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Fresh Fruit Bunches Forecasting with the Double Exponential Smoothing Method

[1]Yuli Anggraini, [2]Nuriadi Manurung, [3]Febby Madona Yuma
[1,3]Program Studi Sistem Informasi, Fakultas Ilmu Komputer, Universitas Royal, Asahan Sumatera Utara, Indonesia
[2]Program Studi Rekayasa Perangkat Lunak, Fakultas Ilmu Komputer,
Universitas Royal Asahan Sumatera Utara, Indonesia
Email: [1]yulianggraini4646@gmail.com, [2]nuriadi0211@gmail.com, [3]febbyyuma@gmail.com

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ABSTRACT
PTPN IV Regional 1 Huta Padang Plantation is an oil palm plantation unit in North Sumatra that manages the cultivation, harvesting, and processing of Fresh Fruit Bunches (FFB) to produce palm oil. During the harvest process to produce Crude Palm Oil (CPO), a lot is often wasted due to unstable market demand. This research aims to implement the double exponential smoothing method for the production of fresh fruit bunches to be used as CPO. The problem faced is that production uncertainty often causes an imbalance between crop yields and market demand. If production is excessive, the company risks a spike in storage costs and potential product spoilage. Conversely, if production is too low, the company may miss out on market opportunities. This forecasting uses historical data from the previous year. The results of research at PTPN IV Regional 1 Kebun Huta Padang show that palm oil production forecasting for February 2025 amounted to 982.97 Kg with an error rate of 7.44%. This value is obtained using an alpha constant of 0.8 which gives the smallest forecasting error rate.

Corresponding Author:
Yuli Anggraini,
Program Studi Sistem Informasi, Fakultas Ilmu Komputer
Universitas Royal Asahan Sumatera Utara,
Jl. Prof.H.M.Yamin No.173, Kisaran Naga, Kec. Kota Kisaran Timur, Kab. Asahan, Sumatera Utara 21222.
Email: yulianggraini4646@gmail.com
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1. INTRODUCTION

Palm fruit plants are plantation crops that are widely cultivated in the tropics, especially in Indonesia [1]. The plant is known as the main source of palm oil, which is used in various industries, such as food, cosmetics, and biodiesel [2]. Palm trees can grow up to 20-25 meters with large pinnate leaves. The fruits are red-black when ripe and grow in bunches. The plant requires high rainfall and sufficient sunlight to grow optimally.

Palm oil is closely related to Crude Palm Oil (CPO), which is the main product of palm fruit processing. Ripe palm fruits are harvested and processed through an extraction process to produce CPO. This oil is obtained from the mesocarp of the fruit, which is rich in oil content [3]. CPO is an important commodity in the global industry due to its wide range of uses, ranging from raw materials for food, cosmetics, to renewable energy such as biodiesel. biodiesel. Indonesia is the world's largest CPO producer, making palm oil the backbone of the country's economy. as the backbone of the country's economy.

PTPN IV Regional 1 Huta Padang Plantation, as an oil palm plantation manager, faces serious challenges in planning and forecasting FFB yields. Production uncertainty often leads to an imbalance between crop yields and market demand. If production is excessive, the company risks a spike in storage costs and potential product spoilage [4]. Conversely, if production is too low, companies may lose market opportunities as well as customer trust. Planning errors also have a significant impact on logistics efficiency and labor management, ultimately affecting the company's profitability [5].

To overcome this problem, a forecasting method is needed that is able to produce accurate and reliable predictions of FFB production. One of the relevant methods for this problem is the Double Exponential Smoothing method. This method has the advantage of capturing data patterns that contain trends, so it is suitable for use on FFB production data that tends to have a tendency to increase or decrease over time [6]. By using this method, PTPN IV Regional 1 Kebun Huta Padang is expected to make production planning more measurable and data-based, so as to optimize resources and increase the company's competitiveness in the market.

This study was conducted to analyze the application of the Double Exponential Smoothing method in forecasting FFB production at PTPN IV Regional 1 Kebun Huta Padang. The results of this study are expected to not only provide direct benefits for PTPN IV Regional 1 Kebun Huta Padang, but also become a reference for other plantation managers in facing similar challenges, thus supporting the sustainability of the palm oil industry in Indonesia. The amount of production per year reaches 73,650,950 Kg if the prediction is not correct, a lot of CPM stock is wasted, resulting in losses for the company.

