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Leaf Decomposition Rate in the Pond of Purwodadi Botanic Garden–BRIN

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A B S T R A C T

The Purwodadi Botanic Garden contain a diverse collection of plants and trees that continuously shed leaves and other plant parts. Trees produce large amounts of leaf litter, which plays a crucial role in maintaining soil fertility through microbial decomposition. On land, leaf litter decomposes into compost, while in aquatic environments, it contributes as a nutrient source for microbes and aquatic biota. No study on the rate of leaf decomposition has been conducted in the Purwodadi botani garden, highlighting the need to investigate the decomposition rate of specific plant species in the ponds. This study aims to observe the decomposition rate of Dillenia suffruticosa, Terminalia catappa, and Barringtonia asiatica in pond 10 of the Purwodadi Botanic Garden over a 28-day period by monitoring morphological changes and weight reduction. The results indicate that Barringtonia asiatica exhibited the highest decomposition rate, whereas Terminalia catappa had the lowest. The decomposition rate provides insight into the pond's potential to support acclimatized plants and aquatic organisms such as fish. Additionally, these findings contribute to understanding the natural decomposition process of leaves in aquatic ecosystems

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INTRODUCTION

The Purwodadi Botanic Garden (PBG) is located in the Purwodadi district, East Java, Indonesia. The existence of the PBG plays a crucial role in conserving plant species from extinction and serves as an educational field (Saris et al., 2004). The Purwodadi Botanic Garden are often referred to as the "hortus of the dry climate of Purwodadi" due to its drier climate compared to other Indonesian botanical gardens, such as the Bogor Botanic Garden, Cibodas Botanic Garden, and Bali Eka Botanic Garden. In addition, the Purwodadi Botanic Garden are home to over 10,000 plant species, including collections of Spermatophyta, Magnoliophyta, and Pteridophyta (Renjana & Firdiana, 2020). The PBG is situated at the foot of Mount Baung, at an elevation of 300 meters, with coordinates 7°47'54.96" S and 112°44'18.28" E. Covering an area of 845,148 m², the PBG is divided into 25 sections (vaks) and two side areas, with the main road serving as a dividing line. Each of these areas is further subdivided into three wards (Sugiarto, 2001). According to Laksono (2008), as the PBG has developed, its area has expanded into two side area and six part area, from 25 sections (vaks) to 183 sections, with each section typically containing several plant families.

The Purwodadi Botanic Garden host a diverse variety of plants and trees that continuously shed leaves and other plant parts. Trees are significant producers of organic matter, playing a key role in maintaining and restoring soil fertility. The term "litter" refers to organic matter, such as dry leaves, grass, and other plant remnants, that accumulate on dry, often colorless soil. Leaf litter is biodegradable, but its decomposition process takes time. The natural decomposition time for leaf litter to transform into compost, which can subsequently be utilized by plants or other organisms, typically takes about four months (Safriani et al., 2017). Decomposition is both a physical and chemical transformation process, facilitated by soil microorganisms, and is sometimes referred to as mineralization. The process begins with the fragmentation of plant material and dead organic matter by small insects. This is followed by a biological process in which bacteria and fungi break down organic particles. The decomposition process by bacteria and fungi is assisted by enzymes that can break down organic materials such as proteins, carbohydrates, and other compounds (Hanum et al., 2014).

LITERATURE REVIEW

Leaf litter from crops and trees in the Purwodadi Botanic Garden (PBG) often falls into the ponds. Ponds serve as water reservoirs and as habitats for aquatic organisms, such as fish and microorganisms. On land, leaf litter undergoes decomposition and contributes to the formation of compost. However, when it enters the water, it becomes a nutrient source for microbes and aquatic biota. To date, no studies have been conducted to observe the rate of decomposition of leaves in the botanical gardens, particularly in the ponds. Therefore, it is important to investigate the decomposition rate of various plant species in this environment. This study aims to assess the decomposition rates of three plant species—Dillenia suffruticosa, Terminalia catappa, and Barringtonia asiatica—found around the PBG pond, while monitoring changes in morphology and weight reduction.

METHODOLOGY

The study was conducted from June to July, 2022. Observations and measurements of the deposition rate were carried out at the pond of Purwodadi Botanic Garden (PBG). The layout of the pond in the Purwodadi Botanic Garden (PBG) is illustrated in Figure 1.

