TROPICAL LIFE SCIENCES RESEARCH

Dynamics of Litter Production and Decomposition: A Case Study from A Tropical Coastal Lagoon, Malaysia

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Highlights

- The total annual litter fall production was recorded ~1325 g/m^2, and leaves were the major contributor (59%) to litter production throughout the year.

- In litter decomposition, both the decay rate and the percentage of wet losses were high(50%) during the first ~30 days of the study.

- Significant difference (F= 14.19, $p < 0.001$) was found in the decay constant at different positions during the experimental period, and the pattern of loss was highest on the forest floor, followed by hanging and burial positions for both species.

EARLY VIEW

Dynamics of Litter Production and Decomposition: A Case Study from A Tropical Coastal Lagoon, Malaysia

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Running head: Ecosystem Functions of Mangrove Forest

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Abstract: Litter production and decomposition are the controlling factors in carbon dynamics and energy fluxes within mangrove ecosystems. The rate of decomposition is regulated by biotic and abiotic factors in many mangrove ecosystems worldwide. The limited information on litter production in a tropical lagoon and faunal effect in decomposition process makes it challenging to understand the impact on ecosystem functioning. Thus, study was examined: i) Monthly rate of litter production and ii) the decay pattern of leaf litters of two mangrove species, Bruguiera *gymnorrhiza* and *Rhizophora mucronata* at different positions i.e., forest floor, hanging position, and burial position, using 0.50 mm mesh litter bags. To estimate the litter production one seasonal year was observed and 120 days research trial was carried out to examine the decay pattern of leaf litters in a tropical lagoon mangrove ecosystem. The total annual litter fall production was recorded ~1325 g/m^2, and leaves were the major contributor (59%) to litter production throughout the year. In litter decomposition, both the decay rate and the percentage of wet losses were high (50%) during the first ~30 days of the study. Due to the different physicochemical characteristics of the leaf (i.e., toughness, lignin content, C:N ratio, and other phenolic) of two mangrove species a significant changes ($F= 4.55$, $p< 0.05$) were found in the decay pattern. There was also a significant difference ($F= 14.19$, $p< 0.001$) in the decay constant at different positions during the experimental period, and the pattern of loss was highest on the forest floor, followed by hanging and burial positions for both species. Findings suggest that employing various positions in decomposition experiments can enhance the overall understanding of ecological impacts on ecosystem functioning and dynamics in tropical mangrove ecosystems.

Keywords: Ecosystem Functions, Mangrove Forest, Litter Production, Decay Constant, Malaysia

INTRODUCTION

Mangrove forests are the world's most productive wetland ecosystems in intertidal coastal zones of tropical and subtropical countries (Kathiresan 2002, Roy and Krishnan 2005, Proffitt et al. 2006; Hoque et al., 2015 a, b; Islam et al. 2024) and dispersed over 123 countries (Billah et al. 2022). Mangrove ecosystems are unique and providing numerous ecosystems functions and services such as biodiversity provisions and blue carbon sinks (Islam et al. 2024). Mangrove litter productions are important ecosystem functions and significant contributions to the nutrient budget to the surrounding ecosystems. The quantification of litter production is important to assess the net productivity of a mangrove ecosystem (Lee, 1999; Imgraben and Dittmann, 2008). A large portion of the mangrove's above-ground primary productivity comes from leaf litter, which is also reported to be the main source of mangrove litter (Hoque et al., 2015b). Furthermore, litter breakdown is related to three primary components: i) leaching of soluble inorganic compounds; ii) physical fragmentation and biological decomposition; and iii) microbial degradation of refractory organics such as cellulose and lignin (Valiela et al., 1985; de Oliveira et al., 2013; Zimmer, 2019). Studies have revealed that litter leaching accelerates litter decomposition by generating ideal positions for microbes and also by enhancing the litter's palatability to detritus feeders (Zimmer, 2019).

Nutrient cycling (Lu and Lin, 1990; Steinke et al., 1993) and productivity (Ashton et al., 1999) of mangrove depend on the rate of nutrient and organic matter release during the decomposition process (Islam et al. 2024). This is also determined by both the physicochemical characteristics of litters, such as the toughness of lignin and other phenolics (Kristensen et al., 2008; Zimmer, 2017; Abu Hena et al., 2020), and the surrounding environment, such as temperature and moisture (Smith and Bradford, 2003; Zimmer, 2017), as well as the decay rate of litters (Triadiati et al., 2011).

Decomposition depends on the degree and frequency of tidal inundation, climatic factors such as temperature, humidity and rainfall, substrate positions and the presence of leaf detritus-consuming fauna (Twilley et al., 1986; Tam et al., 1990; Mackey & Smail, 1996; Alongi, 2009; Galeano et al., 2010; Islam et al. 2024). Studies by Fourqurean and Schrlau (2003) demonstrated that litterfall in burial creates anoxic positions, which may slow down the decomposition process. To understand the differences within different environmental setups and positions, i.e., forest floor, hanging, and burial positions, studies on litterfall decomposition are important to examine.

