Jurnal E-Komtek
Vol. 8 No. 2 (2024) pp. 228 - 244
https://jurnal.politeknik-kebumen.ac.id/index.php/E-KOMTEK
p-ISSN : 2580-3719 e-ISSN : 2622-3066

Linear Regression Analysis in Minitab and Fuzzy Logic in Matlab as Tools for Calculating Oyster Mushroom Yields at Thara Farm, Ciawi, Bogor

Djabar Sidik[1], Elan Nurul Paozan[2], Naufal Syifa Abdul Karim[3] , Fisrawati[4], **Annisa Kartinawati**[5]

[1-5]Departement of Industrial Management, IPB University, Indonesia, 16128

djabar_sidik@apps.ipb.ac.id

https://doi.org/10.37339/e-komtek.v8i2.2114

Published by Politeknik Piksi Ganesha Indonesia

Artikel Info
Submitted:
15-11-2024
Revised:
20-11-2024
Accepted:
25-11-2024
Online first :
25-11-2024

Abstract

As a tropical country with abundant biodiversity, Indonesia has ideal conditions for mushroom cultivation at temperatures of 22-28°C, humidity levels of 70-90%, and lighting of 85-540 lux. However, mushroom farmers often face challenges with inconsistent yields during specific periods, such as harvests reaching 600 kg per day from July to December while dropping to 200 kg from January to June. This study aims to determine the precise values of various input parameters expected. Based on the research findings, lighting has a correlation level of 92.6%, watering 93%, temperature 95.3%, and humidity 95%, all strongly influencing yield. Thus, if the lighting level is 85 lux, watering is conducted twice a day, the temperature is maintained at 22°C, and humidity at 90 Hg, the resulting yield is 600 kg of oyster mushrooms per day.

Keywords: Oyster Mushroom; Temperature; Lighting; Watering; Humidity

Abstrak

Sebagai negara tropis dengan keanekaragaman hayati yang melimpah, Indonesia memiliki kondisi ideal untuk budidaya jamur pada suhu 22-28°C, kelembapan 70-90%, dan pencahayaan 85-540 lux. Namun, petani jamur sering menghadapi masalah hasil panen yang tidak stabil di waktu tertentu seperti kondisi hasil panen jamur dari Juli-Desember bisa mencapai 600 kg per hari, sementara dari Januari-Juni bisa turun hingga 200 kg per hari. Penelitian ini bertujuan untuk mengetahui nilai pasti dari sejumlah input yang diharapkan. Berdasarkan hasil penelitian, pencahayaan memiliki tingkat korelasi sebesar 92,6%, tingkat penyiraman sebesar 93%, temperatur sebesar 95,3%, dan kelembaban sebesar 95% yang semuanya menunjukkan pengaruh kuat terhadap hasil panen. Dengan demikian, jika tingkat pencahayaan 85 Lux, tingkat penyiraman sebanyak 2 kali sehari, tingkat suhu sebesar 22°C, dan kelembaban 90 Hg, maka hasil panen yang diperoleh yaitu 600 kg Jamur Tiram per hari.

Kata-kata kunci*: Jamur Tiram, Suhu, Kelembapan, Pencahayaan, Penyiraman*

1. Introduction

As a tropical country with high biodiversity, Indonesia has great potential for oyster mushroom cultivation [1]. However, fluctuations in production yields, such as those experienced by PT Thara Farm in Citapen Village, West Java, remain problematic. Harvest variations range from 200 to 800 kg per day, which are believed to be influenced by various environmental factors such as temperature, humidity, lighting, and mushroom house management. Oyster mushrooms are fungi that can grow in environments with temperatures between 22–28°C, humidity levels of 70–90%, and lighting of 150–540 lux. In the cultivation process, special care is required, especially in managing temperature, air humidity, and lighting to support optimal oyster mushroom growth [2]. During the incubation process, low light intensity and high temperature can accelerate the effectiveness of enzymes in synthesising cellular materials to support the metabolic processes of mushrooms during incubation [3]. In addition, unstable temperatures during cultivation in the mushroom house will affect the size and shape of the mushrooms; temperatures that are too high (33°C) will cause the mushrooms to become stiff and yellow, while temperatures that are too low (18–22°C) will cause them to rot [4].

Air humidity is also a critical factor in the success of oyster mushroom cultivation [4]. Lighting and humidity in the mushroom house are other essential aspects supporting optimal harvests. Proper light intensity allows oyster mushrooms to grow with healthy, broad leaves that are not wilted [5]. On the other hand, insufficient lighting can hinder mushroom growth, causing the leaves to wilt, become serrated, and light, decreasing weight and harvest quantity [6]. However, these studies generally focus on one factor at a time, and no integrated method analyses the simultaneous effects of these factors on oyster mushroom productivity. This research offers a new approach using correlation analysis and fuzzy logic with Minitab and Matlab software to determine the impact of temperature, humidity, lighting, and watering levels on harvest quantity.

