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RESEARCH PAPER

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Control Watering Nutrients for Rice Plants with a Drip Irrigation System Using Arduino and RTC

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ABSTRACT

Indramayu Regency is one of the largest rice-producing areas in West Java, but its rice productivity, averaging 6 tonnes per hectare, falls short of the national target of 8 tonnes per hectare. One key problem contributing to this gap is the nutrient imbalance in rice plants, which can lead to pest and disease attacks. To address this, an automated drip irrigation system was developed to optimize nutrient delivery and improve crop yield. The aim of this study was to design a nutrient control system for hydroponic rice using Arduino and an RTC (Real-Time Clock), allowing for precise and scheduled watering of nutrients. The system contributes to better plant health, higher crop productivity, and more efficient use of water and nutrients. The method involved testing eight water pumps, each controlling different nutrient doses, in a hydroponic rice planting system. The system was set to irrigate according to a programmed schedule, with pumps activated at specific times to deliver nutrients to rice plants grown in polybags with fine sand. Data collection was conducted over 30 days by analyzing the condition of rice plant leaves for each nutrient dose. The results showed that the drip irrigation system successfully controlled nutrient delivery, and the analysis identified the optimal nutrient dose for healthy plant growth. In conclusion, the automated drip irrigation system using Arduino and RTC not only improved water and nutrient efficiency but also contributed to higher rice yield quality and quantity. The system shows promise for reducing production costs by lowering water and fertilizer usage while minimizing environmental impact.

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1. INTRODUCTION

Rice is the staple food for the majority of Indonesia's population, rice is a food commodity that must be guaranteed availability because it can affect economic conditions and national development and requires government intervention [1]. Rice farming has developed rapidly during the period of Hindu-Buddhist and Islamic kingdoms in Indonesia [2], [3], [4]. Archaeologically, traces of rice in the archipelago since thousands of years ago are still faint. Some of the oldest evidence includes the discovery of traces of rice husks at a hearth site in Maros Cave, South Sulawesi, dated to around 500 AD (Glover 1985). Paz (2005) also found traces of rice dated to 2000 BC from the same location. The Dutch colonial period brought changes in agriculture, introducing forced cultivation and monoculture [5]. During independence, the government promoted an agricultural programme to increase rice production with the launch of the National Rice Movement (GNP) with the aim of achieving food self-sufficiency [6]. Indonesia has a variety of local rice varieties that have adapted to local climate and soil conditions, local varieties often have resistance to certain environmental conditions and are important genetic assets [7], [8]. The selection of varieties that have high yield potential, disease resistance, and have a growth cycle that is suitable for local conditions [9]. Rice breeding programmes in Indonesia are conducted by various institutions, including the Agricultural Research and Development Agency (Balitbangtan) and universities [10]. Rice cultivation methods used are traditional and modern, where traditional methods are wet and dry methods using paddy fields or rainfed, while modern methods are agricultural intensification with advanced technology, fertiliser use, and efficient water management. Some factors that affect the success of rice plants include environmental factors, in tropical climates rice grows well with sufficient rainfall, on fertile soils such as fertile loam or sandy soil into a good rice cultivation site, as well as water and a good irrigation system is very important for rice growth. In addition to environmental factors, the development of agricultural infrastructure, especially in the development of irrigation, the use of modern technology in soil management, including fertilisers and nutrient nutrient balance is very important in supporting rice cultivation [11].

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Along with the development of technology, the application of technology in agriculture is very necessary [12]. Fertiliser watering is usually done manually, but this method is less effective because it allows the fertiliser dose to be inappropriate, besides that farmers often forget the fertiliser schedule that must be done [13]. Based on research, the technology for an automatic fertiliser system based on nutrients uses supp2877 PH Sensor technology as a PH indicator, RTC as a scheduling time instruction, 12V DC Pump for the fertiliser water process and NodeMCU ESP8266 as a microcontroller programmed to run the tool and manage the fertiliser application process [14]. The automatic fertiliser tool can work automatically but there is still a delay in both RTC instructions, pump performance [15]. This delay is caused by network instability and the voltage used due to the condition of the RTC battery which has weakened. As for other research on automatic watering technology with an RTC timer system based on ATMEGA16 microcontroller [16], the working principle of this tool is that the roots are buried in the air cavity under the pipe and sprayed with nutrient solution in the form of mist. Furthermore, mist spraying is carried out alternately on and off according to predetermined hours. RTC can work according to its function, namely adjusting the time on a real time system, but the provision of nutrients has not been evenly distributed throughout the plant so that the results of plant development are not close to perfect [17].