Litter production and decomposition are important indicators of ecosystem functioning and are directly linked to nutrient dynamics and energy transfers in mangrove habitats (Kristensen et al., 2008; Zimmer, 2017). Leaf litter is the major contributor (30-70 %) to annual detritus production (Abu Hena et al., 2020) and nutrient release (Kristensen et al. 2008; Ainley and Bishop 2015; Zimmer 2017). Litter production of different species have been studied for decomposition analysis (Lima and Colpo 2014; Nordhaus et al. 2017), and effect of environmental condition (Ainley and Bishop 2015), and pollution (Hayes et al. 2017) on leaf litter decomposition are relatively understood. However, decay and decomposition of leaf litter have been rarely been studied in Malaysia (Hoque, 2015; Abu Hena et al., 2020; Hossain and Othman, 2005; Ashton et al., 1999; Japar Sidik, 1989; Ong et al., 1980; Islam et al. 2024). Previous studies on litter decomposition rates for different positions in mangrove ecosystems in a tropical mangrove are somehow limited. In this respect, the present study was carried out to determine the annual litter production along with the decomposition rates in different positions of the two dominant mangroves, i.e., *Rhizophora mucronata* and *Bruguiera gymn*orrhiza).

The following corresponding hypotheses were tested to broaden the understanding of the mangrove ecosystem functioning and dynamics:

1. Based on stand structure, litter production would be different in different seasons (Kamruzzaman et al., 2019) and is influenced by climatic factors such as rainfall, air temperature, and wind speed.
2. Different positions of leaf litter may change the decomposition rate in the mangrove ecosystem (Bradford et al., 2002; Kamruzzaman et al., 2019).

MATERIALS AND METHODS

Litter production and decomposition experiments were carried out in the tropical Seitu lagoon, Terengganu, Malaysia (Fig. 1). The species composition of mangroves in this lagoon has already been described in our previous investigations (Islam et al., 2022). High aquaculture and fisheries significance are associated with this wetland. It covers an area of 1025 km^2 with an approximate length of 14 km (Salim et al., 2015), and the depth ranges from 0.3 to 3.2 m. Tidal ranges are less than 2 m (Phillips, 1985). Due to the shallow structure of this lagoon, aquaculture activities, especially cage culture, are increasing considerably (Zainol et al., 2021). The tropical humid climate is characteristic of the region, and average rainfall was recorded at 208 mm month^{-1} (Nordhaus et al., 2017). This lagoon system hosts characteristics of mangrove habitats (Islam et al., 2022).

