SCHEDULED FOG IRIGATION SYSTEM USING ARDUINO UNO AND RTC *(REAL-TIME CLOCK)* ON FERTILIZATION OF MUSTARD PLANT *(Brassica juncea L.)*

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ABSTRACT

The watering of seedings can be done automatically by leveraging the development and advancement of technology, one of which is by utilizing a microcontroller that can be programmed to do watering according to the preferred time. This research aims to design and implement a scheduled fog irrigation system using the Arduino UNO microcontroller and utilizing the RTC (real-time clock) component in the mustard green seeding. In this research, the fog irrigation system is applied to green cabbage by optimizing the Arduino Uno microcontroller, which is used to design electronic circuits to automate the control of watering fog irrigation. Through this system, it is expected that plant watering can be done on time and the plant's water needs can be fulfilled. This research uses the experimental method or experiments with direct observation in the field through several stages, including preparing, designing, and making irrigation installations, constructing a series of scheduled fog irrigation systems, making scheduled irrigation program languages, calibrating RTCs, and working on scheduled fog irrigation systems. The research parameters include water use efficiency and the operation of the scheduled fog irrigation system. The observation parameters were water discharge (mL/min), water use efficiency (%), plant height (cm), number of leaves (strands), and performance of the scheduled fog irrigation system. Three treatments were applied in this study: first-time watering, second times watering, and third times watering. The scheduled fog irrigation system ran well during the research and aligned with the plan. In testing, the fog irrigation system has a water use efficiency of 75.86%, and in the treatment of fog irrigation, three times a day has the highest value of height and number of leaves with an average height of 3.72 cm and an average number of leaves 2.77 strands.

Keywords: Fog Irrigation System, Microcontroller, RTC (Real-Time Clock), Seeding

INTRODUCTION

In agricultural cultivation, water is crucial for plant growth and productivity. Water is one of the abiotic factors influencing plant physiological processes, such as photosynthesis, respiration, transpiration, and nutrient transportation (Matondang and Nurhayati, 2022). Plants need water in sufficient and balanced amounts according to their specific needs, and this amount is undoubtedly different between one plant and another. Even one plant can have different water needs in each growth period. Lack or excess water can cause stress to plants and compromise their health and quality (Zhang et al., 2023). Therefore, effective and efficient water management is one of the keys to success in crop cultivation. An irrigation system is a way to provide water for crops by regulating the flow and distribution of water (Weerahewa et al., 2023). A well-managed irrigation system should meet crop water needs, conserve water resources, prevent soil erosion, and increase crop productivity.

In the early period of plant growth, plants have a high level of sensitivity to environmental temperature (Wirnas et al., 2020) and water availability. They are prone to soil erosion if the water delivery system is not monitored. The initial period starts from the seeding period, a crucial period in plant growth. Many previous studies have examined the water needs of various types of plants (Lavergne et al., 2019; Hatfield and Dold, 2019). However, this research aims more specifically to determine the water needs and design the right irrigation system for plants at an earlier period, namely the seeding period. For this reason, an experiment was carried out in this study to design a scheduled fog irrigation system using Arduino UNO in the mustard green seeding. In this research, the mustard plant is studied because it has extraordinary prospects for supporting efforts to increase farmers' income, expand employment opportunities, develop agribusiness, increase national income through reducing imports and boosting the rate of export growth (Prasetyo et al., 2019).

A fog irrigation system is a method of watering plants that uses water sprayed as a fine mist onto the plants. This system can release water into the air around the plant with smaller water droplets than sprinkler irrigation. Mist irrigation is not designed to deliver water directly to the root zone, but mist irrigation systems can provide enough water to meet plants' water needs (Agarwal et al., 2023). Fog irrigation also maintains air humidity to reduce transpiration rates (Sulasih, 2022). This irrigation system is suitable for seeding period because it can distribute water well, maintain ambient temperature, and prevent plant soil erosion (Indradewa et al., 2021). Therefore, this research aims to design and implement a scheduled fog irrigation system using the Arduino UNO microcontroller and utilizing the RTC (real-time clock) component in the mustard green seeding.

METHODS

Tools and Materials

The tools used are Lenovo Legion 5 laptop with AMD Ryzen 7 4800H processor, Arduino UNO, Relay, jumper cable, 12 V water pump, Real Time Clock (RTC), 1x4 Numpad, 20X4 LCD, I2C backpack module, power supply, component box, hose, spray nozzle (mist nozzle 0,8 mm fogger with slip lock tee 6 mm pneumatic), seeding tray, water bucket.

