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Seed morphology and germination type of some species of dipterocarps

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Abstract. *Ekasari I, Oktaviani L. 2024. Seed morphology and germination type of some species of dipterocarps. Nusantara Bioscience 16: 192-200.* The dipterocarps seed conservation and effective seedling management of threatened plants required basic information on morphology and germination type to provide information on biological, ecological, and characteristics with taxonomic relevance. Seeds and seedlings characters can provide useful data in the delimitation and identification of species, including wings, sizes, shapes, germination type, and stages. The study aims to investigate the morphology and germination type of the seeds of some species of dipterocarps to contextualize and understand their ecological implications because the seed was the fundamental stage for the propagation and perpetuation of the species. This study was conducted for three months from seed collection, seed morphology measurement, seed sowing, and observation for germination type. The seeds from five species of dipterocarps (*Shorea selanica*, *S. pinanga*, *S. stenoptera*, *Hopea gregaria*, and *Vatica pauciflora*) were collected from the Forest Research and Development, Ministry of Forestry (FORDA), Dramaga, Bogor, Indonesia and they were brought to seed conservation laboratory in Bogor Botanical Gardens. The results showed six characters to describe each species seed (seed shape, the dimensions of longer wings, the dimensions of shorter wings, seed weight, seed length, and seed width). The *S. pinanga* showed the longest wings among others (152.25±9.93 mm), and *H. gregaria* showed the lightest weight (0.49±0.06 g). All species showed the same germination type (epigeal) with cotyledons that rise above ground. There were five stages of seed germination from radicle growth until cotyledon was removed or perfectly germinated for 90 days. The plantings and pathogens management were required to increase the Dipterocarpaceae seedlings' growth success. This finding was crucial for developing methods for seed conservation and tropical rainforest restoration.

Keywords: Dipterocarps, germination type, seed, seed conservation, seed morphology

INTRODUCTION

Tropical rainforests in Southeast Asia are suitable habitats for dipterocarp trees, and these tree canopies provide ecological services. This taxon comprises many tree species (approximately 500 species in Southeast Asia) closely related, but the growth has environmental stress tolerance (Aoyagi et al. 2013; Ediriweera et al. 2020; Kenzo et al. 2023). In recent decades, many of the dipterocarp species in this region have been threatened by logging and other human activities that have critically reduced the numbers of their individuals and populations. The main threat to the dipterocarp species were habitat conversion into pine (*Pinus merkusii*) and coffee (*Coffea canephora*) plantations and degradation due to timber and fuel wood harvesting (Zulkarnaen et al. 2023). Accordingly, the sustainable management of remnant dipterocarp populations has become increasingly important for their sustainable use and species conservation (Naito et al. 2008). Their prevalence and broad geographical distribution means that different species, or groups of species from the Dipterocarpaceae family, are well-adapted to cope with diverse climatic and disturbance regimes (Hamilton et al. 2019).

The heavier seeds performed better than lighter seeds at germination and seedling establishment in the same species; in particular, only seed mass significantly affected seedling establishment. Since the seed mass of selfed progeny is lighter overall than that of the outcrossed progeny, the failure to germinate or establish may be more likely among lighter, selfed seeds than heavier, outcrossed seeds (Naito et al. 2008). Morphological studies of this family have typically analyzed small sample numbers and/or are locally focused (Hamilton et al. 2019). In tropical rain forests, many species, often within the same genus, can be differentiated regarding dispersal strategies. The inherent ability of seeds to resist deterioration and decay is also crucial from an ecological perspective. Some plant species might conduct strategies by producing seeds with different depths of dormancy to maintain the species presence in soil seed banks and thereby contribute to ecological diversity and species persistence over extended periods (Rehmani et al. 2023).

Therefore, seed characteristics can provide useful species delimitation and identification data. The morphologic features of different seed structures provide a wide range of characters that can play an important role in the identification of taxa and have traditionally been used to solve systematic and phylogenetic problems (Gabr 2014). The seed features of the dipterocarps family include wings, sizes, and colors. Thus, the study of seeds provides biological and ecological information on the species and characters with taxonomic relevance, and it offers eco-physiological information on the species; in this manner, the seed morpho-anatomical characteristics indicate the strategies of the species in response to a loss or increase of precipitation, and other factors (i.e. temperature); as a result, the findings of these studies can help establish which species are ecologically suited for planting in restoration (Montaño-Arias et al. 2022). Upon germination, the seed may normally grow, halt at various stages of development, or give rise to seedlings with abnormal morphology that fail to survive. Seed germination was a tightly regulated process ensuring that germination occurs under conditions that ultimately lead to the completion of the plant life cycle. As a result, seed or timber production companies must be able to create high-quality vigor seeds to produce high-quality timber as a final product. Therefore, commercial seed testing routines did not include abnormal seedlings in final germination percentages. These seedlings would likely fail, leading to discrepancies between percentage germination and viability (Rehmani et al. 2023). The study aims to investigate the morphology and germination type of the seeds of some species of dipterocarps to contextualize and understand their ecological implications because the seed was the fundamental stage for the propagation and perpetuation of the species.

