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# LEDA (*Eucalyptus Deglupta Blume*) Increment on Various Dimensions of Growth

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***Abstract***

*Setting stands to produce the optimal growth of Leda (Eucalyptus deglupta Blume) is necessary to achieve maximum and sustenable results. The study aims to determine the growth and accretion of growth (increment) of Leda (Eucalyptus deglupta Blume) stands. The research was conducted in the area of Industrial Forest Plantation Inhutani Company Gowa-Maros, South Sulawesi, on Leda stands aged 1 year, 2 years, 3 years, 5 years, and 7 years. The research was conducted using survey methods and purposive sampling techniques that chose age-class stands at the research site. The data was gathered through the 15 sample plots, each measuring 0.04 ha (20 x 20 m), by striving in a particular way so that the sample plot represents the growth conditions of the stand. The growth analysis of the Leda stands used Richard's Model equation, which was then extrapolated to obtain the increment values of CAI and MAI at the dimensions of height, diameter, and area of the based area. The results showed that the growth of the 7-year-old Leda reached a height of 17.20 m, with a Mean Annual Increment (MAI) of 2.46 m and a Current Annual Increment (CAI) of 2.00 m. The diameter of the 7-year-old Leda's trunk reached a diameter of 14.60 cm, with a Mean Annual Increment (MAI) of 2.09 cm and a Current Annual Increment (CAI) of 2.30 cm. The basal Area (BA) of 7-year-old Leda reached 15.6 $cm^2$. The mean accretion of the based area (MAI) was 2.23 $cm^2$, and the annual accretion of the based area (CAI) was 2.40 $cm^2$. The diameter of the 10-year-old Leda's trunk reached tree level with a trunk diameter of 21.1 cm.*

**Keywords:** *Foreshadows Growing Trees, Tree Base Area, Tree Diameter, Tree Harvesting Arrangement, Tree Height.*

## 1. Introduction

Leda (Eucalyptus deglupta Blume) is classified as a fast-growing plant and has a fairly wide spread of growing sites (Awaliyan et al. 2017; Pitopang et al. 2011). It grows naturally in Sulawesi, Maluku, Irian Jaya, Seram, and Mindanao (Kuswandi and Murdjoko 2015; Rosmarlinasiah 2019). Leda belongs to the strong classes II and III as well as the durable class IV (Pitopang et al. 2011). If viewed

from the density of fibers, the Leda is better than the Silk tree (Albizia chinensis) and buflower tree (Neolamarcika cadamba). Leda is a type of wood that is used in the construction of Industrial Forest plantations (Awaliyan et al. 2017; Pitopang et al. 2011). The action of the applied silviculture determines the success of Leda's growth. Proper management will deliver the expected growth and achieve optimum and sustainable results (Sihombing 2015).

Growth can be interpreted as an ecological expression because it is a representation of a type's genetic ability to interact with environmental factors, such as climate factors, soil, topography, and competition with other organisms (Liu et al. 2018; Marquis et al. 2021; Payette 2007). The accretion of growth or increment of a variety is crucial information in developing a type of Leda to know the appropriate management actions to achieve the principle of sustainability. Some growth models commonly used in describing the stand growth model are: 1) asymptote models, such as Richard's Model; and 2) un-asymptote models, such as the Exponential Model and the Uplift Model (Malamassam 2009). The best image of the stand growth model is determined by the determination coefficient of its regression equation. In addition, a growth model is good if the shape of the curve approaches the growth conditions in the field. The results of the Rosmarlinasiah 2019 study revealed that the best growth model from several dimensions of Leda growth is using the uplift model (un-asymptote) and Richard's model (asymptote). Based on the growth model of a type, it can be used to predict the accretion of growth (increment).

Therefore, research on Leda's (Eucalyptus deglupta Blume) stand growth that can describe Leda's accretion of growth from various growth dimensions such as height, diameter, and area of the base area is necessarily conducted. This study aims to determine the growing conditions of the Leda (Eucalyptus deglupta Blume) through the models of high growth, diameter growth, and growth of the base area of the Leda stand. Furthermore, it is important to know the Mean Annual Increment (MAI) and Current Annual Increment (CAI) in each dimension of the stand's growth. The results of this study are expected to be used as basic information to determine appropriate management actions to achieve optimum and high-quality results in developing a type of Leda in a region.