Experimental Parameters

The parameters to be measured in this study are as follows:

1. Water discharge (L/min)

Calculating the water discharge using the Equation (1) based on Ali et al. (2020).

$$Q = V/t \quad (1)$$

Where:
Q = Flow discharge (L /min)
V = Volume of water coming out from nozzle (L)
t = Length of test time (minutes)

2. Water use efficiency (%)

Calculate water efficiency in the fog irrigation system using equation (2).

$$Ei = Wa/Q \times 100 \quad (2)$$

Where:
Ei = Water efficiency (%)
Wa = Water distribution to plants (L/min)
Q = Water discharge (L/min)

3. Mustard plant height (cm)

Plant height is one of the growth indicators used to measure the treatment applied, measured in cm. Plant height was measured at the age of 2 days after Sowing (DAS), 4 DAS, 6 DAS, 8 DAS, and 10 DAS.

4. Number of leaves (strands)

The number of leaves was counted at the age of 2 DAS, 4 DAS, 6 DAS, 8 DAS, and 10 DAS.

5. Distributable water (mL/min)

The distribution of water that can be done on a scheduled fog irrigation system is done by testing the amount of water that the fog irrigation system can distribute to the soil surface where the seeding is done.

6. Application of scheduled fog irrigation system tools

Application testing is done by observing the performance of scheduled fog irrigation system tools applied to mustard plant nurseries.

Experimental Methods

The research steps are presented in the flow diagram in Figure 1.

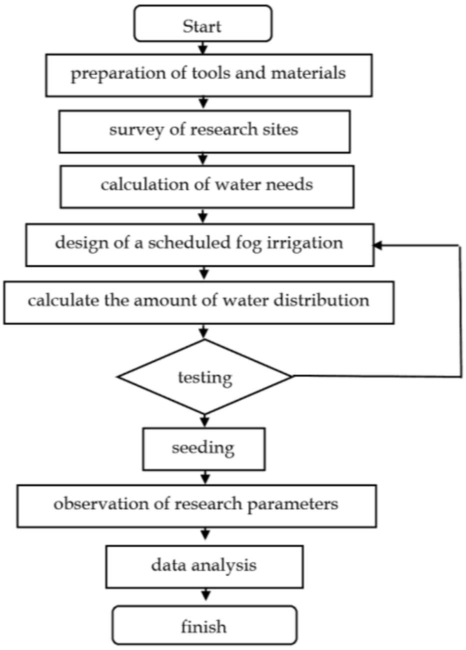


Figure 1. Flow diagram of this research

1. Preparation

Determining the completeness of tools or supplies is the preparation stage.

2. Review of the research site

Reviewing the research site is a stage to determine the research site following the research to be carried out.

3. Calculation of water demand

Plant water demand is the amount of water plants need based on the plant's evapotranspiration (ETc). The amount of ETc is obtained from the Equation (3) based on Syahrul et al. (2021).

$$ETc = Kc \times ETo \quad (3)$$

Where:
ETc = Plant evapotranspiration (mm/day)
Kc = plant coefficient
ETo = Potential evapotranspiration (mm/day)

The plant coefficient (Kc) for mustard plants in the early growth period (0-10 days) is 0.3, the middle growth period (11-20) is 1.2, and the late growth period (21-30) is 0.6 (Anwar et al., 2021). The ETc value is obtained from calculating temperature data, and the research will be carried out using the Hargreaves Method (Fausan et al., 2020).

4. Design of scheduled fog irrigation system

The fog irrigation system is applied to the mustard green plant nursery by utilizing an Arduino Uno microcontroller, which is used to design electronic circuits for control automation of fog irrigation watering. The design is done by installing each circuit, which includes a 12V pump, hose, power supply, and nozzle. Then, install the scheduled fog irrigation control system tools and electrical parts (as shown in Figure 2), adjust the nozzle height, and test the tool.

The process of designing this tool consists of two parts: hardware design and prototype program. The Prototype program is carried out as a system development technique to describe the form of the model so that users or system owners have an idea of the system development that will be carried out next (Martin and Susandi, 2022).