MATERIALS AND METHODS

Study area

The study was carried out from September to December 2023 in Dramaga Experimental Forest of the Forest Research and Development Agency (S6º33'7" E106º45'11"), Ministry of Forestry and Environment, Indonesia for dipterocarps seed collection and Bogor Botanic Gardens Laboratory, for seed morphology and anatomy investigations and nursery for seed germination in West Jawa, Indonesia (Figure 1). Dramaga Experimental Forest's total area was about 60 ha, and the elevation was 244 m asl. Annual rainfall was about 350 mm, and the soil type was reddish latosol. The minimum temperature was 20.1°C and 30.1°C at the maximum.

Procedures

Seed sample and collection

Seed samples from stands of *Shorea selanica*, *S. pinanga*, *S. stenoptera*, *Hopea gregaria*, and *Vatica pauciflora* after natural dispersal in the Dramaga Experimental Forest were carefully chosen and randomly collected. The quantity of seeds produced by these five species varies; roughly 300 seeds were gathered for each species. From 20 to 25-year-old trees that were flourishing in the forest, about 2 kg of seeds were gathered. The collected seeds were placed in cloth bags to prevent heat and preserve freshness. The seeds were brought to the laboratory the same day for additional processing. After the seeds had dropped to the ground, a cutting test was done to determine how fresh the seeds were. The seeds selected were those with brownish fruit wings, and the fallen seeds were collected from the ground (Masano 1991). Then, the seeds were immediately taken to the laboratory and greenhouse for analysis

Seed morphology observation

This study analyzed the morphology of seeds from five species belonging to the dipterocarps family. Each species contains ten seeds, and the wings and the seed's length and width were photographed using a Galaxy Samsung 22 Ultra camera. At least 10 seeds for each species had their morphology measured. They were split longitudinally and transversely using a scalpel to determine their morphological characteristics and photographed using a Dino lite digital microscope MS35B.

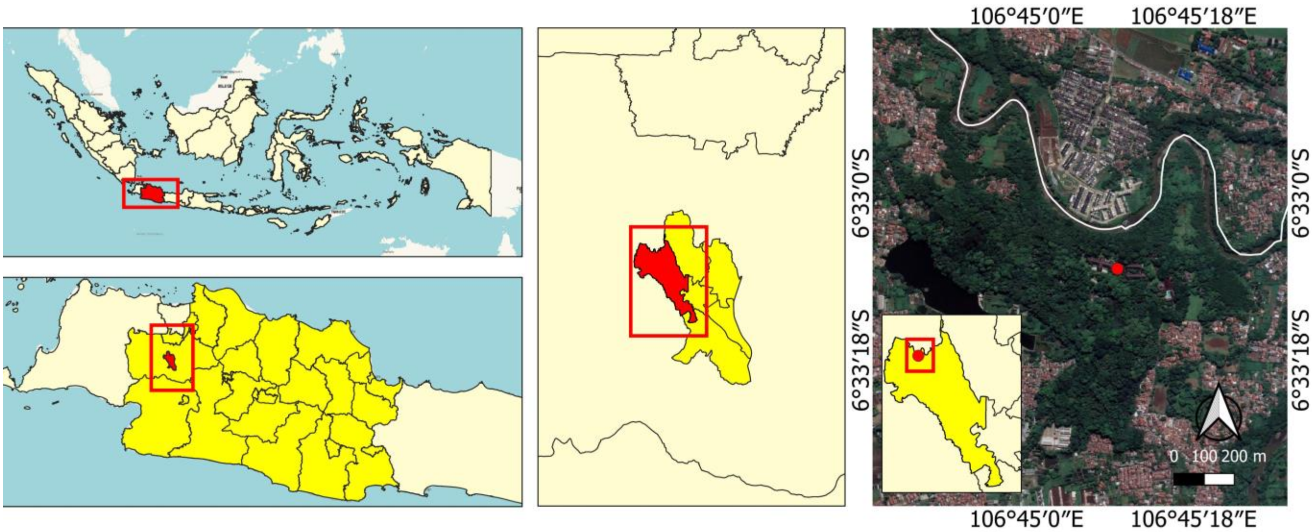

Figure 1. Study site in Dramaga Experimental Forest of the Forest Research and Development Agency, Bogor District, West Java, Indonesia

Germination types observation

Approximately 100 dipterocarp seeds were sown in the sand and germinated within 24 hours in the nursery after being collected from the field. The wings of each seed were removed before sowing. The seeds were selected to be as uniform as possible with large size and brown color, indicating the seeds maturity (Otsamo et al 1996); the already germinated seeds were excluded. The seeds in portray were watered every day, and the observations were conducted once a week.

Data analysis

The description analysis was applied based on observations and examined with a camera and a microscope. The obtained data were presented in tables and graphs, and the color brightness and fish blood profile data were analyzed descriptively.

