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Seed Morphology and Seedling Growth Modeling for *Litsea cordata* and *Sloanea sigun* in Java Montane Forests

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ABSTRACT-

Studies on seed morphology, including size, germination, and seedling performance, of *Litsea cordata* (Jack) Huff. f. and *Sloanea sigun* (Blume) K. Schum, two species of Java montane forests, are still limited. This study aimed to provide insights into the seed morphology and seedling growth characteristics of *L. cordata* and *S. sigun* in a nursery setting. This study was conducted at the Cibodas Botanic Garden nursery using fresh seeds collected from trees. The seeds of *L. cordata* were larger than those of *S. sigun.* Over a four-month observation period, the germination index and performance scores of *L. cordata* were 51.25% and 1.98, respectively. The chlorophyll content at the seedling stage of *L. cordata* and *S. sigun* was 43.71±3.51 Nmol/cm² and 33.40±6.32 Nmol/cm², respectively. Regression analysis of height-collar diameter growth in *L. cordata* showed an increase from the first-month observation to the fourth month, whereas *S. sigun* seedlings exhibited a stronger relationship between the third and fourth months. Overall, both the seed size and seedling performance of *L. cordata* were higher than *S. sigun*. Studying seed morphology and seedling growth modeling is useful for ensuring the sustainability of seed distribution and seedling survival in the field. The larger seed size of *L. cordata* results in seedlings remaining close to the parent tree. Low seedling survival in the field requires human intervention to preserve these two species.

1. INTRODUCTION

The germination and growth of seeds into seedlings are essential for the reproduction and continuation of plant species [1-3]. Seeds are the primary propagules utilized in ecological restoration to counteract environmental degradation and species extinction by promoting the regeneration of plant species. Seed morphology could be used to characterize plant genotypes based on phenotype. Fruit attributes could serve as predictors of seed attributes, which are highly correlated [4]. Seed quality determines crop quality and yield. The quality of the seeds directly affected many factors, such as relative humidity, storage temperature, and seed wetness [5, 6].

Seed yield, breeding, storage, and transportation may all be impacted by seed size detection, but it can also improve seed quality [7]. An important input of quality seed has been recognized in the plantation system, such as restoration or agriculture. The plant's growth and yield, as well as its capacity to withstand abiotic stressors in the future, are mostly determined by two factors: seedling vigor and germinability. Additionally, seed morphology, including seed structure, specifically seed size and weight, embryo size, and hull thickness, is a crucial factor in the plantation system that helps distinguish one cultivar from another. It is linked to seed vigor [8-10].

Seed germination is the fundamental checkpoint for natural regeneration and represents the first phase of population establishment, plant growth, and the development of degraded populations of some endangered species. It also determines seed vigor [11-14]. Additionally, viable seeds may not germinate due to dormancy or unfavorable environmental conditions. The morphological and physiological characteristics of the seed influence dormancy, a state in which seeds are inhibited from germinating even in environments that are typically conducive to germination. For seeds to sprout and produce seedlings, both dormancy and inactivity must be eased [1, 15]. The conservation and regeneration of endangered populations are typically aided by the more inexpensive and efficient use of higher-quality seedlings to create seedlings [12].

Chlorophyll content, a component in plant resource allocation that affects the photosynthetic activity of leaves, is another crucial element for seedling establishment. Herbivores find leaves with a high chlorophyll content more attractive since it indicates a greater need for nitrogen and a lower investment in other characteristics [16]. Because chlorophyll plays a crucial role in photosynthesis, which is essential for optimizing photosynthetic efficiency, it was measured in this study. Chlorophyll content and environmental factors such ambient temperature, vapour pressure deficit, atmospheric CO_2 levels, soil water potential, plant conditions, and developmental phases all affect photosynthetic rates [17, 18]. A key indicator of leaf maturation is the attainment of full photosynthetic capacity, since leaves are the predominant organs of plant productivity [19, 20]. This study reviews the morphology of seeds and seedling growth in two species of the late-successional stages of Java montane forest ecosystem formers that have not been widely examined in previous studies, such as *Litsea cordata* (Jack) Huff. f. and *Sloanea sigun* (Blume) K. Schum [21, 22].