In this context, researchers using Arduino (an open-source microcontroller platform) and RTC (Real-Time Clock) provide the ability to control watering with high time precision [18], [19]. The Arduino will act as the main brain of the system processing data and controlling the water pump according to a predetermined schedule. This research aims to develop a nutrient watering control system for rice plants using a drip irrigation system by utilising Arduino and RTC technology [20]. It is expected that this system will increase the efficiency of nutrient and water use, reduce waste of resources, and increase the productivity and quality of rice crops [21].

The purpose of this research on a drip irrigation system developed to control nutrient delivery for hydroponic rice plants using Arduino and RTC includes several contributions. Firstly, this research aims to advance modern agricultural technology through an automated irrigation system that utilizes digital technologies to enhance precision and efficiency. Secondly, the system is expected to improve the quality and quantity of crop yields by optimizing the growth conditions of rice plants. Additionally, it is designed to reduce water and nutrient wastage by precisely controlling resource usage. Lastly, the system ensures accurate and consistent nutrient delivery tailored to the specific needs of rice plants, thereby supporting better growth.

2. MATERIALS AND METHOD

This research uses a qualitative method with the stages or steps of research as in the following figure: orientation as shown in Fig. 1. The EMG signal was recorded using a Bagnoli EMG recorder (Delsys, Massachusetts, USA) with sampling frequency of

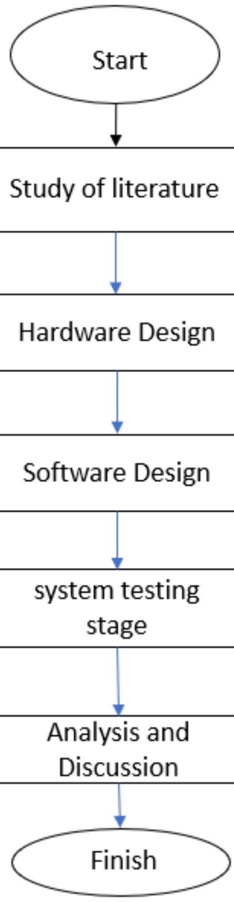

Fig. 1. Research Flow Chart

Figure 1 explains the research diagram, starting from a literature study conducted by reading articles/journals related to this research. In this research, several designs were carried out including hardware design and software design. Hardware design includes assembling the system according to the circuit scheme, and software design includes programming on the Arduino IDE to create source code that is used as a command to run the system on Arduino [18], [22]. The first stage carried out by researchers is to determine what nutrients are used in this study. To determine the amount of nutrients needed by rice plants, it is necessary to understand the nutritional needs of these plants. Rice plants need various essential nutrients to grow well [23], [24]. The nutrients used in this study are using 8 different nutrients including:

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TABLE 1. Nutrient Dosages of Nutrients

No	Type of Formula	Nutrients that are omitted	Nutrients added	Composition
1	Without P	MKP	Merouke SOP	150gr
2	Without Micro Nutrient	Fitaflex		
		Iron eddha		
3	Without Kalsium	Calnit	Kalinitra	200gr
			Magnit	150gr
4	Without Kalium	MKP	MAP	225gr
		Kalinitra		
	Without Phosphat	MKP	Meroke SOP	100gr
5	Without N	Calnit	Kalsium Manohara	700gr
		Kalinitra		
6	Without S	MAG-S	Reduce Calnit	1300gr
			Change magnit	650gr
			Kalsium Manohara	150gr
7	Without Magnesium	MAG-S	Belerang	150gr
8	Normal Nutrition		MKP	2901gr
			Meraoke Vitaflex	
			Magnesium Sulfate (Heptahydrate)	
			MeraokeCALNIT CaNO3	
			Iron eddha	
			SiO2	