PT Thara Farm is one of the oyster mushroom producers in Citapen Village, Ciawi, West Java. The daily production of oyster mushrooms is 600 kg, and PT Thara Farm maximises the management of humidity, temperature, lighting, nutrient maintenance, and pest protection. However, a variation in production results is less optimal at certain times, with production reaching only 200 kg per day and exceeding 800 kg per day at other times.

Based on interviews, this fluctuation indicates the influence of external factors such as temperature, humidity, and lighting and internal factors like mushroom house management.

This research aims to analyse the impact of the critical factors in oyster mushroom cultivation to achieve optimal harvests. With results that can show strong or weak correlations, this research is expected to help manage these factors to improve the quality of oyster mushroom production in Indonesia.

2. Method

Methodologically, this research uses a qualitative method with several approaches, including observation, interviews, and documentation **[7]**. The qualitative method is a concrete and empirical research approach involving data in numbers and statistical analysis.

2.1 Location and Time of Research

Data was collected at CV Sumber Urip Farm and PT Thara Farm. The CV Sumber Urip Farm research occurred on October 31, 2024, at Gg. Kp. Jati No. 005 RT. 004, Parung, Parung District, Bogor Regency, West Java 16330. The study was conducted directly at PT Thara Farm on November 5, 2024, in Citapen Village, Ciawi District, Bogor Regency, West Java 16725. PT Thara Farm serves as one of the suppliers of oyster mushrooms to CV Sumber Urip Farm to gather data on oyster mushroom cultivation

2.2 Data Collection

Several approaches have been used in the data collection process for this research. These approaches have solid correlations and will influence the final results of the entire research process. The approaches are as follows:

a) Observation: Observation is a data collection technique conducted by observing and recording the situation and environment targeted in the research **[8].** In this research, observations were made directly at PT Thara Farm, one of CV Sumber Urip Farm's regular suppliers. The observations were conducted alongside field technicians in the mushroom cultivation house.

b) Interviews: The interview process occurred in two stages. The first stage was with sources from CV Sumber Urip Farm, and the second interview, related to the data to be analysed, was conducted with experts and field technicians at PT Thara Farm.

c) Literature Review: A literature review was conducted to gather more information about oyster mushroom cultivation. The review used journals, articles, books, and other sources that can be verified for accuracy.

2.3 Data Analysis

The data analysis process was conducted using Minitab and Matlab applications to determine the correlation and regression levels and the significant influence of these factors on the oyster mushroom harvest at PT Thara Farm. The research flow diagram can be seen in **Figure 1**.

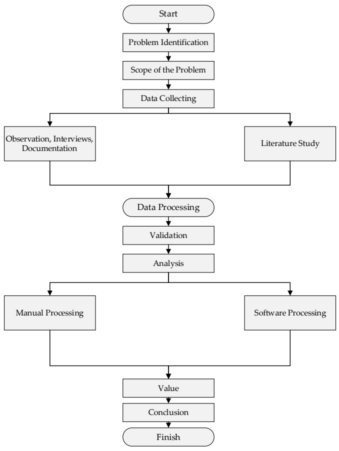

Figure 1. Research Flow Diagram

2.4 Simple Linear Regression

Regression analysis is a statistical method used to explain the relationship between two variables, namely the dependent variable (y) and the independent variable (x) [9]. Simple linear regression is an analytical technique that examines the relationship between one dependent variable and one independent variable. The basic equation for linear regression is as follows:

$$y = a + bx$$

Where:

a) y: the value of the dependent variable;

b) a: intercept or constant;

c) b: regression coefficient, which indicates how much change occurs in Y for each unit change in X;

d) x: input index (t = 1, 2, 3, ..., n).

2.4.1 Fuzzy Sugeno

Sugeno Fuzzy generates a single or crisp decision output, depending on the problem domain. The stages include fuzzification, rule application, defuzzification, and final output production **[10]**. The steps in applying fuzzy logic are: (1) determine the input and output variables and (2) build fuzzy sets for each variable. Triangular membership function, left side:

$$\frac{x - a}{b - a}$$

Triangular membership function, right side:

$$\frac{c - x}{c - b}$$

a) Define fuzzy operators (IF-THEN-ELSE)

b) Define the implication function

c) Compose all outputs

d) Perform defuzzification

3. Results and Discussion

3.1 Regression and Correlation Analysis Using Minitab Application

Table 1 represents historical data on PT Thara Farm's management of oyster mushrooms. This requires the researcher to perform regression and correlation analysis between the input and output variables. The input variables consist of four variables: Watering Frequency (times), Lighting (Lux), Temperature (°C), and Humidity (Hg), while the output variable is a single variable, Harvest Yield (/kg). **Table 1** shows historical data on oyster mushroom management.