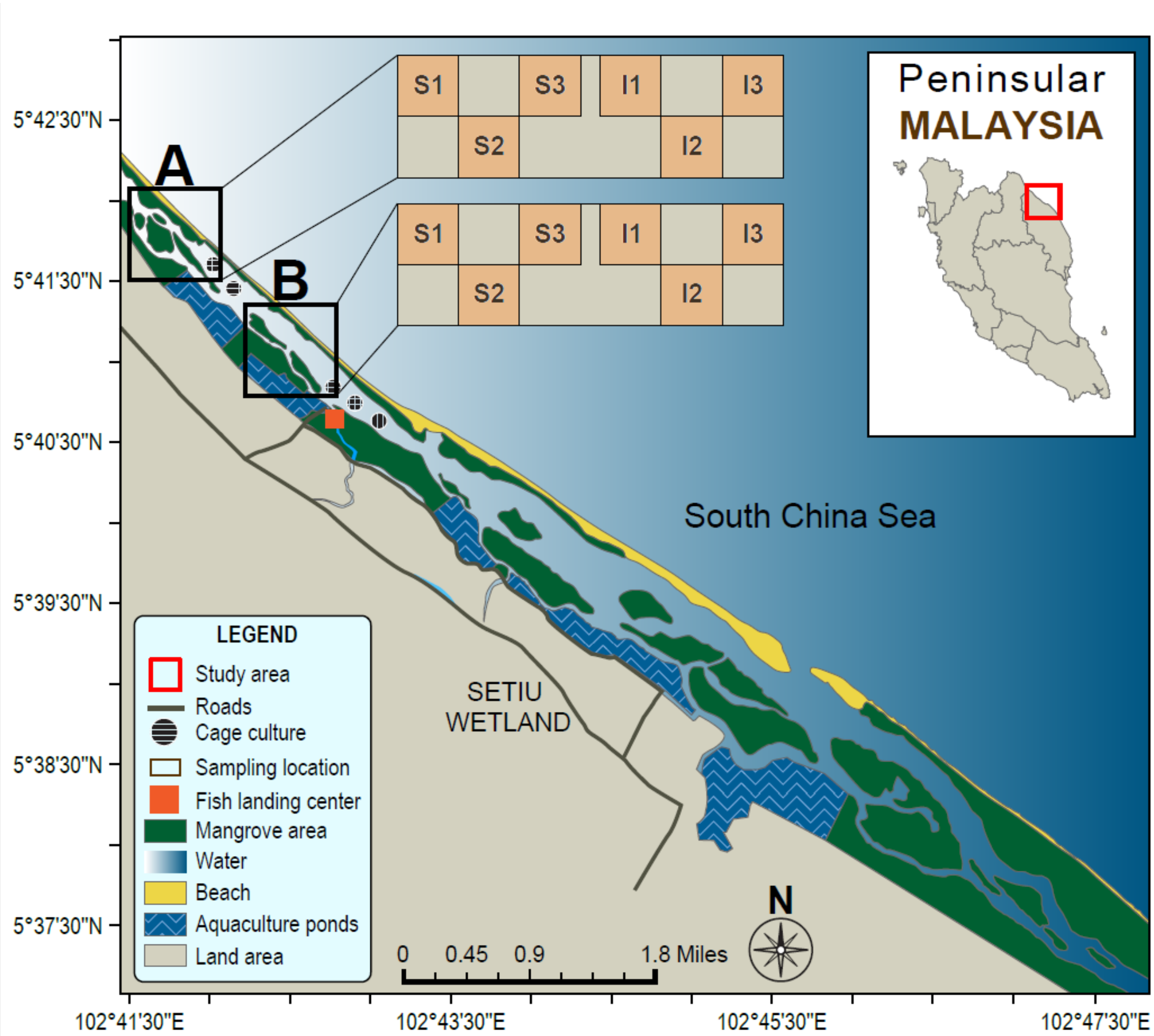

Figure 1: Study area map of Setiu lagoon showing sampling location, Terengganu, Malaysia.

Litterfall Study

Twelve (12) litter traps were prepared using plastic PVC pipe and fixed in two sampling sites (Site A-5°41'43.8"N 102°41'37.9"E; Site B-5°40'58.9"N 102°42'30.6"E; Fig. 1). The size of the litter traps was 1 m × 1 m and attached with a conical nylon bag (mesh size: 1 mm × 1 mm). Three litter traps at the Shore site (S) and another three at the Island site (I) were set up randomly in every 10 m × 10 m subplots of each sampling area above the tide level height under the forest canopy, following the methods of Brown (1982). The trapped litterfalls were collected monthly from September 2021 to August 2022 in labeled plastic bags and brought back to the laboratory for further processing. The litterfalls of the individual traps were sorted into leaves, twigs, stipules, flowers, propagules, and branches and then air-dried for 24 hours. The air-dried litterfall components were then oven-dried at 60 °C until they reached a constant weight. Once reached a constant weight, litterfall components were taken out of the oven and kept in a desiccator to cool down to room temperature, and then weighed for monthly calculation.

The Decomposition Study

In the present investigation, a field experiment was carried out at one forest plot (Site A-5°41'43.8"N 102°41'37.9"E; Fig. 1) in the intertidal area of Setiu lagoon. This mangrove habitat is characterized by sandy sediment (Table 1). Tree species richness in this mangrove system is high, including 20 true mangrove species dominated by *R. mucronata*, *B. gymnorrhiza*, *Avicennia alba*, *Ceriops tagal*, *Sonneratia alba*, and the palm *Nypa fruticans*. The mean stem density ranged between 1533 and 3800 individuals/ha (Islam et al., 2022). The riverbank is dominated by *N. fruticans,* especially in freshwater feeder canals or rivers, and vegetation in the middle zone is mainly composed of *R. mucronata* and *B. gymnorrhiza* (Islam et al., 2022; Rahman et al., 2023).

Table 1. Abiotic parameters (mean (±SD); *n*= 5) measured in the Setiu wetland during the study period.

Environmental matrices	Temp. (°C)	pH	Salinity (PSU)	Dissolved Oxygen (mg/L)	Soil Texture		
					Sand (%)	Silt (%)	Clay (%)
Surface water	28.33 ± 0.58	7.18 ± 0.02	12.42 ± 1.14	5.46 ± 2.19	-	-	-
Pore water	27.67 ± 0.58	6.93 ± 0.04	6.67 ± 0.83	-	-	-	-
Sediment	29.00 ± 2.00	5.90 ± 0.36	-	-	79.00 ± 4.00	7.33 ± 0.58	13.67 ± 3.51

The study reported that *R. mucronata* (relative density, 23.66%) is the most dominant species in the Setiu lagoon, followed by *B. gymnorrhiza* (15.53%) (Islam et al., 2022). Thus, in the present investigation, we considered leaf litter from these two major mangrove species for the decomposition experiment and tested our hypotheses.

Experimental design

For the decomposition study, the experiment was conducted over four months (120 days) from October 2021 to January 2022, taking into account the high decomposition rate of litter in the mangrove ecosystem (Oliveira et al., 2013; Loria-Naranjo et al., 2018; Abu Hena et al., 2020).

The “confined-loss” litter bag technique is an established and accepted method of investigating the decomposition rate of leaf litter (Mosom 1980; Fell et al., 1984; Middleton and Mckee, 2001). Senescent leaves were collected from the forest floor from study sites (Lecerf and Chauvet, 2008). In the laboratory, the leaves were then air dried at room temperature for 48 h to remove moisture from the leaves (Imgraben and Dittmann, 2008). A litter bag (20 cm × 15 cm; 0.5 mm mesh) was filled with 10 g of dried leaf material and set up on the study site (Fig. 2).

Figure 2: On field pictures of litter bags at different positions.

A total of 72 bags (2 species × 3 treatments × 3 replicates × 4 times) were tied at hanging positions, forest floor positions, and burial positions. During the study, randomly selected litter bags were collected from the study sites on 15, 30, 60, and 120 days. In the laboratory, the leaves from the collected bags were gently rubbed and washed under tap water on a sieve (220 µm mesh size) to remove the sediment. Then, the litter was dried at 60 °C for 96 h to obtain at constant mass (Silva et al., 2007).

