

Growth and survival rate analysis of *Avicennia lanata* seedlings in Mempawah mangrove areas, West Kalimantan, Indonesia

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Abstract. *Avicennia lanata* is one of the true mangrove species with limited distribution only in Southeast Asia. This species is listed as vulnerable according to the IUCN Redlist due to deforestation and declining habitat. Growth and survival rate studies of *A. lanata* seedlings were conducted in the mangrove area of Sungai Pinyuh and Peniti, Mempawah Regency, West Kalimantan. The growth parameters observed were: stem diameter, total height and survival rate at the end of the observation. Observations were conducted at 2 week intervals and in sessions of 3 months. The results showed that the growth rate of *A. lanata* seedlings based on the diameter and height of the seedling varied in each observation period. The average diameter growth of *A. lanata* ranged from 0.01 to 0.16 cm month⁻¹ and the average height growth ranged from 0.05 to 3.55 cm month⁻¹ at the two study sites. There was no significant difference in the growth rate of diameter (ANOVA: $F=3.508$, $p>0.05$) and high (ANOVA: $F=12.053$, $p>0.05$) of *A. lanata* seedlings between the Sungai Pinyuh and Peniti locations in Mempawah, West Kalimantan. *A. lanata* seedling survival rates in the mangrove forest area of Mempawah District ranged from 73.33 to 86.67%.

Key Words: diameter growth rate, height growth rate, Peniti, Sungai Pinyuh, true mangrove.

Introduction. Mangrove ecosystem degradation in the last few decades has occurred in Indonesia's coastal ecosystems, caused by the intensity of the exploitation by human population in the coastal areas, including settlements and infrastructures. In many cases in Indonesia, mangroves are used by timber processing industries such as residential building, boat construction and for firewood. Mangrove ecosystem conversion into ponds is also a cause of mangrove declining in Indonesia.

Mangrove forests play an important role in the fisheries economy in the tropical area. Mangroves have high organic material productivity and produce a lot of detritus, thus their ecosystem is very rich in nutrients sources (LIPI 2014). Mangrove forests have major environmental benefits: they raise a barrier against the tidal waves and wind from the sea, they reduce seawater intrusion and they offer a habitat for various species of estuary fish, water birds, crabs and primates. The decline of mangrove forests area needs to be assessed, given the significant role of this ecosystem, related to biota and human habitats development in coastal areas.

Avicennia lanata is a true mangrove with limited distribution in Southeast Asia (Giesen et al 2006). This species is classified as vulnerable due to its habitat degradation. Research and conservation plans are needed (IUCN 2019). In Indonesia, the distribution of this species according to Giesen et al (2006) was found in Bunaken, North Sulawesi and possibly in the western part of Indonesia, in Kalimantan and Sumatra. According to Khairuddin et al (2015), *A. lanata* species were found at three research stations in Sungai Pinyuh, Mempawah Timur and Mempawah Hilir in the Mempawah District. A report (unpublished) from Rafdinal in 2018 found *A. lanata* species in Sungai Pinyuh Subdistrict and Peniti Village, Mempawah District. Mangrove vegetation on the investigated sites had been damaged by an intensive timber use due to residential activities and to sea border

roads opening. On the explored sites, *A. lanata* was the dominant species, sharing the seaward zones, with other mangrove species, such as *A. officinalis* and *Acanthus ilicifolius*.

Growth rate is one of the important factors describing the forest dynamics. Many factors affect the vegetation growth in a tropical forest, including the patch location, stand age (Davis & Jhonson 1987), nutrition and light (Toledo et al 2011) and soil fertility (Russo et al 2005). Research on *A. lanata* conservation in Sungai Pinyuh Subdistrict and Peniti Village, Mempawah District has a magnified impact derived from the mangrove ecosystem's initial seaward zone occupancy by this pioneer species. Thus, *A. lanata* becomes the first barrier against the seawater intrusion and protects the mangrove species behind it, which have a narrower range of tolerance and adaptability to seawater intrusion (Giesen et al 2006). Research on growth and survival analysis of *A. lanata* seedlings can provide new information, crucial for the restoration of mangrove ecosystems and for the protection of local and endemic species of Southeast Asia. This research aimed to analyze the survival and growth rate of *A. lanata* in Mempawah mangrove area, Mempawah Regency, West Kalimantan, Indonesia.

