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ORIGINAL RESEARCH

Leaf Litter Decomposition and Associated Nutrient Release Dynamics Under Varying Temperature and Precipitation in a South Asian Tropical Forest

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ABSTRACT: Litter decomposition plays a vital role in nutrient cycling and maintaining ecosystem functionality, particularly in forested landscapes. However, the decomposition dynamics of common tropical timber species remain underexplored in many regions, including Bangladesh. This study investigated the leaf litter decomposition and associated nutrient (nitrogen, phosphorus, potassium) release patterns of five widely planted timber species, *Chukrasia tabularis, Dipterocarpus turbinatus, Hopea odorata, Tectona grandis, and Swietenia macrophylla* on the Chittagong University campus. Using the litter bag method, decomposition rates were measured across both dry and wet seasons to assess seasonal variability and environmental influences. The results revealed that *Chukrasia tabularis* exhibited the highest mass loss (33% in the dry season and 60% in the wet season), followed by *Hopea odorata* (38% and 55%), while *Tectona grandis* showed the lowest decomposition rates (23% and 25%). Decomposition was most rapid in Hopea odorata during the dry season (0.57 g/month) and *Dipterocarpus turbinatus* in the wet season (0.89 g/month). In the wet season, decomposition rates were significantly ($p < 0.05$) correlated with temperature and precipitation across all species. In contrast, during the dry season, only *Tectona grandis* and *Hopea odorata* showed significant correlations with temperature, while only *Chukrasia tabularis* and *Hopea odorata* were significantly influenced by precipitation. Nutrient release patterns varied by species and nutrient type: nitrogen release was highest in *Chukrasia tabularis* (26.89 mg/g), phosphorus in Hopea *odorata* (16.53 mg/g), and potassium in *Dipterocarpus turbinatus* (53.53 mg/g), whereas *Swietenia macrophylla* consistently showed the lowest nutrient release rates. These findings highlight species-specific and seasonal variations in litter decomposition and nutrient dynamics, offering insights for forest management, species selection, and ecosystem nutrient budgeting in tropical forest plantations.

KEYWORDS: Decay constant, decomposition, leaf litter, nutrient dynamics, temperature and precipitation.

1. Introduction

Litter fall plays a crucial role in the nutrient cycle, influencing soil organic matter accumulation, nutrient input and output, nutrient replenishment, biodiversity conservation, and various other ecosystem functions within forest ecosystems (Giweta, 2020). Litter dynamics is an important aspect of nutrient cycling and energy transfer in forest ecosystems. However, the growth and productivity of forest ecosystems mainly depend on the amount, nature, and rate of decomposition of forest litter (Krishna and Mohan, 2017). Nutrient cycling is one of the many elements of the plant-soil system that is closely linked to the terrestrial ecosystem's productivity (Zhao and Riaz, 2024). Compared to other portions of the litter that are available during the decomposition process, leaf litter is the primary and fastest supply of organic matter and nutrients to the soil (Prescott and Vesterdal, 2021). In developing countries such as Bangladesh, litter is predominantly used as fuel, and the majority of people burn litter as fuel (Hasanuzzaman et al., 2014b). Litter falls normally in small quantities throughout the year, but peak (up to 90%) fall is observed during the spring and early summer periods with long days, higher air temperature, limited availability of water, higher wind speed, and lower air humidity (Toffanin et al., 2019). A vital step in the cycling of nutrients in all ecosystems is litter decomposition (Kwon et al., 2021).

Climate directly influences decomposition by enhancing decomposition activity due to rising temperatures and increased precipitation (Dash et al., 2019). Climate change-driven variations in temperature, precipitation, and soil moisture are anticipated to alter forest productivity, phenology, mortality rates, and species composition (Dalmolin et al., 2015). These changes in a forest also change litter decomposition (Fang et al., 2015). Litter decomposition globally is strongly mediated by climatic regimes by influencing microbial activity (Bradford et al., 2016), i.e., doubling of microbial activity with every 10°C increase in temperature (Chakravarty et al., 2020). In terrestrial ecosystems, litter decomposition is an essential process for the cycling of nutrients. It is primarily regulated by ambient factors, substrate quantity and quality, and the composition and abundance of the microbial population (Kwon et al., 2021). Global warming can impact litter decomposition rates in negative, neutral, or positive ways by influencing environmental factors, litter quality, and the activity of decomposers. Generally, leaf litter decomposes faster under warmer conditions in both the grassland ecosystem and wetland ecosystem (Song et al., 2014).

