Simple Regression Modeling on the Number of Fronds Increases with Age on Oil Palm Seedling's Growth

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DOI: https://doi.org/10.51584/IJRIAS.2023.8620

Received: 01June 2023; Revised: 16 June 2023; Accepted: 22 June 2023; Published: 15 July 2023

Abstract: - The productivity of oil palm crops is a crucial factor in the current oil palm plantation industry, considering the prevalent issues and criticisms about the environmental impact of land clearing for oil palm plantations. Given that the productivity of oil palm crops is determined by their quality and growth rate, it is important to study the speed and quality of oil palm crop growth during the early stages, namely seedling growth, where the number of fronds can be measured. This research aims to analyse the number of seedling fronds growing during their 9-month growth period since being transferred from the pre-nursery to the main nursery plantation. The fronds growth observation results of 300 seedlings over nine months are evaluated using the distribution analysis each month, and the growth model in the form of a linear equation is developed using a statistical linear regression method. The correlation coefficients indicate a reasonably significant increase in the number of fronds as the age of the seedlings, with R values = 0.6728, R = 0.8346, and R = 0.9489 for the minimum, the maximum and average number of fronds, respectively. It is concluded that the growth of the number of oil palm fronds can be easily simulated using the developed regression model.

Keywords: -frond number growth, oil palm, modelling, productivity, simple linear regression

I. Introduction

Indonesia is one of the most important countries that produce oil palm-based products and has a large oil palm plantation area. The main characteristic of the oil palm plantation in Indonesia is that nearly 50% of the oil palm plantations are owned by the people as a household cultivation business(Herdiansyah et al., 2020). However, considering that oil palm plantations are always associated with deforestation problems(Murphy et al., 2021), the 2004 Roundtable on Sustainable Palm Oil (RSPO) agreed to oblige producers to no longer carry out deforestation and recommend implementing the concept of the oil palm industry(Pareira, 2021). Consequently, the increase of productivity on oil palm plantations must be improved. Regarding this fact, promoting oil palm cultivation methods for farmers is essential. Thus, studying the development of oil palm growth is quite important to support the development of oil palm smallholders.

To estimate the oil palm's productivity, we could use the oil palm's age as a primary indicator. Some researcher has studied the growth and productivity of oil palm related to age. For example,Carolita et al. (2015)developed the oil palm productivity as a function of its age using NDVI analysis and regression analysis based on SPOT 6 data. The rate of increase in the number of fronds during the seedling's growth will determine the quality of oil palm growth and, in turn, will affect the quality of the fruit produced. Therefore, the number of fronds influences oil palm production, especially fresh fruit bunch weight(Gromikora and Yahya, 2014). In another study, Marcelino and Diaz (2016) found that frond pruning can enhance the growth and yield of eight-year-old oil palm. So, the survey of the increase in oil palm frondsfrom year to year is significant.

The growth of oil palm plants, like the growth of other plants in general, is highly dependent on the ability of the roots to absorb nutrients and the ability of the leaves or fronds to process them through chlorophyll by utilising the help of sunlight. Pradiko and Koedadiri (2015)use fronds to measure sap flow using a sap flow meter to measure plant transpiration. Another study byBayona-Rodríguez and Romero (2016) and by Woittiez et al. (2017) shows that the number of fronds contributes to the acquisition of oil palm yields. So, the frond plays a significant role in the subsequent oil palm growth. Therefore, a study on oil palm fronds can significantly assist in managing oil palm plantations. To support this critical role, a mathematical model is needed that can be used to predict the growth of fronds according to the age of the oil palm plant. One form of a mathematical model that can be developed to meet this goal quickly but quite accurately is a regression model developed based on

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

observational data on the growth of the number of fronds of oil palm plants over a long period and an adequate number of observational samples.

This research aims to analyse the uniformity of oil palm seedling growth, especially the number of fronds from each seedling planted in the main nursery. The increase of the frond and its distribution as a function of plant age is the main objective of this research. With the information obtained from this research, a strategy for pruning management could be carried out well.The statistical regression method was used to produce a simple model, which can then be used to simulate the growth of the number of fronds as a function of plant age.

