**Research Journal of Life Science**
APRIL-2023 Volume 10 No. 1 (13-20)
journal homepage: www.rjls.ub.ac.id

# Forecasting Model of Coffee Berry Borer (*Hypothenemus Hampei*) in Pasuruan District

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**KEYWORDS**

Coffee;
*Hypothenemus hampei;*
Forecasting accuracy;
Pest lifecycles;
Humidity.

**Abstract** Coffee, a globally important commodity, faces difficulties in Indonesia due to pests that reduce its quality and productivity. The coffee berry borer (*Hypothenemus hampei*) is particularly dangerous, causing hollowed-out coffee seeds and causing massive annual losses worldwide and in Indonesia. Factors such as climate, weather, and other environmental aspects play a pivotal role in influencing pest lifecycles, emphasizing the necessity of understanding the intricate relationship between pests and their environment for effective management. This research aims to contribute to minimizing coffee production losses and harvest failures resulting from *H. hampei* infestations. This study relies on secondary data from the BBPPTP in Surabaya and NASA. Using panel data regression analysis, the study discovers that coffee berry borer attacks in the Pasuruan District follow a seasonal pattern. Furthermore, with a forecasting accuracy of 15.94%, the model reveals that air humidity, temperature, and previous attacks are the dominant variables influencing current coffee berry borer attacks. The developed model provides a reliable tool for forecasting coffee berry borer attacks, with humidity and previous month's attacks emerging as the most influential factors, particularly in the Pasuruan District of East Java.

## Introductions

Coffee remains one of the most important commodities in the world. Since 1986, coffee exports began to surpass rubber exports, which previously dominated the plantation subsector in Indonesia. However, pest issues in Indonesia have emerged as a significant concern in agricultural production, especially in the plantation sector. The main problem with local coffee cultivation is its low productivity and quality that often fails to meet export standards. This low productivity is largely attributed to pest infestations, which can cause both qualitative and quantitative losses in coffee production.

One of the primary pests affecting coffee plants is the coffee berry borer (*Hypothenemus hampei*). Infestation results in decreased coffee quality due to the hollowed-out seeds. *Hypothenemus hampei* typically targets mature coffee fruits, although immature ones can also be affected. Soft-seeded coffee fruits are usually bored into for food and then left behind. These hollow seeds primarily result in physical quality deterioration, while the taste of coffee

**How to cite this article:** Nadiah, A., Himawan, T., Tarno, H. (2023). Forecasting Model of Coffee Berry Borer (*Hypothenemus Hampei*) in Pasuruan District. Research Journal of Life Science, 10(1), 13-20. https://doi.org/10.21776/ub.rjls.2023.010.01.2

is influenced by the combination of chemical compounds within the seed. Coffee borer infestations cause annual worldwide losses of up to $500 million (Vega et al., 2002). In Indonesia, the estimated losses from this pest amount to $6.7 million annually.

Climate, weather, natural enemies, food availability, and human activities are external factors influencing pest lifecycles. Climate and weather play crucial roles, both directly and indirectly, in pest distribution, occurrence, abundance, and behavior. An insect's basic metabolism relies on the surrounding air temperature. When analyzing insect-climate relations, climatic factors like air temperature, rainfall, humidity, and wind significantly influence microclimates affecting insect development. A notable factor impacting coffee pest growth is the phenomenon of climate anomalies. Climate change can lead to alterations in insect cycles, possibly causing increased pest infestations and triggering outbreaks. To anticipate this, an Early Warning System is essential. Understanding a pest's lifecycle and its relationship with its environment is critical. Here, the environment primarily refers to climate. Recognizing the lifecycle of pests in correlation with the local climate can assist in managing and controlling *H. hampei* infestations, eventually aiding national production enhancement.