Material and Method

Description of the study sites. This research was conducted at Sungai Pinyuh and Peniti in Mempawah mangrove area, Mempawah Regency, West Kalimantan, Indonesia. According to the Schmidt & Ferguson (1951) climate classifications, the coastal areas of Mempawah Regency are classified as wet areas of type A climate, with temperatures ranging from 20 to 34°C. Rainfall intensity is quite high between 2,000 and 3,000 mm with 80 to 200 rainy days a year. The condition of the mangrove forest area in Mempawah District is strongly influenced by tidal waves and the surrounding river flow. In this area, two high and low semi-daily dominance tides occur each day. When the tide rises, the flow of water from the west (Natuna Sea) enters the estuary of the Peniti River and other mangrove areas, while at low tide the water flow originating from the surrounding rivers enters the estuary of the Peniti River towards the Natuna Sea (Figure 1).

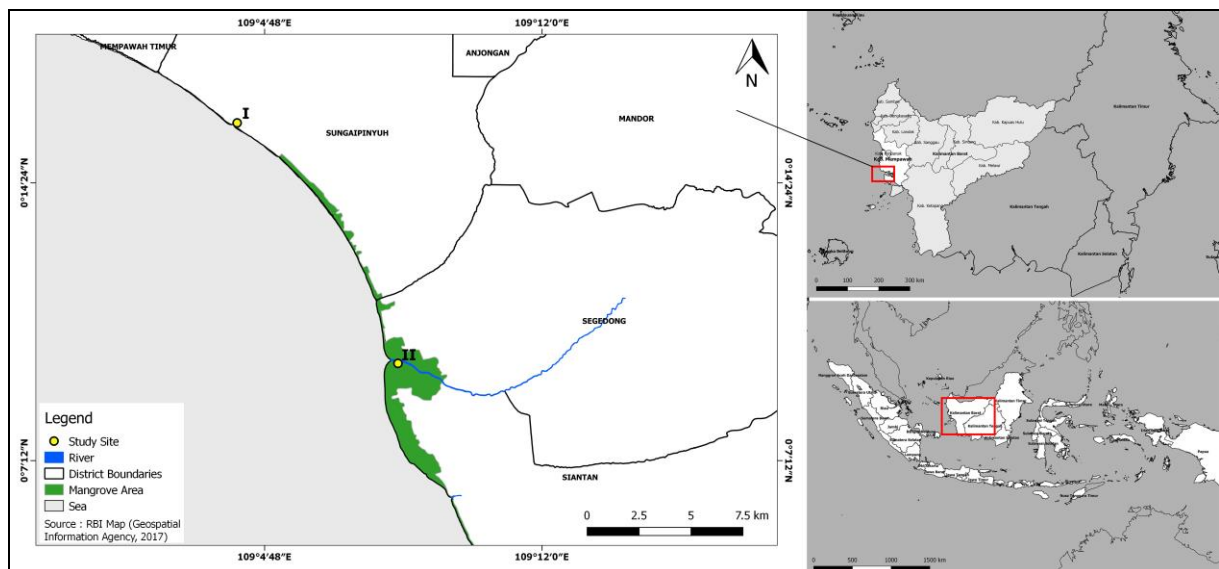


Figure 1. Research location at Mempawah mangroves area, Mempawah Regency.

Survival and growth rate. This research was carried out by repeated census techniques on *A. lanata* seedlings in the Mempawah mangrove forest area at the Sungai Pinyuh and Peniti, with a 15 *A. lanata* seedlings sample at each location. Estimation of seedling growth was based on the average growth of stem diameter and on the total height of seedlings, counted at census intervals (seven daily observations by period, T1 to T7, every 2 weeks). The survival rate estimation was based on the number of

individuals still living at the end of the study. The average growth was estimated as the average relative diameter change during the observation period. Relative diameter growth is measured in mm/month. The relative growth of seedlings is calculated using the formula Hunt (1982):

$$\text{RDGR} = (\text{Ln Dbh}_0 - \text{Ln Dbh}_1) / \Delta t$$

Where:

RDGR - relative diameter growth rate (mm month^{-1});

Dbh_1 - diameter counts at the end of the measurement (mm);

Dbh_0 - diameter counts at the beginning of the measurement (mm);

Δt - observation period (month).

Population mortality was estimated through the Sheil & May (1996) equation:

$$N_t = N_o (1-m)^t$$

Where:

N_o and N_t - population counts at the beginning and at the end of the measurement interval, t . Thus, m (mortality) may be estimated as:

$$m = 1 - (N_t/N_o)^{1/t}$$

Constant fraction m ranged from ($1 \geq m \geq 0$).

