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Growth Increment and Slenderness of 15-Year-Old Ulin (*Eusideroxylon zwageri* T. et B.) Plants in the *Ex-situ* Conservation Area of the State Agricultural Polytechnic of Samarinda

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Abstract: This research was motivated by the lack of information regarding growth dynamics, increment rates, and the slenderness ratio of Ulin (*Eusideroxylon zwageri* T. et B.) at the juvenile stage in an *ex-situ* conservation area. Ulin is an endemic tree species of Bornean tropical rainforests that is categorized as rare and protected, making conservation efforts and growth evaluation essential. The purpose of this study was to determine the diameter increment, height increment, and slenderness ratio of 15 year old Ulin plants. The research was conducted in the *Ex-situ* Conservation Area of the State Agricultural Polytechnic of Samarinda by measuring 68 individual plant samples. The observed parameters included stem diameter, total height, annual increment, and the slenderness ratio (H/D). The results showed that the average diameter of the 15 year old Ulin plants reached 9.78 cm, and the average total height reached 10.24 m. The average annual increments were recorded at 0.65 cm/year for diameter and 0.68 m/year for height. Meanwhile, the stand slenderness ratio ranged from 72.23 to 143.33 with an average value of 108.70, indicating that the trees grew under relatively intense growing space competition.

Keywords: *Eusideroxylon zwageri, Increment, Height, Diameter, Slenderness, Ex-situ Conservation.*

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I. INTRODUCTION

East Kalimantan is a region where the majority of its territory is still covered by tropical rain forest ecosystems. This area possesses a very high level of plant species diversity, where hundreds of flora species with various biological variations can be found within a single hectare. One of the endemic tree species as well as a regional mascot flora that characterizes the Bornean tropical rainforest is Ulin (*Eusideroxylon zwageri* T. et B.) (Suroso et al., 2021

Ulin (Ironwood) is known as a high economic value utility timber due to its strength, Class I durability, and resistance to weather and wood-destroying organisms (Prasetia et al., 2020). Naturally, the geographical distribution of Ulin includes South Sumatra, Jambi, Bangka Belitung, and almost the entire island of Kalimantan. However, the existence of Ulin populations in their natural habitat (*in-situ*) is increasingly threatened and experiencing significant degradation. This population decline is triggered by a combination of its naturally very slow growth characteristics (*slow-growing species*), low germination success rates and natural regeneration under the stand, and high exploitation pressure and illegal logging without being balanced by adequate cultivation programs (Kusmana, 2021)

Efforts to rescue the germplasm of Ulin are absolutely necessary to counter the threat of extinction and maintain the availability of its genetic reserves. In general, forest tree conservation is pursued through two main approaches, namely *in-situ* conservation within its native area and *ex-situ* conservation outside its natural habitat. Considering that *in-situ* conservation areas often face obstacles such as forest security disturbances and encroachment activities, the development of *ex-situ* conservation such as introductory planting in arboretums or campus conservation areas

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becomes one of the strategic alternatives for species rescue (Sari et al., 2021; Hidayat et al., 2022)

Nevertheless, the success of developing *ex-situ* Ulin stands needs to be evaluated periodically through growth studies, which are generally reflected by the magnitude of diameter and height increments. Information regarding increments at various age levels is very important to understand the adaptability of Ulin in new environments. A number of previous studies indicate that the growth rate of Ulin varies depending on plant age and site conditions; for instance, studies at you ng to juvenile ages show specific increment patterns that continue to adapt as the stand age increases (Pamoengkas et al., 2021; Nirsatmanto et al., 2022).

In addition to linear growth rates (diameter and height), another important aspect rarely explored in depth in 15-year-old Ulin plants is the slenderness ratio (the ratio of tree height to stem diameter H/D). The slenderness ratio is an important indicator in forest biometrics to diagnose the level of competition among trees within a stand while evaluating the mechanical stability of plants against the risk of windthrow). Stands with excessively high slenderness values indicate that trees grow under vertical stress due to tight light competition, whereas balanced values reflect sturdy stem growth (Castedo-Dorado et al., 2020).

Based on this background, this study aims to determine the magnitude of diameter increment, height increment, and the slenderness level of 15-year-old Ulin (*Eusideroxylon zwageri*) plants in the *Ex-situ* Conservation Area of the State Agricultural Polytechnic of Samarinda. The results of this study are expected to provide scientific information for forest managers, academics, and practitioners in formulating silvicultural strategies, stand management, and the continuity of future Ulin conservation programs.

II. RESEARCH METHODOLOGY

➢ *Location and Time*

This research was conducted in the *Ex-situ* Conservation Area of the State Agricultural Polytechnic of Samarinda, East Kalimantan Province. The research activities, which included field measurements, periodic monitoring, and growth data collection, were carried out over six months.

➢ *Tools and Materials*

- *Tools:*

✓ Phi band (to measure tree stem diameter precisely).
✓ Height pole / measuring staff (to measure total plant height).
✓ Field stationery and tally sheets.
✓ Data processing software (statistical and computer).