5. Calculating the water distribution that can be done

Fog irrigation systems are highly likely to lose water in the air when distribution is carried out. For this reason, the amount of water distribution that can be done is calculated. The calculation is done by experimenting with watering fog irrigation and then collecting water in the area to be watered. Using Equation (4), the fog irrigation system's water distribution to plants was determined.

$$Wa = Vi / t \quad (4)$$

Where:
Wa = water distribution to plants (L/min)
Vi = volume of water collected in the fog irrigation watering area (L)

t = duration to fulfill the container volume used (minutes)

6. Scheduled fog irrigation system testing

Testing is an important part of this research, which is done to find out if the tools that will be used can run well and according to the program language plan that has been made. In this scheduled fog irrigation system, three trials will be conducted at different watering frequencies, including first-time watering, two-time watering, and three-time watering.

7. Seeding

Using planting trays, mustard plants were seeded for seven days. One mustard plant seed is placed in each of the 144 tray holes on the seeding tray, with mustard seeds sown in each hole. It is thought that the mustard seeds must be fully buried in the soil during this process.

8. Observations

The water discharge used and the development of mustard green seedlings are among the observations recorded in this study. The height and quantity of leaves on mustard green seedlings were measured for seven days to observe their growth.

Tool Design

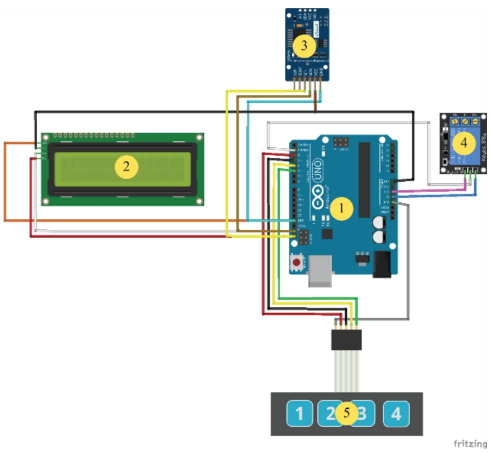


Figure 2. Tool design

The description of each number of tool design in Figure 2 is as follows: (1) Arduino UNO is a microcontroller that manages other supporting components and transmits data; (2) 20x4 LCD serves to display data or information that has been programmed on the microcontroller; (3) RTC DS3231 serves to run time and calendar functions in real-time; (4) Relay functions as a switch that disconnects and connects the flow of electricity; and (5) Keypad 1x4 serves to input data to the microcontroller by what has been programmed before. A detailed explanation of each component used in this tool is as follows:

1. RTC DS3231

The RTC DS3231 is a component that operates as a digital timer using I2C or two wires (SDA and SCL); four of its six pins are attached to the Arduino UNO. Table 1 shows the pairing of components with their corresponding pins.

Table 1. RTC DS3231 component pins to Arduino UNO

Component	Pin	ARDUINO UNO
RTC DS3231	VCC	VIN
	GND	G
	SDA	SDA
	SCL	SCL
	32K	Not Applied
	SQW	Not Applied

2. 1x4 Keypad

The keypad is a button that functions to input data. It has five pins: VCC pin, pin 1, pin 2, pin 3, and pin 4. Table 2 shows the pairing of components with their corresponding pins.

Table 2. 1x4 Keypad component pins to Arduino UNO

Component	Pin	Arduino UNO
Keypad 1x4	1	D2
	2	D3
	3	D4
	4	D5
	5	3V3

3. Relay

The three pins of a relay—the VCC (+) pin, the GND (-) pin, and the IN pin—are used as switches. These pins are then linked to the Arduino UNO, specifically the VCC pin to the 5v pin, the GND pin to the G pin, and the IN pin to the D23 pin. The pairing of components with their corresponding pins is shown in Table 3.

Table 3. Relay component pins to Arduino UNO

Component	Pin	Arduino UNO
Relay	VCC	5V
	GND	G
	IN	D1

4. 20x4 LCD

The 20x4 LCD is connected to I2C and has four pins: VCC, GND, SDA, and SCL. Table 4 shows the pairing of components with their corresponding pins.

