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# Automatic Plant Watering System for Local Red Onion Palu using Arduino

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**ABSTRACT**

Central Sulawesi Province in Indonesia has great potential for horticultural commodities, namely local red onion Palu. In the current climate change, local farmers are still watering plants in the conventional way. The automatic watering system simplifies the work of local farmers. This device uses a soil moisture sensor as a soil moisture detector and Arduino as a program brain. This study aims to determine the position of soil moisture sensor, the optimal length of watering time and analyze the quality of data stored. The experiment was carried out using a Completely Randomized Design (CRD). The position of the soil moisture sensor was analyzed by Profile Analysis. The optimal length of watering time was determined by Analysis of Variance (ANOVA) and Least Significant Difference (LSD). The quality of data stored was determined by a number of missing values and frequency of watering. The results showed that in soil planting media the position of soil moisture sensor had no significant effect, while in others planting media (water and combination of water and soil) the position of the sensor had a significant effect. The optimal watering time was 3 seconds. The stored data has low quality in terms of missing values and lack of consistency.

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## 1. INTRODUCTION

Central Sulawesi is one of the Provinces in Indonesia that has great potential in the agricultural sector. This potential is supported by a good level of soil fertility, the availability of adequate ground water and rainwater, and an appropriate climate [1]. One of the agribusiness commodities that have been well known is a local red onion Palu (*Allium ascalonicum L.*). In 2011, the Ministry of Agriculture Indonesia released one of the local red onion Palu as the superior national red onion [2].

The increase in domestic consumption of red onion must be balanced with an increase in domestic production, both in quantity and quality. Increased production can be done by intensification or extensification. Red onion production is currently changing from year to year. This is due to changes in the planting area and the productivity of these plants [3].

Local red onion Palu are one of the plants that need water for the development of their life. Fertile soil is a prerequisite for plants to grow well. Fertility levels can be influenced by the intensity of the water it contains. However, currently humans still have difficulty in watering, because it must be done manually and do not know how much water is needed by plants[4].

The automatic watering system can facilitate human work in terms of watering plants. This device is made with a function to water plants automatically using a soil moisture sensor as a soil moisture detector and Arduino as a program brain. The relay component as a water pump controller receives data from Arduino Uno which has been programmed to detect soil moisture and then pumps water automatically [4].

In the automatic watering system, how sensitive the soil moisture sensor is used and the length of time for watering plants are important things that need to be considered. A reliable automatic plant watering system is a plant watering system that can detect soil moisture accurately and consistently maintains soil moisture quality so that plants can grow well. The sensitivity of the sensor used can be analyzed using Profile Analysis. Profile analysis is an analysis used to compare the similarity of several treatments performed on two or more objects/populations [5]. The optimal length of watering can be determined by conducting experiments and analyzing the experimental results using Analysis of Variance (ANOVA).

As mentioned in [6], who describes various experimental designs in agriculture and health, One of the recommended experimental designs in the agricultural field is Complete Random Design (CRD). ANOVA is a method for testing the similarity of the mean values of a population or treatment. The results of the ANOVA will show whether the average treatment level of the observed response variables has the same average value [7]. When the F-ratio from ANOVA suggests rejection of the null hypothesis, The least significant difference (LSD) test helps to identify the populations whose means are statistically different [8].

This research involves four studies that have been conducted by previous researchers. First, research that examines the stability of the local red onion Palu genotype on the environment by [9] and[10]. Second, research on an automatic watering system in the form of a dashboard by [11] and research on an automatic watering system with the optimal length of time for watering the watering system determined through simulations by [12]. The research objectives to be achieved are: (1) Determining the position of the soil moisture sensor in the automatic plant watering system, (2) Determining the optimal length of time for watering plants automatically on local red onion Palu plants and (3) Analyze the quality of the data stored on the tool for use in machine learning modeling.

