The Use of Temporary Immersion System Double Vessel Method and Regression Tree in Orchid Seed Planting

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Abstract— This research aims to explore the use of the Temporary Immersion System (TIS) Double Vessel and Regression Tree methods in planting orchid seeds. The TIS-DV method will be used to optimize the growth and development of orchid seeds through tissue culture. Regression trees will be used to predict temperature and humidity values inside the vessel. Explained in graphic form such as histograms, line charts, and scatterplot charts. The results of measurements and predictive analysis related to air temperature and humidity inside the vessel have air temperature measurements with temperature variations in the range of 23℃ to 25.5℃, and the highest frequency occurs at 24.5℃. Furthermore, the temperature prediction analysis shows a very high degree of accuracy with the R^2 values of 99.22%, which indicates a strong relationship between predictions and actual data. the results of humidity measurements show that the highest frequency occurs at 97%. Humidity prediction analysis shows a high degree of accuracy, with R^2 values of 98.95%.

I. INTRODUCTION

Orchids are characterized by their exquisite flowers and boast the highest diversity among plant types. These varieties are found across a broad range of regions, spanning from wet tropical zones to circumpolar areas [1]. Orchid populations are witnessing a major decline in their natural habitat mainly due to unregulated commercial collection, deforestation, and massive habitat destruction. Commercial orchid production through traditional propagation is not always effective because it is slow, time consuming, and requires high levels of labor [2].

Sowing orchid seeds is the process of planting orchid seeds into a certain planting medium to start the growth and development of orchid seeds. One technique used for sowing orchid seeds is to use a Temporary Immersion System (TIS), also known as a temporary soaking system. TIS is a plant tissue culture technique that allows plant seeds to grow efficiently in large quantities and in a relatively short time.

In the TIS technique, plant seeds are placed in a container containing a small amount of nutrient media, and the container is inserted into a special device that provides an automatic supply of nutrient media through a temporary soaking system. Most papers report that TIS produces plants that survive the ex-vitro acclimatization stage more successfully than those produced on semi-solid media or continuous soaking systems. [3]. TIS is a technique for sowing orchid seeds that uses a small amount of nutrient media but is supplied continuously through a temporary soaking system.

One of the TIS methods commonly used is TIS Double Vessel. TIS Double Vessel is a plant tissue culture technology used to cultivate plants in a laboratory environment [4]. In this method, plant tissue culture grows automatically using a container or vessel consisting of two parts, one for in vitro shoots and another for liquid culture media which is connected to a silicone tube that allows the liquid media to flow from one vessel to another. This method has been tested for mass propagation of plants such as: fruit trees (pineapples, bananas), ornamental plants (orchids, chrysanthemums) [5].

The design was previously developed by Abu Hassan A. (2022), in the mass propagation using low-cost bioreactor protocol. Although their focus was on optimization for mass propagation and creating a low-cost bioreactor, the design is effective for banana, pineapple and orchid cultivation and this system can operate with minimum training [6]. The implementation of Regression Tree to predict the temperature and humidity inside the vessel can be used for the proactive adjustment of optimal orchid growing conditions, a missing feature in Abu Hassan's work. This research makes it possible to anticipate and overcome challenges, which has the potential to improve orchid quality and growing efficiency

Regression tree is a type of variable where the target algorithm is the predicted variable, and the method used to do so [7]. This will be determined by related criteria such as temperature and humidity. A regression tree divides the dataset into nodes based on the values of an explanatory variable. The goal is to forecast the response values of an observational unit as it moves down the tree, using the mean of the terminal (non-split) node where it lands [8]. The accuracy of the regression tree model is measured using the R^2 metric. R^2 is a metric used to measure the performance of regression analysis in machine learning to see how much influence a particular independent variable has on the dependent variable [9].

Regression tree can be used to predict the temperature and humidity in the orchid vessel based on relevant independent variables, such as temperature, humidity, or other environmental factors. In this context, regression tree helps understand the relationship between these variables and plant moisture. The DHT11 sensor can be used in analysis to objectively measure the temperature and humidity values in the vessel.