Edaphic factor. Soil sampling was conducted by purposive random sampling at the research sites. Five soil sampling points were taken to a depth of 30 cm, with intervals of depth 0-5, 5-10, 10-20 and 20-30 cm at each location. Soil samples were taken sequentially from the top layer to the bottom layer using a 5 x 5 x 5 cm soil ring sample. Soil rings were placed on each soil layer consistently to obtain representative examples. After the soil samples were taken and placed into plastic, their wet weight was measured, then the samples were taken to the laboratory for further analysis. In the laboratory, the soil samples were dried in an oven at 105°C for 2 days, then their dry weight was estimated. The weight content of the soil was calculated using the Hairiyah & Rahayu (2007) formulation. Soil carbon measurements (% C) were carried out in a circle of 5 cm in each corner of the sample plot measuring 10 x 10 m, plus one circle in the middle of the 10 x 10 m plot. Soil samples were also taken for analysis of physical and chemical properties. The physical-chemical properties of the soil were measured as follows: soil texture (percentage of clay, sand and dust content) by the pipette and sieve method; soil pH by comparison to H₂O and KCl; organic C by the Walkley and Black method (Soil Research Institute 2005) using a spectrophotometer; total N by the Kjeldahl method; available P by the Bray method (Bray & Kurtz 1945), available Si by the calorimeter method; K, Ca, Mg, by the cation exchange capacity method; Al and Fe by concentration determination. Litter nutrient measurements were carried out once a month for five months. Measurement of litter nutrient content included C, N, and P. Analysis of the physical-chemical properties of soil and litter nutrient were performed at the Soil Laboratory of the Faculty of Agriculture, Tanjungpura University and the Chemistry Laboratory of the Faculty Mathematics and Natural Sciences, Tanjungpura University, Pontianak.

Statistical analysis. Comparison of growth rate of *A. lanata* for each location was analyzed using one way ANOVA. The differences were evaluated at $P < 0.05$. The relationship between the growth rate of *A. lanata* and the edaphic factor were analyzed using Spearman's regression and correlation. All statistical analyzes used the SPSS Graduate Pack™ 14.0 program for windows. A difference was evaluated at $P < 0.05$.

Results and Discussion

Survival and growth rate. The results showed that the survival rate of *A. lanata* was 73.33%, with the highest mortality at the fifth observation (T5), in Sungai Pinyuh. The survival rate of *A. lanata* was higher in Peniti with 86.67%, with the highest mortality found at the fourth observation (T4) (Figure 2a). Seedling mortality at both locations was in a low category (Figure 2b). The difference in survival rates and mortality values between the two locations was caused by the external disturbance conditions such as from humans and mangrove crabs (keramak) that live at the location.

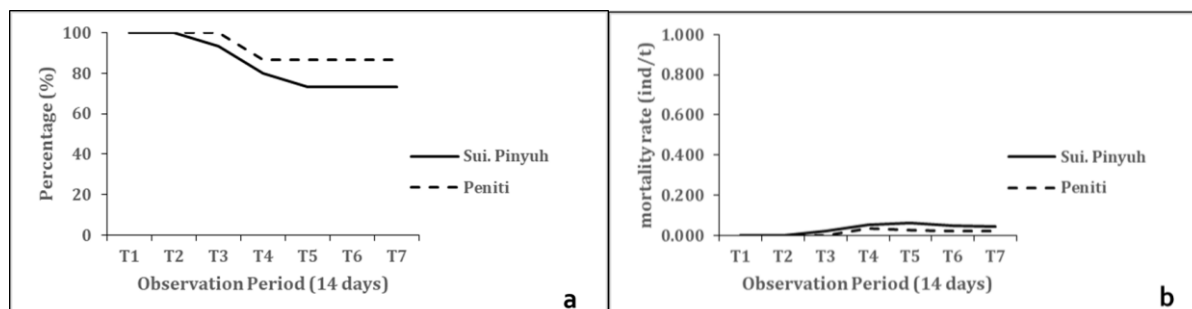


Figure 2. Survival rate (a) and mortality rate (b) of *Avicennia lanata* mangrove seedlings at the Sungai Pinyuh and Peniti mangrove forests.