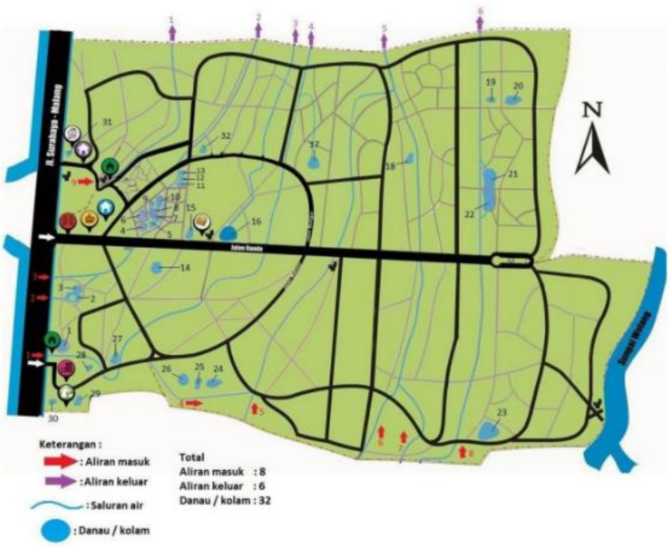

Figure 1. Layout and Distribution of the Purwodadi Botanic Garden Pond

Materials and Instruments

The tools and materials used in this study include weights, sound recorders, scissors, and ovens. The required specimens consist of Dillenia Suffruticosa, Terminalia catappa, and Barringtonia asiatica, with 18 leaves from each species. Additional materials include black nets, plastic ropes, millimeter blocks, tags, and stones as ballast.

Experimental Setup

The observed vegetation consisted of three species: Dillenia suffruticosa, Terminalia catappa, and Barringtonia asiatica. The selected pond was chosen due to its potential for rapid decomposition, supported by the presence of abundant microorganisms, algae, and other aquatic organisms. Leaf samples were collected from the selected plant species, with 18 leaves per species. These leaves were placed in nylon mesh bags (12 cm × 30 cm) with a mesh size of approximately 1 cm. The mesh bags were secured with a binder at the end to prevent loss of material.

Measurements were Conducted in Two Stages: Wet Weight Measurement and Dry Weight Measurement.

a. **Wet Weight Measurement:** Fresh leaf samples were weighed and then placed in the pond for four weeks. Observations were conducted every two weeks to monitor morphological changes during the decomposition process.

b. **Dry Weight Measurement:** Leaf samples were retrieved from the pond, dried, and weighed. The dried samples were then placed in paper bags and oven-dried at 600°C for three to five days. Finally, the samples were weighed again to determine the dry weight.

Decomposition Rate Calculation

The decomposition rate was determined based on the weight loss of the sample over a specific time interval. The rate was calculated using the following equation, as described by Firmansyah (2020):

$$R=(W0-Wt)/T$$

Keterangan:

R = Decomposition Rate (g/day)
W0 = Initial Sample Weight (g)
Wt = Final Sample Weight (g)
T = Observation Interval (days)

RESULTS AND DISCUSSION

Condition of the PBG Pond

The PBG contains 32 identified ponds. The observed pond, located in Pond 10 (Vak XII.G), is a closed, stagnant water body with no flow. The pond hosts several aquatic plant species, including *Pistia stratiotes* and *Nymphaea rubra*. *Pistia stratiotes* dominates the pond, giving it a dense green appearance.

Figure 2. Pond 10 of the PBG (Personal Documentation)