Table 1. Historical Data on Oyster Mushroom Management

Period (Month)	Watering (Freq/Day)	Lighting (Lux)	Temperature (°C)	Humidity (Hg)	Yield (/Kg)
January 2023	1	146	34	77	6665
February 2023	1	157	35	76	6345
March 2023	1	196	38	74	5482
April 2023	1	139	33	78	6837
May 2023	1	183	36	74	5887
June 2023	1	166	35	76	6189
July 2023	2	67	26	86	10406
August 2023	2	57	25	86	11008
September 2023	2	131	30	81	8034
October 2023	1	174	36	74	5923
November 2023	2	71	27	85	10061
December 2023	2	64	26	86	10412
January 2024	2	97	27	85	9671
February 2024	2	126	29	82	8482
March 2024	2	108	28	83	8923
April 2024	2	85	27	85	9865
May 2024	2	117	29	83	8741
June 2024	2	59	25	86	10782
July 2024	3	55	24	87	12310
August 2024	3	50	22	90	15469

3.2.1 Linear Regression and Correlation Analysis

Based on Minitab calculations, the linear regression equations for the lighting (1), watering frequency (2), temperature (3), and humidity (4) variables against the harvest yield are as follows:

a) Linear Equation for Lighting vs. Harvest Yield

Harvest Yield (Kg) = 14448 – 49.58 Lighting (Lux) (1)

b) Linear Equation for Watering Frequency vs. Harvest Yield

Harvest Yield (Kg) = 2366 + 3719 Watering (Freq) (2)

c) Linear Equation for Temperature vs. Harvest Yield

Harvest Yield (Kg) = 24146 – 515.9 Temperature (°C) (3)

d) Linear Equation for Humidity vs. Harvest Yield

Harvest Yield (Kg) = -30310 + 479.6 Humidity (Hg) (4)

Equation (1) has large T-values (25.02 and -10.44) and very small P-values (0.000 for both), indicating that both the constant and the lighting coefficient are statistically significant. This means the relationship between harvest yield and lighting is not occurring by chance. Visuals of T-Value and P-Value can be seen in **Table 2**.

Table 2. Visual of T-Value and P-Value

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1448	578	25,02	0,000	
Lighting (Lux)	-49.58	4,75	-10,44	0,000	1,00

The R-squared value is 85.83%. This determination indicates that the lighting variable can explain approximately 85.83% of the variability in harvest yield. This suggests that the regression model is quite good at explaining the relationship between the two variables. **Table 3** shows a visual of the r-square.

Table 3. Visual of R-Square

S	R-sq	R-sq(adj)	R-sq(pred
987,461	85,83%	0,85	81,16%

Equation (1) has data points that tend to form a line sloping downward from the top left to the bottom right. This indicates a strong negative relationship between lighting intensity and harvest yield—in other words, the higher the lighting level, the lower the harvest yield. The r value is -0.926, showing a robust and negative correlation between the two variables. The closer the value of r is to -1, the stronger the negative linear relationship between the two variables. The correlation between lighting and yield is presented in **Figure 2**.

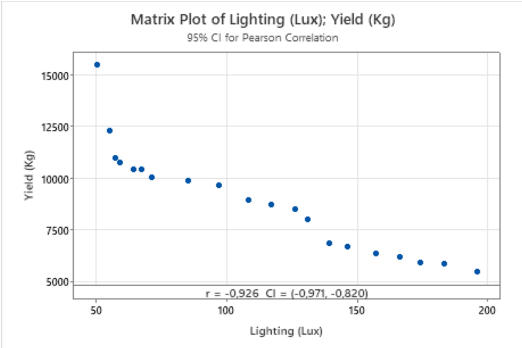

Figure 2. Correlation Between Lighting and Yield

Equation (2) has large T-values (3.68 and 10.76) and very small P-values (0.002 and 0.000 for both), indicating that both the constant and the watering coefficient are statistically significant. This means the relationship between harvest yield and watering frequency does not occur by chance. **Table 4** presents a visual representation of the t-value and p-value.

Table 4. Visual of T-Value and P-Value

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2366	642	3,68	0,002	
Watering Level (Freq/Day)	3719	346	10,76	0,000	1,00

The R-squared value of 86.54% indicates that the watering frequency variable can explain approximately 86.54% of the variability in harvest yield. This suggests that the regression model effectively describes the relationship between the two variables.