## 2. Materials And Methods

### Materials and Tools

The material used is a tree or Leda stand (*Eucalyptus deglupta Blume*) aged 1 year, 2 years, 3 years, 5 years, and 7 years with a varied planting distance of 2 x 2 m (stand aged 1 year), 3 x 3 m, and 4 x 2.5 m. Equipment used includes a haga hypsometer (measuring tree height), a gala meter (measuring tree height less than 5 m), a roller meter (measuring area of observation plot), a tape meter (measuring tree diameter at chest height), paint and brushes (markers of observed tree objects), a camera (research documentation), a tally sheet (field measurement data record sheet), a rope (observing plot limiter), rulers, and other stationery.

### Method

This research method used a survey approach with a purposive sampling technique by selecting Leda stands for all age classes at a research site. The square-shaped observation plots (20 x 20 m) used are 15 plots.

### Variables and Data

The observed variables are the grade of height and diameter of the tree and the age of the stand. The data collected are primary and secondary data. Primary data obtained through direct measurements in the field include the number of trees in the observation plot, tree height, chest-height trunk diameter (cm), tree age (year), and topographic conditions. Secondary data obtained from reports or archives related to the study, such as the existing data on observations of stand growth conditions, Physical data are rainfall (mm), rainy days (days), humidity (%), temperature (oC), height of the place (mdpl), and tilt (%).

### Data Analysis

The collected *Leda* growth data was then analyzed to obtain an overview of the average conditions about some aspects of the stand growth.

- The diameter of the tree (d) is obtained from the conversion of the circumference:

**d = circumference/π**

- The Based Area of the tree (BA) is obtained from:

$$BA = \frac{1}{4} * \pi * d^2$$

Where: *BA* : Based Area

d : diameter

π : phi value 3.14

circumference : circumference of the trunk measured at chest height (130 cm)

- The height (h) of the tree is obtained through indirect measurement using the principles of angle measuring science (Malamassam, 2009) as in the Figure below:

$$T = tg\ \alpha * L$$

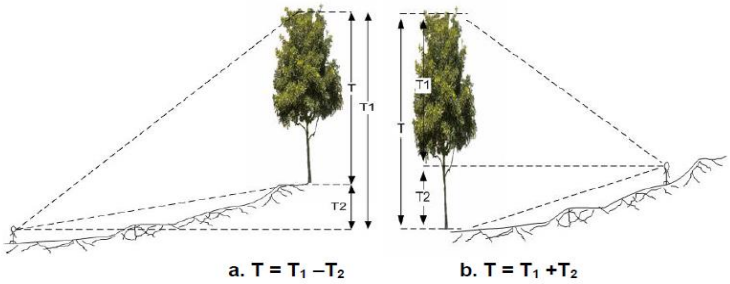


Figure ( 1 ) : Measurement technique of tree height in hilly land position

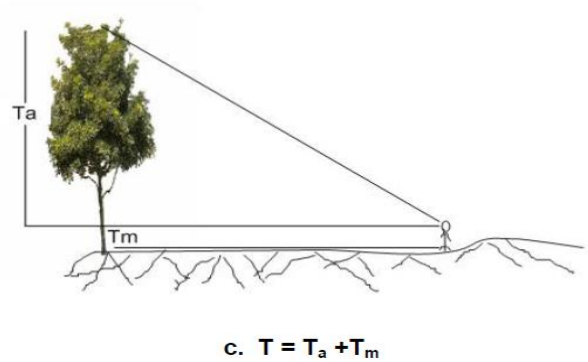


Figure ( 2 ) : Tree height measurement technique on flat land position

Where T : Tree height
T1: Ta : scale perusing while shooting for the peak of the tree
T2 : scale perusing while shooting for the base of the tree
L : the distance of the gauge with the tree
α : angle formed by a flat line with a shot line to the peak of the tree
Tm : Observer's Eye Height

**Analysis of Stands Growth**

Stand growth analysis was conducted using the growth model commonly used to describe the relationship of tree height (Y) with tree age (X), diameter (Y) with age (X), and based area (Y) with age (X). The analysis refers to Richard's model, and it is written as follows:

$$\text{Richard's model} : Y = A\,(1 - a0\, e^{-a1\, X^{1/1-m}})$$

where: Y : height/diameter/area of the based area of the tree or stand
X : age of stands
a0 & a1 : constants
A : asymptote value of growth
e : 2.7183
m : alometric constant (m = 2/3)