## 2. METHOD

The location of this research was carried out in the academic garden of the Faculty of Agriculture and the Applied Statistics Laboratory of the Statistics Study Program, Faculty of Mathematics and Natural Sciences Tadulako University. This research data will be analyzed by Profile Analysis and ANOVA. The response variables observed were local red onion Palu weight (grams) and number of tubers. To determine the best soil moisture sensor position, we conducted a sensor sensitivity test using CRD experiment on two response variables ($Y_1$) 20 ml and ($Y_2$) 50 ml. The optimal length of time for watering plants automatically was determined by CRD as well. The experimental treatment level of watering time is 3 seconds ($P_1$), 8 seconds ($P_2$), and 15 seconds ($P_3$). As a comparison, this study also carried out the planting of local red onion Palu using the conventional watering method ($P_0$).

### 2.1. Experimental Design

The experimental design for the optimal length of time for watering plants automatically was carried out using the Completely Randomized Design (CRD) method. Each treatment was repeated 3 times. The treatment given consisted of 3 levels, so the number of observations needed for this experimental design was 12 observations. The experimental design is as follows:

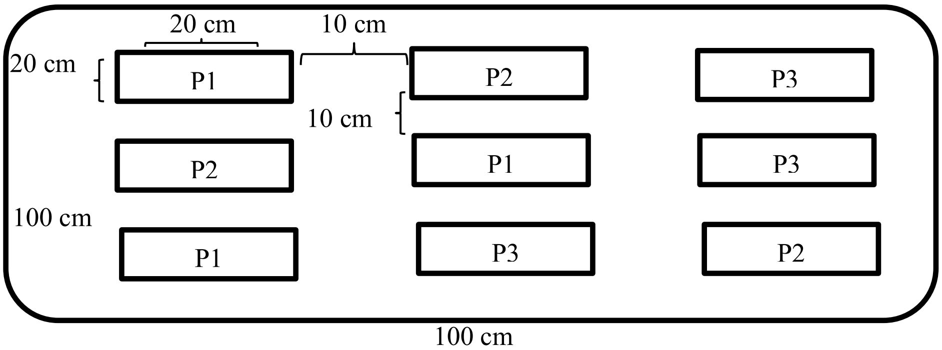


Figure 1. Optimal length of time for watering plants experimental design

The experiment was carried out in a container made of wood measuring 100 cm long, 100 cm wide and 30 cm high. The planting media using soil media that had been previously treated and the spacing between plots of plants was 10 x 10 cm. The area of one plant plot is 20 cm x 20 cm. The distance between plots of plants is intended as a barrier that separates the amount of water in each plot. As a comparison, a control treatment was also provided using the same experimental design. The control treatment was local red onion Palu plants which were watered using conventional methods.

The sensitivity test was carried out using the CRD method as well. Each response variable was repeated 4 times. So, the number of observations needed for this experimental design was 8 observations. In the sensory sensitivity test, the soil moisture sensor was inserted into the planting media such as water (X1), soil (X2), and combination of soil (50 ml) and water (20 ml) (X3). The experiment was carried out in a measuring cup with a size of 0-50 ml.

### 2.2. Design of Automatic Watering Plant System Based Arduino

An algorithm is compiled to regulate the mechanism of watering plants automatically. In this study, the algorithm used utilizes conditional statements as an indicator of when to water. We hope that the results of this study can be used to the stage of machine learning modeling in watering plants for further research, so that watering activity data is stored. The algorithm for automatic watering tools is as follows:

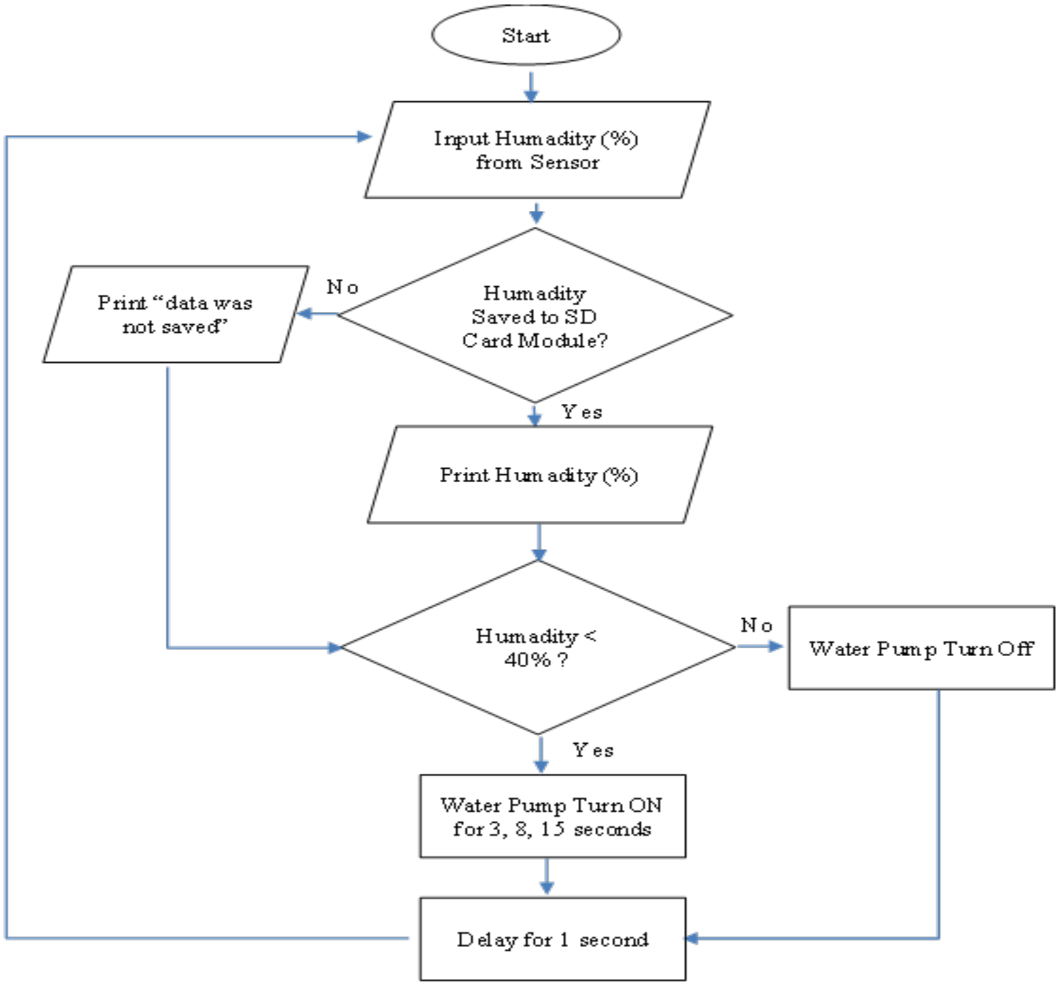


Figure 2. Algorithm of Automatic Watering Plant System Based Arduino

An automatic plant watering system will be made based on Arduino. The components and design of an Arduino-based automatic plant watering system are as follows:

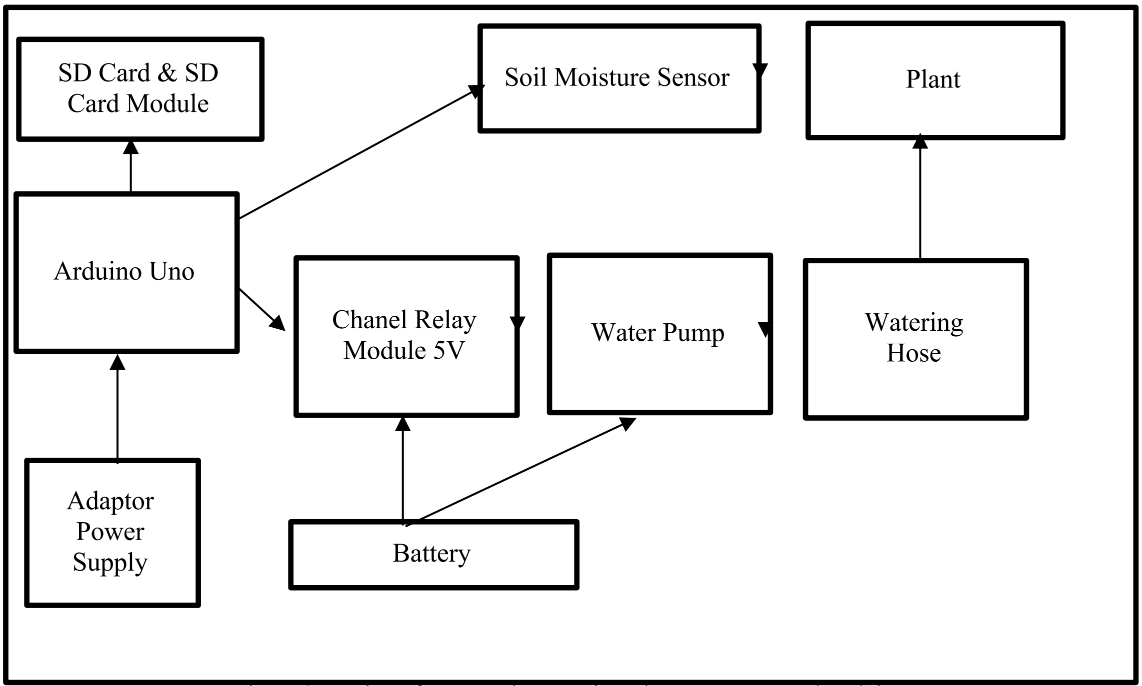


Figure 3. Design of Automatic Watering Plant System Based Arduino

### 2.3. Data Analysis

The data analysis stages carried out in this research are as follows:

a. Build an automatic watering system using arduino
b. Designing an experiment by determining the experimental design, treatment and replication that will be used in this study.
c. Conduct the sensitivity test of soil moisture sensor. The experimental results will be processed using profile analysis. Profile analysis was carried out using the R software with the profileR packages [13].
d. Conduct an experiment on automatic watering systems using Arduino. The experiment was conducted using a completely randomized design (CRD).
e. Calculating the number of tubers and weight of local red onion Palu produced by experiments
f. Perform analysis of variance (ANOVA) to obtain an overview of the effect of watering time on the number of tubers and the weight of local red onion Palu. ANOVA was performed using R software with stats packages [14].
g. Performing the difference means testing using Least Significant Difference (LSD) on the ANOVA results. The LSD test was carried out using software R with agricolae packages by [15].
h. Interpret the research results and draw conclusions.

## 3. RESULTS AND DISCUSSION

### 3.1. Automatic Watering Plant System Based on Arduino

The Arduino-based automatic watering system circuit is based on the design in Figure 3. The automatic watering system will collect data related to soil moisture using a humidity sensor. The data is then processed on Arduino by using an algorithm. The output of the Arduino is the instruction to run the water pump for a certain time interval. Then, all activities of the automatic watering system will be saved. The results of a series of automatic watering systems are as follows:

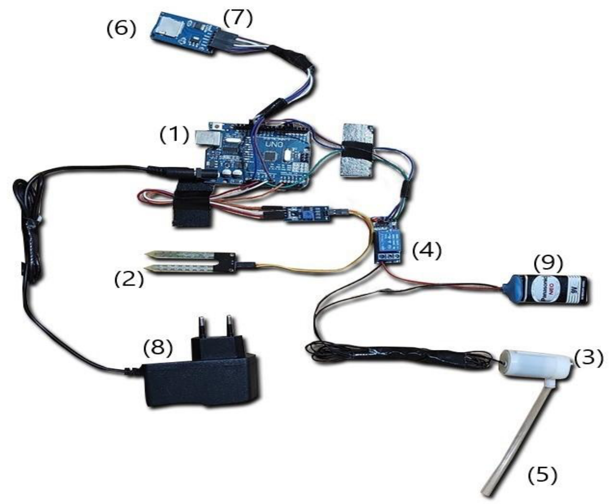


Figure 4. Automatic Watering Plant System Based on Arduino

The components of the Arduino-based automatic watering system in Figure 4 are 1) Arduino Uno, 2) Soil Moisture Sensor, 3) Water Pump, 4) 5V Channel Relay Module, 5) Watering Hose, 6) SD Card, 7) SD Card Module 8) Power Supply Adapter and 9) AA Power Battery. As previously explained, the main components of this watering system are (1), (2), (3), (5), (6) and (7). While the other components (4), (8) and (9) are resistors and power supply devices.