Table 4. 20x4 LCD component pins to Arduino UNO

Component	*Pin*	Arduino UNO
LCD 20x4	VCC	VIN
	GND	G
	SDA	SDA
	SCL	SCL

RESULTS AND DISCUSSION

The Scheduled Fog Irrigation Control System

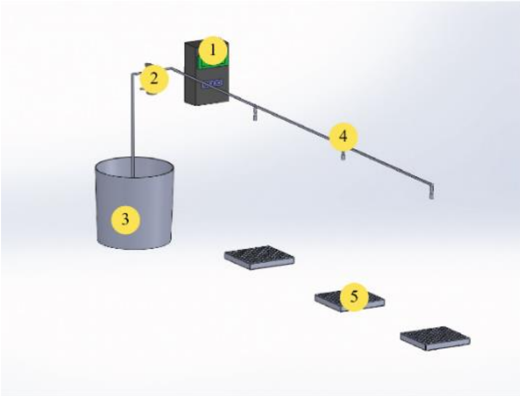
The planned fog irrigation system's hardware includes the RTC DS3231, 1x4 Keypad, Relay, and 20x4 LCD. These parts are connected to the Arduino UNO microcontroller, which will be utilized using jumper wires. The program code is input into the microcontroller so that the control system can run.

Program Language Creation

The Arduino IDE requires multiple steps to create the programming language, including producing sketches, headers, variable declarations, and structures. The scheduled fog irrigation system program language consists of a header, void setup, and void loop. To build a programming language on the Arduino IDE, launch the Arduino IDE 1.8.19 software on a PC or laptop, then add the necessary library, and the program can be deafened as planned.

The Design of Scheduled Fog Irrigation System Tool

The design is completed by installing each circuit, which includes a 12V pump, hose, power supply, and nozzle. Then, proceed with installing scheduled fog irrigation control system tools and electrical parts, adjusting the nozzle height, and testing the tool. Figure 3 shows a visualization of the scheduled fog irrigation system design in the greenhouse.



Note: (1) The location of the system controller circuit; (2) Location of the 12v water pump; (3) Place the air collection bucket; (4) Location of the mist nozzle and hose; (5) Seedling tray

Figure 3. Scheduled fog irrigation system tool design

Testing of System Tool Scheduled Fog Irrigation

Testing is done to determine whether the tool can function properly and according to the created program language plan. Following the time, the 20x4 LCD effectively displays the date and time when the test is run, and the Numpad and pump run well. Based on that, the scheduled fog irrigation system can run properly, as shown in Figures 4a and 4b.

(a) (b)

Figure 4. (a) Fog system testing; (b) LCD

Clock Calibration on RTC DS3231

Calibration verifies the tools' accuracy by comparing them with other tools as a benchmark standard (Thorarinsdottir and Schuhen, 2018). In this study, calibration was conducted to ensure that the RTC DS3231 component's displayed time was precise and in line with the comparison. The calibration Results are shown in Table 5.

Table 5. RTC DS3231 calibration results

Sample	RTC DS3231 (second)	*Smartphone* (second)
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	13
13	13	14
14	14	15
15	15	16
16	16	17
17	17	18
18	18	19
19	19	20
20	20	21
21	21	23
22	22	24
23	23	25
24	24	26
25	25	27
26	26	28
27	27	29
28	28	30
29	29	31
30	30	32

Following the acquisition of the second value on the RTC DS3231, it is then compared with the second-hour value on the Smartphone, and the comparison value can be seen in Figure 5. A mathematical model was obtained through linear regression analysis of the relationship between the RTC DS3231 second value and the Smartphone second value. From this comparison, the equation $y = 1.091x - 0.4437$ is obtained, and the coefficient of determination is 0.9991. The coefficient of determination is used as information on the fit of a model by being calculated to determine the extent of the fit of the independent variables in multiple linear regression equation models, which can simultaneously explain the independent variables (Chin et al., 2020).

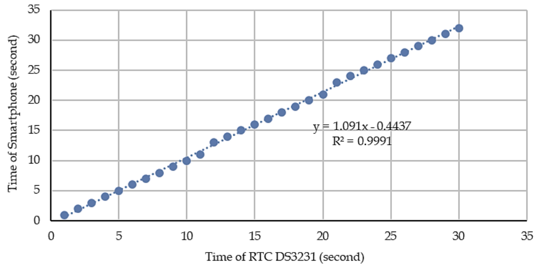


Figure 5. RTC DS3231 calibration chart

Calculation of Plant Water Requirements

Calculating water requirements is to determine the amount of water plants need daily. The amount of ETc (plant evapotranspiration) that mustard plants endure is used to calculate how much the necessity of water. In the computation for the ETc value, the Kc value (plant coefficient) of mustard is needed, and ETo (potential evapotranspiration (mm/day). The mustard seedbed in this study was carried out for ten days with the obtained value of the plant coefficient (Kc) at 0-10 days of 0.3. ETo value, obtained from calculations using the Hargreaves method (Katipoğlu, 2023) are listed in Table 6.