**Mean Annual Increment (MAI)**

In order to determine the mean score of increment in several dimensions of *Leda* growth through MAI (Mean Annual Increment) calculation:

$$MAI\ h = h / X$$
$$MAI\ d = d / X$$
$$MAI\ BA = BA / X$$

Where: h : tree height at 't' age (m)
d : tree diameter at 't'age (cm)
*BA* : based area at 't' age (cm^2)
X : age (year)

**Current Annual Incerment**

The increment over a period of one year can be written in CAI (Current Annual Increment) notation and it can be best described as the accretion of tree's growth or stands from per-year. It can be calculated by the formula:

$$CAI\ h = (ht2 - h1) / (X2-X1)$$
$$CAI\ d = (d2-d1) / (X2-X1)$$
$$CAI\ ba = (ba\ 2 - ba\ 1) / (X2 - X1)$$

Where: h1 : tree height at 't' age (m)
d1 : 1st year diameter (cm)
d2 : 2nd year diameter (cm)
*ba* : based area at 't' age (cm^2)
X : age (year)

**3. Results and Discussion**

It is called 3 plots x 5 age levels (plants aged 1 year, 2 years, 3 years, 5 years, and 7 years). The size of each plot is 0.04 ha. The number of individual hectares of plants ranges from 775 to 1350, or an average of 877 individuals per hectare.

**Leda Growth (Eucalyptus deglupta Blume)**

Leda Growth is defined as the increase in the dimensions of trees or forest stands over a certain period of time (Vanclay, 1994). Stand growth is the process of increasing a stand's size over a certain period of time. The amount of growth, which is also called stand, can be seen from the parameters of height, diameter, or volume (Mindawati et al. 2010). Therefore, the growth dynamics of trees or stands can be estimated using a mathematical model of the relationship between growth parameters: number of trees, base area, diameter, height, and age. The equation used to describe the relationship of *Eucalyptus deglupta Blume* growth with age using Richard's model Some researchers use the Chapman-Richards model (Enzinga and Jiang 2019; Popoola and Adesoye 2012; Sharma et al. 2019).

**Table 1.** *Leda Growth* Model (*Eucalyptus deglupta Blume*) on the use of equations Mathematical Model of Richard

| Model | Model Richard | Remarks |
|---|---|---|
| Relationship of Height (Y) and Age (X) | Y = 25 (1-0.76 e^ -0.267 X) ^3 | $R^2$ = 0.903 |
| Relationship of Diameter (Y) and Age (X) | Y = 50(1-0.680 e^ -0.100 X)^3 | $R^2$ = 0.673 |
| Relationship of Based Area (BA) (Y) and Age (X) | Y = 25 (1-1.009 e^ -0.276 X) ^3 | $R^2$ = 0.952 |

The value of the coefficient of determination (R2) of Richard's model shows a value greater than 65%. It means that the independent variable (age) can explain at least 65% of the total variation of the dependent variable (growth dimension). Extrapolation from Richard's equation to describe the growth dimensions of height, diameter, and Based Area (BA) can be seen in Table 2.

As seen in Table 2, the growth in height, the diameter of the trunk, and the area of the base plane tend to increase with increasing age. There is a relatively linear relationship between height, diameter, and volume with the age of the stand. This means that the greater the age of the stand, the higher the growth dimension (Soares et al. 2020).

**Table 2.** Mean growth stands of *Leda* (*Eucalyptus deglupta Blume*) using Richard Equation Model

| Age (years) | Total height (m) | Diameter (cm) | *BA* (cm^2) |
|---|---|---|---|
| 1 | 1.8 | 2.8 | 0.3 |
| 2 | 4.3 | 4.4 | 1.8 |
| 3 | 7.2 | 6.1 | 4.4 |
| 4 | 10.1 | 8.1 | 7.4 |
| 5 | 12.8 | 10.2 | 10.4 |
| 6 | 15.2 | 12.3 | 13.2 |
| 7 | 17.2 | 14.6 | 15.6 |
| 8 | 18.9 | 16.8 | 17.6 |
| 9 | 20.2 | 18.9 | 19.2 |
| 10 | 21.3 | 21.1 | 20.5 |

The growth of 7-year-old Leda reached 17.2 m high, 14.6 cm diameter, and Based Area (BA) 15.6 $cm^2$. (Hartati, 2008) explained that the 7-year-old Leda planted in Sabah, Malaysia, has a height of 25.4 m and a diameter of 19.5 cm, while in Bangladesh, at the age of 2 years, it reached a height of 8 m and a diameter of 15 cm.