Litter generally improves soil quality by adding organic matter, which improves soil water-holding capacity, filtering capacity, biodiversity, soil microbial activity, and nutrient concentration (Kooch et al., 2017; Rastogi et al., 2023; Zhao and Riaz, 2024) . More than half of the nutrients taken up by plants are released back into the soil through a variety of pathways, with litter decomposition contributing the most (Krishna and Mohan, 2017). Nutrients are absorbed by plants to promote their growth and development, and some nutrients accumulate in plants. A considerable amount of those nutrients return to the soil through

litter, which plays an important role in the biogeochemical cycle of nutrients (Berhe et al., 2018).

A number of studies have been conducted in Bangladesh to understand the mechanism of leaf litter decomposition from major Agroforestry (Hasanuzzaman and Hossain, 2015; Hasanuzzaman and Hossain, 2014a; Hasanuzzaman and Mahmood, 2014), Mangrove forest (Hossain et al., 2014; Kamruzzaman et al., 2019), Ratargul swamp forest (Hossain et al., 2020) and Modhupur sal forest (Nazrul Islam et al., 2021; Islam et al., 2021; Kibriya et al., 2019) tree species.However, no attempt has been taken to screen or prioritize major plantation tree species of the hill forests based on nutrient return capacity as well as the effect of temperature and rainfall on the rate of litter decomposition in Bangladesh. Therefore, this study aimed to prioritize the commonly planted tree species in the Chittagong University campus based on leaf litter decomposition rate, and nutrient recycling as a result of temperature and precipitation gradient. This finding will aid in motivating people in Bangladesh and other nations to prioritize potential tree species for sustainable forestry methods and to use leaf litter as manure rather than fuel.

2. Materials and methods

2.1 Study area

The study was conducted in the Chittagong University campus (Figure 1) which is located at Fatehpur union under Hathazari upazila in Chattogram district. It lies between 22º27'30" and 22º29'0" North latitudes and 91º46'30" and 91º47'45" East longitudes. The campus lies some 12 miles north of Chattogram city, about 2 miles southwest of the Chattogram-Rangamati road, and a little closer to the Chattogram-Nazirhat railway branch lines (Akhtaruzzaman et al., 2020). Topographically the campus is lodged at a safe elevation from seasonal flooding (Akter et al., 2022). Soils are yellowish brown to yellowish red and are sandy to clay-loam. More than 60% of soils are formed in moderately coarse to fine textured, folded tertiary hill sediments (Akhtaruzzaman et al., 2020). The mean monthly temperature ranges from 14.6 ºC to 26.3 ºC and the mean annual rainfall is 2796 mm with monthly variation from 6 mm to 583 mm.

2.2 Methodology

2.2.1. Selected species

Five planted tree species in Chittagong University campus were selected as sample species for the study. The species are Garjon (*Dipterocarpus turbinatus*), Telsur (*Hopea odorata*), Chickrassi (*Chuckrasia tabularis)*, Mehogony (*Swietenia macrophylla*), and Teak (*Tectona grandis*)

2.2.2 Collection and processing of leaf samples

The leaf litter decomposition experiment was conducted using a litterbag technique (Xie, 2020) for four months of the dry season and four months of the wet season. Bulks of yellowish senescent leaves of selected species were collected during the late autumn. Leaf litter was air-dried at room temperature and mixed thoroughly. Two grams of leaf litter for individual species were taken as an individual sample. Individual samples were placed into a nylon bag of 150 mm × 150 mm with a 1 mm^2 mesh size.