RESULTS AND DISCUSSION

Seed morphology

The seeds morphological characteristics enable us to distinguish between some species of dipterocarps. The dipterocarps were characterized by their winged fruits or nuts with zero to five wings and were generally poorly dispersed by gravity or gyration. Secondary seed dispersal was unlikely to play a significant role in species dispersal as dipterocarp seeds are highly recalcitrant and germinate rapidly after reaching the forest floor (de Morais et al. 2015). In this study, species *S. selanica, S. pinanga, S. stenoptera, H. gregaria,* and *V. pauciflora* showed similar fruiting times, but *H. gregaria* was the first to fruiting. The mature fruits, indicating the dark reddish brown on the wings, were heavier than the immature ones. Ripe fruit was distinguished by color, weight, and the seeds' flawless form. Fruits of the *S. pinanga* and *S. stenoptera* species were asymmetrically shaped when they were young, but when they ripened, they became perfectly round and were comparatively larger than unripe fruits.

Examination of available specimens yielded a wealth of information concerning seed morphology and sculpture of seed surface. Variation in these aspects among the species is listed in Table 1 and recorded comparatively illustrated for individual species in Figure 2. In this study, six characteristics describe the seeds, they were seed shape, the dimensions of longer wings, the dimensions of shorter wings, seed weight, seed length, and seed width (Table 1). The results of seed shape were round with tapered ends (*S. selanica, S. pinanga*, and *S. stenoptera*), round (*H. gregaria*), and round with wavy curves (*V. pauciflora*). The seed shape would support an interesting pattern to be observed in the cotyledons during the germination process (Maharani et al. 2013). Species *S. selanica* showed the longest wing lengths among others. Furthermore, the seed weight of *S. selanica* was heavier than other species. Species *S. stenoptera* had the longest wing length (64.63±1.87 mm) and seed width (36.63±1.87 mm) than other species' seed lengths.

Three genera of *Shorea*, one genus of *Hopea*, and one genus of *Vatica* were observed in this study (Figure 2). The uniqueness of the *Shorea* spp. seed was the overlapping petals, clearly thickened in the middle and swollen at the base. Species *S. pinanga* and *S. stenoptera* were well-known as Tengkawang with large seeds. The seed shape of *S. pinanga is* usually ovate to round and relatively has the same size in length and width. The seed surface of *S. stenoptera* was short hairy. Species *S. selanica* seeds surface was glabrous, smooth, and punctuate, and they can be either opaque or shiny, but those of *S. pinanga* were dark reddish brown or yellowish red. The *S. stenoptera* seeds were black or reddish brown. The color was determined using Munsell soil color charts. The seed surface of both *S. pinanga* and *S. stenoptera* species showed fracture lines; however, in *S. selanica*, they gave an exfoliated appearance. Seeds coat surfaces in *S. stenoptera* were reticulate, and each space enclosed by the reticulation was densely rugose, while in *S. pinanga* only an irregularly rugose pattern was observed.

Species *H. gregaria* showed round with short same length wings, but species *V. pauciflora* showed an interesting curvy shape in their surface seed coat. The seed wings of *V. pauciflora* have the same length and almost disappeared. The seed surfaces in both species, *H. gregaria* and *V. pauciflora*, were glabrous, smooth, and opaque. The seed coat colors were dark brown, reddish brown, or black. It was also determined that the seeds of both species were hard since they were necessary to exert force to break the seed coats. Therefore, seed characters can provide useful data in the delimitation and identification of species. The morphologic features of different seed structures provide a wide range of characteristics that are important in identifying taxa and have traditionally been used to solve systematic and phylogenetic problems (Gabr 2014).

Table 1. Mean characters of *Shorea selanica, S. pinanga, S. stenoptera, Hopea gregoria* and *Vatica pauciflora*

Characters	*Shorea selanica*	*Shorea pinanga*	*Shorea stenoptera*	*Hopea gregaria*	*Vatica pauciflora*
Seed shape	Round with tapered ends	Round with tapered ends	Round with tapered ends	Round	Round with wavy curves
Longer wing length (mm)	73.01±7.97	152.25±9.93	101.15±7.44	4.83±0.68	2.84±0.39
Shorter wing length (mm)	40.54±5.51	96.9±10.29	79.26±7.15		
Seed weight (g)	0.88±0.09	20.88±0.08	17.89±3.43	0.49±0.06	6.06±1.65
Seed length (mm)	19.11±0.83	43.15±3.58	64.63±1.87	12.86±1.29	24.71±2.05
Seed width (mm)	10.56±0.39	25.36±1.15	36.63±1.87	8.85±0.44	23.78±2.81

Note: Wings of *Hopea gregoria* and *Vatica pauciflora* seeds have the same length (no longer and no shorter)

