants, compared to those subjected to 60-80% field capacity or lower moisture levels.

3.4 Recapitulation of Treatments

The research findings indicate that varying soil moisture treatments have a significant impact on the growth and yield of water spinach. This is evidenced by the recapitulation of the variance analysis of sater spinach growth, which was irrigated automatically using an Arduino microcontroller under different soil moisture conditions.

3.5 Plant Height

The observations on plant height reveal significant differences across the various treatments. The treatment involving soil moisture levels of 80-100% field capacity resulted in the highest average plant height (Table 2). These findings align with Franatah's research (2017), which highlights the critical role of water in plant physiology, as it constitutes 85-90% of the total weight of plant tissues and is a key component of the protoplasm. Similarly, Nurhayati (2009) emphasizes that water is essential for photosynthesis and hydrolysis processes. Additionally, water acts as a solvent for salts, gases, and other materials, facilitating their movement into plants through cell walls and essential tissues, thereby maintaining turgor pressure, promoting cell growth, stabilizing leaf shape, and regulating stomatal opening and closing (Novenda, 2016).

Table 1. Recapitulation of the Analysis Results on Water Spinach Growth Under Automated Arduino-Controlled Irrigation with Varying Soil Moisture Treatments.

Variables	Treatments	Groups
Plant height (cm)	*	*
Amount of leaf (strand)	*	*
Leaf length (cm)	*	ns
Plant fresh weight (gr)	*	ns
Root fresh weight (gr)	*	ns
Leaf greenness	*	ns
Root length (cm)	*	ns

*significant ($\alpha = 5\%$), ns = Not significant ($\alpha = 5\%$)

Table 2. The Effect of Soil Moisture on Water Spinach Height.

Treatments	Average of plant height (cm)
20-40% FC	45,8 d
40-60% FC	57,55 c
60-80% FC	64,9 b
80-100% FC	77,85 a
LSD 5%	3,4

Note: Values followed by the same letter do not differ significantly, as determined by the 5% LSD (Least Significant Difference) test.

Table 3. Data on the Average of the Amount of Water Spinach Leaf.

Treatments	Average amount of leaf (strand)
20-40% FC	10,25 d
40-60% FC	10,75 c
60-80% FC	12,75 b
80-100% FC	14,25 a
LSD 5%	1,4

Note: Values followed by the same letter do not differ significantly, as determined by the 5% LSD (Least Significant Difference) test.

Table 4. Data on the Average of Plants' Fresh Weight.

Treatments	Average of fresh weight (gr)
20-40% FC	13,9 d
40-60% FC	19,35 c
60-80% FC	25,3 b
80-100% FC	47,65 a
LSD 5%	4,2

3.6 Amount of Leaf

The analysis of variance reveals that differences in soil moisture significantly influence the number of leaves. The treatment with 80-100% field capacity yielded the highest average leaf count, with 14.25 leaves (Table 3). These findings are consistent with the research conducted by Febriyono (2017), which identifies sunlight, water, and nutrients as critical factors supporting plant growth. When these factors are adequately met during the growth period, crop production is likely to increase.

3.7 Fresh Weight

The analysis of variance indicates that the application of soil moisture at 80-100% of field capacity tends to increase the wet weight of the plants (Table 4). This suggests that variations in soil moisture significantly influence the fresh weight of water spinach (Sunaird, 2013). Fresh weight is a critical parameter in assessing plant growth, with an average fresh weight of 47.65 grams observed in this study. According to Fadhlillah (2019), the fresh weight of water spinach is an important indicator of marketability, typically ranging from 16 to 33 grams. In this study, Water Spinach grown under soil moisture conditions of 40-60% of field capacity achieved a fresh weight of 19.35 grams, demonstrating that this moisture level successfully produced marketable water spinach. Providing sufficient, yet moderate, water that meets the plants' needs while maintaining high quality can contribute to environmental conservation by reducing water usage. Thus, the use of an Arduino microcontroller and soil moisture sensor for automatic irrigation offers a practical solution for water conservation by precisely regulating soil moisture according to programmed parameters.

4. CONCLUSION

The integration of the Arduino microcontroller and soil moisture sensor has proven to be effective and consistent with the pre-established program parameters, successfully meeting the moisture requirements of water spinach through automated irrigation. The application of varying soil moisture levels has a significant impact on the growth and development of water spinach. Among the treatments, soil moisture at 80-100% of field capacity yielded the most favorable outcomes for water spinach growth and productivity.

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