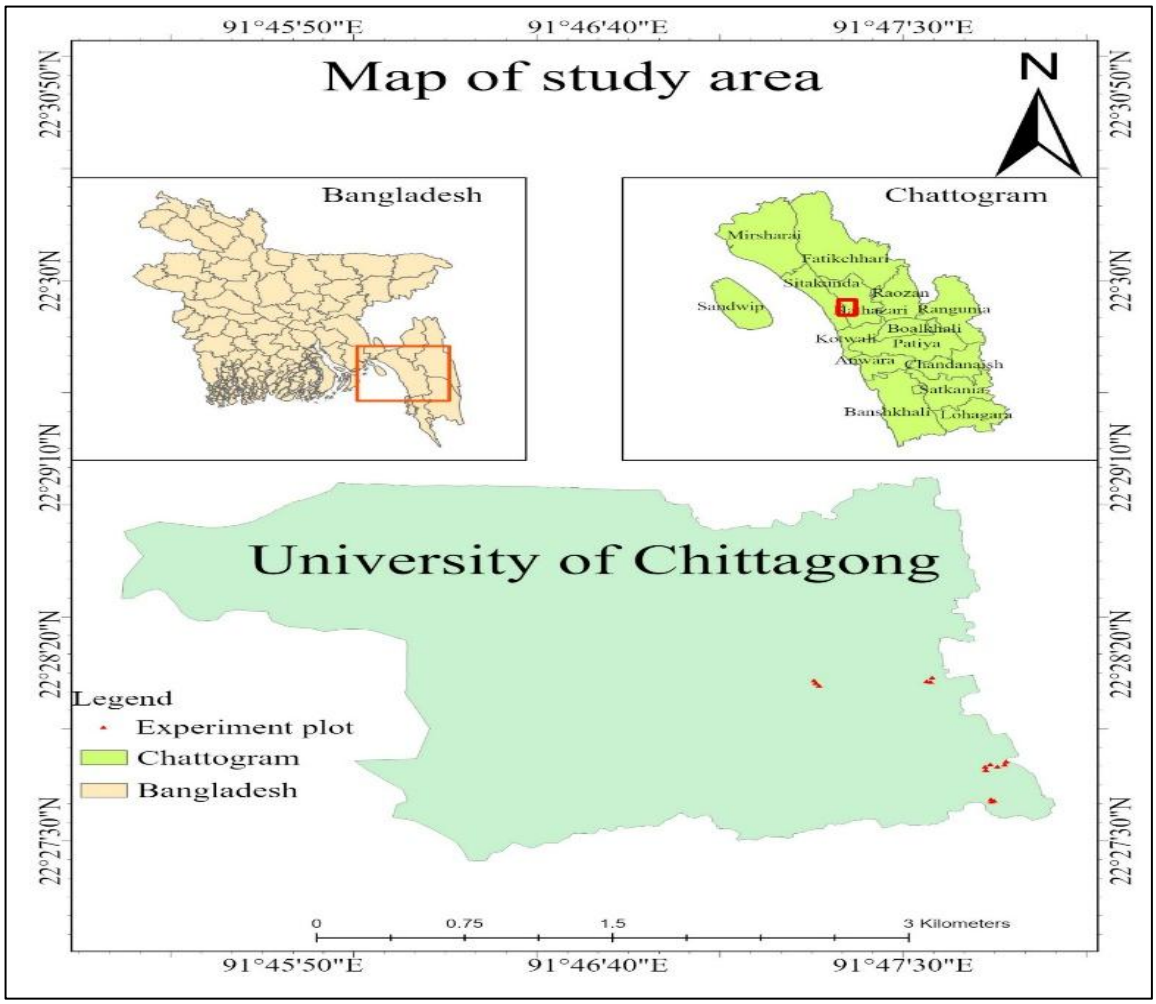

Figure 1. Study area map of the experimental site. The red dot represents the experimental plot.

To prevent the leaves from folding and clumping they were laid flatly inside the bags. Thirty bags for each species were placed in the field and three bags were brought back to the laboratory for calculating fresh to oven-dry weight ratio at 80ºC to constant weight. Later, three bags for each species were collected from the field at fifteen days' intervals for the initial month and subsequently at monthly intervals till March 2022 to represent 15 days, 30 days, 60 days, 90 days and 120 days of decomposition in the field. The collected samples were gently washed with a soft brush under slowly running tap water to remove sediments and dirt particles, and were then rinsed with distilled water for a final clean. Each sample was then oven-dried at 80^0C to constant weight. In this way a total of ninety bags were collected for five selected species during the dry season for analysis in the laboratory. Similar procedure was also followed for the wet season experiment starting from June 2022 and ending in October 2022. Thus, a total of 180 samples were collected for both the seasons, weighed separately to get the oven dried weight and

then sent to SRDI laboratory for further analysis of nutrient concentrations (N, P & K) from the litter samples.

2.2.3 Mass loss and decay constant

Using the initial converted oven-dry weight and remaining mass, the loss in dry mass of the samples was computed. The percentage of mass loss divided by the corresponding days of collection was used to compute the rate of decomposition. (Keerthika et al., 2024) was followed in the equation (1) of the decay constants for leaf litter using a negative exponential decay model.

$$\frac{X}{X_0} = e^{-kt} \quad (1)$$

Where, X is the weight remaining at time t, X0 is the initial weight, k is the decay rate coefficient and t is the time in year.