II. DEVELOPED SYSTEM

In the proposed system illustrated in Figure 4, the ESP32 microprocessor serves as the central intelligence, orchestrating the functions of the DHT11 and water pump within the context of Vessel 1. The DHT11 diligently measures temperature and humidity, acting as the sentinel of environmental conditions. When the temperature is below 23 degrees, the ESP32 commands the water pump to spring into action, providing a refreshing 10-second burst. Conversely, should the mercury rise above 26 degrees, the water pump gracefully takes its cue to power down. The intricacies of temperature and humidity readings captured by the vigilant DHT11 are seamlessly transmitted to Firebase, a robust platform chosen for its process in data processing.

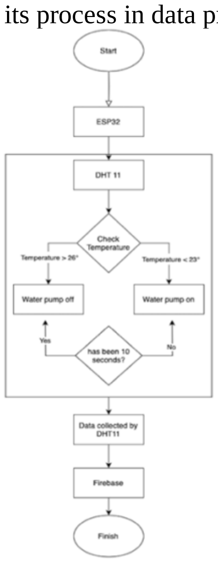

Figure 1. Tool Flowchart

A. Tool Design

NodeMCU is an electronic board based on the ESP8266 chip with the ability to carry out microcontroller functions and supports integrated Wi-Fi connectivity. There are several I/O pins so that it can be developed into a monitoring and controlling application for IoT projects [10]. NodeMCU has the ability to process powerful data and has large storage so it can be integrated with development and loading during runtime.

Figure 2. NodeMCU

DHT11 or temperature and humidity sensor is a sensor that can be used to measure the temperature and humidity values of the air in a room. The advantages of the DHT11 are the responsive quality of the sensor readings and the speed in measuring temperature and humidity objects [11]. This sensor has high accuracy and has a temperature measurement range of -40°C to 80°C, humidity measurements range from 0% to 100% RH.

DHT 11 is used in this design to measure the temperature and humidity values in vessel 1. The temperature and humidity values are one of the important factors in planting orchid seeds so that they have good growth quality so they can provide input for training the temperature and humidity prediction model that is created.

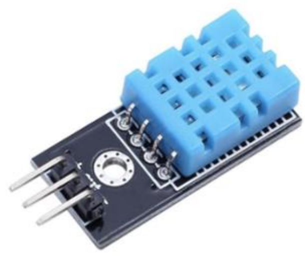

Figure 3. DHT11

The data received by the DHT11 sensor is connected to NodeMCU so that it will periodically be sent to Google Sheets via HTTP requests on the Google Sheets API. The data sending process is carried out every 1 minute and forwarded to Google Sheets using Wi-Fi by the NodeMCU ESP32. The data that has been collected in Google Sheets will be used for the calculation process.

A water pump is a water circulation pump that uses an AC motor as a pump motor. An AC motor is a device that converts electrical energy into mechanical energy (rotation). Mechanical energy is obtained because the electric current flowing through the conductor is in a magnetic field so that a mechanical thrust arises [12]. The water pump in the design of this tool is used to push water from vessel 1 to vessel 2 periodically. Water pushing from vessel 2 to vessel 1 is carried out every 10 seconds.

Figure 4. Water Pump

A relay can be described as an electrically controlled switch, constituting an electromechanical device with two primary components: the coil and the mechanical assembly. Utilizing electromagnetic principles, relays facilitate the movement of switch contacts. With a low electric current, they enable the conduction of higher voltage electricity. [13]. The relay is used as a switch for the water pump so that it can be wired to turn on every 10 seconds.