### 3.2. Soil Moisture Sensor Sensitivity Test

The sensitivity test of the soil moisture sensor is carried out by experimenting with inserting the sensor into water and soil at a certain depth as a response variable (Y). The response variable in this test is the depth of soil or water (ml) in the measuring cup. The response variables observed in the sensitivity test were 20 (ml) and 50 (ml). This response variable was chosen by considering the sensor size of 6 cm. It is hoped that the response variable can represent the state of the sensor in the field, whether it is placed in a completely closed position by soil/water or only partially. The illustration of the sensor sensitivity test process on the automatic watering system can be seen in Figure 5.

(a) (b)

Figure 5. Illustration (a) the level of treatment using water media with a response variable of 50 ml ($Y_2$) and (b) the level of treatment using soil media with a response variable of 20 ml ($Y_1$)

The treatment in this sensitivity test is the planting medium used. There are 3 levels of treatment used, namely water, soil and combination (50 ml of soil and 20 ml of water). Observations were made 3 times (time) according to the number of treatment levels. At each treatment level, observations were made for 12 hours with soil moisture data (%) stored for every second. The results of the profile analysis are as follows:

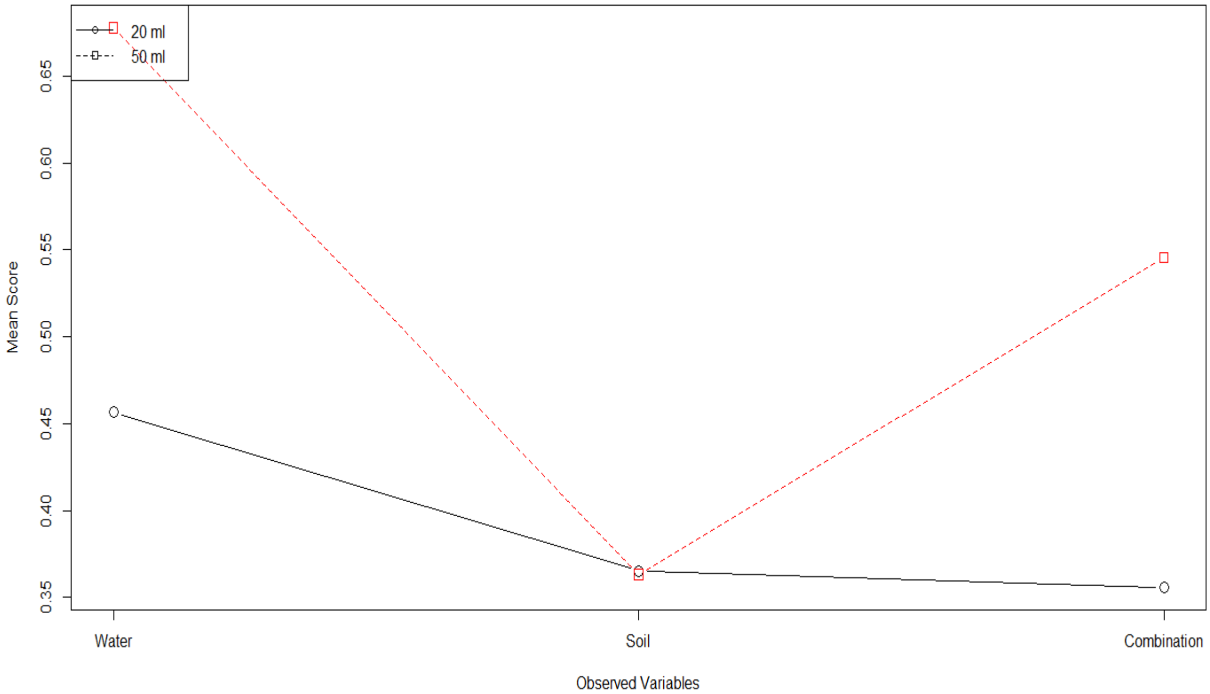


Figure 6. Analysis of the soil moisture sensor profile at a depth of 20 ml ($Y_1$) and 50 ml ($Y_2$)