CPO that is stored for many days can experience quality deterioration due to oxidation and hydrolysis. The oxidation process causes an increase in Free Fatty Acid (FFA) content, which reduces the quality of CPO and makes it less suitable for further processing. In addition, improper storage can lead to microbial contamination, accelerated deterioration and rancidity. This reduces the economic value of CPO and hinders the refining process. Therefore, CPO storage should be done in controlled temperatures and closed containers to maintain its quality.

Forecasting is the art and science of predicting events that will occur using historical data in the form of mathematical models and projecting them into the future [7]. The Double Exponential Smoothing method also has several advantages that can help in using a smaller amount of data when compared to other methods [8]. In this method, the smoothing process is done twice [9]. Although more complex than Single Exponential Smoothing, Double Exponential Smoothing is usually simpler than the Triple Exponential Smoothing method. This is because Double Exponential Smoothing only takes into account levels and trends [10], while Triple Exponential Smoothing also takes into account seasonal components. Therefore, Double Exponential Smoothing can be a good choice when the data does not have significant seasonal patterns [11].

Research conducted by Asanwi and Kurniawan in 2025 [12] This study successfully developed an information system for predicting oil palm yields at PTPN IV Bah Jambi using the Double Exponential Smoothing (DES) method. This system is able to analyze production trends based on historical data and provide more accurate prediction results than the manual recording method. By applying the DES method, the company can more easily anticipate production fluctuations, optimize harvest planning, and improve operational efficiency. In addition, the web-based system developed with PHP and MySQL facilitates real-time data access and management, thus supporting faster and more precise decision making in the Company's business strategy.

The next research by Ena et al in 2025 [13] concluded that the tests carried out by providing 9 alpha value parameters, namely 0.1 to 0.9 using the Mean Absolute Percentage Error (MAPE) method obtained the smallest MAPE value of 6.35% with an alpha parameter value of 0.5. The prediction results obtained with this alpha value are 590 students who will enroll at the Tribuana University Kalabahi campus in the 2024/2025 academic year.

Another study by Batarius and Jensen in 2024 [14] The DES method used to predict the demand and supply of blood bags is influenced by the range of training data used. Based on the existing data patterns for further prediction, it can be said that the larger the range of training data used does not guarantee a good level of accuracy. Likewise, if the training data used with a small range, it does not guarantee a good level of accuracy. In this study, the accuracy level for prediction in 2023 (6 months ahead) is still in the good forecast group.

Research by Alfinatuzzahro et al in 2024 [15] It is concluded that the results of forecasting the Gross Domestic Product (GDP) of the Indonesian furniture industry in 2022 quarters 1, 2, 3, and 4 using the Double Exponential Smoothing-Holt method obtained an α value of 0.658, β of 0.008 and a MAPE value of 0.737% are 7,602 billion rupiah in quarter 1, 7,676 billion rupiah in quarter 2, 7,759 billion rupiah in quarter 3, and 7,822 billion rupiah in quarter 4. Other research by Saragih et al in 2024 [16] The alpha value used in the calculation of corn production has the smallest Mean Squared Error (MSE) Value of alpha = 0.3 with total value 88349750273 for Single Exponential Smoothing. While for Double Exponential Smoothing the MSE value at alpha = 0.4 is 2,306,629,068.

From the research conducted, it can be concluded that the double exponential smoothing method is more flexible and accurate than the single smoothing method. This method is also simple, easy to implement, and fast in calculation, suitable for short-term forecasting. In addition, DES is adaptive, able to adjust to changing trends, making it ideal for business and economic applications [17].

2. RESEARCH METHOD

This type of research is quantitative with the following research stages as shown in Figure 1.