Early warning involves forecasting potential *H. hampei* attacks on coffee in specific areas over forthcoming periods. These forecasts become more valuable when conducted across various locations simultaneously. With synchronized forecast information, potential hotspots of heightened infestations can be identified. These forecasts are more insightful when incorporating other influential factors, with high rainfall being a primary catalyst for increased *H. hampei* attacks. To obtain a forecast of *H. hampei* attacks on coffee, one needs historical data on these pest attacks and recent rainfall data. Often, pest attack data is incomplete or even nonexistent in coffee-growing regions due to remote locations and vast coffee plantation areas. This research aims to contribute to minimizing coffee production losses and harvest failures resulting from *H. hampei* infestations.

## Matrials and Methods

*Data collection*

Secondary data obtained from the Major Seedling and Plantation Protection Center (BBPPTP) in Surabaya and the United States Aeronautics and Space Administration (NASA) website were used in this study. Panel data was used, which is a combination of cross-sectional and time series data. It combines data on the percentage of coffee fruit borer pest attacks, rainfall, specific humidity, and air temperature in the Pasuruan District from January 2017 to December 2022. This study's variables include one dependent variable and five independent variables. The intensity/percentage of attacks by coffee fruit borer pests (%) is the dependent variable.

*Data analysis*

The panel data regression analysis method was used to analysis data in this study. The pattern of coffee berry borer pest attacks was identified and used to build a multiple regression equation model. The Residual Normality Assumption Test, the Multicollinearity Assumption Test among Independent Variables, the Homoscedasticity Assumption Test of Residual Variance, and the Non-autocorrelation Assumption Test of Residuals were then performed. Furthermore, the Simultaneous F-test and the Partial t-test were used to estimate and test the regression model parameters. The next step was to


**E-ISSN 2355-9926**

identify the most powerfully influential variable. The Goodness of Fit test was used to assess the model's effectiveness. Finally, a multiple regression model was developed and tested for forecasting accuracy.

## Results and Discussion

*Identification of Coffee Berry Borer Attack Patterns*

The results showed that the fluctuations of coffee berry borer attacks in the Pasuruan District follow a seasonal pattern. To account for seasonal effects on the data and autocorrelation between residuals, lagged variables representing previous month attacks and 12 months prior attacks were added to the regression model (Figure 1).

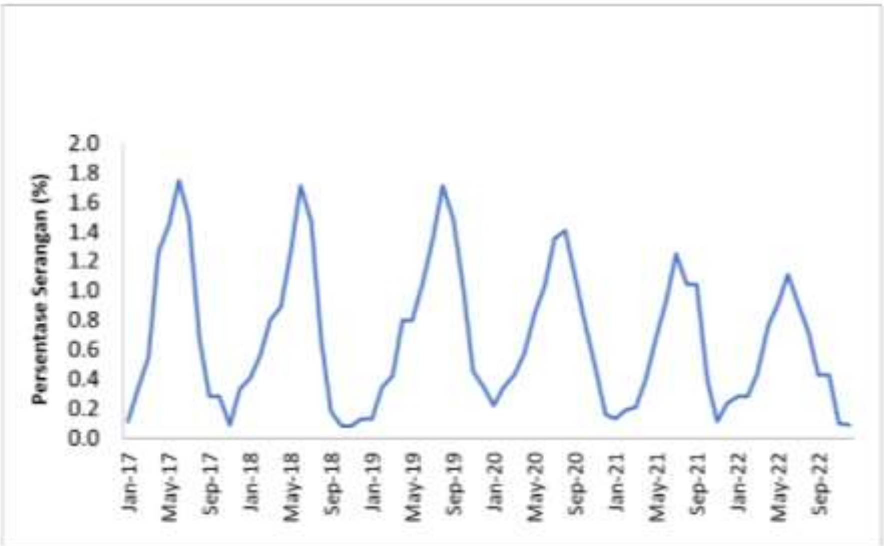


**Figure 1.** Variations in coffee fruit borer attacks in the Pasuruan District.

*Residual Normality Assumption Test*

The first assumption that needs to be met in multiple regression analysis is that the residual data should be normally distributed. The normality test of residuals was carried out using the Kolmogorov-Smirnov test. Based on the above normality test results, it can be concluded that the test's significance value is greater than the significance level of 0.05. This indicates that the residual data is normally distributed. Hence, the normality assumption is met.