Based on Figure 6, it can be seen that the 20 ml profile ($Y_1$) is not parallel to the profile ($Y_2$). In addition, the two profiles do not coincide and are not completely constant. In soil media, the results of the two response variables coincide and are constant. In other words, based on the graph the increase in the number of planting media (Y) for each treatment level is different. In soil planting media the sensor position has no significant effect, while in other planting media (water and combinations) the sensor position has a significant effect. The results of the profile analysis hypothesis testing are as follows:

Table 1. Profile Analysis Results

| No | Hypothesis Null | F-Value | P Value | Conclusion |
|---|---|---|---|---|
| 1 | *Profiles are parallel* | 6.053131 | 0.04618886 | $H_0$ Rejected |
| 2 | *Profiles have equal levels* | 8.614 | 0.0261 | $H_0$ Rejected |
| 3 | *Profiles are flat* | 19.95002 | 0.004138169 | $H_0$ Rejected |

Table 1 shows that the amount of planting media (Y) is not parallel, coincides, and constant (H0 is rejected). Therefore, the position of the sensor can affect the quality of the soil moisture data. Based on the results of the sensitivity test of the sensor, when conducting the experiment, the position of the sensor used was a position that was completely covered by the planting medium.

### 3.3. Experiment

The automatic watering plant system experiment on local red onion Palu took time for 74 days. First of all, red onions are grown and watered conventionally in a polybag until the local red onion Palu are 30 days old. Secondly, the local red onion Palu was transferred to an experimental container that had been previously prepared with an automatic watering plant system. Normally, local red onion Palu can be harvested at the age of 60 days old. However, it takes 14 days for local red onion Palu to adapt to the experimental container. The container is shown as follows:


(a) (b)

Figure 7. Documentation of (a) experimental design and (b) an automatic watering plant system installation

Figure 7(a) shows the area of one plant plot is 20 cm x 20 cm and the spacing between plots of plants was 10 x 10 cm. Figure 7(b) shows automatic watering plant systems device installation. There are 9 units of automatic watering plant systems device installed around the experimental container. Each of these units (Figure 4) is adjusted for cables and hoses to be used based on the location of the experimental unit as shown in Figure 7 (b). The experimental data are as follows:

Table 2. Automated watering system experiment data

| Level of Treatment | Replication | Weight (Gram) | Number of tubers |
|---|---|---|---|
| P0 | 1 | 17 | 9 |
| P0 | 2 | 17 | 10 |
| P0 | 3 | 18 | 6 |
| P1 | 1 | 59 | 10 |
| P1 | 2 | 40 | 10 |
| P1 | 3 | 38 | 8 |
| P2 | 1 | 19 | 8 |
| P2 | 2 | 21 | 8 |
| P2 | 3 | 33 | 16 |
| P3 | 1 | 59 | 17 |
| P3 | 2 | 15 | 9 |
| P3 | 3 | 43 | 8 |

Table 2 shows the results of measuring the weight of local red onion Palu (grams) and the number of tubers. The highest weight of local red onion Palu was found in treatment 1 (3 seconds) replication 1 ($P_1U_1$) and the highest number of tubers was found in treatment 3 (15 seconds) replication 1. The data will be processed using analysis of variance to determine the effect of the level of treatment.

### 3.4. Analysis of Variance

Analysis of variance was carried out for each response variable. ANOVA was carried out using R software with *stats* packages. The null hypothesis ($H_0$) of the ANOVA test is that the mean of treatment level has the same value. For the ANOVA test, the confidence level value used is 90% ($\alpha = 0.10$). The results of the ANOVA are as follows:

Table 3. Analysis of Variance Results

| Response Variable | F-Value | P-Value | Conclusion |
|---|---|---|---|
| Weight | 2.96 | 0.09* | $H_0$ rejected |
| Number of tubers | 0.42 | 0.742 | $H_0$ accepted |

*Significant at α = 0.10

Table 3 shows that there is at least one level of treatment that has different mean values on the weight response variable. While the other response variable, number of tubers, has the same mean level of treatment. Thus, the results of this study indicate that the length of watering can affect the weight of the local red onion Palu. To find out the treatment level of the optimal length of time for watering plants automatically which was significantly different, the analysis was continued with the further test of LSD.