2.3 Nutrients concentration in leaf litter

2.3.1. Nitrogen concentration

The oven-dried samples were processed according to Delgado-Baquerizo et al. (2015). The processed leaf samples were weighted to 0.2 g and put into a digestion flask. Micro-kjeldahl digestion, available at the Soil Resource Development Institute (SRDI) in Chittagong University campus, was carried out for the samples and the extract was filtered and diluted to 100 mL with distilled water (Delgado-Baquerizo et al. 2015). Total Kjeldahl Nitrogen (TKN) was calculated in equation (2) with the following equation according to Nonghuloo et al., (2020) using UV Spectrophotometer (SHIMADZU, UV-160A, Japan).

TKN (mg/g) = (C × df × fv) ÷ (W × 1000) (2)

Where, C = Concentration obtained from spectrophotometer in ppm or mg N/L, df = Dilution factor (times), fv = Final volume of the digest (ml), W = Weight of plant taken in digest (g)

2.3.2. Phosphorus concentration

Phosphorus (P) concentrations in sample extracts were measured according to Nonghuloo et al., (2020) using UV-Visible Recording Spectrophotometer (SHIMADZU, UV-160A, Japan) with the equation (3)-

P (mg/g) = (C × df × fv) ÷ (W × 1000) (3)

Where, C = Concentration obtained from spectrophotometer in ppm or mg P/L, df = Dilution factor (times), fv = Final volume of the digest (ml), W = Weight of plant taken in digest (g)

2.3.3. Potassium concentration

Potassium concentration in sample extracts was measured by Atomic Absorption Spectrophotometer (PERKIN ELMER 4100, USA) using the equation (4):

K (mg/g) = (C × df × fv) ÷ (W × 1000) (4)

Where, C = Concentration obtained from Flame Photometric absorbance in ppm, df = Dilution factor (times), fv = Final volume of the digest (ml), W = Weight of plant taken in digest (g).

2.4 Nutrients added to the soil

The oven-dried leaf samples of the selected species were grounded, processed, and acid digestion according to (Hossain et al., 2015). The amount of nutrients released from leaf litter to soil was calculated as

differences between initial and final absolute amounts.

2.5 Temperature and rainfall data extraction

The temperature and rainfall data for Chittagong University was extracted from the official website of the Bangladesh Meteorological Department (BMD) at AWS Data Server. The BMD is the national meteorological authority of Bangladesh and provides reliable weather information. The data extraction process involved navigating to the BMD website, locating the climate data station (Sitakunda Station), and specifying the desired variables (temperature and rainfall) along with the period of (November 2021 to October 2022). The data was downloaded in CSV format, which allowed for further analysis.

2.6 Statistical analysis

The rates of mass loss and nutrient (N, P, and K) concentrations in leaf litter were compared among the different stages of decomposition of the study and also with the tree species by using SPSS. Moreover, the relationships among the rate of leaf litter decomposition, the relationship between temperature and mass loss, and the relationship between rainfall and mass loss were evaluated by regression analysis using MS Excel.

3. Results

3.1 Microbial decomposition and mass loss

During the experiment, it was found that various microorganisms caused the decomposition of leaf litter. Due to this decomposition, litter lost its weight causing the mass loss in litter. Comparatively higher (46.5%) mass loss was found for *Chuckrassia tabularis* and *Hopea odorata* and the lower (24%) was observed for *Tectona grandis* during 120 days on average (Figure 2).

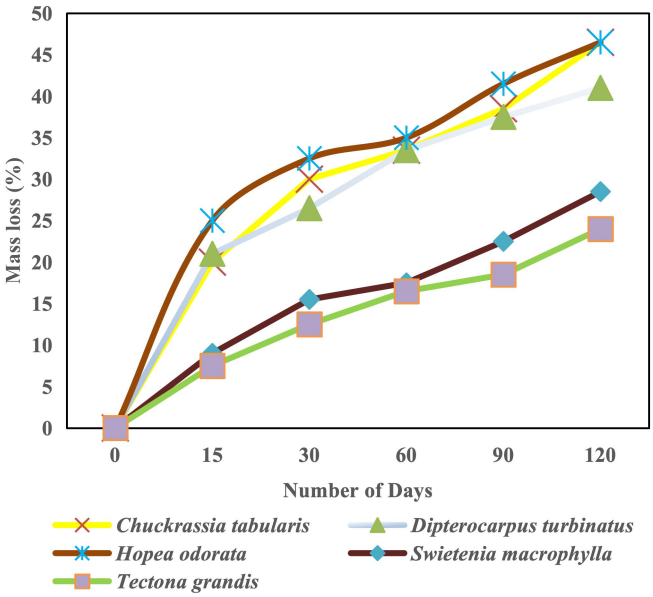

Figure 2. Mass loss (%) due to microbial decomposition.