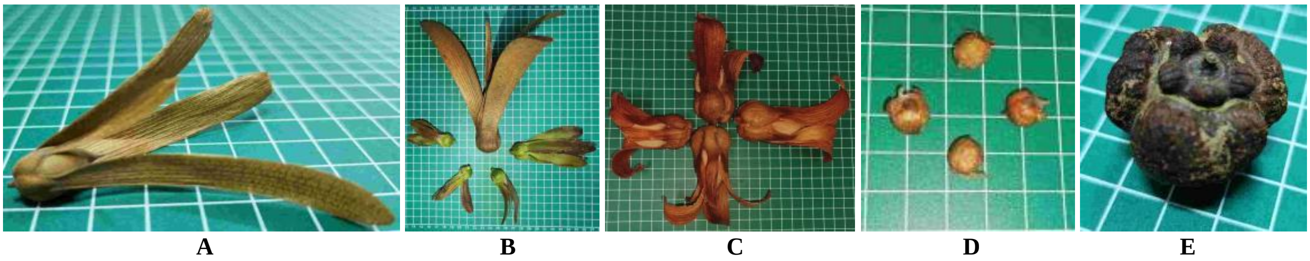

Figure 2. Seed shape of five species of dipterocarps. A. Round with tapered ends for *Shorea selanica*, B. Round with tapered ends for *Shorea pinanga*, C. Round with tapered ends for *Shorea stenoptera*, D. Round for *Hopea gregaria*, E. Round with wavy curves for *Vatica pauciflora*

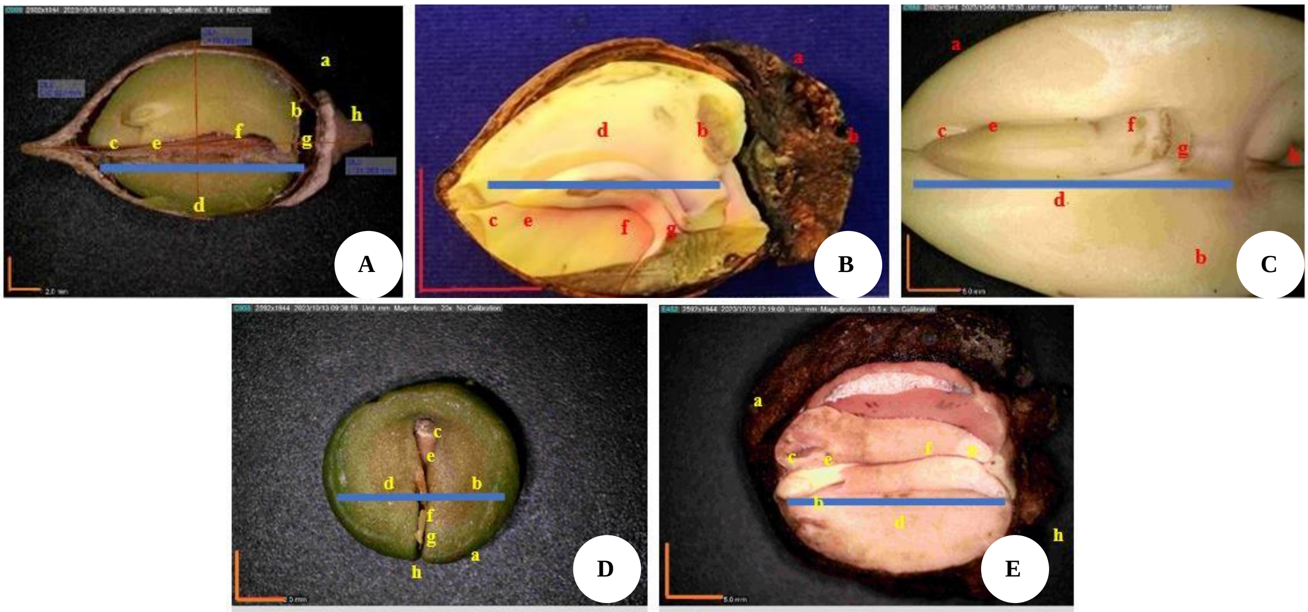

Figure 3. Seed transversely morphology of five species of dipterocarps A. *Shorea selanica*, B. *Shorea pinanga*, C. *Shorea stenoptera*, D. *Hopea gregaria*, E. *Vatica pauciflora*. Note: a. Testa; b. Cotyledon; c. Radicle; d. Embryo; e. Hypocotyl; f. Epicotyl; g. Plumule; h. Hilum. Scale: 1:2.0 mm (*S. selanica*, *S. pinanga*, and *H. gregaria*). Scale: 1:5.0 mm (*Shorea stenoptera* and *Vatica pauciflora*).