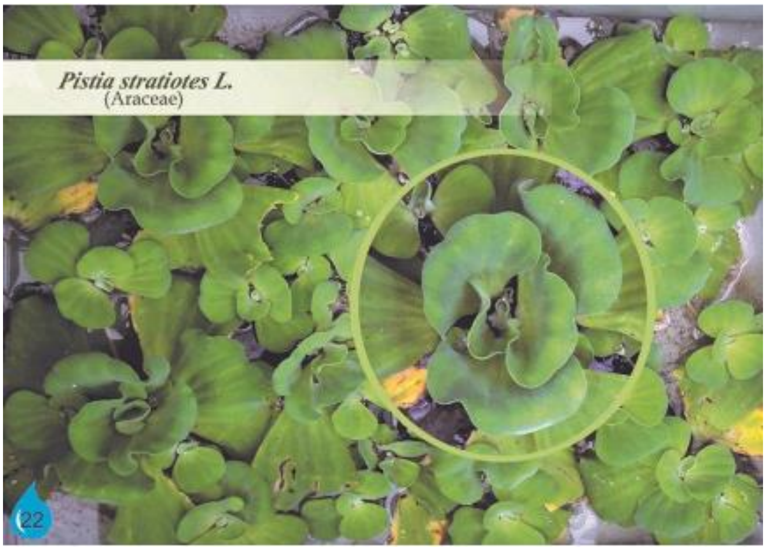

Figure 3. Pistia Stratiotes
(https://kebunrayaprwdd.wixsite.com/tumbuhanakutikkrp/post/pistia-stratiotes)


Figure 4. Nymphea Rubra
(https://kebunrayaprwdd.wixsite.com/tumbuhanakutikkrp/post/the-real-reason-you-have-wanderlust)

The process of decomposition and microbial activity is influenced by climatic and environmental factors such as oxygen levels, light intensity, humidity, temperature, and pH. During the study, the water conditions in Pond 10 of the Purwodadi Botanic Garden were as follows: pH 7.30, humidity 38%, water temperature 28.7°C, and light intensity of 113 lux. In general, most microorganisms grow optimally within a pH range of 6–8. However, some microorganisms can also thrive outside this range (Askari, 2010). Idawaty (1999), as cited in Saibi & Tolangara (2017), stated that microorganisms can efficiently break down organic matter at a pH of 5.5 or higher. Conversely, when the pH falls below 5.5, microbial growth is inhibited, leading to a decline in decomposition rates. Given that the observed pH during this study was 7.30, the water quality in Pond 10 was suitable for microbial growth and decomposition processes.

Water temperature influences the concentration of dissolved gases, including oxygen (O_2). The optimal temperature range for the growth of aquatic microorganisms is between 20°C and 30°C (Effendi, 2003). During the study, the water temperature in Pond 10 was recorded at 28.7°C, which is favorable for the decomposition process. Temperature plays a crucial role in the growth and survival of microorganisms. It also affects light penetration into the water. Limited light penetration reduces the depth at which photosynthesis by phytoplankton can occur, leading to lower oxygen production. Consequently, this condition results in a decline in the distribution of aerobic bacteria at greater depths. In contrast, anaerobic bacteria tend to increase in abundance with depth, provided that environmental conditions support their growth and development. Pond 10 of the PBG was at Level 4, indicating that it was fully filled with water. The dense growth of Pistia stratiotes and Nymphaea rubra extensively covered the pond's surface, partially obstructing the decomposition process by limiting light and oxygen availability.

Terrestrial Plants

The terrestrial plant species used in this study include Barringtonia asiatica, Dillenia suffruticosa, and Terminalia catappa.

Barringtonia asiatica is a mangrove-associated plant commonly found on sandy beaches, coral sands along coastlines, and mangrove swamps at elevations ranging from 10 to 1,700 feet (0 to 350 meters) above sea level. This species has been traditionally used by local communities as a remedy for stomach ailments, rheumatism, and wound treatment. The fruit of B. asiatica contains saponins and triterpenoids, which, when combined with extracts from other plants, have potential benefits for human health (Septiarusli, 2012). In addition to its pharmaceutical value, Barringtonia asiatica plays a crucial role in coastal protection. Its robust and sturdy root system acts as a natural barrier, helping to absorb tidal waves and strong winds while preventing coastal erosion.

The Following is the Taxonomic Classification of B. Asiatica (Plantmor, 2022):

1. Kingdom : Plantae
2. Subkingdom : Tracheobionta
3. Superdivision : Spermatophyta
4. Division : Magnoliophyta
5. Class : Magnoliopsida
6. Subclass : Dilleniidae
7. Order : Lecythidales
8. Family : Lecythidaceae
9. Genus : Barringtonia
10. Species : Barringtonia asiatica (L.) Kurz

Figure 5. Barringtonia Asiatica (L.) Kurz

Dillenia suffruticosa is a shrub that grows between 6 to 10 meters in height. It has alternating, simple, oval-shaped leaves with smooth surfaces, measuring 12–40 cm in length and 6–12 cm in width. The plant produces large, yellow, odorless flowers that do not produce nectar. Its fruit is pink and star-shaped, containing fleshy purple seeds (AsianPlant, 2016).