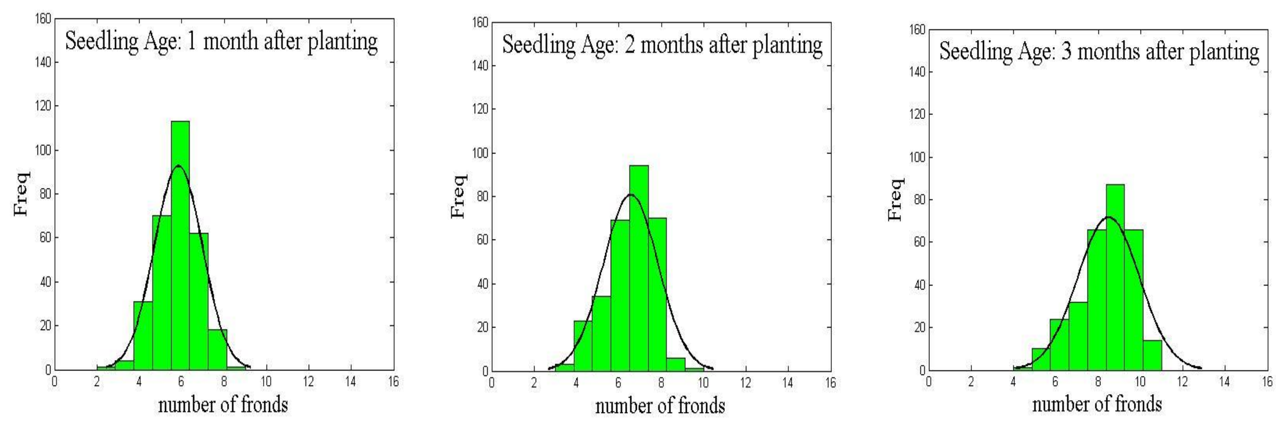
II. Materials and Methods

The study was carried out in the primary seedbed at the Marihat Research Center, a property of the Indonesian Oil Palm Research Institute in the Simalungun District, North Sumatra. The oil palm saplings, which were three months old, were sourced from a pre-nursery plantation. These chosen saplings were relocated to the primary seedbed, where they were studied for nine months, starting from the day they were first planted in this seedbed. Operations like spacing between plantings, applying fertilisers, irrigation, and overall maintenance followed the standard practices for managing oil palm plants as per the existing standard operating procedures. The field research used a demonstration plot in the main nursery. The polybag seedlings were placed with a spacing of 90x90x90 cm using an equilateral triangle planting pattern of 324 samples.

The primary subject of this research, the frond count, was recorded on a monthly basis for nine months. Each month, from a total of 324 samples, it is chosen 300 data, resulting in a total of 2700 data points for nine months of observation. This data then undergo a series of analytical steps. Initially, the researchers plotted the data to observe the evolution of the frond count over time. Then, the distribution trends of these 2700 data points were examined. Next, the data was divided into segments, and the distribution patterns were reevaluated to understand the growth pattern. The third phase of analysis aims to understand the monthly distribution trends from the spread of frond count data while also considering the direction of each month's mean value. The final step will be an analysis to determine the feasibility of using mathematical models to represent oil palm frond growth, which would allow for the simulation of increasing frond numbers as the plant ages.

III. Results and Discussion

For nine months, the observed and documented count of fronds was systematically arranged to study the spread of fronds across different growth stages of the seedlings. Figure 1 represents the distribution of frond numbers at the first three MAP (Months After Planting). First, it perfectly appears as a normal distribution for 1 MAP (Figure 1*c*). Then, for 2 MAP in Figure 1*b*, the histogram's distribution seems left skewed and right skewed at 3 MAP, as presented in Figure 1*c*.