**Table 1. Residual Normality Test Results**

| | Shapiro-Wilk | | |
|---|---|---|---|
| | Statistic | df | Sig. |
| Unstandardized Residual | 0.982 | 60 | 0.508 |


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*Non-multicollinearity Assumption Test among Independent Variables*

The second necessary assumption in multiple regression analysis is that there shouldn't be a linear relationship (linear correlation) among independent variables. The multicollinearity test was performed using the Variance Inflation Factor (VIF). Multicollinearity is absent if VIF <10 (Table 2).

**Table 2. The Multicollinearity Test among Independent Variables**

| Variable | Collinearity Statistics | |
|---|---|---|
| | Tolerance | VIF |
| PLS_1 | 0.279 | 3.580 |
| PLS_12 | 0.322 | 3.102 |
| CH | 0.162 | 6.163 |
| KS | 0.204 | 4.892 |
| SU | 0.542 | 1.844 |

*Homoscedasticity Assumption Residual Variance Test*

The third necessary assumption in multiple regression analysis is that the variance of the residuals is homoscedastic. A scatter plot between the Standardized Predicted Values and the Studentized Residuals can be used to determine whether the residual variance is homoscedastic or heteroscedastic. According to the scatter plot above, the points scatter randomly around the zero line, with no discernible pattern. This implies that the residuals of the regression model are homoscedastic. As a result, the homoscedasticity assumption is satisfied (Figure 2).

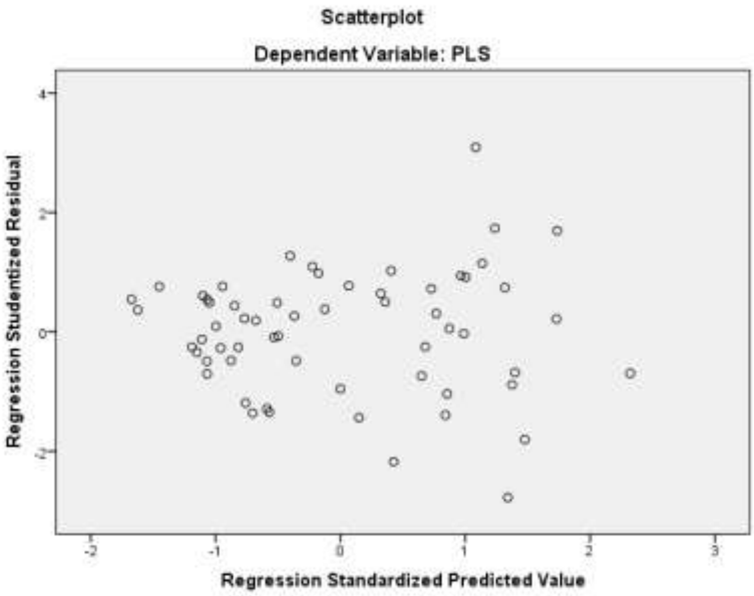


**Figure 2.** Residual Variance Scatter Plot for Homoscedasticity Assumption Test


**E-ISSN 2355-9926**

*Residuals Non-autocorrelation Assumption Test*

The fourth necessary assumption in multiple regression analysis is that there should be no residual autocorrelation. The Durbin-Watson statistic can be used to calculate autocorrelation. The following are the rules for calculating autocorrelation with the Durbin-Watson statistic (d):

1. Autocorrelation is present if d < dL or d > 4-dL
2. Autocorrelation is absent if dU < d < 4-dU
3. A conclusion can't be drawn if < d < dU or 4-dU < d < 4-dL

Based on the above Durbin-Watson statistic, the Durbin-Watson value (d<1.40832). This indicates the presence of positive autocorrelation among the model's residuals. Thus, the non-autocorrelation assumption isn't met. This also means the residuals from the regression analysis model still have a positive influence on the prediction results.

*Estimation and Testing of Regression Model Parameters*

*Simultaneous F-test*

In multiple regression analysis, the simultaneous test is used to determine the significance of the combined influence of independent variables on the dependent variable. Based on the output of the simultaneous test in the above multiple regression analysis, it can be determined that the significance value of the F-test = 0.0001. This implies that all the independent variables, namely rainfall, specific humidity, average air temperature, and the extent of the attack from 1 month and 1 year prior, simultaneously influence the coffee fruit borer attack significantly.