The second stage is designing an automatic irrigation installation system. Designing an automatic irrigation installation system is an important step to ensure that plants get enough water without the need for manual intervention. This design is very useful for controlling the irrigation system by periodically pouring water using nutrients. The following is a design for an automatic irrigation installation for research on detecting nutrient deficiencies in rice plants using image processing:

a. Hardware Desain

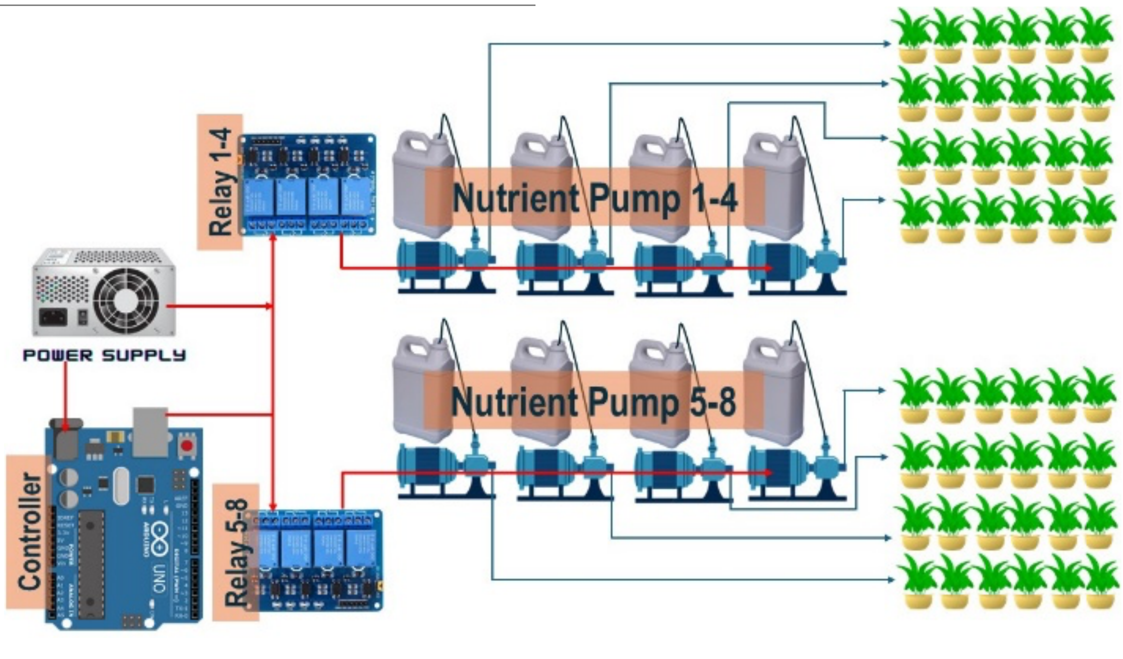

Fig 2. Automatic Irrigation Installation Wiring

Figure 2 is an overview of the wiring of the Automatic irrigation installation, which is the design of the equipment to be done [25]. Some of the equipment in Figure 2 are as follows:

1) Water Pump

Is an important device for this research that functions to drain nutrients. In this study using 8 water pumps because the nutrients that are flowed to rice plants have 8 different types of nutrients and compositions, the water pump used in this study has a voltage of 12 volts, has a pressure of 100Psi (6.5 Bar) auto cut off [26], [27], [28], [29] .

2) Potentiometer

Is an electrical component that has various functions in electronic circuits, The function in this study is to control the voltage applied to the motor, which can affect the rotation

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speed of the motor so that it affects the water flow rate produced by the pump [30], [31].