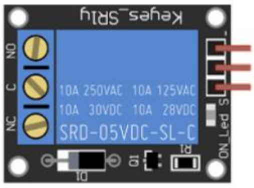

Figure 5. Relays

Regression tree works by following a set of logical if-then conditions. The process starts with a main node that includes all the observations. It then explores different ways to divide the data into two groups to reduce volatility within each subset [14]. In this research, Regression Tree models the input variable (time) and target variables (temperature and humidity) partitioning the data into smaller and smaller subsets based on certain criteria, and then predicting the average value of the target variable within each subset.

In the context of regression modeling, the advantages of a regression tree include its computational efficiency, enabling the handling of large-scale problems, and the capability to manage unknown values for variables [15]. However, the disadvantage of regression tree is discretizing continuous variables by forming partitions and assuming a constant central tendency (mean) within each partition. Therefore, regression tree may mask linear relationship with the data [16].

Regression Tree has been widely used for environmental monitoring, including for predicting temperature and humidity. in research by M. Apaydin (2022), showed that Regression Tree could be used for weather predict with a good accuracy and better result than the other machine learning method [17].

B. Research Methods

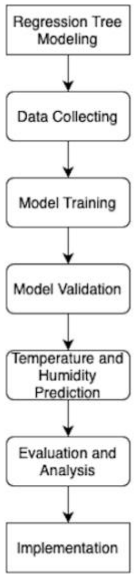

Figure 6. Research Method Flowchart

Figure 6 shows a flowchart of the research methods carried out. First, regression tree modeling is carried out as a method to create a relationship between temperature and humidity variables and time or other influencing variables. Regression tree is a machine calculation method that can create non-linear relationships between existing variables.

Next, data collection is carried out from the tools that have been created. The data collected is the value from the results of temperature and humidity measurements. Measurements are carried out at predetermined time intervals. The measurement of temperature and humidity in vessel 1 is conducted to understand the optimal conditions for orchid growth. This involves observing the development of orchids to determine the specific temperature and humidity levels conducive to optimal growth.

Model training is carried out to train a model from a regression tree with the temperature and humidity data that has been collected. Regression trees will learn patterns in data that are related to temperature and humidity. Followed by model validation to help ensure that the model can work well. Model validation is carried out using data that is not used in training so that it can be generalized to data that has never been seen.

After training and validating the model, the regression tree model is used to predict the temperature and humidity values in vessel 1 at the specified time using the data that has been collected. After making predictions, evaluation and analysis of the model prediction results are required. This evaluation is carried out by comparing the model's predicted values with the original data. Analysis of these results can help to understand the quality of the model in predicting and identifying factors that influence model calculations.

Finally, implement the prediction results to improve the planting process by controlling temperature and humidity according to model predictions.

C. Measurement and Analysis

Measurements in this method use R^2 to calculate how optimal the regression model is in line with the collected data. R^2 provides information about the percentage of the dependent variable that can be explained by the independent variable.

Regression tree used to predict temperature and humidity, can calculate R^2 which provides information about the variability of temperature and humidity predicted by the regression tree. The R^2 formula is:

$$R^2 = 1 - \left(\frac{SSE}{SST}\right)$$

Where Sum of Squared Errors (SSR) is the sum of the squares of the differences between the predicted value and the actual value (residuals). Sum of Squared Total (SST) is the sum of the squared differences between the actual value and the average value [17].

Mark from R^2 has a range between 0 and 1. The R^2 value is said to be better the closer it is to 1. If it is close to 1, it shows that the model is good at explaining variations in the data. On the other hand, if it is close to 0, it shows that the model is not working well because the model cannot explain the variations in the data. In this test, if the R^2 value is close to 1, it shows that the regression tree model can explain variations in temperature and humidity based on the data that has been collected.

D. Tool Design

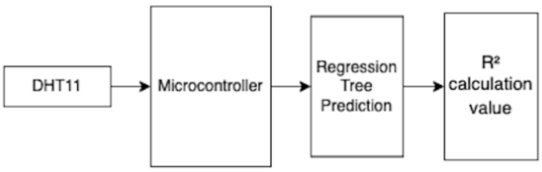

Figure 7. Block Diagrams

Figure 7 shows the block diagram of the tool that has been designed. In this test, DHT11 functions as a temperature and humidity meter in vessel 1. The data received by DHT11 will be input for the prediction calculations carried out. The microcontroller used in this test, namely NodeMCU ESP32, functions as the control center for the system being created. NodeMCU also works for collecting, sending, and processing data.