There was limited information about *L. cordata,* while some Litsea genera had been reviewed for previous studies. Several species of Litsea, one of the largest genera of Lauraceae, are an essential part of tropical forests found primarily in tropical Asia, with a small number of species also found in the Pacific Islands, Australia, and North and Central America. Litsea is a rare, fast-growing, evergreen, deciduous tree or shrub that grows to a height of approximately 8 meters. It grows naturally in tropical regions (such as Myanmar, Thailand, Cambodia, Laos, Malaysia, Indonesia, and Vietnam) as well as the eastern Himalayas, Assam, Manipur, and Arunachal Pradesh, up to 2,700 meters above sea level. Fruits of the Lauraceae family, such as the seeds of *L. cubeba* and *L. coreana*, are typically spread by frugivorous birds or other animals. As sources of significant secondary metabolites and producers of odor-active chemicals, various species of the genus Litsea have been utilized as traditional herbal medicines since 600 A.D. In addition, fruits are used as a source of natural ingredients and for flavor in a variety of cuisines and contain physiologically active components [23-26]. Additionally, the tree trunk of *L. cordata* can be used as a shade tree in the forest, and the fruit and leaves are used as animal feed [27]. Because of its dense foliage, which offers cover, nesting places, and roosting areas, *L. cordata* also serves as a habitat for a range of animals, such as insects, birds, and small mammals. According to reports, the Javan hawk-eagle (*Nisaetus bertelsi*) uses *L. cordata* as one of the tree species for nesting [28]. The existence of *L. cordata* is significant as a wildlife habitat provider since the Javan hawk-eagle is a protected species in Indonesia and listed as endangered on the IUCN Red List.

The Elaeocarpaceae family, which includes 12 genera and approximately 615 species, is a pantropical family within the order Oxalidales. *S. sigun,* commonly referred to as Beleketebe, is a species within the Elaeocarpaceae family, which is found in the Java montane forest at elevations of 800–1200 m a.s.l. It is an evergreen tree reaching up to 40 m in height with 80-120 cm in diameter at breast height. This family of fruits is known for having many valves (locules); when the fruits are mature, they have three to five valves and a dry pericarp because they have already begun to dehisce and discharge the seed into the forest floor. Given their symmetry and a characteristic shared by all living Sloanea species, which are many fruit valves with four to five valves [29-31]. Though specific information about *S. sigun* is limited, its ecological roles in general contributes to the structural complexity and biodiversity of forest, providing habitat and resources for various species. Although no immediate threats have been documented, and due to limited research, conservation may be essential as the species plays a role in forest ecosystems at specific altitudinal ranges such as in Java montane forest.

Due to limited information and research on the biological characteristics of *L. cordata* and *S. sigun*, this study aimed to collect data on their seed morphology and seedling growth characteristics in a nursery setting. Estimating the diameter growth rate and growth equation for these two species not only provides significant information but also improves the accuracy of height growth predictions in the Java montane forest ecosystem.

2. RESEARCH METHODS

2.1 Research site and seed collections

The seed materials were collected from the tree collection of the Cibodas Botanic Garden (CBG)–National Research and Innovation Agency of Republic Indonesia (BRIN), West Java, Indonesia. This site, with geographical coordinates 6°44′14″S 107°00′29″E, has a tropical climate with an altitude of 1,300–1,425 m above sea level. The mean temperature, humidity, and rainfall were 20.04°C, 80.82%, and 2,950 mm/year, respectively. The botanic garden serves as both a research centre and a tourist attraction. Certainly, all plant collections in the botanical garden are well maintained (fertilized with compost), and the origin and time of planting in the garden are documented, as well as their growth. The species *L. cordata* and *S. sigun* originate from the Java montane forest and are planted close to their natural habitat, so they do not meet any significant growth pressure.