Table 5. Visual of R-Square

S	R-sq	R-sq(adj)	R-sq(pred
987,461	85,83%	0,85	81,16%

Equation (2) has data points that tend to form a line sloping upward from the bottom left to the top right. This indicates a positive relationship between watering frequency and harvest yield. In other words, the more frequently the plants are watered, the higher the harvest yield. The r value is 0.930, showing a robust and positive correlation between the two variables. The closer the r value is to 1, the stronger the positive linear relationship between the two variables.

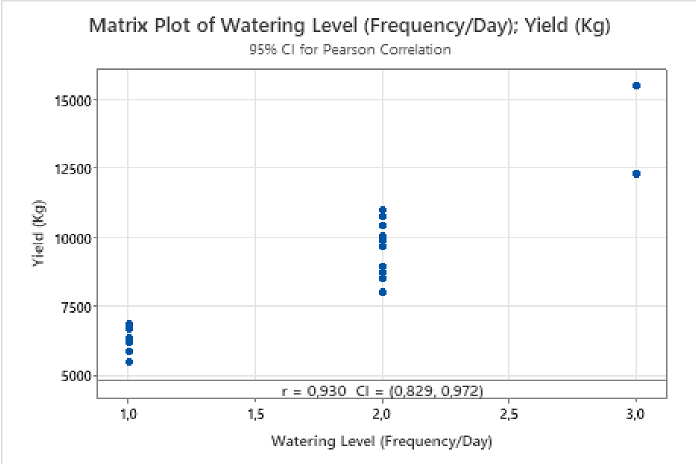

Figure 3. Correlation Between Watering Frequency and Yield

Equation (3) has a large T-value (13.37) and a very small P-value (0.000) for the temperature coefficient, indicating that this relationship is statistically significant. This means the negative relationship between temperature and harvest yield does not occur by chance.

Table 6. Visual of T-Value and P-Value

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	24146	1156	20,89	0,000	
Temperature (°C)	-515,9	38,6	-13,37	0,000	1,00

The R-squared value of 90.85% means that temperature changes can explain approximately 90.85% of the variability in harvest yield. This indicates that the regression model effectively describes the relationship between the two variables.

Table 7. Visual of R-Square

S	R-sq	R-sq(adj)	R-sq(pred
793,561	90,85%	0,90	86,99%

Based on Figure 4, the data points tend to form a line sloping downward from the top left to the bottom right. This indicates a strong negative relationship between temperature and harvest yield. In other words, the higher the temperature, the lower the harvest yield. The r (-0.953) value is close to -1, indicating that the correlation between the two variables is robust and damaging. The closer the value of r is to -1, the stronger the negative linear relationship between the two variables.

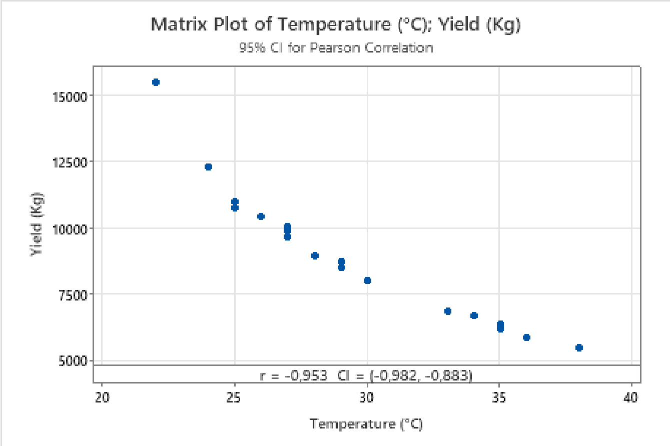

Figure 4. Correlation Between Temperature and Yield

Equation (4) has a large T-value (12.93) and a very small P-value (0.000), indicating that the humidity coefficient is statistically significant. This means the relationship between harvest yield and humidity level does not occur by chance.

Table 8. Visual of T-Value and P-Value

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-30310	3036	-9,98	0,000	
Humidity (Hg)	479,6	37,1	-12,93	0,000	1,00

The considerable R-squared value of 90.28% indicates that the humidity level variable can explain approximately 90.28% of the variability in harvest yield. This suggests that the regression model effectively describes the relationship between the two variables.

Table 9. Visual of R-Square

S	R-sq	R-sq(adj)	R-sq(pred
817.902	90,28%	0,89	86,37%

Equation (4) has data points that tend to form a line sloping upward from the bottom left to the top right. This indicates a strong positive relationship between humidity level and harvest yield. In other words, the higher the humidity level, the higher the harvest yield. The r (0.950) value shows a robust and positive correlation between the two variables. The closer the r value is to 1, the stronger the positive linear relationship between the two variables.