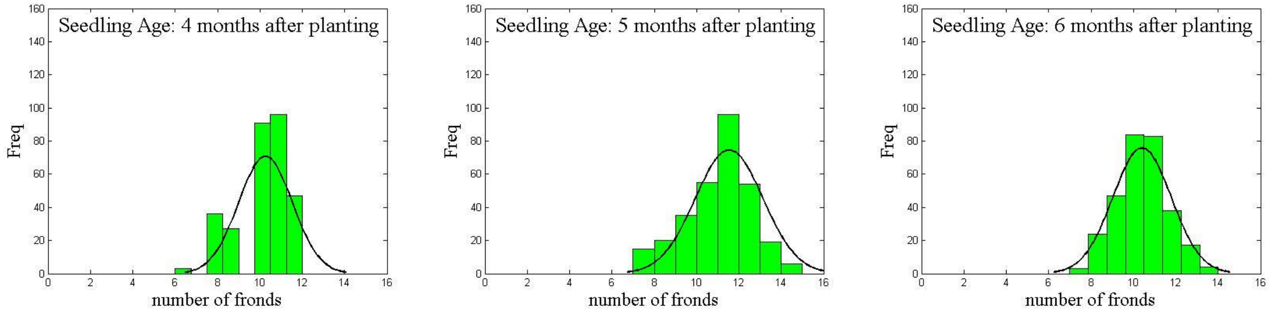
(a) (b) (c)

Figure 1. The first three months after planting distribution of oil palm frond number in the main nursery: (*a*) at 1 MAP, (*b*) at 2 MAP, (*c*) at 3 MAP.

At the second three MAP, the frond growth still tends to a normal distribution with a slight shift at the age of 4 MAP, concentrating in certain interval groups so that there are empty interval classes. Figure 2 shows the number of fronds distribution in the second 3 months after planting. At the age of 6 MAP, the growing fronds began to decline apparently. This occurrence shows the phase of falling off the fronds from the beginning of the seedlings' growth. Figure 2*c* shows the same initial histogram bar class (about six fronds) as Figure 2*b*, and there was a decrease in the final histogram bar class, which was initially 15 fronds at

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

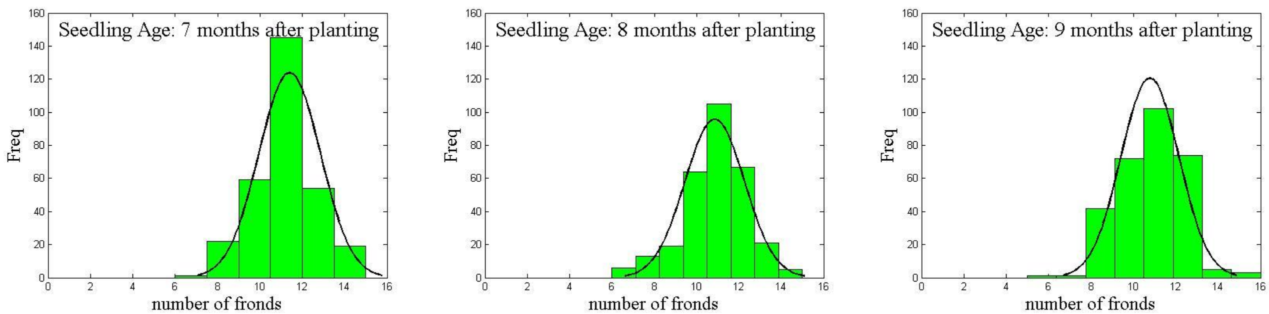
the age of 5 MAP down to 14 fronds at the of age 6 MAP. This phenomenon can also be observed in the change in the middle class (10 to 12 fronds).



(a) (b) (c)

Figure 2.The second three months after planting distribution of oil palm frond number in the main nursery: (*a*) at 4 MAP, (*b*) at 5 MAP, (*c*) at 6 MAP.

The frond number distribution change dynamically continues for the third three months after planting (see Figure 3). At this stage, the frond number distribution is relatively constant, but the frequency variation dynamically changes between classes.



(a) (b) (c)

Figure 3.The third three months after planting distribution of oil palm frond number in the main nursery: (*a*) at 7 MAP, (*b*) at 8 MAP, (*c*) at 9 MAP.

Overall, an examination of 300 seed samples showed a consistent pattern in the monthly frond counts, as depicted in Figure 1 to Figure 3. A significant uptick in the number of fronds was discerned across the nine distributions, correlated with the increasing age of the seedlings. This occurrence can be inferred from the alteration in the frond count, occurring most frequently at each seedling growth stage.