BRIN manages four botanical gardens in Indonesia, and one of them is the CBG. It is envisaged that these four botanical gardens will be able to serve as ex-situ conservation areas for all plant species in Indonesia. The CBG's plant collections represent Java and Sumatra montane forests. Every botanical garden in Indonesia includes monthly activities to observe the flowering and fruiting of all plant collections. Flowering and fruiting observations can provide information on the best time to collect seeds and estimate the vegetative growth time of a plant. On average, each collection of tree-habitus plants has regular flowering and fruiting every year (starting from October to February), although not every year has mass fruiting. This study selected the species *L. cordata* and *S. sigun* because both still have limited information on seed and seedling growth and have mass fruiting compared to previous years.

Fruits were sorted from immature to mature fruits in the laboratory using a cutting test to evaluate the fruit maturity and seed freshness [32]. This study used all mature fruits and seeds. Seeds were manually extracted from the mature pulp by washing with water to remove adhering pulp. The seeds were cleaned from the pulp, dried in a cool, ventilated place for 24 hours at room temperature, and then tested.

2.2 Seed morphology

Freshly extracted seeds were wiped with filter paper, and one hundred randomly chosen seeds from each species were counted. The seeds were then left to air dry so that their morphological traits could be measured. Each selected seed was evaluated based on its weight (g), width (mm), and length (mm) measurements. Single seed weight was determined with a 0.01 precision balance. The seed length and width were measured with a digital calliper, and their weight was determined using a digital scale.

2.3 Seed germination test

The seed germination test for two species used eighty seeds for *L. cordata* and one hundred seeds for *S. sigun*. In the nursery, they were sown in polybags with a 2:1 ratio of sterilized soil to rice husk and watered every afternoon. Seed germination was observed every 3 days ± 1 day until no more seeds germinated. After three observations, no seeds had germinated, so the observation was stopped to conduct the first observation of seedling growth. Before beginning the first seedling growth observation, a cut test was performed on seeds that did not germinate to determine whether the seeds were dead or dormant.

The first measurement of seedling growth was carried out in the fourth month after sowing and ended in the eighth month (4 measurements). Measurements were carried out every month by recording the seedling height (cm), the seedling basal diameter (mm), and the number of leaves growing. A digital calliper was used to measure the seedlings' diameter, and a ruler was used to measure seedling height. The amount of chlorophyll in the leaves (Nmol/cm^2) was measured using the SPAD-502 Plus instrument. This technique was an effective and efficient non-destructive alternative technology for figuring out how much chlorophyll is in leaves [33].

The parameters for seedling performance are seed viability and seedling survival until the eighth month after sowing the seeds. Moreover, the seeds germination index (%) was calculated by the following formula [32]:

$$\text{Germination index (\%)} = \frac{Total\ number\ of\ seedlings\ growth}{Total\ number\ of\ seed\ tested} \times 100\%$$

Based on seedling establishment (the number of surviving seedlings divided by the total number of seeds sown) and mean seedling diameter across all surviving seedlings eight months after sowing, a performance score was determined for each species. Due to its tight and positive correlation with plant biomass and its greater stability compared to height (which can be impacted by broken stems, wind damage, etc.), this term utilized mean seedling diameter as a measure of seedling size [9].

$$\text{Performance score} = \frac{Number\ of\ surviving\ seedlings}{Number\ of\ seed\ sown} \times \text{Diameter}$$

A combined performance score because a few large plants might help restore the ecosystem more than a number of smaller ones (by weeding out weeds and restoring structural complexity). The equation suggests that seedling size and stocking density are equally weighted.