*Partial t-Test*

The significance values for the variables PLS1, PLS12, KS, and SU are less than 0.05 (Table 3). This suggests that specific humidity, average air temperature, the previous month's attack, and the attack a year ago all have a significant impact on current coffee fruit borer attacks. Because the significance value for the rainfall variable is greater than 0.05, it is concluded that rainfall has no significant influence on the intensity of the coffee fruit borer attack.

Positive figures in the coefficient of specific humidity and the attack from 1 month and 1 year prior indicate that as the humidity and previous borer attacks increase in a location, the coffee fruit borer attacks in the current month will also be higher. Conversely, the lower the humidity and the previous attacks, the fewer the attacks in the current month. Negative figures in the coefficient for rainfall and temperature indicate that the influence of these two variables is inversely proportional to the extent of the coffee fruit borer attack. In other words, the lower the rainfall and air temperature in a location, the greater the extent of the coffee fruit borer attack. Conversely, the higher the rainfall and air temperature, the lesser the extent of the attack.

*Determine the Most Dominant Influencing Variable*

All the significant independent variables, we will determine which variable has the strongest influence on the coffee fruit borer attack. This determination is done by observing the standardized coefficient beta value. Based on the partial test table above, it can be seen that the two variables with the highest standardized coefficient beta values are PLS1 (percentage of the previous month's attack) and KS (specific humidity). This means that the percentage of the previous month's


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attack and specific humidity are the two variables with the most dominant influence on the current percentage of coffee fruit borer attacks.

**Table 3. Partial t-Test Results in Multiple Regression Analysis**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 1.766 | 1.156 | | 1.527 | 0.133 |
| | PLS1 | 0.702 | 0.117 | 0.696 | 6.021 | 0.000 |
| | PLS12 | 0.209 | 0.098 | 0.229 | 2.131 | 0.038 |
| | CH | -0.001 | 0.000 | -0.211 | -1.395 | 0.169 |
| | KS | 0.090 | 0.044 | 0.275 | 2.039 | 0.046 |
| | SU | -0.122 | 0.051 | -0.200 | -2.406 | 0.020 |

*Formulating the Regression Model for Forecasting Coffee Fruit Borer Attacks*

Based on the estimation results of the multiple regression model parameters in the above partial t-test table, the regression model for coffee fruit borer attacks as:

$$PLSt=0.1766+0.702PLSt-1+0.209PLSt-12-0.001CHt+0.090KSt-0.122SUt+\varepsilon i$$

Where:

| | | |
|---|---|---|
| PLSt | : | Attack Percentage in month t (%) |
| PLSt−1 | : | Attack Percentage in month t-1 (%) |
| PLSt−12 | : | Attack Extent Percentage in month t-12 (%) |
| CHt | : | Rainfall in month t (mm) |
| KSt | : | Specific Humidity in month t (g/kg) |
| SUt | : | Air Temperature in month t (Celsius) |

*Measuring the Accuracy of the Regression Model in Forecasting Coffee Fruit Borer Attacks*

There are several metrics to determine the accuracy level of a forecast model. One of them is by using the MAPE (Mean Absolute Percentage Residual) value. Based on the calculations, the obtained MAPE value is 15.94%. As the MAPE value is below 20%, it can be said that the forecast results from the multiple regression model in predicting coffee fruit borer attacks have reasonably good accuracy.

## Conclusions

The multiple linear regression model can be used to predict coffee fruit borer attacks with reasonably good forecasting accuracy. Additionally, it can explain the relationship between rainfall, air humidity, and air temperature on the coffee fruit borer pest attacks. Air humidity, air


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temperature, and coffee fruit borer attacks from 1 and 12 months prior significantly influence the coffee fruit borer pest attacks. The attacks that occurred 1 month prior and the specific humidity are the two most dominant factors affecting the coffee fruit borer pest attacks in a given location.

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**E-ISSN 2355-9926**