To assess differences in degradation rates, we calculated percentage loss day^{-1}. This approach was used instead of fitting the data to exponential models because we were more interested in the refractory material contributing to organic matter accumulation than the pattern of loss over time. Total percentage remaining (X) for leaves were calculated from the weight at the end of the study (X_t) and the initial biomass (X_o) as: X = 100 (X_t/X_o). Total percentage loss (L = 100 – X) was then divided by the number of days in the study (Middleton and Mckee, 2001).

Data analysis

Decay constant (*k*), half-life ($T_{0.5}$) and 95% lifespan ($T_{0.95}$)

The negative single exponential decay model was followed to describe the decomposition process (Olson, 2007). The equation is as follows:

$$W_t = W_0 \, e^{-kt}$$

Where, W_0 (g) is the initial dry mass, W_t (g) is the dry mass at time “t”, *k* is the decay constant, and t (day) is the decomposition time in days.

Half-life ($T_{0.5}$) and 95% lifespan ($T_{0.95}$) were estimated from *k* values using the following equations:

$$t_{(0.5)} = \frac{ln\,(0.5)}{(-k)} = \frac{-0.693}{(-k)} \quad \text{(Bockheim et al., 1991)}$$

$$t_{(0.95)} = \frac{ln\,(0.05)}{(-k)} = \frac{-2.996}{(-k)} \quad \text{(Chandrashekara, 1997)}$$

Statistical Analysis

One-way and Two-way Analysis of Variance (ANOVA) were used to test whether the studied variable (i.e., weight remaining, decay constant) was different among sampling time (5 levels; 0, 15, 30, 60, and 120 days) or treatments (3 levels; forest floor, hanging position, and burial position) or species (2 levels) by using arcsine square root transformed data (SAS JMP 1998). Further, post-hoc pairwise comparisons were also performed in cases of significant differences (Sokal & Rohlf 1981). Single degree of freedom contrasts of interest were conducted to distinguish among three or more levels of factors where ANOVA indicated a significant difference (SAS JMP 1998). All statistical analyses were performed in Past (Ver 4.03) and R Studio.

RESULTS

Litterfall Biomass Production and Seasonal Change

A relatively high leaf litter production (58.98 g/m^2) was recorded in March, followed by December (58.22 g/m^2), May (56.61 g/m^2), and January (56.26 g/m^2), as shown in Fig. 3. Peak flower and propagule litterfalls were 18.04 g/m^2 and 4.52 g/m^2, respectively, recorded in September, with the highest fruit litterfall recorded in November (39.54 g/m^2) (Fig. 3). Branch litterfall was almost similar all over the year, with small fluctuations in the study area. With some exceptions, the total monthly litterfall production of the forest did not fluctuate throughout the year (Fig. 3).

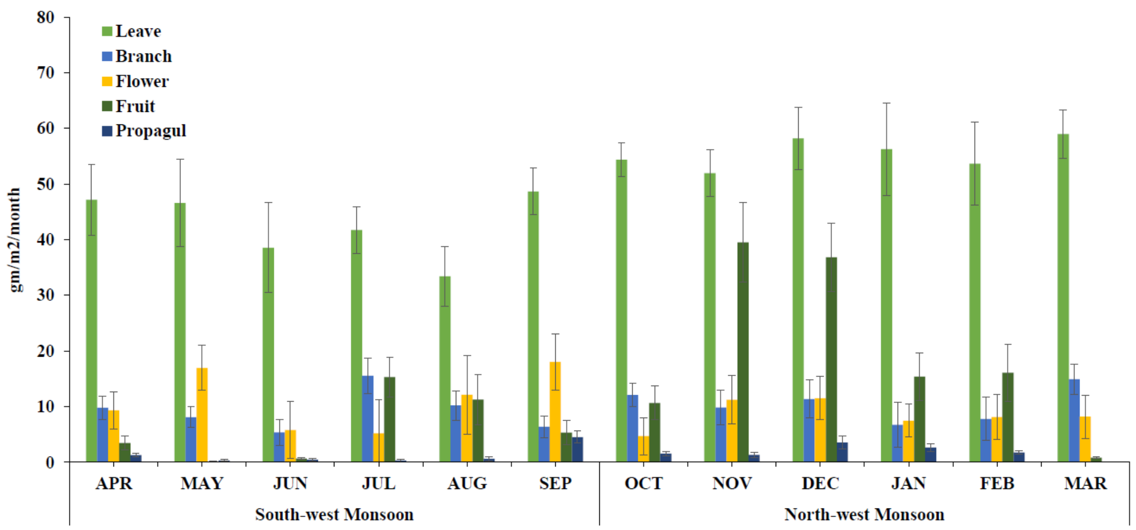

Figure 3: Seasonal changes of litter production at Setiu mangrove forest.

The total litterfall production at site A was higher in the North-west monsoon (752.25 g/m^2) compared to the south-west monsoon (538.31 g/m^2) (Table 2). In site B, the litterfall production in the dry and North-west monsoons was 609.05 g/m^2 and 755.51 g/m^2, respectively (Table 2). In a year, a total of 1290.57 g/m^2 litterfall production was recorded in site A and 1364.55 g/m^2 in site B (Table 2).