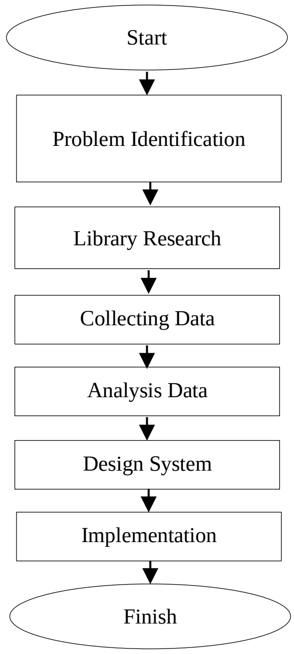

Figure 1. Stage of Research

There are several stages to this research: (1) Problem identification: Observing some of the problems, PTPN IV Regional 1 Kebun Huta Padang faces difficulties in planning Fresh Fruit Bunch (FFB) production due to yield uncertainty caused by external factors such as weather and soil quality. This yield instability affects logistics and labor efficiency, and increases the risk of high storage costs. (2) Library Research: This literature review is in the form of theories and methods, as well as other findings that have been used in overcoming problems that have occurred before. So that from this literature study a good and reliable scientific foundation is obtained. (3) Collecting Data: Data collection carried out in the study to collect data related to the subject matter of the research, namely forecasting the production of FFB which is carried out by direct observation in the field. (4) Analysis Data: The process of analyzing data to be processed into useful information. So that the data can be understood easily and is useful for researchers in conducting research. After analysis, it is believed that this problem can be overcome by implementing a forecasting system for FFB production with the Double Exponential Smoothing method. (5) Design System: Discusses the design of the model using UML, database design, and the design of determining the input to the output that will be produced in accordance with the predetermined objectives. (6) Implementation System: this stage is carried out to create and determine the results of the design that has been made. Where in this stage there are program codes to solve problems that have been designed into the PHP programming language and MySql database.

2.1 Trial Error and Alpha

The error value is used to measure the accuracy of the forecasting model, as it quantifies the difference between the actual data and the predicted values. Smaller error values indicate that the model's predictions are closer to reality, thus reflecting higher forecasting accuracy. Meanwhile, the alpha value commonly used in smoothing techniques such as exponential smoothing determines how quickly the model responds to changes in the data pattern. A higher alpha value places more weight on recent observations, allowing the model to adapt faster to sudden shifts or trends, but it may also increase sensitivity to short-term fluctuations. Conversely, a lower alpha value produces a smoother forecast by emphasizing historical data, which can be beneficial for stable patterns but slower in responding to abrupt changes.

$$\text{Period 1} = S'_2 = (aYt_2) + (1-a)\, S'_{2-1} \quad (1)$$

$$\text{Period 2} = S''_2 = (aS'_2) + (1-a)\, S''_{2-1} \quad (2)$$

Where to calculate Trial Error and Alpha is obtained from value S is Session, α is constranta and Yt is Actual Data.

2.2 Mean Absolute Error (MAD)

MAD is a statistical metric that measures the average of the absolute difference between each data value and the average value of the data. To measure the error value using MAD can be calculated using the formula (3).

$$\mathrm{MAD} = \frac{\sum \mathrm{At-Ft}}{\mathrm{n}} \quad (3)$$

Where to calculate MAD is obtained from value Yt is Actual Data, value Ft is observation data of period and value n isTotal Period.

2.3 Mean Sequence Error (MSE)

MSE is another method to evaluate forecasting methods. Each error or residual is squared. It is then summed and divided by the number of observations. This approach manages large forecasting errors because the errors are squared. can be calculated using the formula (4).

$$\mathrm{MSE} = \frac{\sum |\mathrm{At-Ft}|^2}{\mathrm{n}} \quad (4)$$

Where to calculate MSE is obtained from value Yt is Actual Data, value Ft is observation data of period and value of n is Total Period.

2.4 Mean Absolute Error (MAPE)

MAPE is calculated by using the absolute error in each period divided by the real observed value for that period. Then, averaging the absolute percentage errors. MAPE is an error measurement that calculates the size of the percentage deviation between actual data and forecasting data. MAPE can be calculated using the formula (5).

$$\mathrm{MAPE} = \frac{\sum |\mathrm{At-Ft}|(100)}{|\mathrm{Yt}|} \quad (5)$$

Where to calculate MAPE is obtained from value Yt is Actual Data and value of Ft is observation data of period.

2.5 System Design

This forecasting system is made web-based with the php programming language and uses mysql as a database for data storage. In this forecasting system, there is one user, namely the admin who is in charge of inputting data and carrying out the forecasting process and printing reports if needed as an archive. With this forecasting system using the DES method, it can help PTPN IV Regional 1 Kebun Huta Padang to forecast FFB production in the following month quickly so that it can maximize CPO production [18].

3. RESULTS AND ANALYSIS

The results of the needs analysis obtained are input data needed in predicting the amount of oil supply from January 2024 to December 2024. The input data will be processed using the DMA method to calculate data using manual methods and system calculations. While the analysis of output requirements in the form of a web-based program display that can be used when you have activated the local server. Figure 2 is the production data for 2024 which explains that palm oil production is not stable and this poses a problem for CPO production.