Temperature and humidity predictions are carried out using a regression tree model. This model makes predictions based on data that has been collected by NodeMCU by modelling the relationship between input variables from DHT11 and output variables, namely temperature and humidity. This regression tree model will be calculated using the methodR² to see how optimal the model is in making predictions with actual data.

III. EXPERIMENT RESULTS

A. Measurement results

During the observation period which lasted from 7 to 10 November, measurements are conducted regularly every 10 seconds using an ESP32 device. This routine measurement is based on a water pump that operates every 10 seconds to circulate water. Therefore, every 10 seconds, the water pump turns on, and temperature and humidity measurements are taken. A total of 4000 data were collected to record temperature and humidity variability in vessel 1. These observations were aimed at gaining a better understanding of changes in temperature and humidity in the specific context of vessel 1. Data calculations were carried out using the MATLAB application.

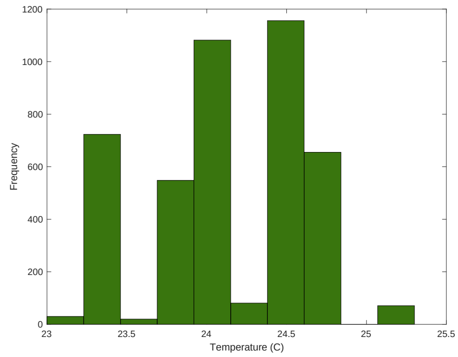

Figure 8. Temperature Histogram

Figure 8 provides a graphical representation of detailed temperature measurement results on vessel 1 during the observation period. The temperature range recorded was in the interval 23°C to 25.5°C, providing a comprehensive picture of the temperature variations in the room. The highest frequency occurred at a temperature of 24.5° Celsius, with the amount of data reaching 1150, followed by a temperature of 24° Celsius which reached a frequency of 1100 data. Apart from that, a temperature of 23.3° Celsius was also recorded with a frequency of 750 data.

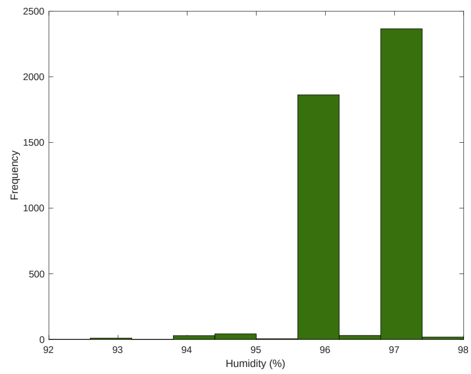

Figure 9. Humidity Histogram

Figure 9 depicts a visualization of the results of humidity measurements in vessel 1. The data displayed via a histogram focuses on a range of humidity values between 92% and 98%. Based on the analysis, it was revealed that the dominant humidity in vessel 1 reached 97%, with a measurement frequency of 2400 data. Apart from that, humidity at the 96% level also has significance, recorded with a measurement frequency of 1800 data.

B. Accuracy Testing Results

Tests using the regression tree have been carried out to evaluate the predicted temperature and humidity estimates for the next 1 minute period, based on previously collected data. The use of R^2 aims to measure the extent of the model's accuracy in predicting temperature and humidity values, providing an idea of how well the model is able to represent changes in vessel 1. The results of the R^2 analysis are a critical indicator for assessing model performance regarding the accuracy of temperature and humidity predictions in a short period of time. .