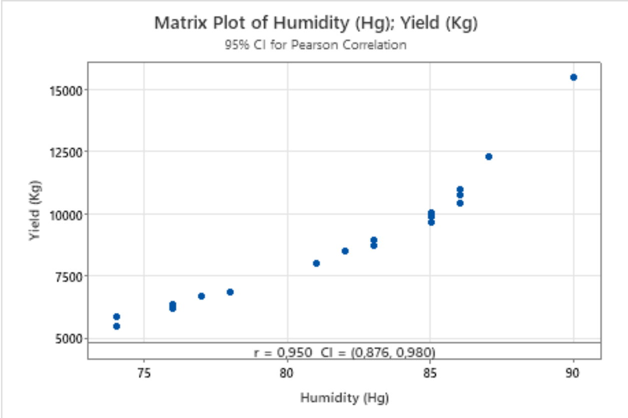

Figure 5. Correlation Between Humidity and Yield

3.2 Logika Fuzzy Sugeno

Sugeno Fuzzy Logic is the method used to manage uncertainty in information during the oyster mushroom cultivation process, especially when dealing with data that cannot be precisely described with fixed numeric values. The cultivation of oyster mushrooms is influenced by many factors that are difficult to measure accurately, such as lighting, watering, temperature, and humidity, which can all affect the harvest yield. Fuzzy Logic helps model these factors more flexibly.

The application of Sugeno Fuzzy Logic can assist in determining the harvest yield of oyster mushrooms. Based on information from the farmers, the expected intensity of input for oyster mushroom cultivation includes a lighting level of 85 lux, watering frequency of 2 times, room temperature of 22°C, and humidity level of 90 Hg during one harvest period. With this data, the harvest yield can be determined through several steps: identifying input and output variables, fuzzy set formation, fuzzy rule base, and defuzzification.

3.2.1 Input and Output Variables

The data processed in this study includes lighting level (lux), watering intensity, air temperature (Celsius), and room humidity (Hg), which experts determined as the research's input variables.

Table 10. Variable Name

No	Variable Name	Unit
1	Lighting	Lux
2	Watering	Frequency/Day
3	Temperature	Celcius
4	Humidity	Hg

The harvest yield data is the output variable, influenced by lighting level, watering intensity, air temperature, and humidity. **Table 11** shows the daily harvest amounts: 600kg, 300kg, and 200kg.

Table 11. Harvest Yield

No	Yields	Unit
1	600	Kilogram
2	300	Kilogram
3	200	Kilogram

3.2.2 Fuzzy Set

Fuzzy sets aim to convert quantitative numerical data into qualitative membership degrees, allowing for more flexible decision-making that aligns with human thinking. The fuzzy set can be seen in Table 12.

Table 12. Fuzzy Set

No	Variable Name	MF Model	Value Range	Domain	Fuzzy Set
1	Lighting	Trim	50 - 105 Lux	[50 105]	Low
			75 - 200 Lux	[75 137.5 200]	Medium
			150 - 300 Lux	[150 300]	Light
2	Watering	Trim	1 - 2 Kali	[1 2]	Low
			1 - 4 Kali	[1 2.5 4]	Medium
			3 - 4 Kali	[3 4]	High
3	Temperature	Trim	16 - 22°C	[16 22]	Low
			18 - 28°C	[18 23 28]	Medium
			25 - 38°C	[25 38]	High
4	Humidity	Trim	65 - 75 Hg	[65 75]	Dry
			70 - 90 Hg	[70 80 90]	Humid
			80 - 90 Hg	[80 90]	Wet

The MF (Membership Function) model is the triangular membership function (trim) applied to a specific range of values for each variable. The domain represents the input values entered into the Matlab application, mainly when calculating the corner points of the triangle on the graph. The fuzzy set represents environmental conditions classified as low, medium/average, and high for lighting, watering, and temperature, while humidity is classified as dry, damp, and wet.

The harvest yield is the output variable affected by the input variables. The highest daily harvest that can be obtained is 600kg of oyster mushrooms, which is also the standard requirement for CV Sufarm to be met by Thara Farm. The other two categories are medium, 300kg, and low, 200kg. These variations can occur due to several factors, two of the main reasons being environmental conditions and poor management practices.