- *Materials:*

15-year-old Ulin (*Eusideroxylon zwageri* T. et B.) Plants growing in the *ex-situ* conservation area of the State Agricultural Polytechnic of Samarinda.

➢ *Procedures and Data Collection Techniques*

Field data collection was carried out through direct measurement of stand growth parameters. The observed parameters included:

- Stem Diameter (D): Measured at a specific diameter level (diameter at breast height/dbh) using a phi band
- Total Plant Height (H): Measured from the stem base above ground level to the highest crown tip using a height pole.
- Slenderness Ratio: The slenderness parameter was calculated based on the ratio between plant height and stem diameter.

➢ *Data Analysis and Calculation Formulas*

Field measurement data were analyzed quantitatively descriptively and using basic statistics to determine mean values, standard deviation, diversity levels, increment magnitudes, and stand slenderness ratios. The formulas used include:

- *Mean Value*

$$\bar{x} = \frac{\sum x}{n}$$

Where:

✓ $\bar{x}$ = Mean value (height or diameter)
✓ Σx = Total sum of individual observation values
✓ n = Total number of individual observation samples

- *Standard Deviation*

To determine the distribution or variation of data from its mean:

$$Sd = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n-1}}$$

Where:

✓ Sd = Standard deviation
✓ N = Number of individual observations
✓ Σx = Sum of individual values
✓ ΣX^2 = Sum of squared individual values

- *Growth Increment*

Mean Annual Increment (MAI):

$$i_x = \frac{X_t}{t}$$

Where:

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- ✓ i_x = Mean annual increment
- ✓ X_t = Parameter value at a specific time/age
- ✓ t = Plant age (years)

- *Slenderness Ratio*

The slenderness (stability degree) of Ulin plants was calculated using the following formula (Ruchaemi, 2002):

$$Slenderness\ ratio = \frac{H\ (m)}{d\ (cm)}\ x\ 100$$

Where:

- ✓ SR = Slenderness ratio (unitless or adjusted in cm/cm or m/cm)
- ✓ H = Total plant height
- ✓ D = diameter

Stand Stability Interpretation Criteria**:** To interpret the stand stability calculation results, tree slenderness measurements according to Ruchaemi (2002) are used as follows:

- h/d < 100 : Stable tree
- h/d > 100 : Unstable tree

- Mean Annual Increment (MAI) (Ruchaemi, 2002):

$$i_x = \frac{x_t}{t}$$

Where:

- ✓ i_x = Mean annual increment
- ✓ X_t = Parameter value at a specific time/age, and
- ✓ t = Plant age at the time of measurement

III. RESULTS AND DISCUSSION

➢ *Growth Characteristics of Ulin Plants*

Field measurements of 68 individual 15-year-old Ulin (*Eusideroxylon zwageri*) samples in the *Ex-situ* Conservation Area of the State Agricultural Polytechnic of Samarinda showed quite dynamic diameter and height growth variations. In detail, the descriptive statistical values of these measurement parameters are presented in Table 1.

Table 1 Measurement Results of Diameter and Height of 15-Year-Old Ulin Plants

Variable	Data				
	N	Max	Min	Mean	SD
Diameter (cm)	68	19,30	3,20	9,78	3,28
Height (m)	68	14,96	3,78	10,24	2,56

Based on Table 1, the average diameter of 15-year-old Ulin plants reached 9.78 cm with a standard deviation of 3.28, while the average plant height reached 10.24 m with a standard deviation of 2.56. The range of maximum and minimum values indicates growth variation among individual plants despite being planted at the same age and location. This variation is generally influenced by microclimate factors, solar radiation intensity received by each individual tree, and edaphic soil variation conditions in the *ex-situ* conservation area. This condition is in line with the opinion of Suharja & Jumansi (2017), that the growth of Ulin stands at the juvenile phase is very sensitive to growing space competition and shading from surrounding vegetation.

➢ *Annual Growth Increment*

Increment is an important parameter to evaluate the annual growth rate of a tree species. Based on data analysis results, the annual diameter and height increments of Ulin plants are presented in Table 2.

Table 2 Annual Increment of 15-Year-Old Ulin Plants

Variable	Data				
	N	Max	Min	Mean	SD
Diameter (cm)	68	1,29	0,21	0,65	0,22
Height (m)	68	1,00	0,25	0,68	0,17

Based on Table 2, the average diameter increment of Ulin plants was recorded at 0.65 cm/year, with the highest diameter increment reaching 1.29 cm/year} and the lowest 0.21cm/year. Meanwhile, the average height increment reached 0.68 m/year, ranging from 0.25m/year to 1.00 m/year. When compared with previous research results on younger Ulin plants (such as at age 9 in the same location which recorded an average height increment of 0.78 m and diameter of 0.84 cm (Hasanudin et al., 2021) as well as studies by Abdurachman (2012) and Suharja & Jumansi (2017), the Ulin increment rate shows a dynamic trend along with increasing stand age. At age 15, the diameter increment rate begins to show stability in tandem with stem thickening processes, while the height increment begins to slow down as tree energy starts to be allocated for crown expansion and lateral competition among individuals.

