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Sandalwood Seedling Height Modeling Usinggrowth Model

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***Abstract**: Sandalwood is an Indonesian native plant that grows endemic in East Nusa Tenggara Province. Sandalwood is the only one of the 22 species of the genus Santalum in the world, grown naturally in Indonesia. On NTT Island, formerly known as "Island with Sandalwood Carpet", within 10 years (1987 to 1997) the number of sandalwood trees decreased by 53.95%, from 554,942 trees to 250,940 trees. This condition requires the existence of sandalwood management policies from the Provincial Government so that sandalwood sustainability is maintained and at the same time provides economic benefits for the region. In formulating management policies, tree growth information is needed which can be presented in the form of a growth model. The research conclusion is sandalwood seedlings are more precisely modeled with a gompertz model which has the smallest RMSE value. The growth model is* $\hat{Y} = 11{,}336 * exp(-0{,}203 * exp(-0{,}267x))$ *with a coefficient of determination of 0.98%.*

***Keywords** : Sandalwood, growth model*

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I. Introduction

Sandalwood is an Indonesian native plant that grows endemic in East Nusa Tenggara Province. Sandalwood is the only one of the 22 species of the genus Santalum in the world, grown naturally in Indonesia. On NTT Island, formerly known as "Island with Sandalwood Carpet", within 10 years (1987 to 1997) the number of sandalwood trees decreased by 53.95%, from 554,942 trees to 250,940 trees (Waluyo, 2006). Meanwhile, the demand for sandalwood continues to increase with a very high selling value because the terrace wood contains essential oils that have a distinctive aroma (Suhaendi, 2006). Until 2010, there were only 1,426 sandalwood trees found with a diameter of 20 cm-100 cm, even though in 1998 they had reached 112,710 trees (Raharjo, 2014). This condition requires the existence of sandalwood management policies from the Provincial Government so that sandalwood sustainability is maintained and at the same time provides economic benefits for the region. In formulating management policies, tree growth information is needed which can be presented in the form of a growth model.

Growth is the result of the integration and interaction of various biochemical reactions, biophysical events and physiological processes together with external factors that occur in the body of living things. Growth that occurs in living things cannot be easily studied and described given the complex elements in it. One way to study the growth of living things is by simplification which eventually leads to the formation of growth models.
According to Putranto (2010), the growth model and its environmental conditions can be used to predict, formulate prescriptions and references for policies in the field of forestry. Growth models usually refer to a system of equations that can be used to predict growth and yield of forest stands in various conditions. Some growth models are often used as predictors of tree growth models have been tested hypothetically and the results are close to actual tree growth. However, to be able to use the equation model it needs to be tested with several statistical test criteria because each type of tree shows different growth.

Wahyudi and Pamungkas (2013) modeled Jabon diameter using 5 models, namely the sigmoid, exponential, polynomial, regression and logistical models. From his study, it was found that the sigmoid model was the best for modeling the diameter of Jabon plants. Muskitta, et al. conducted a study on the model of sandalwood growth using logistic models and Gompertz models. Based on the results of the study, it was revealed that the best model is Gompertz model. This present study usedGompertz model and Sigmoid model to find out which model is best used for the growth of sandalwood seedlings.
This study aims to obtain the most suitable model in describing the growth of sandalwood seedlings.

II. Theoretical Framework

Plant Growth Modeling is a key activity in research, especially in the fields of plant cultivation, forestry, and the environment (Fourcaud et al., 2008). Plant growth modeling is based on the processes that occur in plant growth. The model is also very useful in showing plant responses in general to the environment and interactions between processes or components of crop production systems (Gholiopouri et al., 2010).

Plant modeling can be done with several modeling steps. Hoover and Perry (1989)state that in modeling it takes several stages of activity, namely: problem formulation, data collection and analysis, model making, model verification and validation, experimentation and model optimization, and simulation. Gordon (1980) explains that in modeling and simulation analysis several activities are needed, including problem descriptions, defining models, making programs, model validation, and verifying results. Plant growth is a dynamic system, so the dynamic model is an appropriate model for plant growth.

III. Research Method

Research Location

The study was conducted in the green house of the Institute of Agriculture in Malang from February 2018 to April 2018.

Research Procedures

1. Preparing dried sandalwood seeds and purslane plants as hosts and then planted them in Mediterranean soil
2. After the sandalwood seeds germinate, sandalwood sprouts and their host were transferred simultaneously to polybags that had been filled with growing media, namely Mediterranean soil which was given vermicompost fertilizer.
3. Measuring the height of sandalwood seedlings starting a week after the plants were transferred to polybags. The measurement of seedling height (cm) was carried out every 2 weeks starting from February 2018 to April 2018. The plant height was measured from the base of the stem to the end of the plant.

Data Analysis

1. Calculating the average height of sandalwood seeds in each week using the formula$\bar{x} = \frac{\sum X_i}{n}$

in which $\sum X_i$= the calculation of total data

n = the number of data

2. The growth model being used was: (Burkhart, 2003)

a. Gompertz model

$Y = b1 * \exp(-b2 * \exp(-b3 * x))$

b. Sigmoid model

$$Y = \frac{b1b2 + b3x^{b1}}{b2 + x^{b4}}$$

3. Selecting the appropriate model by calculating the Root Mean Square Error (RMSE) with the formula: (Panwar, 2010)

$RMSE = \sqrt{\frac{\sum(x-\hat{x})^2}{n-p}}$, dengan

n = the number of data

p = the number of parameter in the model

The best model is the one that has the smallest RMSE value.