At one MAP of age, the highest modus is around six fronds, then it increases to 7 fronds at twoMAP and becomes nine fronds at threeMAP old. Subsequently, it increases sequentially to 10 fronds in the four MAP and becomes somewhat stable at 11 fronds from 5 to 9 MAP. The distribution of the number of oil palm fronds, which tends to be normally distributed, is in line with the research of Rahmawati et al. (2019), which showed that the frequency of plant height characteristics, the number of productive branches, and flowering dates follow a normal distribution, yet is different from the plant population study by Huzsvai et al. (2022), which resulted in a binomial distribution.

Based on the minimum and maximum values of the number of fronds from all samples each month, their development appears to follow a linear trend as the age of the seedlings, however, with a not-too-strong correlation coefficient (see Figure 4, line *a* and line *b*). However, for the average value of the number of fronds each month, the trend tends to have a relatively strong linear correlation (R = 0.9489), as shown in Figure 4 line*c*. Therefore, the regression model of the growing number of fronds as a function of the age of the oil palm seedlings obtained from this 9-month observation is as follows:

$f = 0.6434\, m + 6.3533$ with R = 0.9489

where *f* is the frond number of oil palm seedlings, and *m* is the seedlings' age calculated as months after planting in the main nursery.

From Figure 4, line *c*, it can be seen that the frond numberincrease with the age of the seedling. However, thereis a decreasing frond number for the 8th and 9th month. This decrease indicates wilting and death of fronds from old fronds.

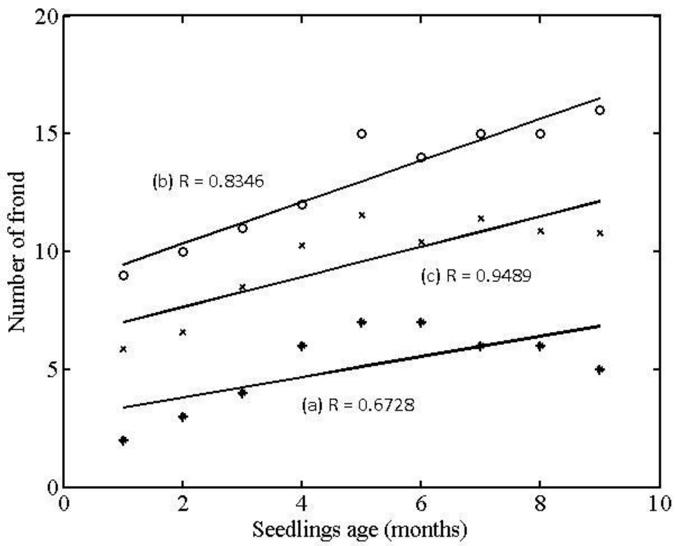


Figure 4.The development of the number of fronds of oil palm seedlings as a function of plant age: *a*) minimum value, *b*) maximum value, *c*) average value

The development of the number of fronds on the growth of the oil palm seedlings observed shows that the growth rate is one frond every two months. Therefore, the rate of increase of this frond can theoretically be calculated using the linear regression model developed above. This model is in line with the study by Purnama and Afrillah (2022), which found an increase of one frond every two months in the growth of oil palm seedlings in the pre-nursery and the main nursery.

IV. Conclusion

A linear regression model has been successfully developed to predict the growth of oil palm seed fronds, with a correlation coefficient of 0.9485. The developed model can easily simulate the increased frond number of oil palms.It shows that the fronds of oil palm seedlings in the main nursery increase by one frond every two months. To improve the accuracy of the model obtained, further research on various growth phases of productive age oil palms needs to be carried out.

Acknowledgement

We want to thank the Indonesian Oil Palm Research Institute for granting permission and facilitating the execution of this research in the Marihat Main Nursery Business Unit. We also thank Final Project Recognition Grant Number 5075/UN1.P.II/Dit-Lit/PT.01.01/2023 for the grant supporting this research.

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ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue VI June 2023

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