The survival rates of *A. lanata* seedlings from both locations are lower than the survival rate of *Avicennia alba* seedling in the mangrove forests of Carey Island, Peninsular Malaysia (Affandi et al 2010). The average survival rate at both locations was also lower than the survival rate of *Avicennia germinans* seedling (Costa et al 2016) on mangrove soils. However, the results found a higher survival rate than for some other species and locations (Table 1).

Table 1
Comparison of survival rates percentage from different mangrove species

Location	Species	Survival rate	Source
Amazon Coast, Brazil	<i>Avicennia germinans</i>	77.7%	Costa et al (2016)
	<i>Rhizophora mangel</i>	69.1%	
	<i>Laguncularia racemosa</i>	54.9%	
Silvofishery Pond, Semarang	<i>Avicennia marina</i>	5.0%	Hastuti & Hastuti (2018a)
Carey Island, Peninsular Malaysia	<i>Avicennia alba</i>	91.66%	Alfandi et al (2010)
Baluti, Philipina	<i>Rhizophora apiculata</i>	77.77% ⁴	Galang et al (2003)
	<i>Rhizophora mucronata</i>	77.77% ⁴	
Sungai Pinyuh, Mempawah	<i>Avicennia lanata</i>	73.33% ⁵	Present study
Peniti, Mempawah	<i>Avicennia lanata</i>	86.67% ⁵	Present study

The results of the ANOVA analysis on mangrove seedling diameter and height growth indicated no significant difference between the growth of mangrove seedlings in both locations (ANOVA: $F=3.508$, $p>0.05$) and mangrove seedling height in both locations (ANOVA: $F=12.053$, $p>0.05$). Randomly selected seedlings from both locations have a range of diameter values, at the initial observation, of 0.15-0.36 cm and the total height of seedlings of 7.02-19.16 cm.

The diameter growth rate from both locations showed growth rate fluctuations for each observation (Figure 3). The average diameter growth of seedling in Mempawah mangrove forest ranged from 0.01 to 0.16 cm month⁻¹. The highest average diameter growth occurred in the second and third observations (T2 and T3) at both locations. The

range of seedling diameter growth at the Sungai Pinyuh location is of 0.01-0.23 cm observation⁻¹, which is an average of 0.07±0.03 cm month⁻¹, and seedlings at the Peniti location had a range of diameter growth of 0.04 to 0.10 cm observation⁻¹ period, with an average of 0.07±0.01 cm month⁻¹. The diameter growth rate of *A. lanata* seedlings in this study was lower compared to *A. marina* and *R. mucronata* seedlings in the Hastuti & Hastuti (2018b) study, with a range of seedling diameter growth of 0.02 to 1.26 cm period⁻¹ for of *A. marina* and of 0.01-1.78 cm period⁻¹ for *R. mucronata*.

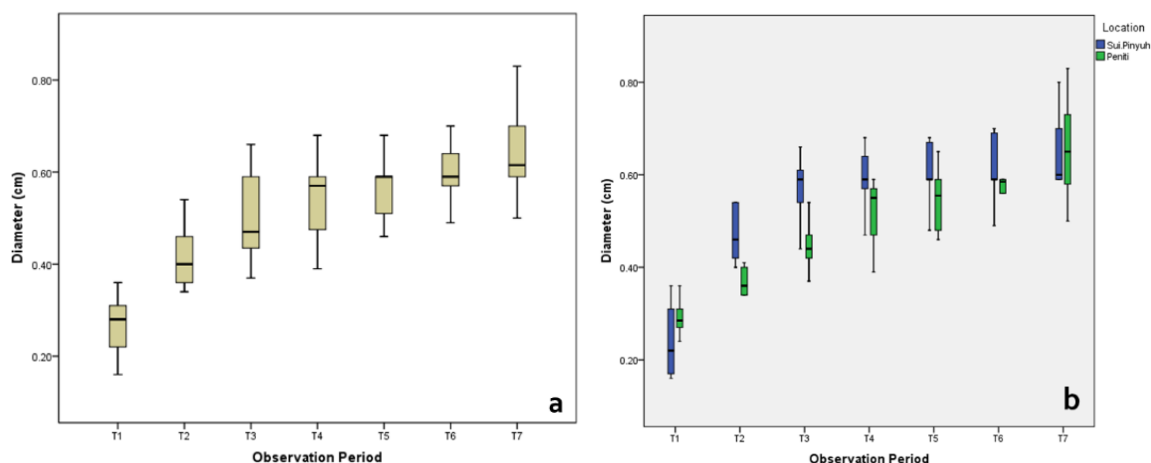


Figure 3. Diameter growth of *Avicennia lanata* seedling at all locations (a) and at each location (b) of the mangrove forest in Mempawah Regency.