The next step is to determine the size of the hose. Determining the right hose size depends on several factors, including the intended use of the hose, the available water pressure, and the required water discharge. The diameter of the hose used is 5/16 inch, this hose size is used based on the water pump used where for water input / output must use a 5/16 inch hose. As for the output hose, it uses a 6mm size hose to adjust to the size of the drip [32], [33], [34].

b. Software Design

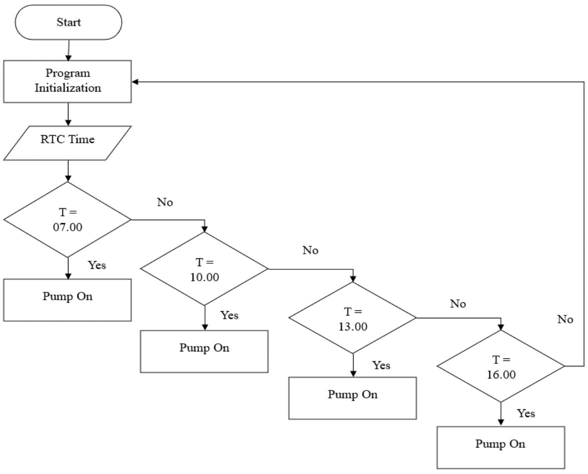

Fig 3. Programming Flowchart

The control tool in this automatic irrigation uses arduino uno and 4 pin relay module as many as 2 pcs. Arduino controls the relay to turn on the water pump with a duration of 3 hours off, and 5 seconds on. Arduino Uno is used to control the control of the relay module device. Arduino is a popular microcontroller, in this study the time to turn the pump on and off is taken from the RTC (Real-Time Clock) module. Arduino is designed to make it easier to control the water pump so that it can flow water for 3 hours once. Arduio uno is connected to a relay module that will produce NO (normally open) and NC (normally close) connections. Next create an Arduino program to control the relay, this program will activate the relay for 5 minutes, then deactivate it for 3 hours.

3. RESULT

The watering control panel circuit can be seen in Figure 4, while the watering system can be seen in Figure 5. In the panel, it can be seen that the device is powered by a 12V 5A power supply that will supply the Arduino and 8 water pumps. To turn on and turn on the pump, a relay is needed which functions to disconnect and connect the electric current based on the command given by the microcontroller.

Fig 4. Control system electrical panel

The nutrient watering control panel circuit is designed to automate and optimize watering and nutrient delivery to plants, particularly in hydroponic systems or automatic irrigation systems. It also helps monitor and control the level of nutrients in the nutrient solution fed to the plants. By ensuring that the nutrient concentration is within the optimal range, plants can grow healthier and produce better yields. The nutrient pump and watering valve use Arduino and RTC to deliver water and nutrients automatically, this ensures that the plants receive a supply of water and nutrients that match their needs. By automating the watering and nutrient delivery process, this circuit helps to optimize the use of water and nutrients. This can reduce wastage of resources and operational costs.

Fig 5. Plant watering system

The results of the automatic watering test can be seen in the following table :

TABLE 2. Pump test results

No	Time	Pump Condition	V	I	P
1	07.00 AM	Pump switches on for 5 seconds	12 V	2A	24W
		standby mode	12 V	0.5A	6W
2	10.00 AM	Pump switches on for 5 seconds	12 V	2A	24W
		standby mode	12 V	0.5A	6W

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3	01.00 PM	Pump switches on for 5 seconds	12 V	2A	24W
		standby mode	12 V	0.5A	6W
4	04.00 PM	Pump switches on for 5 seconds	12 V	2A	24W
		standby mode	12 V	0.5A	6W

The RTC (Real-Time Clock) based drip irrigation system hydroponic rice nutrient watering control works by combining a time sensor with automatic control. The RTC is used to track the time and date in real-time. The RTC is equipped with a backup battery to keep it working even during power failure.

The automatic control system will check the time from the RTC, if the time is correct and the conditions require, the pump will be activated. Based on table 2, it can be seen that the pump can run normally for 5 seconds at 07.00, 10.00, 13.00, and 16.00. Apart from these hours, the pump will turn off.