Dillenia suffruticosa (commonly known as water chime) is predominantly found in swampy areas, along rivers, and in forests at elevations of up to 700 meters (1,700 feet). This species often forms dense thickets and grows naturally in various soil textures, ranging from sandy to clayey substrates (Socfindoconservation, 2020). It is also commonly found in alluvial environments such as swamps, mangroves, and riverbanks (AsianPlant, 2016).

The Following is the Taxonomic Classification of *Dillenia Suffruticosa* (Plantmoor, 2022):

1. Kingdom : Plantae
2. Subkingdom : Tracheobionta
3. Superdivision : Spermatophyta
4. Division : Magnoliophyta
5. Class : Magnoliopsida
6. Subclass : Dilleniidae
7. Order : Dilleniales
8. Family : Dilleniaceae
9. Genus : Dillenia
10. Species : *Dillenia suffruticosa* Griff. ex Hook.

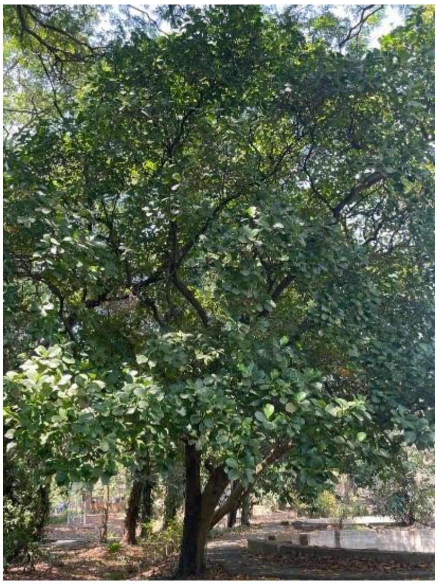
Figure 6. Dillenia Suffruticosa

Terminalia catappa commonly known as the ketapang or Indian almond tree, typically grows in lowland areas. The tree has a straight, vertically growing trunk with large, horizontally extending branches that form a broad, umbrella-like canopy. It can reach a height of approximately 35 meters (110 feet). The tree provides dense shade, with branches spreading out horizontally as they grow. Its leaves are large, ovate, and slightly wavy at the edges, tapering at the base. The leaves expand in parallel to the tips of the serrated margins. The flowers are small and inconspicuous, typically growing in clusters along the twigs (Marjenah & Putri, 2017a).

Terminalia catappa Linn. (commonly known as ketapang or Indian almond) is a widely distributed coastal tree. Native to tropical regions of India, it has spread across northern Asia, northern Australia, and Polynesia in the Pacific Ocean. The tree undergoes two reproductive cycles annually, the first occurs between January and March, and the second between July and September. Once the canopy is bare, all branches develop new leaves, causing the tree to regain its greenery. Following the emergence of new leaves, the ketapang tree produces flowers, and its fruit typically appears at the top of the tree, predominantly on the eastern side (Marjenah & Putri, 2017b). In addition to growing naturally along coastal areas, T. catappa is frequently cultivated as a shade tree in lowland regions.

The Following is the Taxonomic Classification of Terminalia Catappa (Mahfuza *Et Al.*, 2022).

1. Kingdom : Plantae
2. Division : Magnoliophyta
3. Class : Magnoliopsida
4. Order : Myrtales
5. Family : Combretaceae
6. Genus : Terminalia
7. Species : *Terminalia catappa*