Table 2. Seasonal (gm/m^2/season±SD) and annual litter production (gm/m^2/yr±SD) of various components of two different stations in Setiu mangroves during the study period.

Litterfall Components

Study Sites	Season	Leaf	Branch	Flower	Fruit	Propagule	Total
Site A	South-west Monsoon	321.08±18.70[b]	77.97±10.94[a]	63.10±5.27[a]	70.43±18.93[b]	5.73±1.11[b]	538.31±45.07[b]
	North-west Monsoon	402.69±18.90[a]	80.28±3.69[a]	69.33±11.85[a]	169.23±27.34[a]	30.72±2.81[a]	752.25±52.53[a]
	Total	723.77±57.70	158.25±1.63	132.43±4.40	239.66±69.86	36.45±17.66	1290.57±151.26
Site B	South-west Monsoon	411.70±10.88[a]	18.09±2.31[b]	145.93±16.21[a]	30.33±4.70[b]	6.57±2.08[b]	609.05±21.01[b]
	North-west Monsoon	349.53±8.46[b]	34.75±4.98[a]	85.37±7.20[b]	262.28±26.72[a]	23.57±1.85[a]	755.51±20.40[a]
	Total	761.23±43.95	52.84±11.78	231.29±42.82	292.62±164.01	30.14±12.02	1364.55±103.55
	Yearly Mean	742.50	105.54	181.86	266.14	33.29	1327.56

Notes: The mean within a column for each station with different alphabets are significantly different (n=12, Tukey test, $p<0.05$)

The total litterfall production showed a significant correlation with the monthly climate variables, i.e., mean rainfall and wind speed (Fig. 4). The correlation of litterfall production with wind speed was significantly high ($r^2 = 0.73$, $p < 0.05$). However, the Pearson correlation value was not so significant with rainfall ($r^2 = 0.33$, $p < 0.05$) throughout the year.