2.4 Data analysis

Descriptive analysis was used to describe seed characteristics, seed germination, survival of seedlings, and seedling growth of *L. cordata* and *S. sigun*. Linear regression models for data analyses were performed using MS Excel for Windows 11.

3. RESULT AND DISCUSSION

The seeds collected for this study were from trees that had no pests or disease symptoms, had straight and round stems with high diameters, fine horizontal branches, and a considerable number of seeds compared to other tree collections. All collection trees for seed materials were 38-45 years after plantation in the botanic garden (Table 1).

Table 1. Taxonomy and seed details of *Litsea cordata* and *Sloanea sigun*

Species (Family)	Native to*	Location in the Garden	Age (year)	Seed Colour
Litsea cordata (Lauraceae)	Borneo, Jawa, Malaya, Maluku, Philippines, Sulawesi, Sumatra, Thailand	V.B.33	39	Black-brown seed coats
		VII.C.51b	39	
		VII.C.51c	39	
Sloanea sigun (Elaeocarpaceae)	Borneo, Cambodia, China South-Central, Jawa, Laos, Lesser Sunda Is., Malaya, Myanmar, Sumatra, Thailand, Vietnam	VII.B.6	38	Shiny black-brown seed coats, orange to dark red seed flesh
		VIII.B.52	45	
		XVII.B.6c	39	

*POWO (2019)

3.1 Seed morphology variation

The *L. cordata* seed length, width, and weight were 9.40±0.46 mm, 4.15±0.51 mm, and 0.43±0.06 g, respectively. *S. sigun* seed length, width, and weight were 8.98±0.91 mm, 4.91±0.48 mm, and 0.15±0.12 g. Overall, the *L. cordata* seed was bigger than the *S. sigun* seed. Morphological trait findings were useful for preliminary seed evaluation and assessing the genetic diversity of one species within a family or site distribution [8]. All the seed's traits showed a low variation among species in this study. This is because each population of seed species was similar in size. A previous finding stated high-quality seed percentage and seed weight were the basis for indicators including seed viability or germination, vigour, and plant growth directly affected by seed traits shape and size [3, 7].

This study found that each species seemed to correlate (positively and negatively) with the characteristics of the seeds tested (Table 2). It was seen that the longer and wider the seed of *Litsea cordata*, the heavier it would be. In our study, the highest correlated trait of *L. cordata* was seed length with seed weight (r = 0.848). The negative correlation (r) between seed length and seed weight and between seed length and seed width of *S. sigun* were -0.053 and -0.098, respectively. Only the correlation between seed width and seed weight was positive (0.821). This was also found in previous studies, which stated that the relationship between the morphological characteristics of the seed indicated that the length and diameter were all correlated with the seed weight [4]. In general, the imbibition ability, moisture content, and germination percentage of seeds are influenced by the morphological characteristics of the seeds, such as their length, width, weight, etc. [15]. Additionally, differences in seed traits between species may have an impact on a number of species performance factors, such as competitiveness, seedling emergence, and seed dispersal ability.

Besides species *L. cordata*, CBG has collections of Litsea genera. They were *L. elliptica* and *L. umbellata* with smaller seed characteristics than *L. cordata*. The mean length, width, and weight of *L. elliptica* seeds were 7.96±0.46 mm, 5.18±0.51 mm, and 0.17±0.02 g, respectively. *L. umbellata* seeds mean of length, width, and weight were 5.99±0.45 mm, 4.63±0.34 mm, and 0.11±0.01 g. According to observations in the garden, *L. cordata* seeds were quite large and heavy, therefore they were distributed close to the parent trees. This finding is useful for ecosystem restoration using the *L. cordata* species, it would be better to apply a wider space for planting than other species from the Lauraceae family because *L. cordata* regeneration will cluster or not spread far from its parent.