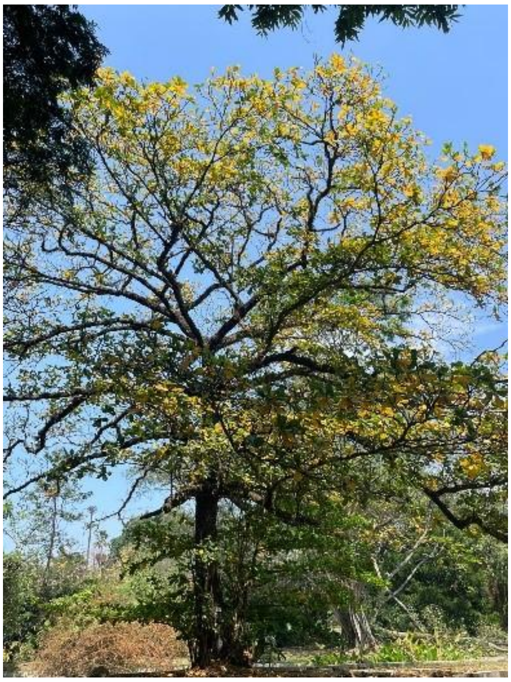

Figure 7. Terminalia Catappa

Superficial Morphological Changes in Leaves During Decomposition

Barringtonia asiatica has thick, dark green leaves with clear vein patterns (Shauqi & Purwani, 2017). *Dillenia suffruticosa* has oval-shaped green leaves with a length of 15–36 cm and a width of 5–12 cm. *Dillenia indica* L. leaves are included in the category of large and stiff leaves (Prananda, 2013). *Terminalia catappa* leaves are wide at the tip and pointed at the base, with a layer of fine hairs on the underside. The center of the leaf is relatively wide, with a pointed tip, smooth leaf edges, thin leaf texture, and pinnate leaf vein patterns (Ningrum, 2021). To assess the decomposition process, leaves were selected that had naturally fallen and started to rot. Leaves that underwent decomposition showed a brownish color and a slightly dry texture.

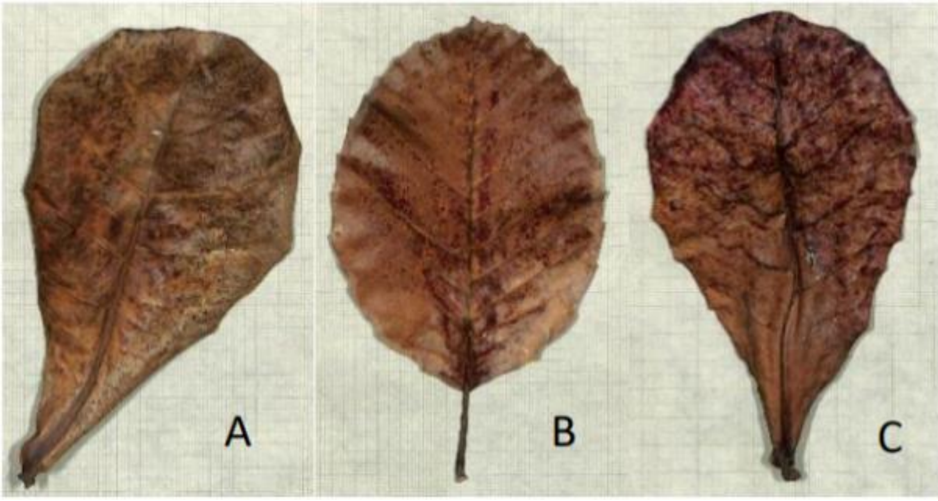

Figure 8. Leaf Litter Decomposition After 2 Weeks: (A) Barringtonia Asiatica, (B) Dillenia Suffruticosa, and (C) Terminalia Catappa (Personal Documentation, July 2022)

The structural characteristics of leaves can also be assessed through their morphological changes. Leaves that turn dry brown and remain pliable when squeezed indicate rapid decomposition. In contrast, leaves that become dry and black, crumble with sharp edges, and feel rigid suggest a slower decomposition process (Hairiah et al., 2004).