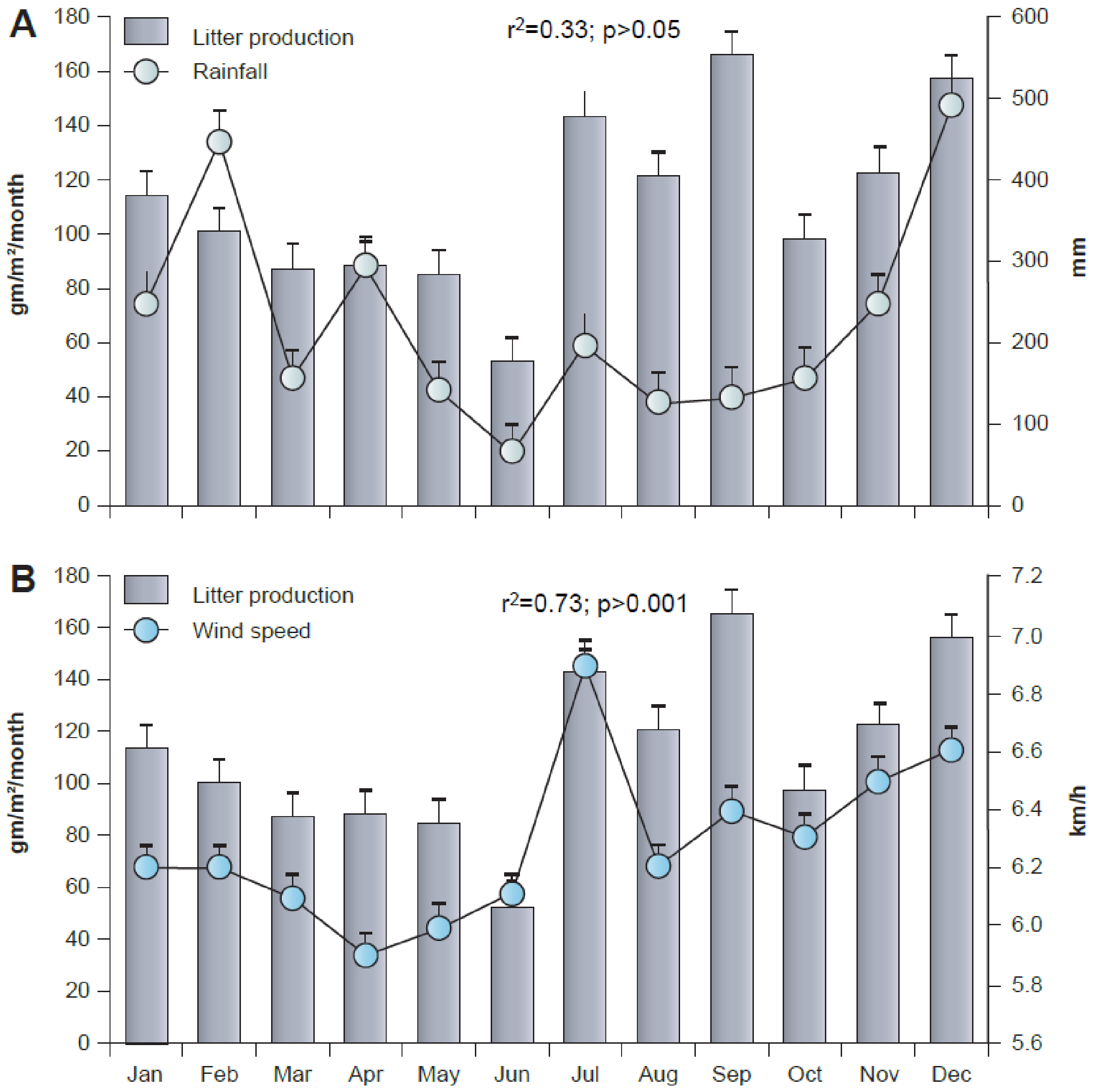

Figure 4: Relation between monthly total litter production and a) Rainfall and b) Wind speed in Setiu mangrove forest.

Dry Mass and Decay Constant

The most rapid mass loss was found within the first 15 days for both mangrove species, with the remaining dry mass of 63%, 80%, 82% for *R. mucronata* and 59%, 64%, 77% for *B. gymnorrhiza* on the forest floor, hanging position, and burial position, respectively (Figs. 5A and 5B). The remaining dry mass was found to be 26% for the forest floor, 35% for the hanging position, and 43% for the burial position at the end of the experiment for *R. mucronata* (Fig. 5A). Considering the whole decomposition period, the mean dry mass showed the following pattern: burial position > hanging position > forest floor for *R. mucronata* (Fig. 5A) and hanging position > burial position > forest floor for *B. gymnorrhiza* (Fig. 5B).

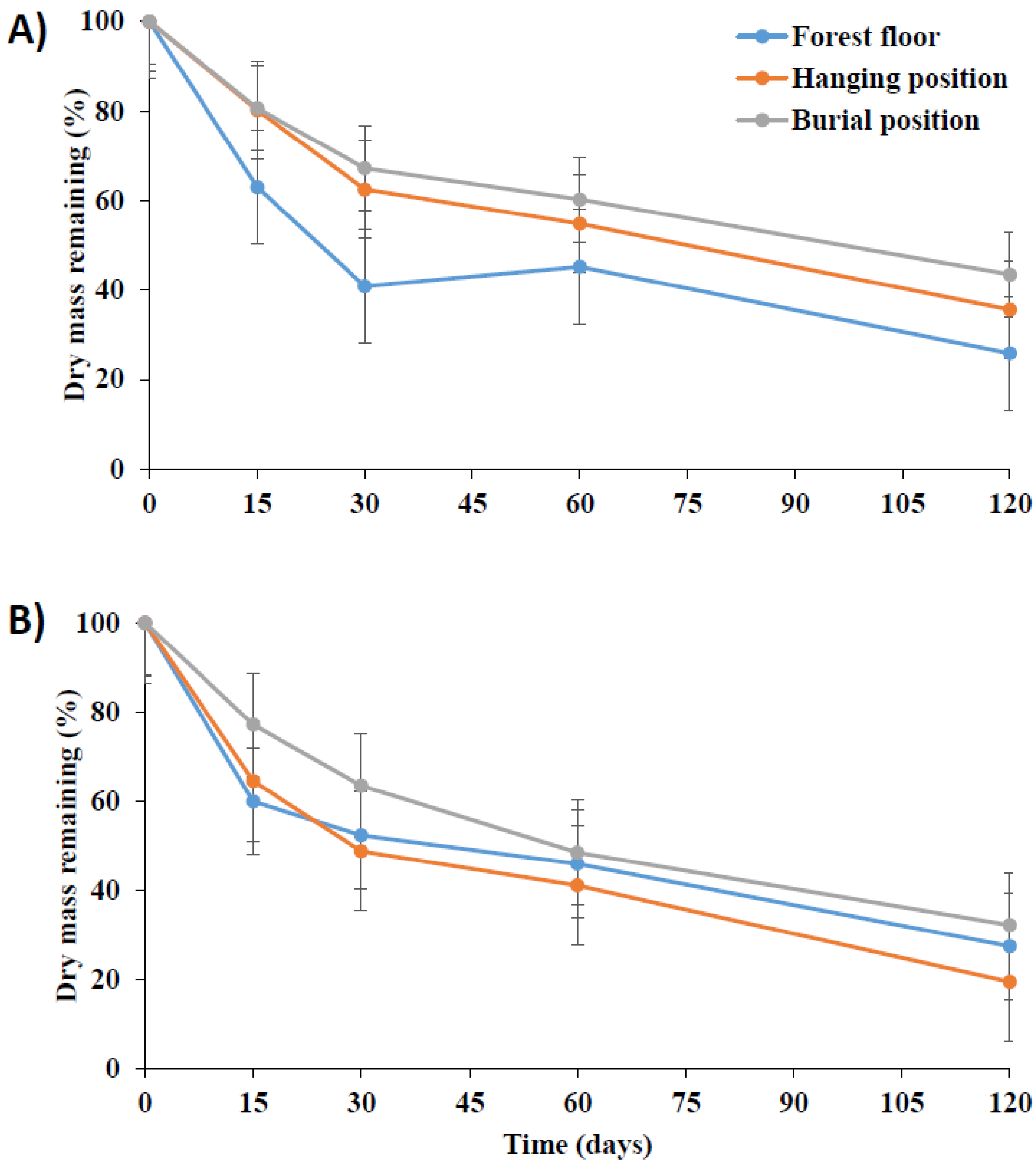

Figure 5: Dry mass remaining of *R. mucronata* (A) and *B. gymnorrhiza* (B) at different positions in Setiu mangrove forest.