Table 2. Pearson correlation coefficients for *Litsea cordata* and *Sloanea sigun* seed morphological characteristics

Species	Length (mm)	Width (mm)	Weight (g)
Litsea cordata	0.848*** 0.220**	0.356**	1
Sloanea sigun	-0.098* -0.053*	0.182*	1

*Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$

The mature *L. cordata* seeds are spherical (round tending to be oval), slightly striped at one tapered side, and dark brown to black in appearance with a smooth surface. As a comparison, the seeds of *L. glutinosa* were 7 mm in diameter and brown colour seed coat with dark spots. The fruits were consumed by the squirrels then the seed passed through their digestive system the excreted seed is already softened but its in original state [25, 26]. *S. sigun* mature seeds are spherical, round to flat, and black, with a red partial membrane along one of the seed edges.

3.2 Seed germination

The quantity number of *L. cordata* mature fruits on the mother trees was smaller than the number of mature fruits on *S. sigun* mother trees at the time of the study. After four months of sowing the seeds on the planting media, the results showed that *L. cordata* seed germination was greater than *S. sigun* seed germination. Eight months after sowing, 44 seeds of *L. cordata* and 52 seeds of *S. sigun* emerged (Table 3). On the other hand, the survival rate of *L. cordata* seedlings was lower than that of *S. sigun*. This finding of *L. cordata* seed germination was greater than the previous study. The germination rate of Litsea spp. seeds in their natural habitat is 17% [25]. The morphological features of the seedling are linked to the seedling emerging force. For instance, the effective pressure area projected vertically (seedling emergence force) applied to the soil is influenced by the size of the emerging seedling. As a result, measuring morphological traits is essential for researching the corresponding emerging force [34]. Creating guidelines for seed germination protocols for ecosystem management will support the conservation of vulnerable species and the preservation of biodiversity values in ecological systems [35].

Table 3. Pearson correlation coefficients for *Litsea cordata* and *Sloanea sigun* seed morphological characteristics

Species	Number of Seed Sowing	Number of Seed Germination in 4 Months After Sowing (GI)	Number of Seed Germination in 8 Months After Sowing (GI)	Performance Score
Litsea cordata	80	44 (55%)	41 (51.25%)	1.98
Sloanea sigun	100	52 (52%)	51 (51%)	1.35

During four months of observation, *L. cordata* had three seedlings die, and *S. sigun* had only one seedling die. It means *S. sigun* seedlings had higher growth performance than *L. cordata* seedlings. Otherwise, *L. cordata* seedlings showed a higher performance index at the final count 8 months after seed sowing (1.98). Higher species performance for direct sowing was indicated by a higher score. Similar to how seedling growth was assessed, species-specific differences in performance scores were also assessed [9]. The ability of the seed to sprout from the soil and develop into a plant in the field under typical circumstances is determined by the seed germination test [36].

Only 51% of the seedlings of both studied species survived in the nursery under controlled conditions. This finding suggests that if these two species are to be used for ecosystem restoration, human assistance will be needed to increase the percentage of seed germination and seedling survival. This means that the survival rate of these two species through direct seeding will be lower than that of seeds germinated in the nursery and fertilised treatments before planting in the field. Another finding showed that a long dormancy phase was possessed by Litsea genera seeds and potentially to a long-lived seed reserves form [24]. Studies on seed germination in other Lauraceae families, such as *L. cubeba*, revealed seed viability of up to 73.3% [37].

The botanic garden collection contains only five individuals of each species, which can result in genetic variations that are often similar. This is a restriction of this study, even though in reality, a variety of factors, particularly environmental ones, influence a species' growth. Furthermore, various elements influence the effective establishment of seedlings, such as seed properties, the environment, and interactions [31, 38].