Table 13. Oyster Mushroom Yield

No	Yield	MF Model	Domain	Fuzzy Set
1	600	Parameter	[600]	Many
2	300	Parameter	[300]	Moderate
3	200	Parameter	[200]	Few

3.2.3 Membership Degree of Lighting Level Variable

The expected lighting level is 85 lux, sufficient to support oyster mushroom growth. Oyster mushrooms cannot grow under bright conditions and must be placed in a relatively dark growing chamber (kumbung). Based on the table above, x = 85 represents the intersection point between the low and medium lighting sets.

$$\mu 1\_\text{Low Lighting Membership} = \frac{d-x}{d-c} = \frac{105-85}{105-50} = \frac{20}{55} = 0.36$$

$$\mu 2\_\text{Medium Lighting Membership} = \frac{x-a}{b-a} = \frac{85-75}{137.5-75} = \frac{10}{62.5} = 0.16$$

3.2.4 Membership Degree of Watering Level Variable

The expected watering level is twice daily, optimal for maintaining the mushrooms' moisture content. Mushrooms with high moisture content can cause their market price to drop. Where x = 2, it intersects between the low and medium sets.

$$\mu 1\_\text{ Low Watering Membership} = \frac{d-x}{d-c} = \frac{2-2}{2-1} = \frac{0}{1} = 0$$

$$\mu 2\_\text{ Medium Watering Membership} = \frac{x-a}{b-a} = \frac{2-1}{2.5-1} = \frac{1}{1.5} = 0.67$$

3.2.5 Membership Degrees for the Room Temperature Variable

The desired room temperature is 22°C, considered an optimal average temperature for supporting oyster mushroom growth. Whare x = 22, where it intersects between the "low" and "normal" fuzzy sets.

$$\mu 1\_\text{ Low Temperature Membership} = \frac{d-x}{d-c} = \frac{22-22}{22-16} = \frac{0}{6} = 0$$

$$\mu 2\_\text{ Medium Temperature Membership} = \frac{x-a}{b-a} = \frac{22-18}{23-18} = \frac{4}{5} = 0.8$$

3.2.6 Membership Degrees for the Humidity Variable

The desired humidity level is 90 Hg, which is recommended to be maintained through proper room humidity control. Where x = 90, it intersects between the "humid" and "wet" fuzzy sets.

$$\mu 1\_\text{ Humid Membership} = \frac{c - x}{c - b} = \frac{90 - 90}{90 - 80} = \frac{0}{10} = 0$$

$$\mu 2\_\text{Wet Membership} = \frac{x - a}{b - a} = \frac{90 - 80}{90 - 80} = \frac{10}{10} = 1$$

3.2.7 Fuzzy Rule Base (AND – Min)

The rule base in this study consists of 81 rules based on the four input variables.

Table 14. Rule Base Sample

NO	Lighting	Watering	Temperature	Humidity	Harvest Yield	Value
1	Low	Low	Low	Dry	Few	200
2	Low	Low	Low	Humid	Moderate	300
3	Low	Low	Low	Wet	Moderate	300
4	Low	Low	Medium	Dry	Few	200
5	Low	Low	Medium	Humid	Moderate	300
6	Low	Low	Medium	Wet	Many	600
7	Low	Low	High	Dry	Few	200
8	Low	Low	High	Humid	Moderate	300
9	Low	Low	High	Wet	Moderate	300
10	Low	Low	Low	Dry	Few	200
...	...	...	...	...	...	...
...	...	...	...	...	...	...
81	High	High	High	Wet	Few	200

In item 1 of **Table 14**, it is stated that IF lighting is low, watering is low, temperature is low, AND humidity is low, THEN the yield is low, which is 200 kg. Using the AND rule, the rule value will meet the expected condition by selecting the smallest value from the membership degree. This means that the minimum value from the membership degrees of each input variable (lighting, watering, temperature, and humidity) will be used to determine the output, which, in this case, results in a yield of 200 kg.

3.2.8 Determining Fuzzy Operators

In **Table 15** and **Table 16** fuzzy operators have been selected according to the conditions expected by the Thara Farm farmers. The specified rules consist of 2, 3, 5, 6, 11, 12, 14, 15, 29, 30, 32, 33, 38, 39, 41, and 42. From these 16 rules, the smallest value between the membership sets of each input variable is then determined, with the bold letters representing the selected values.

Table 15. Fuzzy Operators

NO	Lighting	Watering	Temperature	Humidity	Harvest Yield	Value
1	Low 0,36	**Low** **0**	Low 0	Humid 0	Moderate	300
2	Low 0,36	**Low** **0**	Low 0	Wet 1	Moderate	300
3	Low 0,36	**Low** **0**	Medium 0,8	Humid 0	Moderate	300
4	Low 0,36	**Low** **0**	Medium 0,8	Wet 1	Many	600
5	Low 0,36	Medium 0,67	**Low** **0**	Humid 0	Moderate	300
6	Low 0,36	Medium 0,67	**Low** **0**	Wet 1	Moderate	300
7	Low 0,36	Medium 0,67	Medium 0,8	**Humid** **0**	Many	600
8	**Low** **0,36**	Medium 0,67	Medium 0,8	Wet 1	Many	600
9	Medium 0,16	Low 0	**Low** **0**	Humid 0	Few	200
10	Medium 0,16	Low 0	**Low** **0**	Wet 1	Moderate	300
11	Medium 0,16	**Low** **0**	Medium 0,8	Humid 0	Moderate	300
12	Medium 0,16	**Low** **0**	Medium 0,8	Wet 1	Moderate	300
13	Medium 0,16	Medium 0,67	**Low** **0**	Humid 0	Moderate	300
14	Medium 0,16	Medium 0,67	**Low** **0**	Wet 1	Moderate	300
15	Medium 0,16	Medium 0,67	Medium 0,8	**Humid** **0**	Many	600
16	**Medium** **0,16**	Medium 0,67	Medium 0,8	Wet 1	Many	600