Table 6. Water requirement of mustard plants during seeding

Date	Age of Plant	Kc	ETc (cm/day)	Water needs (mL/day)
19/05/23	1	0.3	0.62	359
20/05/23	2	0.3	0.63	361
21/05/23	3	0.3	0.63	364
22/05/23	4	0.3	0.64	367
23/05/23	5	0.3	0.64	370
24/05/23	6	0.3	0.65	373
25/05/23	7	0.3	0.65	376
26/05/23	8	0.3	0.66	378
27/05/23	9	0.3	0.66	381
28/05/23	10	0.3	0.67	384
Average of Water Needs				371

Description:
Conversion of ETc (mm/day) to ETc (mL/planting area/day)
1 mm/day = 1000 mL/m²/day
Planting area = 576 cm²

Water Debit

Water debit is the amount of water volume out of the nozzle in one unit of time (minute). This study calculates water discharge to determine the efficiency of water use and the length of time the nozzle will water. Three times, the water storage experiment was conducted on the nozzle of the fog irrigation system, and the average water discharge was obtained, as shown in Table 7.

Table 7. Water discharge on fog irrigation nozzle

Trial	Time (minute)	Accumulated water (mL)
1	1	115
2	1	116
3	1	116
Average water debit		115.6/minute

Possible Water Distribution

Measurements were taken to determine how much water could be distributed from the nozzle to the plants. To do these calculations, water was collected on the surface using a nozzle 30 cm above it. The fog irrigation system tool was activated, and three experiments were conducted to collect water. The average water collection results are listed in Table 8.

Table 8. Water distribution by the fog irrigation system tool

Trial	Time (minute)	Accumulated water (ml)
1	1	87
2	1	88
3	1	88
Average Water Distribution		87.7 mL/minute

The value of water distribution that the fog irrigation system can do is lower than the debit value, indicating that water loss occurs when watering because of the distribution of water conducted from the nozzle to the soil's surface. This water loss can be caused by several factors, such as the distance between the nozzle and the plant's surface and the high environmental temperature that causes evaporation when the water particles are still in the air.

Water Use Efficiency

Fog irrigation distributes water to plants with finer and smaller water particles that have a high possibility of water loss during watering (Criscione et al., 2022). For this reason, water use efficiency in fog irrigation is calculated to determine the water loss that occurs when watering. The results are listed in Table 9.

Table 9. Water usage efficiency in fog irrigation system

Average water flow (mL)	Average distribution of water (mL)	Water use Efficiency (%)
115.6	87.7	75.86

Considering the water discharge and distribution calculations that can be made, the water use efficiency is 75.86%. This percentage is quite good because it is within the range of efficient micro-irrigation values that guarantee water consumption efficiency with a value of 50% to 90% (Agarwal et al., 2023). However, in contrast to the drip irrigation system, the efficiency of water usage in this mist irrigation system is still low; in the drip irrigation system, the typical water use efficiency is >90% (Handayani et al., 2022).

Duration of Watering

This study's watering fog irrigation length is divided into three types. Each watering is adjusted to the amount of watering done in one day. Table 10 details the duration of watering used in this investigation.

Table 1. Duration of watering per day

Total Watering in a day (times)	Average Water Requirement (mL/day)	Average water distribution (mL)	Watering duration each 1 time watering (minutes)
1	371	87.7	4.2
2	371	87.7	2.1
3	371	87.7	1.4

The length of each watering that has been adjusted to the need for water in 1 day is 4.2 minutes per watering in 1 day, 2.1 minutes per watering in 2 flushes, and 1.4 minutes per watering in 3 flushes. In this study, three types of treatments were tested. During the study period, these three types of treatments were carried out simultaneously in the same greenhouse but on different seedling trays. Determination of the amount of watering was influenced by factors such as plant water requirements, type of planting media, temperature, and relative humidity.

Plant Growth

Plant growth is an increasing plant size detected from height, width, and weight (Naznin et al., 2019). In this study, plant growth was calculated based on the height and number of leaves of mustard plants in the seeding period.