The RTC (Real-Time Clock) based drip irrigation system hydroponic rice nutrient watering control has many benefits and can provide convenience and efficiency in water usage, in addition to allowing a more automated water delivery system without the need for continuous manual intervention, this makes it easier to use by users. With intelligent timing and sensors, the automatic nutrient watering control can be activated only when needed, this helps reduce energy consumption as it does not need to work continuously. Additionally the RTC (Real-Time Clock) based drip irrigation system hydroponic rice nutrient watering control is very useful in watering the plants, in that the precise timing ensures the plants get water regularly, even when the owner is not around.

4. DISCUSSION

RTC (Real-Time Clock)-based drip irrigation systems are a highly efficient water delivery method, where water is delivered directly to the plant roots through small pipes or hoses connected to drip points. to control nutrient delivery in hydroponic rice cultivation presents many benefits, such as increased energy efficiency, water conservation, reduced manual intervention, flexible scheduling, and precise nutrient dosing. However, despite these advantages, the system is not without its challenges.

One major limitation is the system's dependency on a continuous power supply. In the event of a power outage, the irrigation process is disrupted, leading to inconsistent nutrient delivery, which may affect plant growth. While some similar studies have addressed this by integrating backup power systems or solar panels for energy resilience [35], [36], our system does not currently include such a backup, which could limit its effectiveness in areas prone to power instability.

Another concern relates to the durability and reliability of mechanical components, specifically the pump. The impeller and motor are subject to wear and tear over time, potentially leading to system failure if not regularly maintained. Similar issues have been highlighted in other research, which suggests the need for more robust and self-cleaning pump designs to improve longevity and reliability [26], [32]. Additionally, clogging of the pump's inlet and outlet hoses by debris, such as moss or foreign particles from the nutrient solution, has been a recurring issue. This is consistent with findings from other studies in hydroponic systems, where the buildup of biofilm and sediment poses similar risks [11]. Regular cleaning and filtration systems are critical to mitigating these problems, but they add to the overall maintenance burden.

The limitations of this study include the lack of a backup power system and limited testing of the pump's long-term durability under varying nutrient compositions. These weaknesses highlight the need for future research to explore more resilient pump designs and integrate energy-independent solutions, such as solar power.

The implications of this work are significant for advancing automated irrigation in hydroponic agriculture. However, addressing the system's reliance on electricity and improving its resistance to mechanical failures will be crucial for broader, long-term adoption in both commercial and small-scale farming. Future designs should also consider incorporating remote monitoring capabilities to alert users in real-time to potential system failures, ensuring timely interventions.

This analysis demonstrates that while the RTC-based drip irrigation system provides clear benefits, its practical application in various environments will depend on overcoming these operational constraints.

5. CONCLUSION

The aim of this research was to design and implement a hydroponic rice nutrient control system using a drip irrigation mechanism, controlled by Arduino and RTC (Real-Time Clock). The RTC was utilized to schedule the operation of the pump at specific times to ensure precise and timely nutrient delivery to the plants.

The findings demonstrate that the pump operates as programmed, running for 5 seconds at 07:00, 10:00, 13:00, and 16:00 daily. Outside of these scheduled times, the pump remains off. This system provides several advantages, including improved energy efficiency, significant water savings, reduced manual intervention, flexible timing settings, and accurate nutrient dosing according to pre-established schedules. However, certain challenges were identified, particularly the potential for nutrient flow blockages in the drip system. The study did not measure performance metrics such as the system's overall accuracy in delivering nutrients or the potential error rate in timing or flow regulation, which could be a focus in future studies.

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For future work, it is recommended to develop an advanced control mechanism that can detect and respond to blockages in real-time, ensuring uninterrupted nutrient flow. Additionally, exploring alternative power sources such as solar panels for uninterrupted operation and integrating sensors for remote monitoring could enhance system reliability and performance. Further evaluation of system accuracy and error rates in various environmental conditions would also be beneficial to improve its overall efficiency.

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