3.2.9 Defuzzyfikasi Sugeno

Based on **Table 16** fuzzy operators, the next step is calculating the defuzzification, which will help determine the farmer's anticipated harvest quantity.

Table 16. Defuzzyfikasi Sugeno

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
F	0	0	0	0	0	0	0	0,36	0	0	0	0	0	0	0	0,16
N	300	300	300	600	300	300	600	600	200	300	300	300	300	300	600	600

Table 16 consists of F, which refers to the membership degree (firing strength) values, representing the results of the fuzzy rules applied to each condition. The values in F indicate how strongly a particular rule is activated based on the given input. Meanwhile, N is the output value of each fuzzy rule, representing the result or consequence of each rule after evaluation. Here, if it is 300, the value in N is considered a Moderate Harvest Quantity.

a) Firing Strength Calculation with Output Values

$$(0\times300)+(0\times300)+\ldots+(0{,}36\times600)+\ldots+(0{,}16\times600) = 312 \quad (1)$$

b) Total Membership Degree Calculation

$$0{,}36 + 0{,}16 = 0{,}52 \quad (2)$$

c) Defuzzification

$$312 / 0{,}52 = 600 \text{ kg} \quad (3)$$

3.2.4 Visualization of the Matlab Application

In **Figure 6**, the rule viewer display shows a graphical visualisation for each rule applied. Each rule combines several input variables to generate a single output variable based on the predefined rule base. Each graph corresponds to a rule in the rule viewer display, arranged sequentially from top to bottom. In the table above are 81 graphs stacked vertically, where each input variable visualises the colour, slice, and height between variables.

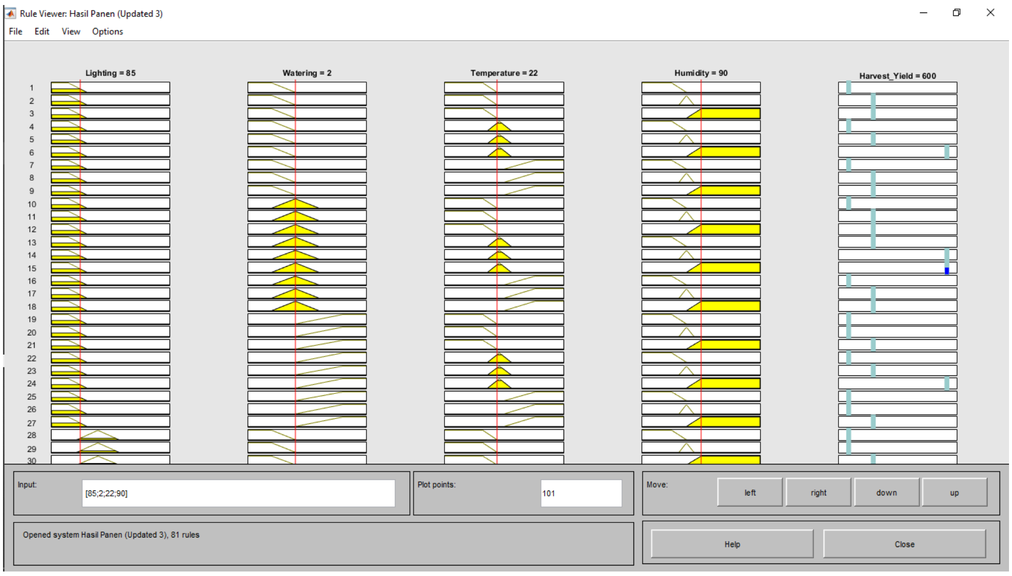

Figure 6. Display of Rule Viewer on Matlab

Figure 6 visualizes the oyster mushroom yield. The yield results from manual calculations and those performed through the MATLAB application show the same outcome. The expected inputs, including 85 lux lighting, two waterings, 22°C room temperature, and 90 Hg humidity, yield 600 kg of oyster mushrooms.