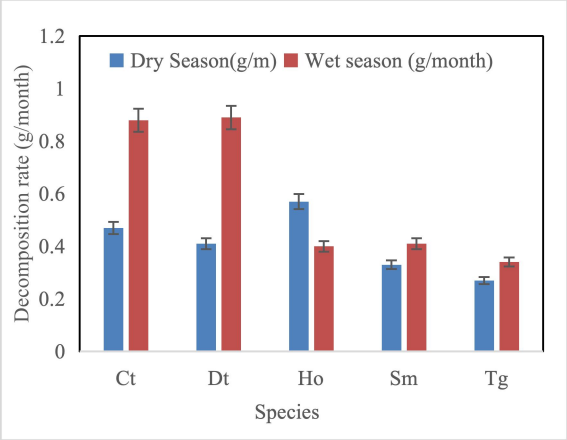

Figure 3. Rate of decomposition (g/month) of leaf litter due to microbial decomposition. Note: Ct-*Chuckrassia tabular*, Dt- *Dipterocarpus turbinatus*, Ho *Hopea odorata*, Sm- *Swietenia macrophylla, Tg- Tectona grandis.*

3.2 Rate of decomposition (g/month) of leaf litter due to microbial decomposition

The rate of decomposition was found the highest for *Hopea odorata* (0.57 g/month)

followed by *Chuckrassia tabularis* (0.47 g/month) and the lowest (0.27 g/month) was observed for *Tectona grandis* in dry season while the rate of decomposition was found the highest for *Dipterocarpus turbinatus* (0.89 g/month) followed by *Chuckrassia tabularis* (0.88 g/month) and the lowest (0.34 g/month) was observed for *Tectona grandis* in wet season (Figure 3).

3.3 Decay Constant (k) and half-life (t50) of leaf litter of selected tree species

The decay constant (k) was found the highest (2.79 ± 0.755) for *Hopea odorata* and the lowest (1.11 ± 0.064) was found for *Tectona grandis* in dry season. On the other hand, *Dipterocarpus turbinatus* possessed the highest decay constant (k = 4.76 ± 1.206), and *Tectona grandis* showed the lowest (2.43 ± 0.431) value. Conversely, the highest half-life was found for *Tectona grandis* (231 ± 13 days), and the lowest (116 ± 25 days) was observed for *Hopea odorata* in dry season. The highest half-life was found for *Swietenia macrophylla* (126 ± 23 days) and the lowest was observed for *Hopea odorata* (68 ± 14 days) (Table 1).

Table 1. Average decay constant and half-life (t50) of leaf litter of selected tree species during decomposition in dry and wet season.

Species name	Dry season		Wet season	
	Decay constant (k)	Half-life (t_{50}) (Days)	Decay constant (k)	Half-life (t_{50}) (Days)
Chuckrassia tabularis	2.14 ± 0.530	146 ± 29	4.47 ± 0.892	66 ± 12
Dipterocarpus turbinatus	1.70 ± 0.367	173 ± 69	4.76 ± 1.206	69 ± 16
Hopea odorata	2.79 ± 0.755	116 ± 25	4.71 ± 1.193	68 ± 14
Swietenia macrophylla	1.32 ± 0.228	214 ± 32	2.43 ± 0.606	126 ± 23
Tectona grandis	1.11 ± 0.064	231 ± 13	2.43 ± 0.431	116 ± 18

Note: ± indicated standard derivations

Table 2. Relationship of temperature with decomposition rate of leaf litter of selected hill forest tree species (dry and wet season).

Species name	Dry season		Wet season	
	R^2	p-value	R^2	p-value
Chuckrassia tabularis	0.446	0.056[b]	0.315	0.046*
Dipterocarpus turbinatus	0.506	0.053[b]	0.185	0.036*
Hopea odorata	0.525	0.036[a]	0.522	0.017*
Swietenia macrophylla	0.406	0.084[b]	0.415	0.044*
Tectona grandis	0.736	0.022[a]	0.441	0.035*

Note: * denotes there is a significant difference in the relationship of temperature with the decomposition rate of leaf litter of selected hill forest tree species

Table 3. Relationship of precipitation with decomposition rate of leaf litter of selected hill forest tree species (dry and wet season).

Species name	Dry season		Wet season	
	R^2	*p-value*	R^2	*p-value*
Chuckrassia tabularis	0.464	**0.049**[c]	0.261	0.011*
Dipterocarpus turbinatus	0.377	0.113[d]	0.071	0.007*
Hopea odorata	0.447	**0.023**[c]	0.238	0.007*
Swietenia macrophylla	0.537	0.228[d]	0.276	0.017*
Tectona grandis	0.233	0.259[d]	0.334	0.012*

Note: * denotes there is a significant difference in the relationship of temperature with the decomposition rate of leaf litter of selected hill forest tree species

Table 4. Nutrients added through leaf litter decomposition of timber tree species in dry and wet seasons per year.