3.3 Seedlings growth pattern

The mean height, diameter, and number of leaves for seedling growth of the two species varied. The mean height growth of *L. cordata* was recorded as 16.66 cm, 17.75 cm, 20.20 cm, and 23.42 cm, respectively, which indicates that from four months of observation of seedlings reached the fastest growth on the third observation to the fourth month (3.22 cm). On the other hand, the mean height growth for *S. sigun* was 6.59 cm, 6.73 cm, 7.65 cm, and 8.71 cm, respectively. Similar to *L. cordata*, the fastest height growth of *S. sigun* was reached in the third month to the fourth month (1.06 cm). Height and root collar diameter concerning seedling age are the main quantitative morphological attributes in all countries [39]. The results of this study highlight the significance of defining species-specific seed characteristics and following those requirements when thinking about seed and seedling treatments for conservation. Because of species seed germination requirements, this study recommends that research efforts should focus on species that have beneficial qualities for the conservation and restoration of montane forests (e.g., species with easy-to-collect seeds, species that benefit communities and the forest ecosystem, species that provide high-quality habitat for fauna, etc.). Germination responses were associated with the mother plant, population, years of seed collection, seed weight, site moisture, and species habitat preferences [40].

In this study, the mean diameter growth of *L. cordata* and *S. sigun* seedlings was 1.54 mm and 1.00 mm for four months. The peak of the seedlings' diameter growth occurred on the third to the fourth-month observation for *L. cordata* seedlings (0.59 mm) and *S. sigun* seedlings (0.54 mm). The growth of the leaves' number for *S. sigun* increased from the second month to the fourth month, but *L. cordata* decreased the number of leaves from the third month to the fourth month. At various phases of their lives, Litsea plants faced limitations in their ability to grow and survive. For this potentially significant medicinal plant, biotechnological interventions are necessary for long-term genetic conservation, as seed propagation is an ineffective method of propagation [24].

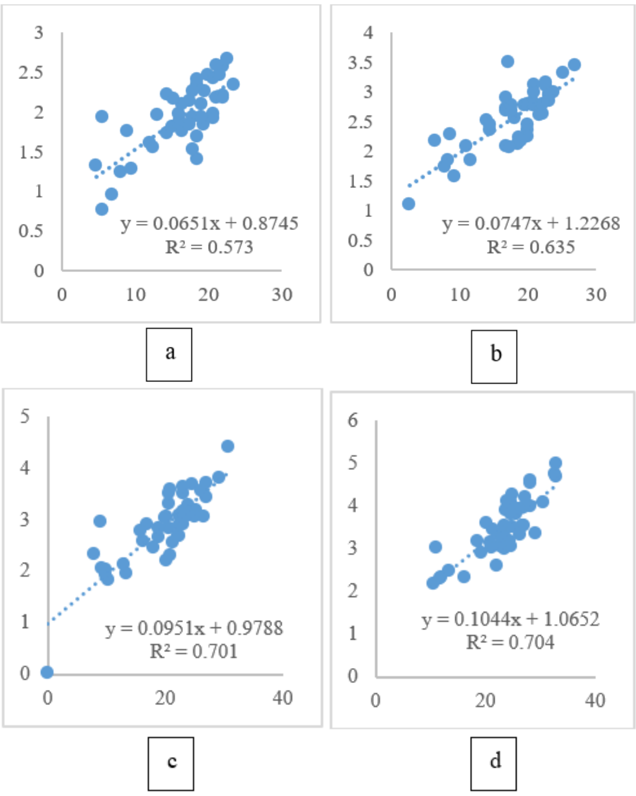

Figure 1. Regression analysis for *Litsea cordata* seedlings (a) first-month observation; (b) second-month observation; (c) third-month observation; (d) four-month observation

Regression analysis for *S. sigun* seedling growth varied during the four months of observation (Figure 1). This study used height parameters as a dependent variable (Y) and collar diameter as an independent variable (X). This study refers to a prior study that found that, during the seedling stage, height tended to expand more quickly than diameter [40]. The highest relationship between seedling height and collar diameter was for the fourth month observation (R^2=0.704), and the lowest was for the first month observation (R^2=0.573) (Figure 1(a)). The other regressions have a positive and moderate correlation (R^2=0.635 for second month observation and R^2=0.701 for third month observation). As a result, this study demonstrated a stronger probability association between height increase and collar diameter increase continuously every observation month, which could be applied to the growth model in *S. sigun* seedlings. The only way to effectively spread and sustain seedlings, a crucial component of the population and a critical stage in the plant life cycle, is through seedling regeneration [41]. Moreover, the development of seedlings is essential for forecasting plant survival and influencing the process of forest regeneration [24].

