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Leaf-litter decomposition and nutrient dynamics of five selected tropical tree species

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Leaf-litter decomposition in terrestrial ecosystems has a major role in recycling the nutrients to the soil. Nutrient dynamics is the way nutrients cycle in an ecosystem. The present study was conducted for five selected tropical tree species *viz*. *Shorea robusta*, *Ficus hookeri*, *Mallotus philippensis*, *Artocarpus lakoocha* and *Dillenia pentagyna* at Hetauda, Makawanpur. This paper aims to determine the litter decomposition rate-constant and nutrient mineralization pattern of the selected species. The litter-bag method was used to assess the decomposition and nutrient dynamics for one year. Both decomposition rate-constant and weight loss were highest for *M. philippensis* (% weight loss = 73.49; k = 0.33) and lowest for *S. robusta* (% weight loss = 54.01; k = 0.18). In general, weight remaining showed a strong negative correlation with N and P concentration but a slightly negative with K. However, the remaining weight of litter showed a strong positive correlation with C : N ratio, thus indicating a good predictor of mass loss and mineralization. The study showed that there was no net release of nitrogen during the one-year study period; however, the net P release was found to be highest for *S. robusta* followed by *D. pentagyna* and the net K release was highest in *F. hookeri* followed by *A. lakoocha*.

Keywords: Immobilization, leaf-litter decomposition, nutrient dynamics, weight remaining

The dead plant materials such as leaves, bark, needles, and twigs that have fallen on the ground are called litter. As the majority of organic matter (OM) produced by plants is returned to the soil as litter, the transfer of nutrients and energy from living biological components to the soil is the important mechanism of nutrient recycling. In the cycling of such nutrients, decomposition processes have a crucial role by releasing a complex organic compounds into the simple usable form for proper growth and development of plants (Saha *et al.*, 2016). Litter has thus occupied the attention of ecologists as it is an important factor in ecosystem dynamics to determine ecological productivity and may be useful in predicting soil fertility (Guendehou *et al.*, 2014).

The process of biological disintegration of dead organic materials whereby mineralization of complex organic compounds into simple inorganic forms takes place is called decomposition (Saha *et al.*, 2016). The process of decomposition is primarily carried out by bacteria and fungi, thus the rate of decomposition entirely depends on microbial activities which in turn, get affected by soil character and climatic condition in an area (Berg and McClaugherty, 2014). Moreover, Gautam and Mandal (2016) have also reported the effect of disturbance on litter dynamics in a moist tropical forest. Litter mass loss or decay is the sum of carbon dioxide release and discharge of compounds that contains both carbon compounds and nutrients (Brady and Weil, 2010). In general, three major factors *viz*. site environmental condition (particularly climate), litter quality and soil biota play a crucial role on decomposition of Leaf-litter; however, climate is known to be the dominant factor followed by litter quality influencing the decomposition process (Austin

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and Vitousek, 2000; Berg and McClaugherty, 2014).

Nutrient dynamics is broadly defined as the way nutrients are taken up, retained, transferred, and cycled over time and distance, in an ecosystem (Hauer and Lamberti, 2006; Allan and Castillo, 2007). Decomposition process plays an important role in maintaining soil fertility in terms of nutrient cycling and formation of soil OM (Usman *et al*., 2000; Singh *et al*., 2007; Guendehou *et al*., 2014). Slow decomposition rates result in the building up of OM and nutrient stocks in soil; however, fast decomposition rates help to meet plant intake requirements (Isaac and Nair, 2005). Litter diversity also influences the activity of soil communities and processes during decomposition (Chapman and Koch, 2007). Moreover, some chemical characteristics of the litter materials like lignin, polyphenol, cellulose, and hemicellulose along with C : N ratio affect decomposition (Silveira *et al*., 2011). A litter with higher initial N concentration usually shows a higher mass loss; however, the importance of initial N concentration decreased with time (Ross *et al*., 2002).

In the traditional mountain farming system of Nepal, there exists a triangular relationship among forest, agriculture, and livestock. In this system, forest trees are responsible to provide nutrient to the soil surface in the form of leaf-litter in both forest and agricultural lands. As a result, the tradition of harvesting leaf-litters from the forests for agricultural use has been a complementary practice of agriculture in rural Nepal. Leaf-litters have been used for livestock bedding and farmyard manure (FYM) production. Thus, decomposed leaf-litters become a major source of plant nutrients to the agricultural field as manure. However, most of the farmers do not know the chemical nature of the leaf-litters and their decomposition mechanism as some of the species are with complex structural biomolecules that do not provide nutrients easily. Therefore, the present study was carried out to compare the leaf-litter decomposition and nutrient dynamics of frequently used species in the study area.

Materials and methods

Study area

The study was carried out in tropical lowland (about 450 m altitude) of Makawanpur district, central Nepal. *Shorea robusta*, *Terminalia chebula*, *T. bellirica*, *Mallotus philippensis*, *Ficus* spp., *Adina cordifolia*, *Acacia catechu* and *Dalbergia sissoo* were the common species found in the study area. The experiment was set up in tropical climatic conditions having the average temperature of 29.18^{0}C and 173.64 mm rainfall during the study period. The temperature and rainfall variations in the study area are shown in Figure 1.