The age of forests can significantly change the organic matter and nutrients of the soil. At ages 10–15, Euchalyptus has more significant growth than at ages 2–6 (Xu et al. 2020). The solum depth and high clay content become inhibitors for the rooting of Leda, making it ineffective in absorbing nutrients (Hartati 2008). The volume ratio of sand, silt, and clay in the soil affects the growth of Euchalyptus. The mud content provides significant growth compared to soils with high clay content (Xu et al. 2020).

In addition, the region of research with climate type C is less suitable for the growth of Leda type A-B climates (Rosmarlinasiah 2019). (Tirkaamiana 2020) also explained that the interaction of genes, environment, and silviculture techniques largely determines the optimal growth of trees. The structure of stands has a major influence on forest growth and productivity. The relationship between structural diversity, including tree size distribution and genetic or species diversity, and forest productivity has contrasting relationships such as positive, neutral, and negative (Forrester and Bauhus 2016).

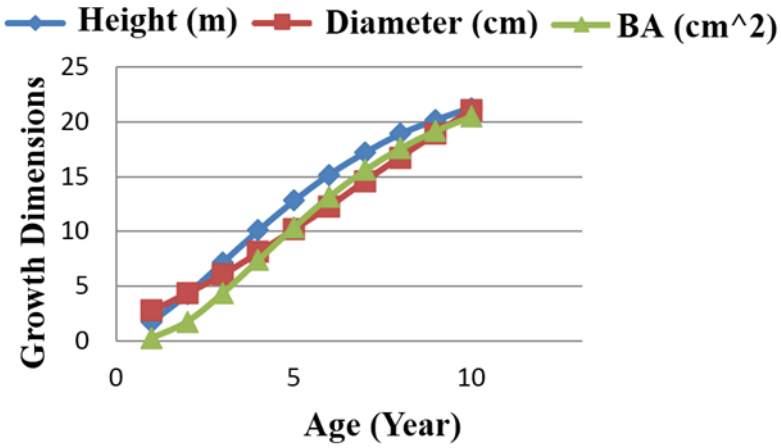


Figure ( 3 ) : Diameter Growth Curve, Based Area (BA), and Leda Height

The Leda growth curve in Figure 3 explains that the height and area of the based area are curvilinear, while the diameter is linear. The trunk's diameter will increase linearly with age, while the area of the base plane and height of the tree will also increase with age, but the increase of these two dimensions decreases further so that it tends to curl (Marquis et al. 2021). To be able to determine the growing accretion of each of these dimensions (Height, diameter, and base area) can be seen in the Mean Annual Increment (MAI) calculation and the current annual increment (CAI), as seen in Table 3.

**Leda (The Accretion of growth)**

Leda used in this study is the Mean Annual Increment (MAI) and Current Annual Increment (CAI) on height growth, diameter, and based area dimensions.

**Table 3.** Height accretion *Leda* (*Eucalyptus deglupta Blume*) age 1 to 10 years

| Age (years) | Height (meters) | | Diameter (cm) | | *BA* (cm^2) | |
|---|---|---|---|---|---|---|
| | MAI | CAI | MAI | CAI | MAI | CAI |
| 1 | 1.80 | 0 | 2.80 | 0 | 0.30 | 0 |
| 2 | 2.15 | 2.50 | 2.20 | 1.60 | 0.90 | 1.50 |
| 3 | 2.40 | 2.90 | 2.03 | 1.70 | 1.47 | 2.60 |
| 4 | 2.53 | 2.90 | 2.025 | 2.00 | 1.85 | 3.00 |
| 5 | 2.56 | 2.70 | 2.04 | 2.10 | 2.08 | 3.00 |
| 6 | 2.53 | 2.40 | 2.05 | 2.10 | 2.20 | 2.80 |
| 7 | 2.46 | 2.00 | 2.09 | 2.30 | 2.23 | 2.40 |
| 8 | 2.36 | 1.70 | 2.10 | 2.20 | 2.20 | 2.00 |
| 9 | 2.24 | 1.30 | 2.10 | 2.10 | 2.13 | 1.60 |
| 10 | 2.13 | 1.10 | 2.11 | 2.20 | 2.05 | 1.30 |
| **Mean** | **2.32** | **2.17** | **2.15** | **2.03** | **1.74** | **2.24** |