Variable height growth rates were found at both locations, for each observation (Figure 4). The most significant average height growth occurred at the second and third observations (T2 and T3), at both locations. The range of seedling height growth at the Sungai Pinyuh location was 0.09-3.55 cm month⁻¹ and an average height growth of 1.13±0.4 cm month⁻¹, and seedlings at the Peniti location had a range of height growth of 0.05-3.55 cm observation⁻¹ period, with an average of 1.43±0.6 cm month⁻¹. In this study, *A. lanata* seedlings had a lower height growth rate than *A. marina* and *R. mucronata* seedlings, whose values ranged 3-39 cm period⁻¹ and 1-34 cm period⁻¹, respectively, according to Hastuti & Hastuti (2018b). This difference between the growth rates was caused by physiological responses to the growth of each species and was related to the adaptation of species to the environmental factors.

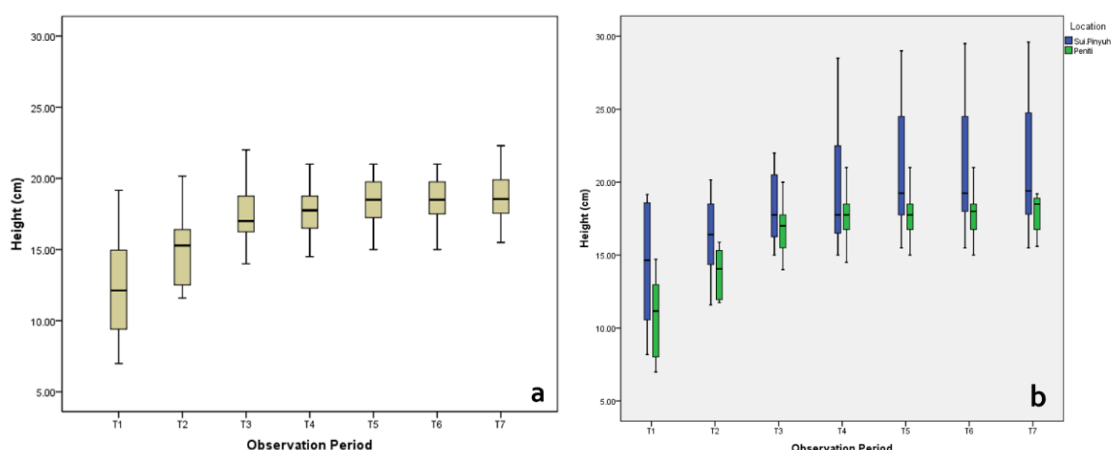


Figure 4. Height growth of *Avicennia lanata* seedling at all locations (a) and at each location (b) of the mangrove forest in Mempawah Regency.

Edaphic factor. The physical-chemical factor analysis of sediments from the two locations showed several differences in the parameter values (Table 2). The C-organic and N-total content at the Peniti site had a higher range compared to the Sungai Pinyuh

location. These growth rate parameters are plant nutrients. The growth rate, derived from the diameter and height growth, showed a higher range of increase in *A. lanata* seedlings at the Peniti location compared to the Sungai Pinyuh location. These two parameters may be the cause of the difference in the growth rates of *A. lanata* seedlings at the two locations.

Table 2

Physico-chemical parameter analysis of Mempawah mangrove areas

No	Parameter	Location	
		Sungai Pinyuh	Peniti
1	pH	5.78-6.13	5.96-6.17
2	C-Organic (%)	2.16-4.68	2.87-6.50
3	N-Total (%)	0.27-0.53	0.34-0.72
4	P ₂ O ₅ (ppm)	0.84-1.03	0.81-1.29
5	Ca (cmol (+) kg ⁻¹)	3.43-6.18	3.36-4.85
6	Mg (cmol (+) kg ⁻¹)	0.73-0.96	0.65-0.95
7	K (cmol (+) kg ⁻¹)	0.31-0.36	0.20-0.24
8	Coarse sand (%)	10.87-46.31	34.94-39.91
9	Fine sand (%)	31.12-52.55	34.68-36.67
10	Silt (%)	22.57-36.58	25.41-28.39

P₂O₅ contents from two locations was relatively similar, also for Ca, Mg and K in units (cmol (+) kg⁻¹). The percentage of sediment texture, analyzed through 3 main components of the sediment (sand, silt, and clay), was relatively similar at both locations. High silt and fine sand components are suitable for *A. lanata* habitats that occupy the initial seaward zones of mangrove zoning. Physical-chemical parameters of sediments from two locations were very suitable for *A. lanata* habitat.