➢ *Slenderness Ratio of Ulin Plants*

The slenderness ratio (the ratio of tree height to stem diameter H/D is an important biometric indicator to assess stand mechanical stability against the risk of lodging or breaking due to wind, while reflecting the level of growing space competition within the stand (Pretzsch, 2022; Weiskittel et al., 2020). The recap of slenderness ratio calculations is presented in Table 3.

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Table 3 Slenderness Ratio of 15-Year-Old Ulin Plants

Variable	Data				
	N	Max	Min	Mean	SD
Slenderness	68	143,33	72,23	108,70	18,57

Based on Table 3, the slenderness ratio of Ulin plants ranges from 72.23 to 143.33, with an average value of 108.70 and a standard deviation of 18.57. In silviculture and forest biometrics, slenderness values above 80 to 100 indicate that most individual trees grow under relatively intense light competition conditions, causing stems to tend to grow taller relative to their diameter (Castedo-Dorado et al., 2020). The relationship pattern between diameter and height of Ulin plants can also be seen visually through point distribution on the Diameter and Height Relationship Graph (Figure 1).

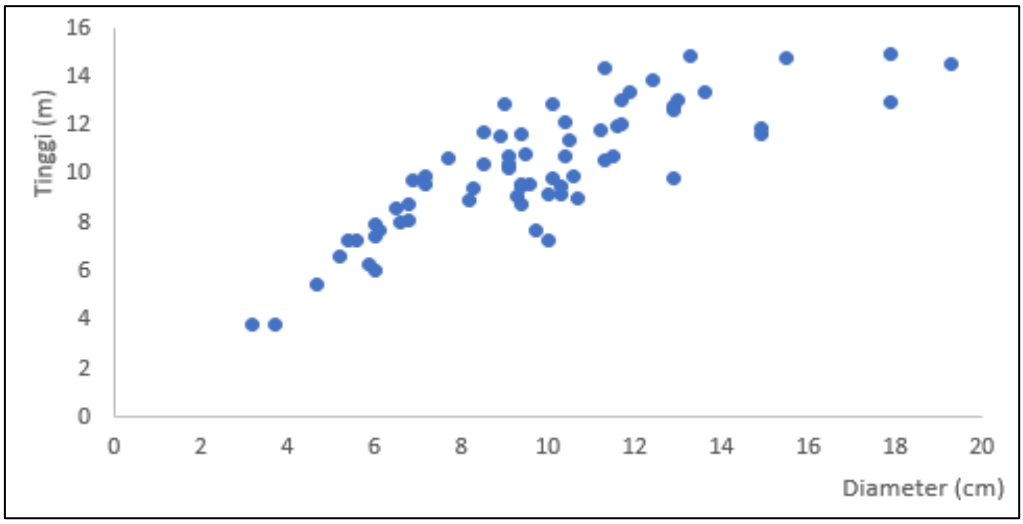


Fig 1 Distribution Graph of the Relationship Between Diameter and Height of 15-Year-Old Ulin Plants.

Based on the distribution graph above (Figure 1), a positive correlation pattern is visible between increases in tree diameter and height. Individual trees with larger diameters are generally followed by more optimal height attainment. However, the varying point distribution in the intermediate diameter class indicates that some plants experienced more dominant height growth spurts due to shading or canopy competition from surrounding plants, resulting in high slenderness values (reaching 143.33). This suggests the necessity for subsequent stand management actions, such as selective thinning in the future, to provide more optimal growing space for individual Ulin trees with the best growth potential in the *ex-situ* conservation area (Cremer et al., 2018; Kurniaty et al., 2023).

IV. CONCLUSION AND RECOMMENDATIONS

➢ *Conclusion*

Based on the results of data analysis and discussion regarding the increment and slenderness of 15-year-old Ulin (*Eusideroxylon zwageri*) Plants in the *Ex-situ* Conservation Area of the State Agricultural Polytechnic of Samarinda, the following conclusions can be drawn:

- The average growth of Ulin plants at age 15 reached 9.78 cm for diameter and 10.24 m for total height.
- The average annual increment of Ulin plants showed a diameter increment rate of 0.65 cm/year and a height increment of 0.68 m/year.
- The slenderness ratio of Ulin plants ranged from 72.23 to 143.33 with an average of 108.70, indicating that the stand is under relatively intense growing space competition.

➢ *Recommendations*

- Considering the high slenderness ratio in several individuals due to light and growing space competition, it is recommended that *ex-situ* conservation managers plan subsequent maintenance activities such as selective thinning.
- Periodic and continuous growth monitoring and measurements need to be carried out to evaluate the dynamics of Ulin increments in subsequent age phases.

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