Dipterocarps seeds were dicotyledonous and share many morphological features with other dicotyledonous species. Their external anatomy consists of an aril attached around the hilum, but there was no visible lens or micropyle on any of the seed samples investigated. However, it was possible that the micropyle could be observed at greater magnifications or that it existed beneath the cuticle layer and was thus hidden from view. The seed morphology was investigated using light microscopy and was found to consist of a seed coat layer and a substantial endosperm surrounding the unattached embryo. The hilum was a scar that remains on the seed at the point where the funiculus attaches to the body of the ovule, connecting the ovule to the placenta (Koen et al. 2017). The pointier side of the seed, rather than the hilum side, is where the root or radicle emerges in all seeds belonging to the dipterocarp species. The hilar slit (or hilar fissure) serves as a natural opening for water and gas exchange for many species, and so do for these five dipterocarps seeds. The seed coat or testa was the protective outer covering of a mature seed. The seed coat consists of layers called integuments that develop from maternal tissue (sacs of the ovule) and are, therefore, determined by maternal genotype. The seed coat protects the seed parts' integrity against injury by mechanical damage and/or attack by pests and disease. The seed coat also modulated seed–environment relationships, regulating gaseous exchange and imbibition.

The embryo includes the region proximal to the cotyledon and extends to the region occupied by the embryonic axis (Figures 3 and 4). The cotyledon shapes were very similar in these five species of dipterocarps since they were constituted by a sheath, varying from fleshy to foliaceous. Five species had auriculate cotyledons. The cotyledon is attached to the seed coat of the seeds. Like dicotyl seed, plumules, and radicles were not covered in dipterocarp seed. Every seed's embryonic axis was straight. In this study, *S. stenoptera* and *S. pinanga* seeds had longer radicle sizes than other dipterocarps seeds; this was directly correlated with the size of their seeds. On the epicotyls, there was no growth of leaf primordia or plumules. The pointier side of the seed emerges, rather than the hilum side, where the root or radicle emerges in all seeds belonging to the dipterocarp species. While the study's seed species were compared, no discernible changes in their morphological structures were discovered. Examining the cellular structure of the seeds could explain variations in their form. These variations might be biological; however, this study provided an overview and did not explore these possibilities.

Germination types

All dipterocarps seeds were germinated under the paranet (55%) with a microclimate state at an average daily temperature of 33.8°C, 48.9% relative humidity of 48.9%, the light intensity of 11,186.67 lux, and wind speed of 0.87 m/sec. Following germination, seedlings' development, morphology, and seedlings' growth habits were important characteristics to study. Some characteristics often used to study the morphology of seedlings of woody plant species are the emergence of seedlings, the position and development of the cotyledons, and the function of the cotyledons (Handayani 2017). Therefore, for each species under investigation, the seeds employed in this study were comparatively similar in size and weight. According to Rachman and Sunaryo (1999), this was because larger seeds will germinate more quickly than smaller ones. The protrusion of the growing radicle to create the primary root and the base of the cotyledonary sheath signals the onset of germination in representatives of *Shorea, Hopea,* and *Vatica*. Plant reproductive success was determined by seedling development patterns, including structures adapted to environmental circumstances, access to seed reserves, and germination control factors (Silva et al 2014). In this study, five seeds of dipterocarps showed an epigeal pattern of seed germination types (Figure 5). A previous study showed that seed germination of *Hopea ponga* in the Dipterocarpaceae family occurs in epigeal (Muralikrishna and Chandrashekar 1997).

All seeds are germinated without any treatment, meaning that after the seeds are collected from the field, the seeds are spread in a sowing tank to germinate (Figures 5 and 6). This study was conducted for approximately 90 days, starting from collecting seeds, spreading seeds, and observing seed germination until the growth of leaves and the shedding of the cotyledon from the stems of dipterocarps seedlings. In the germination, this study described six stages with at least one or more stages of growth and development that can be observed and followed, namely:

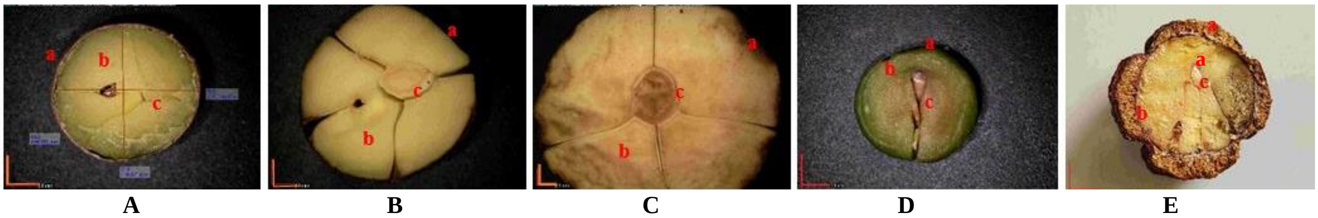

Figure 4. Seed longitudinally morphology of five species of dipterocarps. A. *Shorea selanica*, B. *Shorea pinanga*, C. *Shorea stenoptera*, D. *Hopea gregaria*, E. *Vatica pauciflora*. Note: a. Testa; b. Cotyledon; c. Embryo. Scale: 1:2.0 mm