Species name	N concentration (mg/g)		P concentration (mg/g)		K concentration (mg/g)	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Chuckrassia tabularis	26.89	5.68	3.24	25.39	43.03	30.82
Dipterocarpus turbinatus	25.85	4.08	15.94	3.77	53.53	35.93
Hopea odorata	13.46	8.13	16.53	23.36	35.55	24.19
Swietenia macrophylla	14.96	2.49	12.53	5.19	29.58	14.78
Tectona grandis	14.94	2.96	17.91	5.27	30.38	11.64

In the wet season, the microbial decomposition rate of the studied tree species' leaf litter showed a significant ($p<0.05$) relationship with precipitation and temperature; however, in the dry season, only *Tectona grandis* and *Hopea odorata* showed a significant relationship with temperature; the other three species did not (Table 2). Similarly, the relationship with rainfall in dry season was significant for *Chuckrassia tabularis* and *Hopea odorata* but not significant for the others three species (Table 3).

3.4 Nutrients at different stages of the microbial decomposition process

The nutrient concentration was found to decrease gradually at the end of the experiment (120 days) in both dry season and wet season. The highest concentration of initial N (12.59 mg/g) was detected for the leaf litter of *Chuckrassia tabularis* and the

lowest concentration of N (5.02 mg/g) was found for *Tectona grandis* in dry season (Figure 4a) while the highest initial concentration of N (15.37 mg/g) was found for *Dipterocarpus turbinatus* and the lowest (6.44 mg/g) was found in *S. macrophylla* in wet season (Figure 4b). P concentration was highest for the leaf litter of *Chuckrassia tabularis* (10.31 mg/g) and lowest for *Swietenia macrophylla* (3.57 mg/g) in dry season (Figure 5a) while the highest initial concentration of P was found for *Hopea odorata* (10.56 mg/g) and the lowest concentration of P (2.53 mg/g) was found for *Swietenia macrophylla* in wet season (Figure 5b).