IV. Results And Discussion

Data Description of Sandalwood Seedlings Height

The height of sandalwood seedlings was measured at week 1 after being transferred to polybags up to the 12thweek. The graph of sandalwood seedling height is presented in Figure 1.

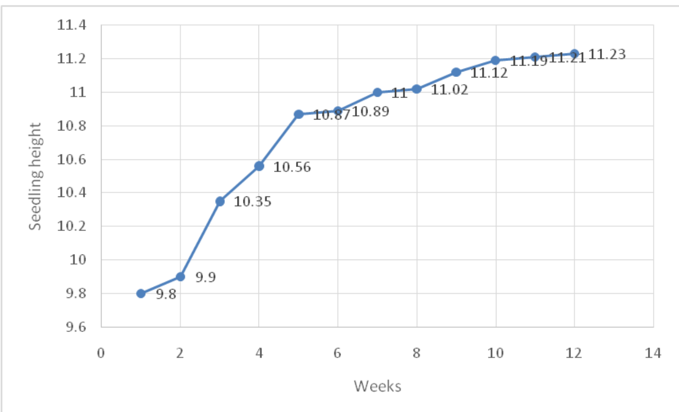

Figure 1. Height of Sandalwood Seedlings

Figure 1 indicates that the height of sandalwood seedlings forms a curve like a parabola. The increase in height is quite rapid in the first week up to the 6thweek and slows down thereafter to the 13th week. A week after the seedlings are transferred to a plant polybag, they reached 9.8 cm. The highest increase in seedling occurred in the 3rdto 4thweek. In the 7thweek, the seedling height increase began to stabilize until the last week of observation, which was the 12thweek. In the last week of this observation, the seedling height reached 11.23cm.

Sandalwood Seedling Height Modeling

Based on data on sandalwood seedlings, the seedling height growth model was obtained using some plant growth models, namely:

1. Gompertz Model

$$\hat{Y} = 11,336 * \exp(-0,203 * \exp(-0,267x))$$

2. Sigmoid Model

$$\hat{Y} = \frac{-0,382 + 0,5x^{2,419}}{-0,158 + x^{0,5}}$$

The coefficient of determination (R^2) for the Gompertz model which is equal to 0.98 means that 98% of the diversity of seedling height can be explained by the model. While the Sigmoid model has an R^2 of 0.876 meaning that 87.6% of the diversity of seedling height can be explained by the model. When viewed from the coefficient of determination, the Gompertz model is better used to model sandalwood seedlings because they have greater value.

Actual data and predictive results of the two models are presented in Table 1.

Table 1. Actual data and prediction of seedling height based on Gompertz and Sigmoid models

t	Actual Data	Seedling height prediction using models Gompertz	Sigmoid
1	9.8	9.71	9.59
2	10.23	10.07	10.38
3	10.35	10.35	10.65
4	10.56	10.57	10.8
5	10.87	10.75	10.88
6	10.89	10.88	10.94
7	11	10.99	10.98
8	11.02	11.07	11.01
9	11.12	11.13	11.03
10	11.19	11.18	11.05
11	11.21	11.21	11.07
12	11.23	11.24	11.08

Graph of actual data and prediction data are presented in Figure 2.

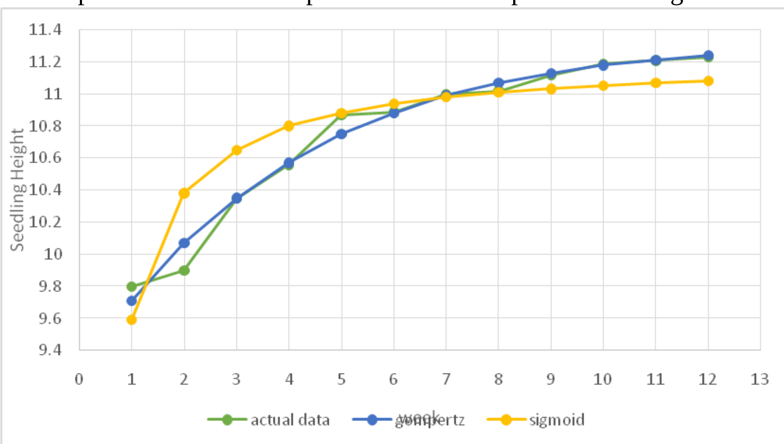

Figure 2. Actual data and Prediction Data

To find out which model is most suitable for sandalwood seedlings, the RMSE value is used. The results of calculation of RMSE Value can be seen in table 2.

Table 2. RMSE Value of Sigmoid Models and Gompertz Models

Model	RMSE
Sigmoid	0.535
Gompertz	0.226

The best model is the model with the smallest RMSE value. Based on table 2, it can be concluded that Gompertz model has a smaller RMSE value of 0.226 compared to Sigmoid model. Therefore, Gompertz model is better used to model the sandalwood seedling level compared to the sigmoid model.

This is also supported by the plot of data in Figure 2. In Figure 2 it can be seen that the prediction data patterns obtained from the two models follow the original data form. The prediction data plot that uses the Gompertz Model is in accordance with the actual data pattern.

V. Conclusion

Sandalwood seedlings are more precisely modeled with a gompertz model which has the smallest RMSE value. The growth model is $\hat{Y} = 11{,}336 * \exp(-0{,}203 * \exp(-0{,}267x))$ with a coefficient of determination of 0.98%.

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