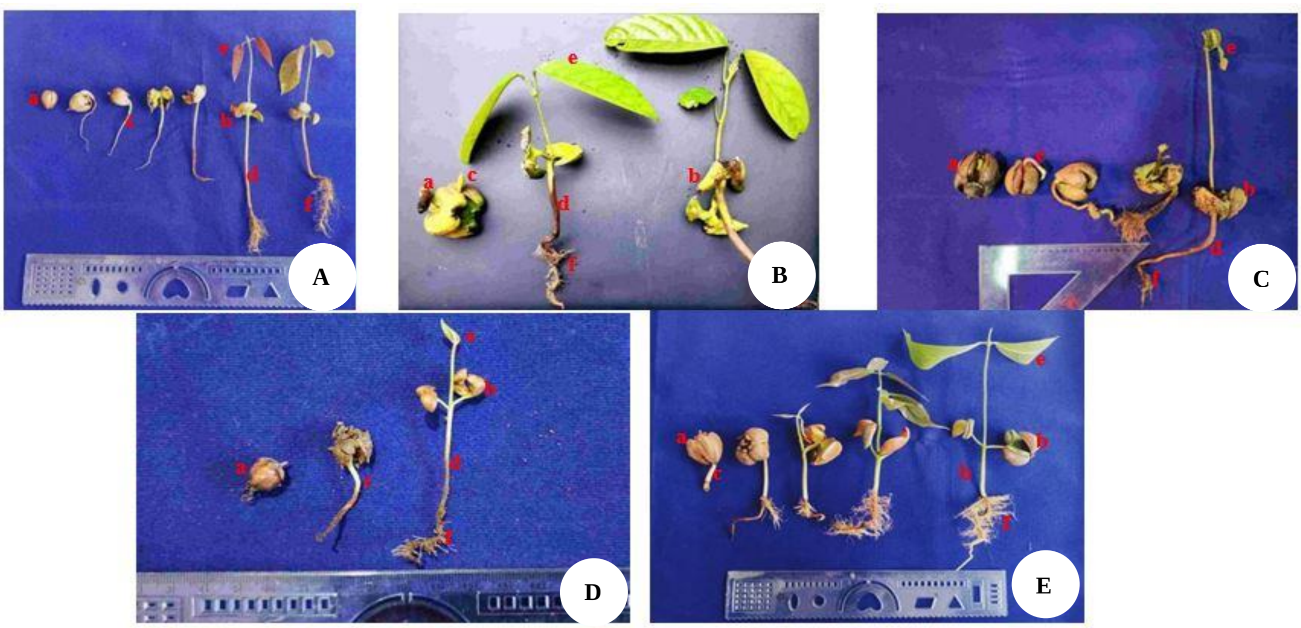

Figure 5. Germination stages of five species of dipterocarps. A. *Shorea selanica*, B. *Shorea pinanga*, C. *Shorea stenoptera*, D. *Hopea gregaria*, E. *Vatica pauciflora*. Note: a. Testa seed coat; b. Cotyledon; c. Radicle; d. Hypocotyl; e. Epicotyl (first leaf); f. Root

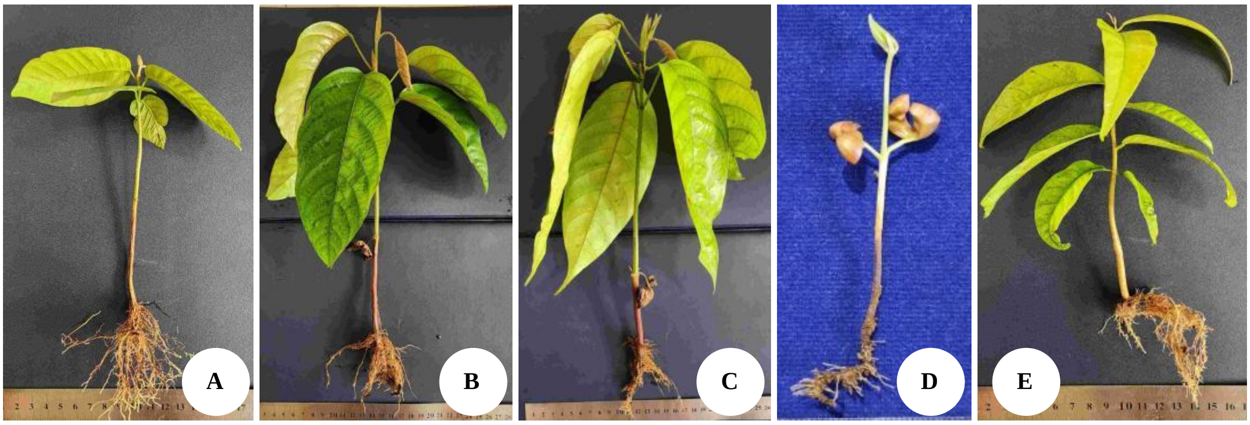

Figure 6. The final stages of five species of dipterocarps. A. *Shorea selanica*, B. *Shorea pinanga*, C. *Shorea stenoptera*, D. *Hopea gregaria*, E. *Vatica pauciflora*

(1) The first stage was the radicle growth stage. There were the initial steps within 14 days for *S. selanica, H. gregaria*, and *V. pauciflora* and within 35 days for *S. stenoptera* and *S. pinanga*. The emerged radicles, pale pinkish, which initially grew vertically upwards, turned positively geotrophic the next day. It continues with the growth of additional roots around the main root.