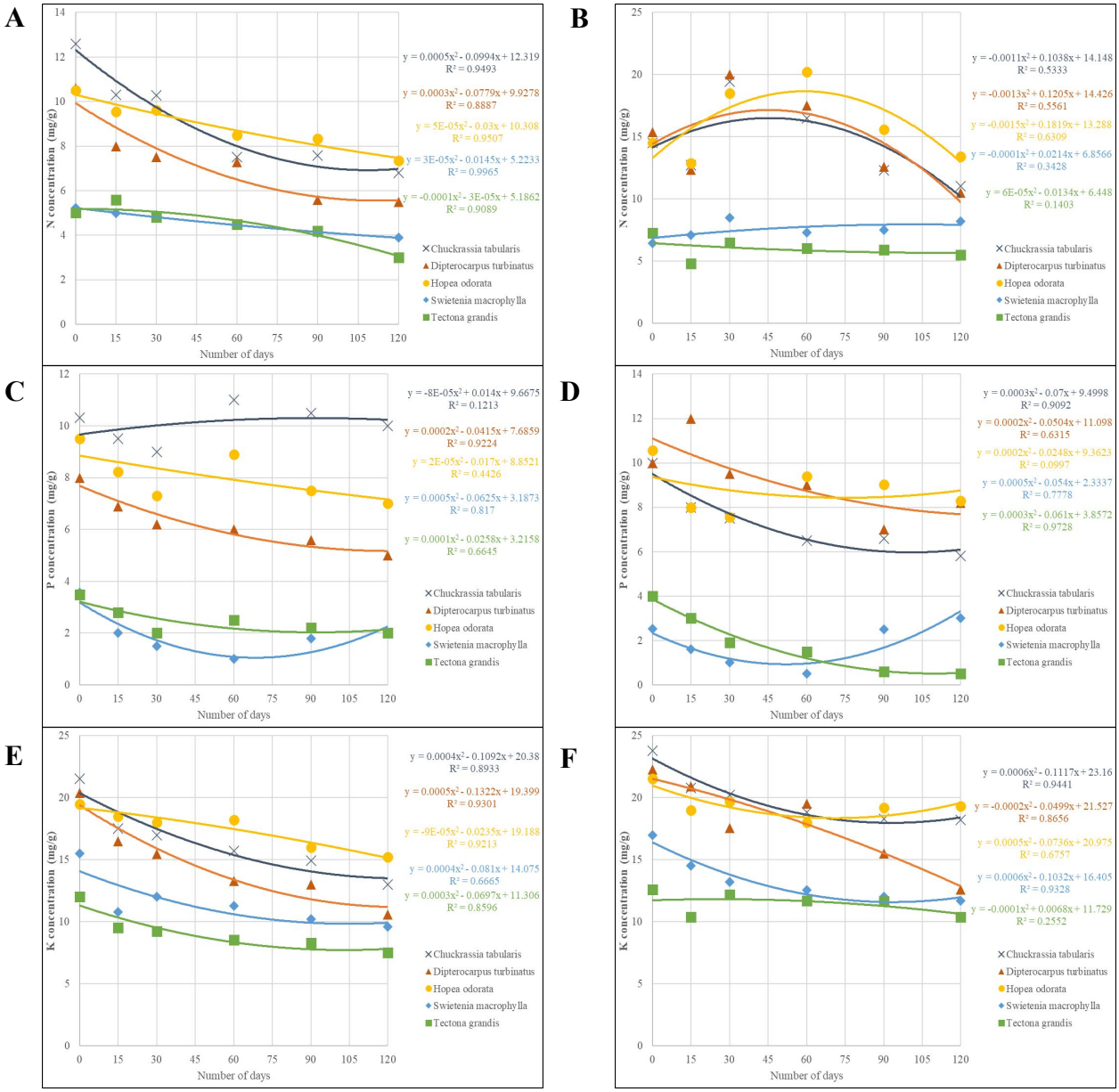

Figure 4. Trends of nutrients concentration changes at the different period (days) of leaf litter decomposition of studied species in (A) N concentration dry in season, (B) N concentration dry season in wet season, (C) P concentration dry in season, (D) P concentration dry season in wet season, (E) K concentration dry in season and (D) K concentration dry season in wet season.

The highest K concentration (21.55 mg/g and 23.78 mg/g) was detected for the leaf litter of *Chuckrassia tabularis* and the lowest concentration of K (12.03 mg/g and 12.58 mg/g) was found for *Swietenia macrophylla* in dry and wet season respectively (Figure 6)

3.6. Nutrients added to the soil

The result of the study suggests that varying amounts of N, P and K were added to the soil due to leaf litter decomposition by different species at different seasons (dry and wet). It is observed that highest concentrations of N (26.89 and 5.68 mg/g) from the leaf litter of *Chuckrassia tabularis*, P (16.53 and 23.36 mg/g) from the leaf litter of *Hopea odorata* and K (53.53 and 35.93 mg/g) from the leaf litter of *Dipterocarpus turbinatus* were added to the soil annually, in both the dry and wet seasons (Table 4). On the contrary, comparatively lowest concentrations of N, P and K were added to the soil from leaf litters of *Swietenia macrophylla* and *Tectona grandis* per year in both dry and wet seasons.

4. Discussion

The result of the study shows that varying amount of mass loss occurred during the whole process of litter *decomposition* due to different decomposition rate in different tree species (Figure 2). The physical and chemical characteristics of leaf litter, the presence of thick waxy cuticle, the presence of different amounts of water-soluble phenolic compounds, flavanoids, and tannin, as well as the litter quality, may all contribute to the variations in mass loss patterns and rates of decomposition seen among the tree species under study (Hasanuzzaman and Hossain, 2015; Hossain et al., 2014). Mass loss of leaf litter increased gradually during the experiment due to decomposition. Higher mass loss of leaf litter was found during the first 30 days, followed by a gradual mass loss for the subsequent 120 days which indicates two stages (Figure 2) i.e. initial stage and advanced stage (Hasanuzzaman and Hossain, 2015b).

The study results clearly show that different seasons, represented by varying temperature and precipitation gradients, definitely affect decomposition of leaf litter of different species. During the wet season, the microbial leaf litter decomposition rate of the studied tree species showed a significant ($p<0.05$) relationship with temperature (Tables 2) and precipitation (Table 3); however, in the dry season, only *Tectona grandis* and *Hopea odorata* showed a significant relationship with temperature; the other three species did not (Table 2). Similarly, the relationship with precipitation in dry season was significant for *Chuckrassia tabularis* and *Hopea odorata* but not significant for the other three species (Table 3).