The mean annual increment (MAI) reaches its maximum value (2.56 m) at 5 years. After that, it shows gradually decreased accretion. The maximum Current Annual Increment (CAI) at the age of 3 and 4 years is 2.9 meters, which is slowly reduced in the age of 5 to 2.7 meters. Soil nutrient deficiencies and accumulating water at the soil's surface can decrease tree growth (McAlister and Timmer 1998; Wolken et al. 2011). The Leda tree in Philipina can reach a height of 78 m and a circumference of 7 m (2.22 m in diameter). The mean height of Leda, age 17 years, at the research site reached only 19.94 m with 321.3 trees per hectare (Hartati 2008). It is further explained that a well-maintained Leda can reach a height of 45 meters with a diameter of 51 cm at the age of 17 years. Soil

and climatic conditions determine the growth of the tree height, not the density of the stand (Marquis et al., 2021; Payette, 2007). Climate change is affecting growth and increasing the occurrence of frost diseases (Liu et al. 2018; Ma et al. 2019).

The trunk's diameter is the dimension of the accretion of the trunk to the side part. It is because wood is a plant with cambium that does cell division towards the side, so there is a diameter increase in the trunk (Husch 1963). The results of the analysis of the accretion of growth data diameter Leda explained that the maximum Mean Annual Increment (MAI) diameter accretion is achieved at a year old and tends to decrease in increments, with an average of 2.15. In contrast, the mean current annual increment (CAI) increased by 2.03 cm. The development of the tree's diameter in the stand is related to the degree of density. The higher the density, the slower the diameter growth. High density will decrease photosynthetic activity, which can affect trunk development (Hardjana, 2013). Competition for nutrients, water, or a combination of both can affect the diameter of the stem in Eucalyptus marginata (Bhandari et al., 2021).

Mean Annual Increment (MAI) and Current Annual Increment (CAI) showed that the broad range of Leda-based areas (BA) tends to increase over the next 5 to 6 years. Then, it slowly decreases until at ten years of age, the mean annual increment (MAI) based area (BA) is 2.05 and the current annual increment (CAI) based area (BA) is 1.30. The crown position of the Leda tree is parabolic (Rosmarlinasiah 2019); this indicates that the tree's crown position will come into contact faster. When the based area (BA) of the tree trunk increases, it will also be followed by the development of the diameter of the crown position, so the necessary action when the crown positions touch each other is required to do the pruning. Pruning exerts a significant effect on the allometric relationship between the diameter, height, and width of the crown of Eucalyptus marginata (Bhandari et al., 2021). The based area (BA) is an overview of the space used by each tree that composes the stand. According to Sahid (2009) stand density can be known through the base area (BA). The information on the based area (BA) is required to set the timing of the thinning and trimming. The absence of trimming will cause the density to increase gradually and will affect the development of the trunk's diameter (Aldafiana and Murniyati 2021). Pruning is a common forest management technique. This technique has the potential to be used in silviculture to increase SOC (Soil Organic Carbon) and affect ecological processes with changes in biotic and abiotic characteristics, e.g., productivity, root density, solar radiation, and litterfall inputs (Dang et al. 2018; Gong et al. 2021; Wic Baena et al. 2013).

## 4. Conclusion

At the age of 7 years, Leda has reached a growth rate with a trunk diameter between 10 cm and under 20 cm. Leda reaches the growth rate of a tree at the age of 10 years (trunk diameter ≥ 20 cm), reaches 21.1 cm, height 21.3 m, and base area of the tree 20.5 $cm^2$. The rapid growth of Leda is described by MAI and CAI values at the dimensions of height, diameter, and base area of the tree, respectively: 2.46 cm; 2.00 m; 2.09 cm; 2.30 cm; 2.23 cm2; 2.40 $cm^2$. Growth optimality is achieved at that age, so considerations can be made in determining policies to develop Leda in a region.

**Conflict of interest**:
The authors declare no conflict of interest.

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