3.1 Forecast

This research tries all alpha values ranging from 0.1 to 0.9 because by selecting the optimal α, it can minimize the error. In this study, the alpha value of 0.8 was obtained as the maximum value because it has the smallest error value in forecasting calculated using formulas (1). For the calculation of MAD, MSE and MAPE can be calculated using formulas (2), (3) and (4) [19]. so that the results are obtained in the following Table 1.

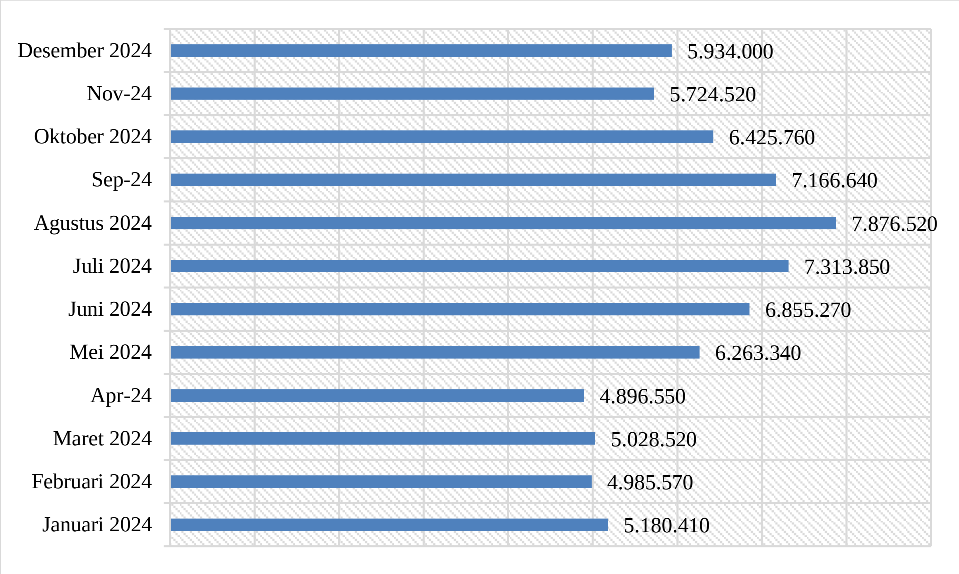

Figure 2. Production Yield in 2024

Figure 3 illustrates the fluctuations in crude palm oil (CPO) production throughout 2024. The data shows that production is unstable from month to month, with notable declines in April and October, while peak production occurs in July and August. This instability indicates the influence of external factors such as weather conditions, crop health, or distribution disruptions that may impact output levels.

From a production planning perspective, the chart highlights the need for accurate forecasting methods to minimize the impact of these fluctuations on supply. High variability in production emphasizes the importance of reliable forecasting to ensure a consistent supply of raw materials for downstream CPO industries.

Table 1. Analysis Forecast Error With Alpa 0,8

Periode	Data Aktual (Yt)	Forecast (Ft-1)	Abs Error	Error^2	APE (%)
Jan 2024	5.180.410				
Feb 2024	4.985.570	5180410	194840	37962625600	0,039
Mar 2024	5.028.520	4868666	159854	25553301316	0,032
Apr 2024	4.896.550	4999734,8	103184,8	10647102951,04	0,021
May 2024	6.263.340	4812248,08	1451091,92	2105667760289,28	0,232
Jun 2024	6.855.270	7045565,84	190295,84	36212506721,31	0,028
Jul 2024	7.313.850	7581362,01	267512,01	71562676992,31	0,037
Augt 2024	7.876.520	7871822,97	4697,03	22062076,54	0,001
Sep 2024	7.166.640	8426610,71	1259970,71	1587526185259,94	0,176
Oct 2024	6.425.760	6960936,16	535176,16	286413526917,92	0,083
Nov 2024	5.724.520	5848551,64	124031,64	15383847082,87	0,022
Dec 2024	5.934.000	5051485,61	882514,39	778831651388,57	0,149
Jan 2025		982,97			
	Total		5173168,5	4955783246595,78	0,818
	MAD		470288,05		
	MSE			450525749690,53	
		MAPE			7,44%

Table 1 presents the forecasting results for CPO production from January to December 2024 using the DMA method with $\alpha = 0.8$. The Absolute Error, Squared Error, and Absolute Percentage Error (APE) are calculated for each month. Although the overall errors are relatively low, certain months such as May and September show significant deviations from the actual values, indicating reduced accuracy in those periods.