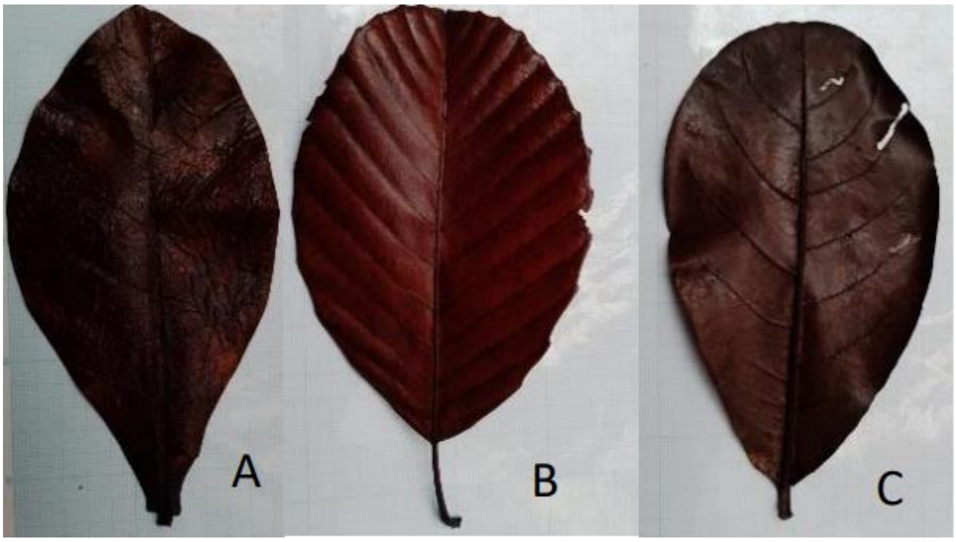

Figure 9. Leaf Litter Decomposition After 2 Weeks: (A) Barringtonia Asiatica, (B) Dillenia Suffruticosa, and (C) Terminalia Catappa (Personal Documentation, July 2022)

After being submerged in the pond for two weeks (14 days), the leaf remains intact but appears slightly thinner.

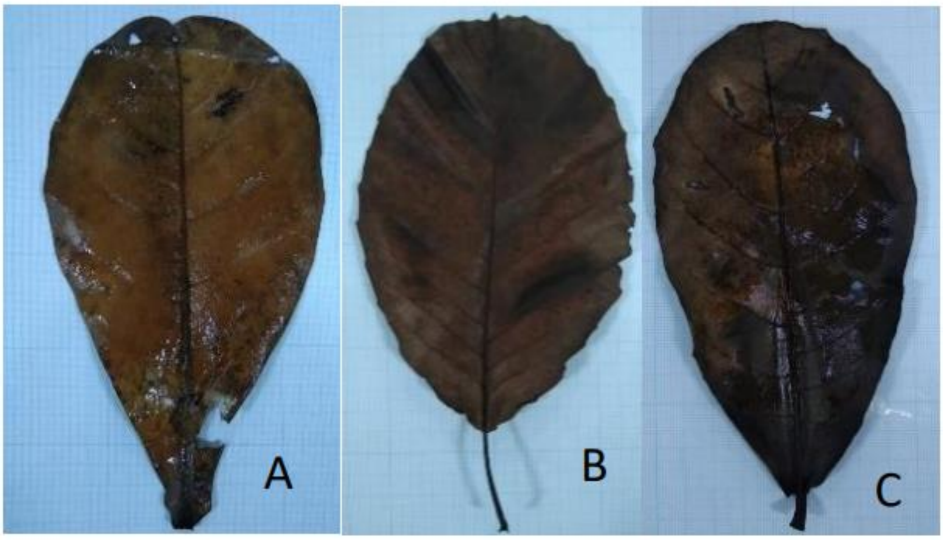

Figure 10. Leaf Litter Decomposition After 4 Weeks: (A) Barringtonia Asiatica, (B) Dillenia Suffruticosa, and (C) Terminalia Catappa (Personal Documentation, July 2022)

After four weeks (28 days), the leaf appears similar to its condition at two weeks. It remains intact but is slightly thinner, with *Barringtonia asiatica* leaves showing small holes along the margins.

Rate of Decomposition

The decomposition of leaf litter from *Dillenia suffruticosa*, *Terminalia catappa*, and *Barringtonia asiatica* over 28 days indicates that none of them have fully decomposed (100%). The decomposition rate of the leaves is presented in Table 1.