A different finding was shown on *S. sigun* seedling growth (Figure 2). Only a relationship between height and collar diameter on the fourth observation (R^2=0.612) showed R^2> 0.500. Almost no relationship between height and collar diameter during the second-month observation (Figure 2b). Even within the same forest stand, the same species may have different tree sizes, stand densities, stand ages, compositions, species, and site conditions and these relationships may change over time, even though many trees have strong height and diameter relationships because of coupled primary and secondary growth [42-44]. Tree function was modeled using growth equations of a species, which are directly dependent on tree size and growth rate and are components of ecosystem services [45].

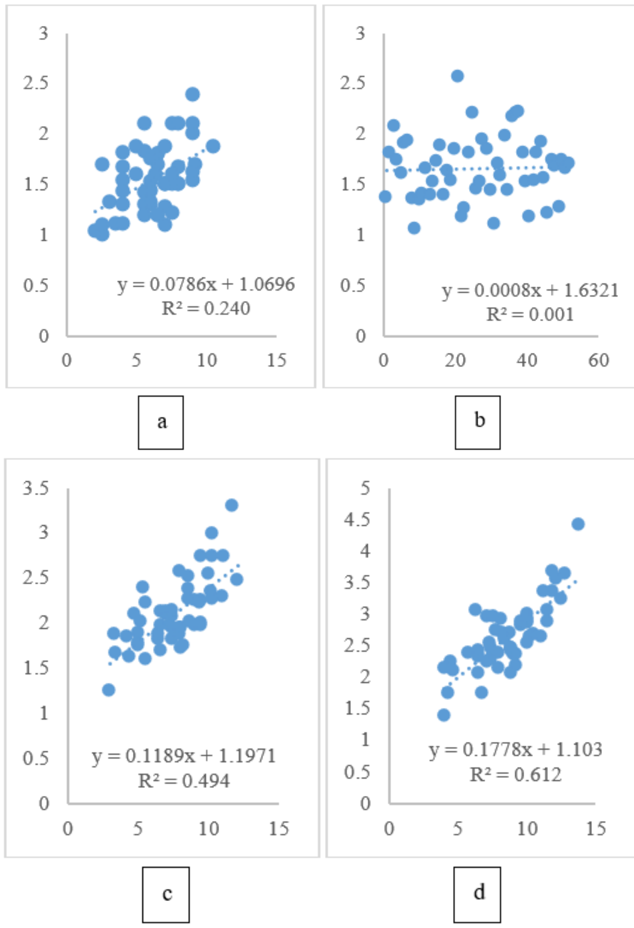

Figure 2. Regression analysis of *Sloanea sigun* seedlings (a) first-month observation; (b) second-month observation; (c) third-month observation; (d) fourth-month observation

The relationship between height and diameter in the third month (R^2=0.494, Figure 2(c)) and fourth month (R^2=0.612, Figure 2(d)) was getting stronger. It means two parameters of seedling growth showed relation growth started after 6 months of germination. A previous study stated that Sloanea genera are categorised as a late-successional species, known as a slow-growing species. The animals are reported as seed dispersers for Sloanea genera in the forest [19, 20].