Overall, the method yields a Mean Absolute Deviation (MAD) of 470,288.05, a Mean Squared Error (MSE) of approximately 4.51×10^{11}, and a Mean Absolute Percentage Error (MAPE) of 7.44%. A MAPE below 10% suggests that the model performs quite well in predicting production, although anomalies in certain months warrant further investigation into the causes of these inaccuracies.

After calculating the forecast for the next month using alpha values of 0.1 to 0.9, the results of the comparison are shown in Table 2.

Table 2. Comparison Forecasting for Alpha Value

No	Alpha	Forecast	MAD	MSE	MAPE %
1	0,1	6.457.901,31	846968,10	1108887343101,63	12,64
2	0,2	6.511.641,80	816315,58	957749413903,48	12,61
3	0,3	6.161.113,38	771504,96	840980254909,13	12
4	0,4	5.811.450,58	653988,14	704215158684,90	9,07
5	0,5	5.609.011,79	577093,24	589227360054,64	9,43
6	0,6	5.565.725,85	520393,27	511691199281,96	8,24
7	0,7	5.640.888,15	485266,14	467580065252,53	7,68
8	0,8	982,97	470288,05	450525749690,53	7,44
9	0,9	5.960.902,25	476268,10	458686838138,18	7,51

This table compares the forecasting results across various α values (0.1–0.9) in terms of error performance. It is evident that α = 0.8 yields the lowest MAPE of 7.44%, representing the smallest error rate among all tested values. Interestingly, despite its statistical advantage, the forecast result for the following month (982.97 Kg) appears unusually low compared to the established data pattern.

This analysis suggests that selecting the optimal α based on historical error performance does not always guarantee realistic future forecasts. Therefore, while α = 0.8 is statistically the best choice, additional validation is needed to ensure that the forecast remains practical and consistent with expected production trends.

3.2 Forecasting

Figure 3 is a forecasting graph with an alpha value of 0.8 which has the smallest forecasting error rate of the previous experiment. On the graph there are two lines, the blue line is the actual data or sales data and the black line is the forecasting generated by the system calculation using the double exponential smoothing method.