Table 1. Wet and Dry Weight Measurements

Time (Days)	Tree Species	Initial Weight (g)	Final Weight (g)
0	*Dillenia suffruticosa*	12,33	7,67
	Terminalia catappa	7,99	5,56
	Barringtonia asiatica	15,63	13,68
14	*Dillenia suffruticosa*	12,48	9,80
	Terminalia catappa	7,83	4,97
	Barringtonia asiatica	14,38	11,29
28	*Dillenia suffruticosa*	11,11	6,09
	Terminalia catappa	8,74	4,81
	Barringtonia asiatica	19,95	9,92

Measurement of plant sample weight showed changes in the three types of vegetation. On day 0, *Barringtonia asiatica* had the highest final weight (13.68 g), while the lowest was *Terminalia catappa* (5.56 g). On day 14, *Barringtonia asiatica* still had the highest final weight (11.29 g), while *Terminalia catappa* had the lowest weight (4.97 g). This trend continued on day 28, with *Barringtonia asiatica* maintaining the highest final weight (9.92 g) and *Terminalia catappa* the lowest (4.81 g). These results indicate that *Barringtonia asiatica* showed the highest leaf mass retention among the six leaf samples. This may be due to its morphological characteristics, as it has dark green and thick leaves (Shauqi & Purwani, 2017).

The litter decomposition rates of *Dillenia suffruticosa*, *Terminalia catappa*, and *Barringtonia asiatica* at each observation period are presented in the following figure:

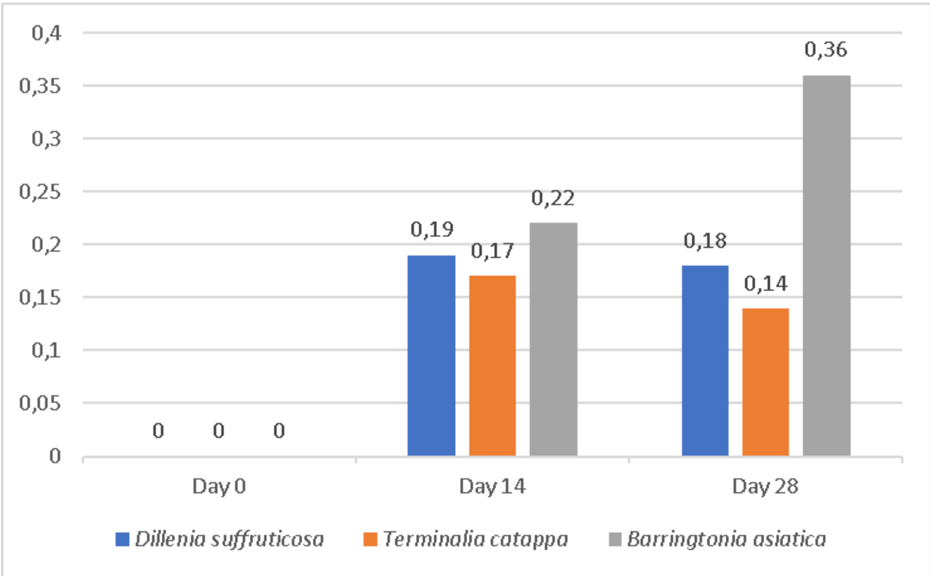

Figure 11. Graph of Litter Decomposition Rate for Dillenia Suffruticosa, Terminalia Catappa, and Barringtonia Asiatica

The data from day 0 do not indicate decomposition but instead serve as a baseline for comparison with subsequent measurements. On day 14, *Terminalia catappa* exhibited the lowest decomposition rate at 0.17 g/day, while *Barringtonia asiatica* showed the highest rate at 0.22 g/day. By day 28, the lowest decomposition rate remained at 0.14 g/day, whereas the highest rate, again observed in *B. asiatica*, increased to 0.36 g/day. The slower decomposition rate of *T. catappa* is likely attributed to its thinner and smaller leaf structure, which provides a lower overall tissue mass available for decomposition compared to *B. asiatica* and *Dillenia suffruticosa*.

CONCLUSION AND RECOMMENDATION

Among the three plant species—Dillenia suffruticosa, Terminalia catappa, and Barringtonia asiatica—the highest decomposition rate was observed in B. asiatica, while the lowest was recorded in T. catappa. This difference is likely due to the greater initial weight of B. asiatica leaf samples compared to those of D. suffruticosa and T. catappa. The decomposition rate provides valuable insights into the pond's potential for supporting aquatic plant growth and serving as a habitat for other organisms, such as fish. Additionally, decomposition measurements can be used to assess the natural breakdown rate of leaf litter in the environment.

FURTHER STUDY

This study was conducted using only three plant species over a one-month period. A comprehensive understanding of the complete decomposition process requires further research over longer durations, with a greater diversity of plant species, and consideration of the influence of specific environmental factors across different ecosystems.

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