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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. The dependence often results in inefficient water use and inconsistent crop yields, showing 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. Therefore, this study aims to investigate the application of Arduino UNO microcontroller integrated with a soil moisture sensor for the cultivation of water spinach (Ipomoea reptans Poir) under controlled irrigation conditions. A total of 4 soil moisture ranges were tested, including 80–100%, 60–80%, 40–60%, and 20–40% of field capacity. The study objectives were to (i) optimize the operation of 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 showed that Arduino-based system reliably regulated soil moisture according to programmed parameters, enabling precise, automated irrigation aligned with crop water requirements. In addition, growth performance varied significantly across treatments, with plants maintained at 80–100% of field capacity showing the highest growth rate and yield. Water spinach cultivated at 40–60% of field capacity still produced marketable crops, showing potential water-saving benefits. This study shows the contribution of low-cost microcontroller technology in advancing precision agriculture for leafy vegetables. It also 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 the rising demand, the adoption of modern technology is essential to assist farmers in their agricultural practices. One such technological innovation is 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. Over the years, microcontroller has been extensively used as automation tools in various sectors, including industry and robotics (Hakim, 2020; Louis, 2016).

According to previous studies, water Spinach is one of the most widely cultivated vegetables in Indonesia. The Central Statistics Agency (BPS) showed that the total water Spinach production in 2020 was 579,748 tons. In the same year, Lampung Province ranked ninth nationally in 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 its 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 the challenges, the implementation of an advanced irrigation system that can automate watering process is essential. The system can help maintain optimal soil moisture levels, thereby meeting water requirements of water spinach. Arduino microcontroller, when integrated with a soil moisture sensor, can automate water flow based on real-time soil moisture levels, leading to enhanced irrigation (Laia, 2020).

2. MATERIALS AND METHODS

2.1 Materials and Tools

This study was conducted at the Integrated Field Laboratory, Faculty of Agriculture, University of Lampung. The materials used were 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. Several tools were used, namely 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, and test pen. Others included a 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 Study Methodology

The study was conducted using a Randomized Block Design (RBD) to assess the impact of different treatments across replications. The study focused on a single factor, namely soil moisture at varying levels of field capacity, specifically 80-100%, 60-80%, 40-60%, and 20-40%, with each treatment replicated 4 times across the experimental units.

2.3 Study Processes

2.3.1 Layout Determination

A total of 4 experimental plots were used to represent the treatments, each subdivided into 4 replications. Each plot measured 1.4 m^2 x 1 m^2, with treatment plots measuring 35 cm^2 x 100 cm^2.

2.3.2 Hardware Design

The hardware setup for the study involved 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). In addition, the hardware design process included: (a) Installing components on 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 m^2 in width and 1.4 m^2 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 used a ¾-inch hose, 1.4 m^2 in length, and 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 when it deviated from recommended levels, dolomite was added to adjust it. To increase soil pH by 1 level, 200 tons/ha of dolomite was required, while 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, namely (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 a spacing of 15 cm^2 x 10 cm^2, which was perforated to a depth of approximately 5 cm^2, and each planting hole was filled with 3-5 seeds.

2.3.8 Fertilization

The first fertilization was conducted 2 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 Arduino-Based Automatic Watering System

The results of this study showed that Arduino-based microcontroller served as an effective automatic watering tool. This was operated by measuring soil moisture levels using a sensor, which transmitted an electrical current through the soil to detect resistance and determine moisture content (Husdi, 2018). The gathered soil moisture data was used to control 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

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

3.3 Arduino Assembly

The automatic watering system was built with Arduino microcontroller, a soil moisture sensor, and water pump (Pamungkas, 2020), as shown in Figure 1.