Among the studied species, *Chuckrassia tabularis* showed a higher decomposition rate on both seasons (Figure 3) which could be an indicator of higher litter quality compared to other studied tree species as reported by Hasanuzzaman et al., (2014). Again, comparatively higher mass losses were observed during wet season compared to dry season as evident from the significantly higher rate of decomposition for different species during wet season in comparison to dry season (Figure 3). In the initial stage, a relatively larger decrease in mass was observed due to the leaching of readily soluble substances and non-lignified

carbohydrates (Hossain et al., 2014; Hasanuzzaman et al., 2014). When in the advanced stage, the release of a higher percentage of resistant fractions like as cellulose, lignin, and tannin in leaf litter may be the cause of the additional decrease in mass loss (Suseela and Tharayil, 2018).

The decay constant (k) was found within the range of 2.79 to 1.11 in dry season and 4.76 to 2.43 in wet season which are more or less similar to the findings of Hasanuzzaman and Hossain (2015), who found within the range of 2.29 to 1.18 in dry season and 3.59 to 1.16 in wet season. Krishna and Mohan (2017) noted that k values often exceed 1.0 for tropical forests, suggesting that leaf litter turnover occurs within a year or less. Higher decay constant ranges were found in the wet season compared to the dry season due to site factors such as precipitation also reported by (Wijas et al., 2024). The decay constant varied from species to species (Hossain et al. 2014; Hasanuzzaman and Hossain 2014) as well as varied within a species for the differences in the length of decomposition period and different land use types (Keerthika et al., 2024).

Comparatively, higher initial concentrations of N, P, and K in the leaf litter of *Chuckrassia tabularis, Dipterocarpus turbinatus,* and *Hopea odorata* indicated that the capabilities of these species to re-translocate these nutrients were lower during the senescence of leaves (Luo et al., 2021). Conversely, nutrient concentration increased at the end of the experiment in wet season. However, a rapid decrease in P concentration was observed at the end of the first month (Figure 5), while a rapid decrease in K concentration was reported within 15 days of leaf litter decomposition in wet season (Figure 6). The concentration of K in leaf litter decreased rapidly because it is a non-structural and highly mobile element, making it the most leachable cation during litter decomposition (Singh et al., 2021). The initial rapid decline in nutrient concentration may be attributed to the loss of soluble nutrient forms during the early stages of decomposition (Averill and Waring, 2018) and a slower release of nutrients during the later stages of leaf litter decomposition is driven by microbial oxidation of refractory components, as well as physical and biological fragmentation (Hossain et al., 2014). In contrast, the increased concentrations of nutrients (N, P, and K) observed at various stages of decomposition during the wet season were attributed to microbial or non-microbial immobilization in the residual leaf litter, which also serves as a substrate for fungi and heterotrophic organisms (Naik et al., 2018;).

According to this study a sizeable concentration of N (14.96 and 2.49 mg/g), P (12.53 and 5.19 mg/g) and K (29.58 and 14.78 mg/g) were added to the soil from leaf litter of *Swietenia macrophylla* per year in dry and wet season, respectively (Table 4). Meanwhile, a different study on cropland agroforest tree species in Southeastern Bangladesh found that N (12.68 and 1.32 mg/g), P (7.04 and 10.53 mg/g), and K (35.16 and 42.79 mg/g) were added to the soil from the leaf of *Swietenia macrophylla,* each year in the dry and wet seasons, respectively (Hasanuzzaman and Hossain, 2015b).

5. Conclusion

Litter decomposition is a key ecological process that recycles essential nutrients like

carbon and nitrogen, thereby supporting soil fertility and overall ecosystem health. This process is influenced by a range of physical, chemical, and biological factors, making it difficult to establish a universal method for accurately measuring decomposition rates. Nevertheless, understanding litter degradation is increasingly important in light of human impacts on biogeochemical cycles. Leaf litter contributes substantial organic matter and nutrients to the soil, much of which is absorbed by plants, with decomposition rates typically higher during the wet season than the dry season. This seasonal variation enhances nutrient availability and soil productivity, which are crucial for sustainable hill forestry. Among the species studied, indigenous trees such as *Chukrasia tabularis*, *Dipterocarpus turbinatus*, and *Hopea odorata* showed higher nutrient return through litter decomposition compared to exotic species like *Tectona grandis* and *Swietenia macrophylla*. This suggests that native species are more effective in enriching the soil and sustaining forest ecosystems. Promoting the plantation of indigenous species can thus play a significant role in improving soil quality and supporting long-term forest sustainability. Additionally, implementing strict regulations to control the collection of leaf litter by local communities could help mitigate forest degradation and preserve ecological balance. These findings underscore the importance of species selection and policy intervention in enhancing the benefits of litter decomposition for forest conservation and soil fertility.

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Conflicts of Interest: The authors declare no conflict of interest.

Availability of Data and Materials: Data will be available on a formal request from the corresponding authors.

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