3.4 Chlorophyll content

This study showed that the chlorophyll content mean of *L. cordata* (43.71±3.51 Nmol/ cm²) was higher than the chlorophyll content of *S. sigun* (33.40±6.32 Nmol/ cm²) (Table 4). The minimum score and the maximum score for *L. cordata* were 31.80 Nmol/ cm² and 50.70 Nmol/ cm², respectively. Furthermore, the minimum score and the maximum score for *S. sigun* were 15.70 Nmol/ cm² and 43.90 Nmol/ cm². Variations in leaf color are caused by the amount of chlorophyll in the leaf. Chlorophyll, carotenoid, and anthocyanin pigments in the leaf tissue are what give leaves their varied colors. Compared to light green leaves, dark green leaves have a higher chlorophyll content [46, 47].

Table 4. Chlorophyll content (Nmol/cm²) 8-month seedlings of *Litsea cordata* and *Sloanea sigun*

Species	Mean±SD	Max	Min
Litsea cordata	43.71±3.51	50.70	31.80
Sloanea sigun	33.40±6.32	43.90	15.70

Since the chlorophyll concentration of young and old leaves differs, this study was only carried out during the fourth month of the seedling stage. The comparatively distinct green hues of the leaves demonstrate this distinction. Higher quantities of chlorophyll may be indicated by the darker green color of the leaves. Additionally, a variety of factors, particularly genetics, light, oxygen, water, and temperature, affect the amount of chlorophyll in leaves. Plants with higher levels of chlorophyll perform photosynthesis more efficiently than those with lower levels. According to this study, a high chlorophyll content may contribute to its capacity for rapid growth and adaptation. The amount of chlorophyll in the leaves in the various habitats can also be impacted by other factors like diet, illnesses, and water availability [18, 45, 48].

Chlorophyll content was not the only factor influencing plant growth. However, chlorophyll content in leaves can offer nutrients for growth. Among the vegetative organs that can reveal details about a plant's development are its leaves, roots, and stems. According to a prior study, the only characteristic that changed in response to the interaction between seed size and foliar damage levels was chlorophyll content. Relatively more leaves and quicker plant growth are the results of high chlorophyll [16, 45, 46].

Species *L. cordata* seeds have bigger morphological characteristics than *S. sigun* seeds. Similarly, *L. cordata* seedlings grow faster, with a higher germination index and performance score than *S. sigun* seedlings. Similar results were demonstrated by the increased chlorophyll content than *S. sigun*. As a result of this study, it can be concluded that *L. cordata* seedlings grow better in the nursery than *S. sigun* seedlings. Even though this study only included two species and had a small sample size, it gave baseline data on the dependability of using the equation produced for the montane forest environment. Ecosystem services are estimated during the early growth stage based on data on the dimensions and growth of seedlings [44].

4. CONCLUSIONS

Quantitative measurements have been made on seeds of *L. cordata* and *S. sigun* from Java montane forest and seedling performances for a result of this research. *L. cordata* showed a bigger size than *S. sigun* seed among tested traits. The germination index and performance score of *L. cordata* seedlings were also higher than *S. sigun* seedlings, as well as, chlorophyll content at the seedlings stage. Regression analysis showed the relation between the height-collar diameter of *L. cordata* increased from the one-month until the fourth-month observation. A stronger probability relationship in *L. cordata* seedlings between height and collar diameter increased every observation month. Otherwise, S. *sigun* seedling growth was getting a stronger relationship between height and collar diameter starting from the third month to the fourth month of observation. It may be useful to describe and to mention the relationship among traits involving seeds, fruit, leaf area index, and cotyledons in field and in the greenhouse conditions, in future studies. Considering the comparatively low rates of seed germination and seedling survival associated with seed propagation, these two species require conservation even though they were not listed as endangered. So far, planting, maintaining, and phenology monitoring Java montane forest species in ex-situ CBG conservation zones was one method to conserve them. Seed morphology and seedling growth models provide essential information for ecosystem management that is crucial for understanding plant development, ecology, and application in forestry and conservation. Additionally, a study on seed storage methods for either species must be found as a species conservation effort.

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