- *Temperature prediction*

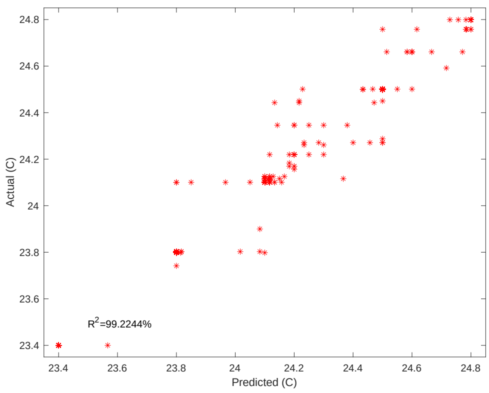

Figure 10. Temperature Prediction Scatterplot

Based on the linear regression graph in Figure 10, it can be concluded that the temperature prediction on the vessel has a high level of accuracy. This is indicated by the valueR^2high, namely 99.22%. MarkR^2A high value indicates that there is a very strong correlation between the predicted value and the actual value. Based on the scatterplot above, it shows that the prediction results have a positive correlation, where the prediction value and temperature value increase over time. Overall, the graph shows that the divessel 1 temperature prediction model is accurate and can be used to predict future air temperatures.

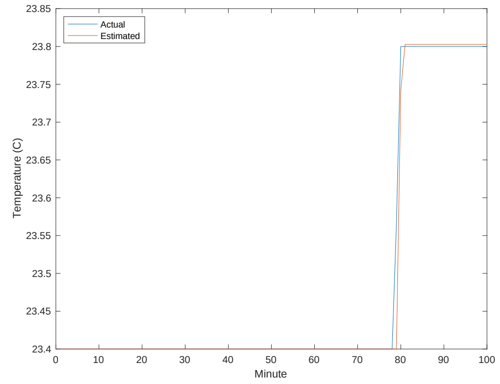

Figure 11. Comparison of Temperature Values

Based on the graph in Figure 11, the air temperature starts from 23.4°C and is stable until the 80th minute where the air temperature starts to increase and reaches its highest point at 23.8°C in the 80th minute. The air temperature then stabilized at 23.8°C until the 100th minute. The red line on the graph shows the predicted temperature value in line with the blue line which is the actual temperature. This shows that the predicted temperature has an accurate value with the actual temperature.

- *Humidity prediction*

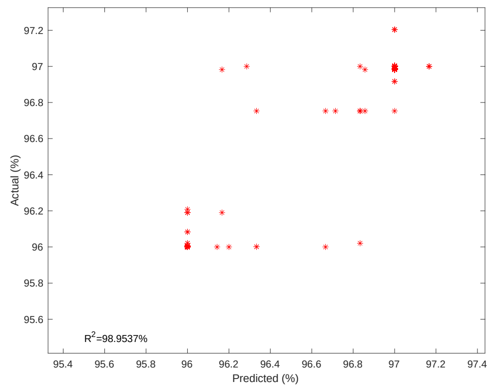

Figure 12. Humidity Prediction Scatterplot

In the graph shown in Figure 12, it shows a plot of predicted humidity with a plot of actual humidity. Based on the graph, it shows a positive correlation between the predicted value and the actual value. R^2 got a high value, namely 98.95%. This value shows that the humidity prediction in vessel 1 has a high level of accuracy.

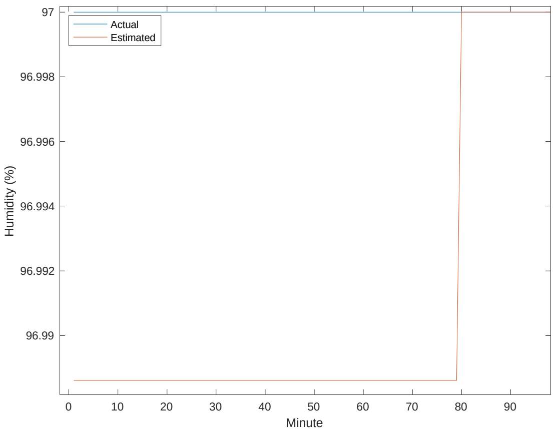

Figure 13. Comparison of Humidity Values

The graph in Figure 13 shows the predicted humidity values with the actual humidity values. The graph shows the predicted value which has a difference from the first minute to the 80th minute. The predicted value has increased up to 97%, matching the actual humidity value and is stable following the actual value. This shows an accurate prediction model with predicted values that are able to follow the actual values.