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

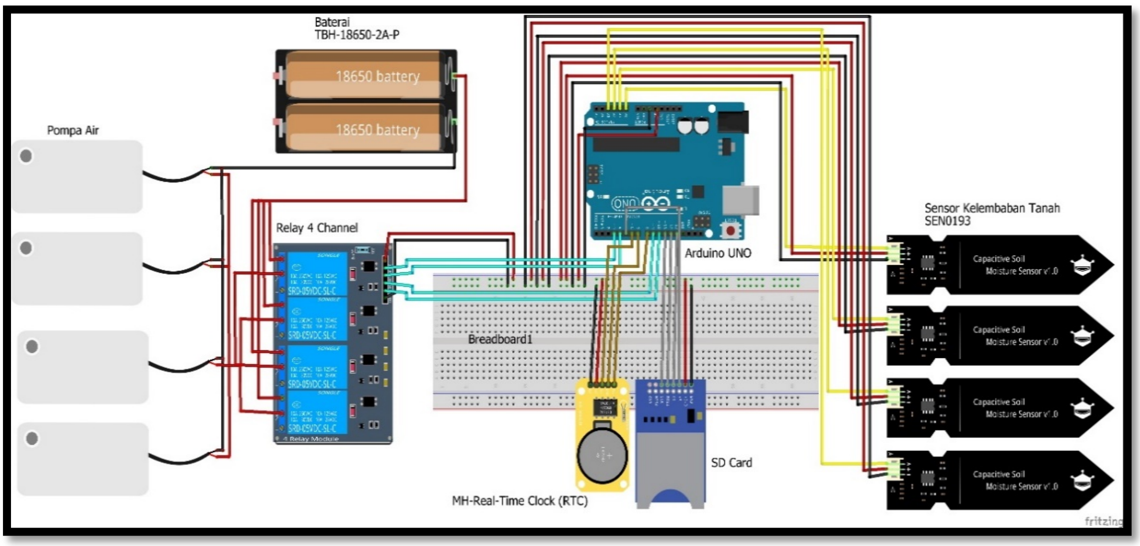

Figure 1. The sketch of Arduino was made using the *Fritzing* application

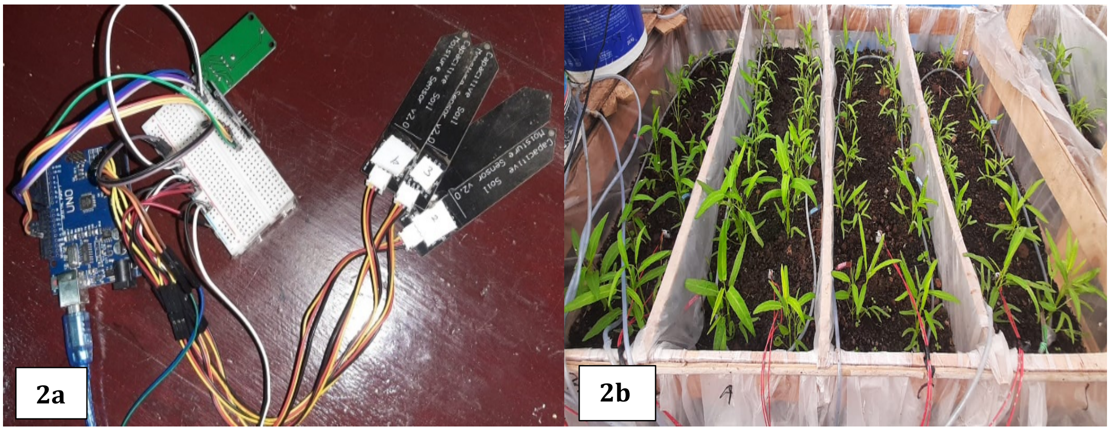

Figure 2a. Arduino microcontroller equipment, Figure 2b. Sensor location in the field

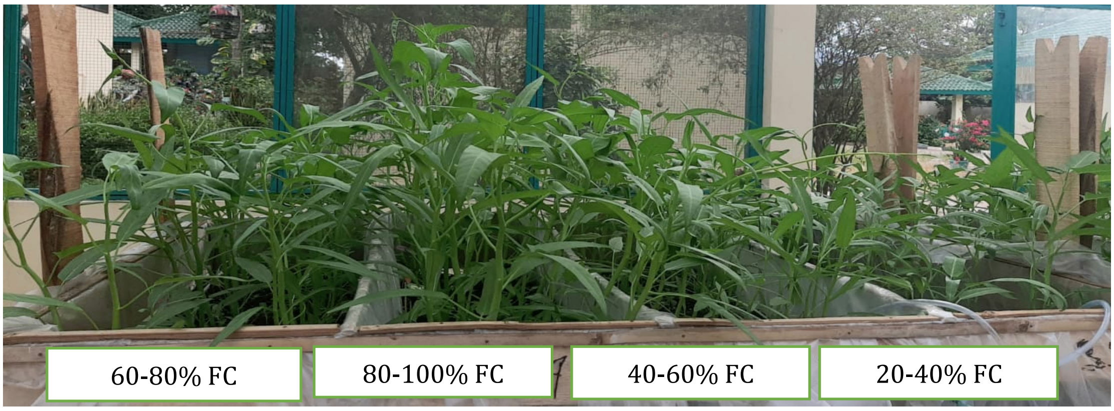

Figure 3. Water spinach growth in the field

The results of this study showed that Arduino microcontroller effectively regulated the growth conditions for water spinach. As shown in Figure 3, Water Spinach plants subjected to an 80-100% field capacity treatment exhibited 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 results showed that varying soil moisture treatments had a significant impact on the growth and yield of water spinach. This was evidenced by the recapitulation of the variance analysis of sater spinach growth, which was irrigated automatically using Arduino microcontroller under different soil moisture conditions.

3.5 Plant Height

Observations on plant height showed significant differences across the various treatments. The treatment requiring soil moisture levels of 80-100% field capacity resulted in the highest average plant height (Table 2). These results were consistent with Franatah's study (2017), emphasizing the critical role of water in plant physiology, as it constituted 85-90% of the total weight of plant tissues and is a key component of the protoplasm. Nurhayati (2009) also reported that water was essential for photosynthesis and hydrolysis processes. In addition, water functioned 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 (α = 5%), ns = Not significant (α = 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 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 showed that differences in soil moisture significantly influenced the number of leaves. Subsequently, the treatment with 80-100% field capacity yielded the highest average leaf count, with 14.25 leaves (Table 3). These results were consistent with the study conducted by Febriyono (2017), which identified sunlight, water, and nutrients as critical factors supporting plant growth. When these factors were adequately met during the growth period, crop production was likely to increase.

3.7 Fresh Weight

Soil moisture at 80-100% of field capacity significantly increased the fresh weight of water spinach (Sunaird, 2013), as shown in Table 4. The average fresh weight of 47.65 grams exceeded the marketable range of 16-33 grams (Fadhlillah, 2019). Even at 40-60% field capacity, the plants were marketable at 19.35 grams. This suggests that using Arduino microcontroller and soil moisture sensor for automated irrigation is a practical water conservation method, as it provides enough water for quality plants while reducing overall water usage.

4. CONCLUSION

In conclusion, Arduino and soil moisture sensor successfully automated irrigation for water spinach. Soil moisture significantly affects growth, with 80-100% field capacity being optimal for productivity.

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