The relationship between edaphic factors and growth rate. The physical and chemical properties of the soil affect vegetation in the forest area. This condition is related to the availability of nutrients and space for the development of plant roots. The physical and chemical characteristics of the soil are closely related to the level of soil fertility. Fertile soil can support plant growth.

Characteristics of soil chemical physics factors in Mempawah mangrove forest based on ordinance analysis of Principal Components Analysis (PCA) are presented on three main axes as seen in (Table 3). Based on the main axis 1 the main physical-chemical characteristics of the Mempawah mangrove forest area were determined by the soil pH value and by the percentages of C, N, P, Ca, K and Mg. The amount of information generated on the main axis 1 was shown by the variance of the growth rate (97.14%) with the individual factors composition change in the aggregate edaphic factor. Based on PCA information on axis 1, soil pH conditions at the study site ranged from 5.78 to 6.78. It means that the concentration of H⁺ ions in the soil were higher compared to OH⁻. This indicated that the pH of the soil at the study site tended to be acidic (Soil Research Institute 2005).

Non-parametric statistical analysis test, using Spearman rho (ρ) correlation coefficients between seedlings' diameter growth rate (RDGR) and height growth rate (RHGR) of *A. lanata* with the physical-chemical properties of Mempawah mangrove forest, showed that the edaphic factor of Mempawah mangrove forest, and especially pH and soil texture, correlated with the diameter and height growth of *A. lanata* seedling. The strengths and weaknesses of the correlation between the growth of *A. lanata* seedlings and the physical and chemical characteristics of forest soils are determined by the correlation value. Based on Table 3, the pH and soil texture correlated very significantly with the seedling growth ($P < 0.05$) in the Mempawah mangrove forest area. It means that soil pH and soil texture are very important chemical-physical factors in determining the diameter and height growth of *A. lanata* seedlings in the Mempawah mangrove forest. Different responses of RDGR and RHGR to soil physical and chemical

factors are also related to the existence of nutritional requirements for growth. Hardjowigeno (1987) suggested that calcium, potassium, and magnesium are macro elements that play an important role in plants.

Table 3

Correlation of the edaphic factor to diameter growth (RDGR) and height growth rate (RHGR) *Avicennia lanata* and three main axes based on principal component analysis (PCA)

Variable	Axis			RDGR (cm month ⁻¹)	RHGR (cm month ⁻¹)
	1	2	3		
pH	-0.005	0.051	0.018	0.738*	0.595
C-Organic (%)	0.043	0.752	0.256	0.095	0.238
N-Total (%)	0.004	0.079	0.031	0.095	0.238
P2O5 (ppm)	-0.002	-0.046	-0.009	0.333	-0.143
Ca (cmol (+) kg ⁻¹)	0.027	0.198	-0.005	0.024	0.262
Mg (cmol (+) kg ⁻¹)	0.002	0.047	0.030	-0.048	0.000
K (cmol (+) kg ⁻¹)	0.000	-0.015	-0.012	-0.590	-0.253
Coarse sand (%)	0.811	-0.051	0.376	-0.976*	0.190
Fine sand (%)	-0.490	-0.172	0.225	0.833*	0.190
Silt (%)	-0.315	0.216	0.690	0.833*	0.190
RDGR (cm month ⁻¹)	-0.003	0.011	-0.005	-	-
RHGR (cm month ⁻¹)	-0.024	0.551	-0.512	-	-
Variance (%)	97.143	1.428	0.854	-	-

* Correlation is significant at the 0.05 level (2-tailed).

Conclusions. Based on this study, the survival rate of *A. lanata* seedlings in the mangrove forest area of Mempawah Regency ranged from 73.33-86.67%, with a low mortality rate. In the mangrove forest area of Mempawah Regency, *A. lanata* seedling growth rate, in terms of seedling diameter and height increase, showed variable values, with a range of diameter increase from 0.01 to 0.16 cm month⁻¹ and a range of height growth of 0.09-3.55 cm month⁻¹.

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