C. *Summary of Results*

Based on the results of measurements and analysis of predictions using the regression tree method, it can be concluded that the temperature value on vessel 1 has predicted results with a high level of accuracy. Can be seen with the R^2 result, namely 99.22% or 0.9922. Similar to temperature prediction, vessel 1 humidity prediction testing had positive results with a high level of accuracy with an R^2 result of 98.95% or 0.9895. This shows that there is a positive correlation between the predicted value and the actual value. The temperature and humidity prediction model proves to be a robust and effective tool, demonstrating high reliability in forecasting future temperatures and humidity. This reliability is crucial for optimizing orchid growth conditions, as accurate temperature predictions help prevent detrimental extremes. Beyond enhancing production efficiency, the dependable results of the prediction model play a pivotal role in ensuring the attainment of optimal orchid quality.

Table I shows the predicted results for temperature and humidity values. In training, calculations are carried out using data based on previous testing. The calculation results at this stage are used to train the model to create predictive patterns and trends using training data. In the validation stage, testing uses data that has not been used in the training stage. This aims to see to what extent the model can apply prediction patterns and recognize data variations.

Based on the prediction results using a regression tree, the data shows that this model can predict the temperature and humidity in vessel 1. The calculation results show a high method value, this shows that the predictions from the model have a high level of accuracy.

TABLE I. COMPARISON OF RESULTS

Metric	Temperature			Moisture		
	Training	Validation	Testing	Training	Validation	Testing
R^2	0.9973	0.9523	0.9922	0.9926	0.9410	0.9895
MSE	8.896e-04	0.0019	0.0011	0.0030	0.0042	0.0024
RMSE	0.0298	0.0434	0.0326	0.0550	0.0644	0.0492
MAE	0.0076	0.0093	0.0075	0.0125	0.0204	0.0082
MBE	-1.246e-14	0.0031	9.783e-04	-3.877e-13	-0.0154	-7.271e-04
NRMSE	0.0130	0.0394	0.0233	0.0100	0.0644	0.0422
NMSE	1.521e-06	3.254e-06	1.817e-06	3.254e-07	4.420e-07	2.595e-07

IV. EVALUATION

The temperature and humidity prediction model in vessel 1 in this test uses the Regression tree method. The temperature data received from NodeMCU has a range from 23℃ to 25.5℃, with the highest frequency at 24℃. The temperature prediction test results have a high level of accuracy, this is shown by the R^2 value of 99.22% or 0.9922. The humidity data collected in vessel 1 ranges from 92% and 98% RH. With the highest frequency at humidity 97% RH. The humidity prediction results in vessel 1 also have prediction results with a high level of accuracy as indicated by the R^2 value of 98.95% or 0.9895. This implies a substantial and reliable correlation between the temperature and humidity predictions for vessel 1 and the corresponding actual data, underscoring the accuracy of the forecasting model. This precision is not only instrumental in generating dependable forecasts but also plays a significant role in enhancing operational efficiency. Additionally, by averting adverse conditions, the accuracy of the temperature predictions contributes significantly to the cultivation of orchids at an optimal quality.

The evaluation metrics in Table I prove that MSE, RMSE, MAE, MBE, NRMSE, and NMSE have relatively high values. This shows that the regression tree model has been successful in predicting the temperature and humidity in vessel 1. Overall, the results of this test show that the regression tree method has high accuracy in predicting air temperature and humidity and can be used in orchid planting. It is advised to implement refinements in the model validation and evaluation processes to enhance its overall performance under diverse environmental conditions.

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