Decay constants differed significantly within species, among treatments, and over investigation time (ANOVA; $p< 0.05$; Table 3). The average decay constant (k), considering the whole decomposition period showed the following pattern: forest floor > hanging position > burial position for *R. mucronata* and *B. gymnorrhiza* (Table 3). Overall, for *R. mucronata,* the mean decay constant was found to be 0.018 g/g/day ($r^2= 0.93$; $p< 0.05$) at hanging position, 0.021 g/g/day (r^2= 0.82; *p*< 0.05) at the forest floor and 0.013 g/g/day (r^2= 0.95; *p*< 0.05) at burial treatment. For *B. gymnorrhiza,* it was found to be 0.017 g/g/day (r^2= 0.91; *p*< 0.05) at hanging, 0.020 g/g/day (r^2= 0.81; *p*< 0.05) at the forest floor, and 0.012 g/g/day (r^2= 0.94; *p*< 0.05) at burial position (Table 3). The lowest half-life ($T_{50\%}$) was found at 33 days on the forest floor for *R. mucronata*, while *B. gymnorrhiza* reached half-life at 34 days (Table 3).

Table 3. Decomposition constant (*k*), half-life ($t_{0.50}$) and 95% lifespan ($t_{0.95}$) of *R. mucronata and B. gymnorrhiza* in different positions obtained from negative single exponential equations.

Treatment	Species	r^2	*k* (g/g/day)	Equation	$T_{50\%}$(days)	$T_{95\%}$(days)
Hanging Position	*R. mucronata*	0.93	0.018	$W_t = 90.397e^{-0.008x}$	57	166
	B. gymnorrhiza	0.91	0.017	$W_t = 84.057e^{-0.013x}$	34	176
Forest Floor	*R. mucronata*	0.82	0.021	$W_t = 79.585e^{-0.009x}$	33	142
	B. gymnorrhiza	0.81	0.020	$W_t = 79.585e^{-0.009x}$	34	149
Burial Position	*R. mucronata*	0.95	0.013	$W_t = 89.758e^{-0.009x}$	53	230
	B. gymnorrhiza	0.94	0.012	$W_t = 89.758e^{-0.009x}$	58	249

The mean rate of remaining dry mass and decay constant was greater on the forest floor on the hanging and burial positions (Table 4). Dry weight loss of leaf litter varied significantly with decomposition time (F= 308.55; *p*< 0.001), among positions (F= 24.20; *p*< 0.001), and between species (F= 15.91; *p*< 0.001) (Table 4). On the other hand, for the decay constant rate, the significant value was F= 4.55 (*p*< 0.05) with decomposition time, F= 14.19 (*p*< 0.001) among positions, and F= 65.83 (*p*< 0.001) between species (Table 4).

Table 4. Summary of ANOVA for weight remaining, decay constant (*k*) in leaf litter after 120 days of decomposition, comparing differences between species (*R. mucronata*, and *B. gymnorrhiza*) and litter bag positions (forest floor, hanging position, and burial position) (***: *p*< 0.001, **: *p*< 0.01, *: *p*< 0.05, ns: not significant).

		Weight remaining			Decay constant (*k*)		
Sources of variation	*df*	*MS*	*F*	*p*	*MS*	*F*	*p*
Species	1	627	15.91	***	0.0001	4.55	*
Position	2	954	24.20	***	0.0003	14.19	***
Treatment	4	12157	308.55	***	0.0015	65.83	***
Residuals	82	39			0.0002		

DISCUSSION

Litter Production

The mangroves at Setiu Lagoon are dominated by *R. mucronata* and *B. gymnorrhiza* (Islam et al., 2022), where they play a significant role in litter production and nutrient inputs into the adjacent ecosystems via decomposition processes. Litterfall production in mangroves depend on tree density, species, forest types, and geographical location elsewhere (Day et al., 1996; Hossain and Hoque, 2008). The total litterfall in the mangrove forest of Setiu Lagoon was found to be 1327.56 g/m^2/yr (Table 2), which was similar to several other *R. mucronata* dominated mangroves in the tropical region. Litterfall production at the Kuala Sibuti mangroves was higher (1640.82 g/m^2/yr) compared to the Setiu mangrove forest (Hoque et al. 2015a). Clough et al. (2000) also reported higher litterfall production in *R. apiculata* dominated mangrove forests in Ca Mau province, Vietnam.