(2) The second stage was the primary root growth stage. It showed that the emergence of the hypocotyl followed root sprouting. The process of photosynthetic assimilation starts at this point. A green color, assumed a chlorophyll, with increasing concentration appears on the entire cotyledon stalk, except the section nearest the major root, and indicates that the primary roots start to actively transport nutrients from the soil to aid in the assimilation process. A yellowish hypocotyl stem emerges with continued growth and extends through the cotyledon, gradually growing longitudinally to form an arch under the ground. The hypocotyl stem grew longer and longer until, at last, both the tip of the stem and the seed pod were above the soil in the next 7-12 days after the first stage for all dipterocarps seeds.

(3) The third stage was the opening process of the cotyledon bulb. The cotyledon bulbs fully split into two equal sections in dipterocarp seeds. The cotyledon bulbs were opened as the epicotyl emerged from the surface towards sunlight. The growths of the hypocotyl, which penetrates the soil, were directly correlated with the epicotyl's rise to the above ground in the next 14 days after the complete second stage for all dipterocarps seeds.

(4) The fourth stage was the epicotyl growth stage. The first leaves began to grow with yellowish-to-green-colored, slowly growing shoots with pointy tips emerging at the tip of the epicotyl stem. The shoot enlarges until it breaks into two sections, eventually giving rise to the first two opposing leaves. The initial leaf was shaped somewhat like an adult leaf but with a slight roundness in the next 10-14 days after the third stage for all dipterocarps seeds was completed.

(5) The fifth stage was the cotyledon removal from dipterocarps seedlings. When the first leaf fully emerges, the cotyledons stay in place, and when the second leaf starts to develop, they decompose. The cotyledons' color changes from green to brown to black, and eventually, they break off on their own, signifying the process of cotyledon shedding. This demonstrates that within 10 to 15 days following the completion of the fourth stage, the seeds have perfectly germinated.

Discussion

These findings generally encouraged using dipterocarps species in restoration, provided that the species' geographic distribution ranges were maintained. The morphology and seed germination type of the five dipterocarps examined here unequivocally demonstrate that the seeds embody every distinguishing trait that three genera (*Shorea*, *Hopea*, and *Vatica*) share. Distinct morphological features that were only developed in three genera of dipterocarps were observed in their wings. The longer wings of the *Shorea* seeds under investigation possessed structural similarities to those of Hopea and *Vatica*. The two additional *Shorea* species, Tengkawang, *S. stenoptera,* and *S. pinanga*, had shorter wings than *S. selanica* (*Meranti*). In addition to being known to aid in seed dissemination, wings were a component of dipterocarps seeds. Moreover, an ecological report was regarding the clumped formations of *S. pinanga* in recently exploited open areas, which were thought to be the result of wind-dispersed seeds (Muralikrishna and Chandrashekar 1997; Smith et all 2015). Based on seed morphological data, only the wings length arguments were found to separate *Shorea* spp. from other genera of dipterocarps.

Therefore, to investigate the methods by which dipterocarps seeds adapt to their environment and the relationship between dormancy and recalcitrance in terms of reproductive success, this study examined the structural characteristics of the seeds. Comprehending the germination and seedling growth ecology is crucial for developing methods for seed conservation and tropical rainforest restoration, in addition to providing insights into plant community processes and succession. It was possible to apply knowledge of how dipterocarps germinate in nature to industrial forest and agroforestry plantings. Human activity was not the only cause of decreased dipterocarps seed development behavior factors (Primananda et al. 2023), but also, irregular flowering patterns may have occurred due to El Niño in 2023. The other causes of seed resistance were short-lived viability (recalcitrant seeds) and seed predators (post-dispersal predation and pre-dispersal predation). Additionally, after escaping seed predation and successfully germinating, seedlings must survive or resist pathogens, herbivory, and mechanical damage, limiting their growth and development (Chong et al. 2016).

Figure 5 illustrates how pathogen infections cause the cotyledons of *S. pinanga* seedlings to decay more quickly in the early development stages, disrupting the seedlings' normal development. A previous study revealed that dipterocarp seedlings are dying at a rate that is rising annually in their natural habitat (Ediriweera et al. 2020). Supposing this species was perpetuated and protected, more pathogens management is required to increase the success of the plantation. When planted in a shallow media, the roots of the *S. stenoptera* species also fold easily. Treatment for this kind of root growth involves maintaining the planting media loose and ensuring the soil is not compacted, particularly when propagating in nurseries. Furthermore, a loose, porous medium was easily penetrated by roots growing from the seed and this kind of media had enough pores for water and air to circulate. A planting media that is too dense will make it difficult for roots to penetrate and cause water stagnation so that the conditions become too humid and the seedlings become decayed (Susanto et al. 2016). Although potrays can be used in nurseries to encourage root growth, it is more advisable to utilize square-shaped containers as they are more effective than round-shaped ones (Rachmat et al. 2018). Dipterocarpaceae, including *S. stenoptera*, had limited seed viability, which raises concerns about forest regeneration in their natural habitat. This was frequently followed by significant levels of vertebrate predation after the seeds fell to the ground or before they disseminated. This, in turn, can differ between forests with different levels of disturbance (Blackham et al. 2013). There may also be interactions between the various stages from seed to seedling establishment; previous processes depend on positive density in avoiding seed predation by insects or vertebrates or attack by herbivores or fungi (Chong et al. 2016).