Table 4. Least Significant Test (LSD)

| Difference of Levels | Difference of Means | T-Value | P-Value |
|---|---|---|---|
| P1 - P0 | 28,3 | 2,65 | 0,029* |
| P2 - P0 | 7,0 | 0,65 | 0,532 |
| P3 - P0 | 21,7 | 2,02 | 0,078 |
| P2 - P1 | -21,3 | -1,99 | 0,081 |
| P3 - P1 | -6,7 | -0,62 | 0,551 |
| P3 - P2 | 14,7 | 1,37 | 0,208 |

*Significant at α = 0.05

Table 4 shows that the treatment level 1 (3 seconds) ($P_1$) was significantly different from the control variable ($P_0$). The difference of means $P_1$-$P_2$ and $P_1$-$P_3$ has a negative value. In other words, the length of time for watering in treatment 1 was better than other treatments. Thus, the optimal length of time for watering plants automatically on local red onion Palu is 3 seconds.

### 3.5. Algorithm Performance Evaluation

The implementation of the sensor and Arduino showed positive results. However, the performance of the algorithm on Arduino needs to be evaluated. In future research, the automatic watering plant system is expected to be able to apply machine learning models in Arduino. To be able to do this, it is deemed necessary to review the data storage information system during the experimental process. The quality of data will bring ease in the machine learning modeling process. In the automatic watering system, soil moisture data is stored into the SD Card periodically every second. Moisture data is in the form of a percentage of 0 - 100%, where the greater the percentage, the more humid the soil condition. As for one example of data from the automatic watering system is as follows:

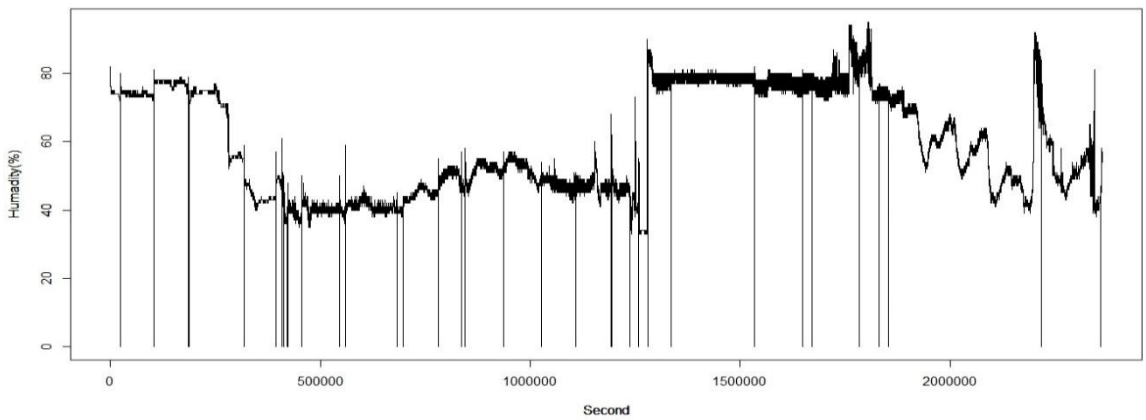


Figure 8. Soil moisture data in treatment 1 (3 seconds) replication 3

Figure 8 shows that the pattern of soil moisture data has a seasonal pattern for the treatment 1 (3 second) replication 3 ($P_1U_3$). The seasonal pattern takes different forms according to the environmental conditions at that time. In Figure 8 also found a downward trend pattern and will increase if the watering plant system works. At some point, the humidity value is at a value of zero. This value indicates data that is not stored on the SD Card Module or *missing value*.