The percentage (56%) of leaf components and non-leaf components (44%) was remarkable compared to the other findings elsewhere. In a subtropical mangrove forest on Okinawa Island, leaf litterfall ranged from 52.8 to 67.9% in five subsequent study periods (Sharma et al., 2012). This study also revealed that total litter production was higher in the north-west monsoon than in the south-west monsoon. Angsupanich and Aksornkoae (1994) also reported significant seasonal changes regarding litterfall production in Phangnga Bay, Thailand. The highest leaf litterfall was also recorded from January to February (the north-west monsoon) (Duke et al., 1981). The flowering time of *R. mucronata* and *B. gymnorrhiza* was found in the south-west monsoon, especially from June to August, and following the sequence of flowering, fruiting was observed in the North-west monsoon, especially in the months of November and December. Similar trends in flowering and fruiting of *R. mucronata* were also reported in north-eastern Australia (Williams et al., 1981) and Papua New Guinea (Leach and Burgin, 1985). Generally, rainfall throughout the year and constant temperature in the tropical region may govern the phenology of mangroves.

The rate of litterfall production is influenced by climatic and environmental variables, particularly wind speed, rainfall, temperature, and evaporation (Hossain and Hoque, 2008; Ye et al., 2013). Sasekumar and Loi (1983) also stated that climatic and environmental factors play a driving force for less than 50% variability of litter production in *Sonneratia*, *Avicennia*, and *Rhizophora* dominated mangroves in Malaysia. In subtropical mangroves in Japan and China, total litterfall production was found to be related to temperature and wind speed (Mfiling et al., 2005; Sharma et al., 2012; Ye et al., 2013). Likewise, the present findings indicated that wind speed also had a profound influence on litterfall production in the semi-arid mangrove forests of Karachi, Pakistan (Farooqui et al., 2012).

Leaf Litter Decomposition in Different Positions

To our knowledge, this study is the first to investigate the leaf litter decomposition in different environmental condition in a tropical lagoon ecosystem in Malaysia. Although there was a variation in the litter decomposition rate at the forest floor, hanging, and burial positions, it is likely a common phenomenon found in other studies (Steinke and Ward, 1987; Mall et al., 1991; Tam et al., 1998). However, the trend of the overall decomposition pattern under different positions suggested that a litter decomposition under different positions differed significantly during the study period (Fig. 5).

Results showed that the decay rate was higher for both species in the first 15 days of the decomposition process (Fig. 5), as reported in several decomposition studies (Robertson et al., 1992; Dick and Osunkoya, 2000; Aké-Castillo et al., 2006; Barroso-Matos et al., 2012). This rapid weight loss results from the high leaching of soluble compounds such as sugars, organic acids, proteins, and phenols (Mfilinge et al., 2002; Davis et al., 2003; Kristensen et al., 2008). During the decomposition experiment, the litterfall lost was 20% of its original mass in the first 60 days, and this loss continued to 50% of its original weight by the end of the experiment (196 days) (Kamruzzaman et al., 2019). The litter on the forest floor lost 50% of its original dry mass after 33 and 34 days for *R. mucronata* and *B. gymnorrhiza*, respectively (Table 3; Fig. 5). This decomposition rate was almost the same (32 days) compared to the decomposition study of the mass loss of leaves of *Rhizophora mangal* in the experiment (Silva et al., 2007). These differences can be explained by the fact that the forest floor is exposed to higher biotic and abiotic agents such as soil fauna, light, physical abrasion, temperature, and water (Austin and Vivanoco, 2006; Bokhorst and Wardle, 2013) compared with burial and hanging positions.

Previous studies reported that the higher decomposition rate observed on the forest floor positions compared to burial positions was expected as the forest floor litter materials are exposed to a wide range of biotic (sediment macrofauna, microfauna, and microbes) (Ashton et al., 1999) and abiotic positions (hydroperiods) (Liu et al., 2012; Chambers et al., 2016). In the case of burial leaf litter, they are exposed to anoxic positions and therefore litter materials are subjected to anaerobic microbial degradation (de Angelis et al., 2010; Loría-Naranjo et al., 2019; Fiard et al., 2022). Bokhorst and Wardle (2013) also mentioned that decomposition is primarily related to substrates (litter) and soil type. However, Kamruzzaman et al. (2019) reported that there was no significant difference in mass loss at different positions (forest floor and burial position) or sites during the experiment period.

CONCLUSION

The results of this study support Robertson and Daniel's (1989) hypothesis that physical factors may be more significant in governing the litter production in tropical mangroves. It is known that the major portion of the litterfall is flushed by the tidal water and transported to nearby ecosystems (Heald and Odum, 1970). Fast decay rates highlight the importance of mangrove litter to liberate limited nutrients for the ecosystem, contributing to carbon and nitrogen budgets. Overall, these findings suggest that the decomposition rate depends on different positions associated with the ecological parameters of the surrounding environment and is the main basis for nutrient availability and storage in a mangrove ecosystem.

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AUTHOR'S CONTRIBUTION

MAI: Conceptualization, field investigation & laboratory treatments, original draft preparation, reviewing and editing; AHMK: Conceptualization, funding acquisition, supervision, project investigation, reviewing and editing; MMB: visualization, reviewing and editing; MKAB: visualization, reviewing and editing; AFMAR: Field investigation & laboratory treatments; MHI: Conceptualization, field investigation, funding acquisition, reviewing and editing

DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article. More detailed data can be provided upon request to the corresponding author.

DECLARATIONS ETHICAL APPROVAL

Not applicable.

CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

COMPETING INTERESTS

The authors declare no competing interests.

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