Moreover, to understand how the adaptive mechanisms of mass flowering can be disrupted by human disturbance, we must study each step of the related process, from seed morphology to seedling establishment. Seeds of certain species damaged by drying below critical levels cannot be stored for long periods (Molina et al. 2017) and are called recalcitrant seeds. The findings of this study showed that the dipterocarp seeds germinated in 14–30 days, allowing them to be classified as recalcitrant seeds. More preservation must be conducted to keep seeds viable, especially for some species with no yearly fruiting. The reason for the complicated loss of viability is the sequential loss of water content that damages the cells with loss of semipermeable character, as evidenced by leaches, and it is thought that the damage to the membrane cannot be repaired by further hydration. Dipterocarps seeds produced in humid environments are usually stubborn because they are not resistant to dehydration and low temperatures, causing loss of viability during storage. Recalcitrant is associated with certain structural and physiological characteristics associated with short dormancy (Silva et al. 2014). Excessive moisture in planting media in the nursery also should be avoided since this can lead to root rot. There was an obvious interaction between the media and methods of breaking seed dormancy at the initial seedling height (Rivai et al. 2015).

Furthermore, very little information is available regarding the eco-physiological aspects of dipterocarps, such as detailed descriptions and no detailed study on the germination process of recalcitrant seeds. The association between dormancy and recalcitrance is crucial to the reproductive success of dipterocarps seeds. Dormancy is an adaptive characteristic of great importance in many species, as it spreads germination over time, making germination under many environmental conditions favourable to seedling establishment more probable, diminishes competition between seedlings, and even contributes to forming a seed bank. As dipterocarps have seasonably variable fruiting, occur in constantly humid environments, and produce recalcitrant seeds with low potential for seed bank formation, it is possible to propose that short dormancy in these species takes on a different but equally relevant role, favouring species dispersal by rapid germination. These study findings can be applied to promote the implementation of dipterocarp restoration in low-impact logging systems and the sustainable and extended growth of high-conservation value forests. Nevertheless, even previous studies mentioned the distance from tourist attractions of at least 50 m must closed to avoid a massive landslide in the dipterocarps restoration location (Fambayun et al. 2020). Policymakers should prioritize the conservation gaps found in this study when creating new protected areas to fulfil the 2030 target. This includes lowland areas of in-situ conservation areas that are preferable for dipterocarps, as earlier studies have shown (Luo et al. 2022). It should be highlighted that the distribution patterns of dipterocarp species are clustered in their natural habitat (Irni 2022). Therefore, it is important to ensure that dipterocarp seed collection occurs closely to the mother tree and that restoration efforts match the distribution patterns found in their native habitat.

Regarding the germination type, the species analyzed in this study have epigeal germination, with cotyledons that rise above the ground. Cotyledons are the first leaves that appear on a plant, playing an important role in seedling development, especially in the early stages. Cotyledons can serve as a food store and/or photosynthetic organs (Handayani 2017). The hypocotyl was long in size in the species analyzed, and the cotyledonary sheath's presence caused the seed elevation. Consequently, it is partially above and, at the same time, partially below the soil. This author suggests that these terms should be used to frame the plant regarding the position of the seed concerning the soil, in which the term epigeal is used for plants that have seeds above ground, and hypogeal is for seeds that remain below ground; this study used the term epigeal since the seed is elevated through the cotyledonary sheath. The final germination rate was observed when no more seeds germinated three months after planting.

In conclusion, this study showed three winged seeds (*S. selanica, S. pinanga,* and *S. stenoptera*) and two winged-less seeds (*H. gregaria* and *V. pauciflora*). Species *S. pinanga* had the longest wings (152.25±9.93 mm) among the five species, while species *V. pauciflora* showed the shortest wings (2.84±0.39 mm). Species *H. gregaria* had the first fruiting time, followed by others, and it had the lightest weight (0.49±0.06 g). Dipterocarps seeds were dicotyledonous and contained the complete and easy-to-identify seed parts (testa, cotyledon, radicle, hypocotyl, epicotyl, plumule, and hilum). It takes around 90 days for all dipterocarps seeds to reach the final stage of germination, indicated by the cotyledons falling off the epicotyl stem. Further research is required to determine the function of wings in dipterocarps seeds for germination, as well as the seeds' resistance to mechanical harm after falling to the ground.

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