Mustard Plant Height

Plant height is one of the growth indicators used to measure the treatment applied. Figure 6 displays the findings of a mustard plant height study conducted in mustard plant nurseries using an Arduino UNO and a scheduled mist irrigation system.

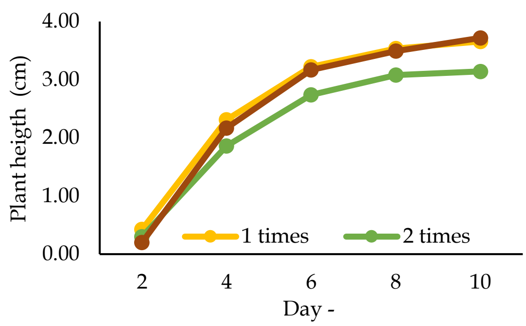


Figure 6. Graph of mustard plants height during the seeding

Based on Figure 6, it is evident that the height of mustard plants during the seeding, the largest mustard plant height is obtained in the seeding using a scheduled mist irrigation system with a treatment of 3 times watering in a day with an average height of 3.72 cm, after which the treatment is one time in a day 3.66 cm, and the lowest value in the treatment two times a day 3.14 cm. Watering 3 times a day produces the tallest plants because by watering 3 times with the same amount, the water loss due to evaporation can be minimized so that more water can be absorbed.

Number of Mustard Leaves

Figure 7 shows the number of mustard leaves based on the research results carried out with a scheduled fog irrigation system using Arduino UNO in mustard seedings. In this study, different irrigation treatments can affect plants' growth and development during the seeding period. In Figure 7, it is clear that the results of research on the number of leaves of mustard plants with the treatment of 3 times watering using a scheduled fog irrigation system has the highest value compared to the others, namely with an average number of leaves of 2.77 strands, then followed by one time watering scheduled fog irrigation with 2.72 strands, and the last with the treatment of 2 times watering with scheduled fog irrigation 2.67 strands. Hence, one plant consists of 2 to 3 strands in 10 days. The total number of plants observed consisted of 144 plants per seedling tray.

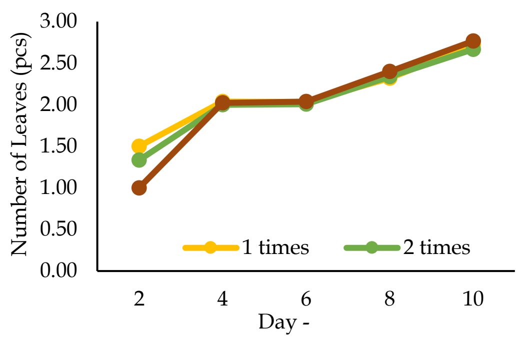


Figure 7. Graph of the number of mustard leaves during seeding

Watering three times a day causes the highest number of leaves because by watering three times with the same amount, the water loss due to evaporation can be minimized so that more water can be absorbed. This certainly affects the height of the plant, where the higher the plant, the more leaves. The more leaves, the greater the weight of the plant.

Performance of Scheduled Fog Irrigation System

Performance testing of the scheduled fog irrigation system was carried out on mustard seedings with a seeding area of 28 cm x 28 cm using a nozzle to trigger fog in watering. Testing is done to determine whether this fog irrigation system works properly. The performance of the scheduled fog irrigation system tool in this study is stated to run well under the plan that has been made. In applying this tool, the results of the growth of mustard plants in the seeding period, both height and number of leaves, are stated to be good. The desirable characteristics of a mustard plant, particularly related to plant height and number of leaves, can vary depending on the specific cultivation goals (e.g., oil production, leaf consumption, or seed harvesting). However, some good characteristics include optimal plant height, leaf characteristics, disease resistance, and seed production. These characteristics certainly affect the height of the plant, where the plant is higher and the more leaves. The more leaves, the greater the weight of the plant.

CONCLUSION

Based on the findings and discussion, this study uses an Arduino UNO to create a planned fog irrigation system for mustard green planting. This study has designed and implemented a scheduled fog irrigation system using a microcontroller and the RTC (real-time clock) component. This research successfully automated the control of fog irrigation, resulting in a water use efficiency of 75.86%. Among the other treatments, the variation in mustard plant height and leaf count during the seeding process utilizing the three-times-daily treatment with a planned fog irrigation system had the highest value.

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