The experiment was carried out for 34 days or 2,937,600 seconds. The proportion of the amount of data stored in the system is as follows:

Table 5. Length of data stored in SD Card Module

| Level of Treatment | Replication | Length of data (Second) | Percentage (%) |
|---|---|---|---|
| P1 (3 Seconds) | 1 | 1474857 | 50.20 |
| P1 (3 Seconds) | 2 | 2135134 | 72.68 |
| P1 (3 Seconds) | 3 | 2363152 | 80.45 |
| P2 (8 Seconds) | 1 | 1629596 | 55.47 |
| P2 (8 Seconds) | 2 | 2108528 | 71.77 |
| P2 (8 Seconds) | 3 | 1790867 | 60.96 |
| P3 (15 Seconds) | 1 | 2051227 | 69.82 |
| P3 (15 Seconds) | 2 | 2025940 | 68.96 |
| P3 (15 Seconds) | 3 | 1372687 | 46.72 |

Table 5 shows that the data stored in the automatic watering system is less than 81%. This indicates that the data storage system/algorithm has not been running optimally. One of the factors that cause this is a power outage, running out of power supply (batteries) on the water pump, and damage to the sensor due to rust.

Good data quality will streamline the machine learning modeling process. For example, in the process of labeling the dependent variable of classification problem (Y), information on when the device is flushing is needed. One way to see that is to use a data pattern that drops slowly and then suddenly rises (seasonal pattern) as shown in Figure 8. In general, the shorter the watering time, the greater the frequency of watering. This study uses a treatment level of P1 = 3 seconds, P2 = 8 seconds and P3 = 15 seconds. P1 is expected to have more watering frequency than P2 and P3. The following are the results of the flushing and non-flushing data patterns based on the following data patterns:

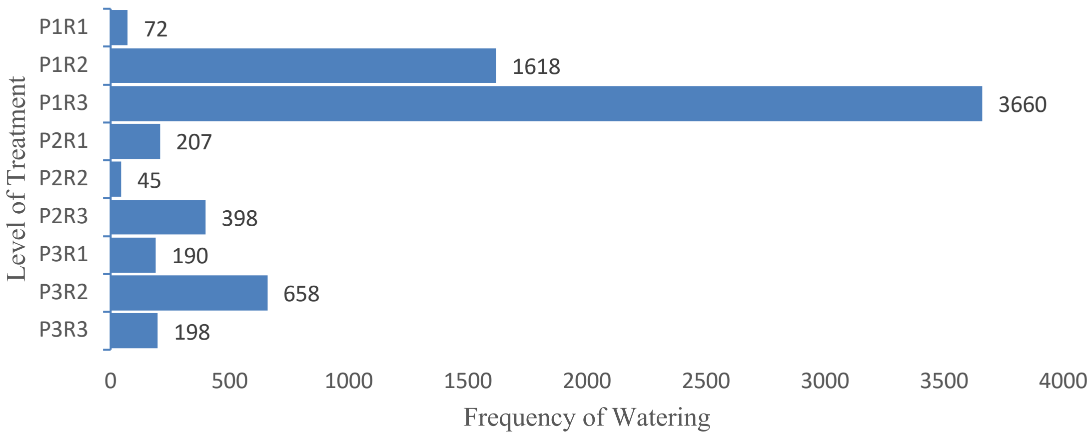


Figure 9. Watering Frequency of Automatic Plant Watering System using Arduino

Figure 9 shows that at some levels of treatment the frequency of watering for 34 days the experimental range is not logically rational. P1 is expected to have more watering frequency than P2. P2 is expected to have more watering frequency than P3. However, this did not happen to P1 replication 1 (P1R1), P2 replication 2 (P2R2) and P3 replication 2 (P3R2). So, it can be said that data storage in each tool lacks consistency. One of the causes is missing values in Figure 8. Lack of consistency and missing values causes the process of data labeling on the dependent variable (Y) cannot be carried out based on patterns of stored data (seasonal pattern).

## 4. CONCLUSION

In this research, it is known that in soil planting media the sensor position has no significant effect, while in other planting media (water and combinations) the sensor position has a significant effect. The monitoring function of the automatic watering system is able to provide slightly better results than conventional watering with a watering time of 3 seconds for the automatic watering plant system. The stored data has low data quality in terms of missing values and lack of consistency for conducting data preparation in machine learning. Therefore, a good application of sensors and Arduino cannot be followed by the quality of the stored data to do machine learning modelling.

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