4. Conclusion

This study demonstrates that light intensity, watering frequency, temperature, and humidity significantly influence the oyster mushroom yield at PT Thara Farm. Regression analysis using Minitab indicates a high significance level for these variables on yield, with R-squared values above 85% for each input variable. This means that the respective variables of lighting, watering, temperature, and humidity can explain more than 85% of the variations in yield. For instance, the regression between lighting and yield resulted in an R-squared value of 85.83%, indicating that proper lighting can significantly affect the yield.

Manual calculations using the Sugeno fuzzy method with Matlab produced output consistent with the Minitab results, yielding 600 kg per harvest based on the desired input data: 85 lux lighting, two daily waterings, 22°C temperature, and 90 Hg humidity. This consistency strengthens the validity of the analysis and supports using a combined statistical and fuzzy approach for cultivation optimisation. These findings provide practical insights for farm managers to optimise environmental factors for mushroom production.

References

[1] F. N. Pramudya and I. Cahyadinata, “ANALISIS USAHA BUDIDAYA JAMUR TIRAM PUTIH (Pleurotus ostreatus) DI KECAMATAN CURUP TENGAH KABUPATEN REJANG LEBONG,” *J. AGRISEP*, vol. 11, no. 2, pp. 237–250, 2012, doi: 10.31186/jagrisep.11.2.237-250.

[2] A. W. Dani, D. Y. Siahaan, Y. Yuliza, F. Sirait, and F. Supegina, “Rancang Bangun Smart Garden Untuk Budidaya Jamur Tiram Dengan Metode Sistem Fuzzy Mamdani Berbasis Internet Of Things (IoT),” *J. Teknol. Elektro*, vol. 13, no. 2, p. 108, 2022, doi: 10.22441/jte.2022.v13i2.008.

[3] F. N. Aini and N. D. Kuswytasari, “Pengaruh Penambahan Eceng Gondok (Eichhornia crassipes) Terhadap Pertumbuhan Jamur Tiram Putih (Pleurotus ostreatus),” *J. Sains dan Seni Pomits*, vol. 2, no. 1, pp. 2337–3520, 2013, [Online]. Available: http://download.portalgaruda.org/article.php?article=89315&val=4187

[4] Padil, H. Etruddin, I. R. Dini, F. Huda, and Febrizal, “Pengaruh Suhu dan Kelembapan Terhadap Produktivitas Jamur Tiram,” *Teknik*, vol. 18, pp. 1–5, 2024.

[5] *et al.*, “Pengaruh Suhu Dan Intensitas Cahaya Terhadap Pertumbuhan Jamur Tiram Di

Tangerang," *Biog. J. Ilm. Biol.*, vol. 5, no. 1, pp. 1–6, 2017, doi: 10.24252/bio.v5i1.3426.

[6] R. Nur *et al.*, "Pengatur Suhu, Kelembaban, Dan Intensitas Cahaya Pada Kumbung Jamur Tiram Menggunakan Iot," *J. Acad. Multidicipline Res.*, vol. 1, no. 1, pp. 15–23, 2021.

[7] D. S. Charismana, H. Retnawati, and H. N. S. Dhewantoro, "Motivasi Belajar Dan Prestasi Belajar Pada Mata Pelajaran Ppkn Di Indonesia: Kajian Analisis Meta," *Bhineka Tunggal Ika Kaji. Teor. Dan Prakt. Pendidik. PKn*, vol. 9, no. 2, pp. 99–113, 2022, doi: 10.36706/jbti.v9i2.18333.

[8] P. Hasibuan, R. Azmi, D. B. Arjuna, and S. U. Rahayu, "Analisis Pengukuran Temperatur Udara Dengan Metode Observasi Analysis of Air Temperature Measurements Using the Observational Method," *ABDIMASJurnal Garuda Pengabdi. Kpd. Masy.*, vol. 1, no. 1, pp. 8–15, 2023, [Online]. Available: http://creativecommons.org/licenses/by-sa/4.0/

[9] R. A. Prasetyo, "Analisis Regresi Linear Berganda Untuk Melihat Faktor Yang Berpengaruh Terhadap Kemiskinan di Provinsi Sumatera Barat," *J. Math. UNP*, vol. 7, no. 2, p. 62, 2022, doi: 10.24036/unpjomath.v7i2.12777.

[10] F. R. Hariri, "Penerapan Metode Fuzzy Sugeno Dalam Pendaftaran Siswa Baru di SDN Sonopatik 1 Nganjuk," *Tek. Inform. Univ. Nusant. PGRI Kediri*, vol. 3, no. 1, pp. 41–46, 2016, [Online]. Available: Penerapan Metode Fuzzy Sugeno Dalam Pendaftaran Siswa Baru di SDN Sonopatik 1 Nganjuk