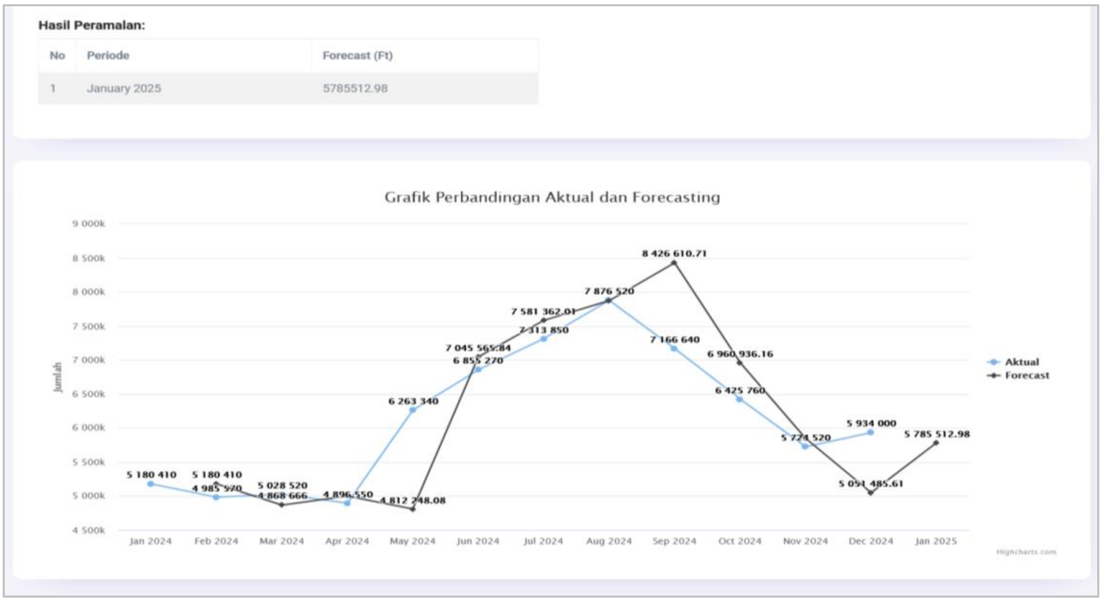

Figure 3. Graphic Forecasting

3.3 Discussion

The double exponential smoothing forecasting method is suitable for forecasting palm oil inventory for the next one-month period, namely February 2025. The selection of the optimal alpha value is done through trials from 0.1 to 0.8 for MAPE optimization. Thus, α is the key to forecast accuracy. After the experiment, the alpha value of 0.8 gets the smallest error result with a MAPE value of 7.44% and a forecasting result of 982.97 Kg. The difference between this research and other research lies in the selection of the alpha value in the forecasting program. This web-based forecasting program can determine which alpha value should be used. This forecasting is suitable for short-term forecasting that uses simple data, is easy to understand, and is quickly applied without requiring complicated calculations [20]. This research is important to conduct as one of the potential methods to reduce CPO production loss. However, to optimize this method, a large amount of data is required [20]. It is recommended that future research test this method using more data such as the previous three to five years of data.

In addition to the statistical results, Figure 2 from the analysis clearly shows that palm oil production in 2024 experienced considerable fluctuations, with certain months such as May, July, and August reaching peak production, while April and October showed notable declines. This irregular pattern reinforces the importance of accurate short-term forecasting, as sudden drops in production can disrupt supply chain planning and inventory management. The application of the double exponential smoothing method with an optimized α value addresses this challenge by providing a data-driven approach to anticipate monthly changes.

Table 1 further demonstrates that although the model performed well overall, large deviations occurred in certain months, such as May and September, where the Absolute Percentage Error (APE) was 23.2% and 17.6% respectively. These deviations suggest that while α = 0.8 yields the lowest MAPE for the overall dataset, the model may still be sensitive to sudden spikes or drops in production. This implies that integrating external factors such as seasonal cycles, weather variations, or market conditions could further refine the forecast accuracy.

The results from Table 2 strengthen the conclusion that α = 0.8 is the most statistically optimal value, producing the lowest MAPE of 7.44%. However, the predicted value for February 2025, 982.97 Kg, appears to be significantly lower than the typical monthly production range seen in Figure 3, which may indicate an overreaction of the model to prior fluctuations. This highlights a potential limitation of relying solely on error-based α optimization without cross-validating against realistic production expectations. Therefore, while the chosen α enhances statistical accuracy, additional model adjustments or hybrid approaches could ensure forecasts remain aligned with practical industry trends.

Overall, the integration of this forecasting method into a web-based system, as described in the uploaded document, offers significant practical benefits. It allows users to experiment with various α values, instantly assess the error metrics (MAD, MSE, MAPE), and choose the most suitable setting for their forecasting needs. By expanding the dataset to include three to five years of historical production data, as recommended, the system could further enhance accuracy, capture seasonal production cycles more effectively, and provide a more robust tool for mitigating CPO production losses.

4. CONCLUSION

The results of research at PTPN IV Regional 1 Kebun Huta Padang show that palm oil production forecasting for February 2025 amounted to 982.97 Kg with an error rate of 7.44%. This value is obtained using an alpha constant of 0.8 which gives the smallest forecasting error rate. This research proves that the DES method can help PTPN IV in making accurate and efficient decisions. With this method, the mill can estimate the amount of palm oil stock that needs to be prepared for CPO production in the following month. However, this research has limitations, especially in terms of the amount of data used. Therefore, it is recommended that future research use more complete data to improve forecasting accuracy.

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Yuli Anggraini, born in Huta Padang, 15 April 2003. Studied at SDN 017124 seinadoras (2011-2016) for elementary school, then continued to SMP Negeri 2 Buntu Pane Satu Atap (2016-2018) and SMA Muhammadyah 8 Kisaran (2018-2021) for secondary education. Currently completing undergraduate studies at Royal University with the Information Systems Study Program (2021-2025).

Nuriadi Manurung was born in Sei Silau, 12 February 1984 Completed his S1 computer study at Panca Budi University Medan in 2009, S2 Computer Upi Yptk Padang in 2014. Career writing became a Royal University Lecturer in 2014 until now.

Febby Madonna Yuma Born in Pekanbaru, August 16, 1986 Completed her undergraduate studies at Lancang Kuning University in 2013. Continuing S2 at the University of Putra Indonesia YPTK Padang, 2016. Writing career as a Lecturer at Royal University 2018 until now.