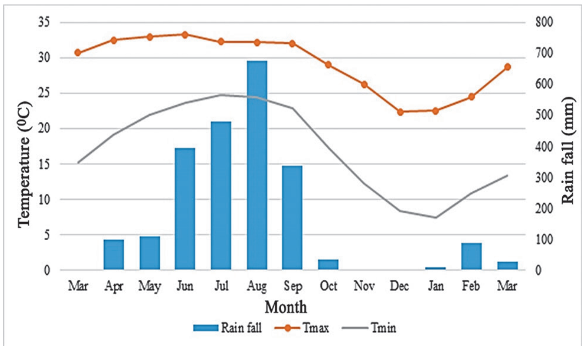

Figure 1: Monthly variation of rainfall, temperature (maximum and minimum) of the study area

Source: Department of Hydrology and Meteorology, 2019

Selection of species

A total of five tree species *viz*. *S. robusta*, *F. hookeri*, *M. philippensis*, *A. lakoocha* and *D. pentagyna* were selected for the study based on the key informant interview with the local farmers focusing on their use-values. Of them, *S. robusta*, *M. philippensis* and *D. pentagyna* were found to be highly used for animal bedding and composting whereas *F. hookeri* and *A. lakoocha* were used for fodder and composting.

Methods

The decomposition of the Leaf-litter of the selected tree species was studied in the open land using a nylon bag technique following Gilbert and Bocock (1960). The newly fallen leaves of the selected five species were collected from the forest-floor during the peak litter fall period (March). The litter samples were identified based on the morphological characters, and oven-dried at 70^{0}C to a constant weight in the laboratory. For each species, 36 litter bags were prepared enclosing a 50g sample of the oven-dried leaves into a 25×25 cm sized 2 mm thick nylon mesh which was small enough to prevent the major losses of the litter sample yet large enough to permit microbial activity, and placed at the open area during March, 2018. The litter-bags were placed separately in an open field in such manner that they were in contact with soil, and care was taken not to disturb the floor vegetation. Three litter bags of each species were recovered randomly at monthly interval from March, 2018 to March, 2019. Afterward, the samples were made free from dust and other unnecessary materials, and oven-dried at 70^0C and weighted. Then, the samples were immediately brought to the Soil Laboratory at Hetauda for nutrient analysis. The nitrogen (N) content was estimated using the Micro-Kjeldahl Method whereas the phosphorus (P) and potassium (K) were determined by adopting the Spectrophotometry Method and Flame Photometer Method, respectively as per Jackson (1967). The climatic data (temperature and rainfall) obtained from the Department of Hydrology and Meteorology were used.

Data analysis

The decomposition rate-constant was calculated using the exponential decay model of Olsen (1963) which is expressed as - $X/X_o = e^{-kt}$,

where, X is the dry weight remaining at time t (year), X_o is the original dry weight of the litter, and k is the decay rate coefficient.

The time required for half-life (t_{50}) was calculated as - $t_{50} = 0.693/k$

Likewise, correlation analysis was used to examine the relationship of the remaining weight with the remaining OM, N, P and K.

Results and discussion

Initial chemical composition

The initial nutrient composition of Leaf-litter showed variation among the selected tree species (Table 1). The highest nitrogen concentration was estimated in *A. lakoocha* (0.07%) followed by *F. hookeri* and *M. philippensis* (0.062%) and so on. The maximum phosphorus was in *D. pentagyna* (0.145%) followed by *F. hookeri* (0.131%). and least in *M. philippensis* (0.078%). Similarly, potassium was highest in *F. hookeri* (21.159%) followed by *S. robusta* (5.62%).

Weight loss pattern

At the end of the study, the maximum weight loss (73.49%) was observed in *M. philippensis* whereas this value was minimum (54.01%) in *S. robusta*. Likewise, the annual decomposition constant (k) values for the different species ranged from 0.18 (*S. robusta*) to 0.33 (*M. philippensis*) and the half-lives (t_{50}) from 3.85 to 2.1, respectively (see Table 2). Comparatively, the rates of decomposition of the leaf-litters of *F. hookeri*, *M. philippensis*, *A. lakoocha* and *D. pentagyna* were found to be higher at the end of the first month followed by a gradual mass loss for the subsequent days. However, the rate of decomposition of *S. robusta* was not higher during the first months as found in the other species; rather the rate was higher at the end of the second month (Figure 2).

Table 1: Initial chemical composition and decomposition constant of Leaf-litter

Species	Local name	OM	N	P	K	C:N
Shorea robusta Gaertn.	Sal	6.19	0.042	0.116	5.620	147.376
Ficus hookeri Miq.	Nimaro	7.28	0.062	0.131	21.159	118.0654
Mallotus philippensis (Lam.) Mull. Arg.	Sindure	6.54	0.062	0.071	2.382	106.189
Artocarpus lakoocha Wall. ex Roxb.	Badahar	6.32	0.070	0.078	5.295	90.26995
Dillenia pentagyna Roxb.	Tatari	6.86	0.048	0.145	2.429	143.9757

(Note: OM - Organic matter; N - Nitrogen, P- Phosphorus, K- Potassium, C - Carbon, k - Decomposition rate-constant)

Table 2: Annual weight loss, decomposition constant (k), half-life (t_{50}) and C: N ratio

S. N.	Species	Dry mass			Initial C:N	Final C:N
		k	Weight loss (%)	t_{50}		
1.	*S. robusta* Gaertn.	0.18	54.01	3.85	147.376	69.94018
2.	*F. hookeri* Miq.	0.24	65.58	2.89	118.0654	70.48909
3.	*M. philippensis* (Lam.) Mull. Arg.	0.33	73.49	2.1	106.189	60.71628
4.	*A. lakoocha* Wall. ex Roxb.	0.29	70.53	2.39	90.26995	54.23127
5.	*D. pentagyna* Roxb.	0.25	70.6	2.77	143.9757	62.31835

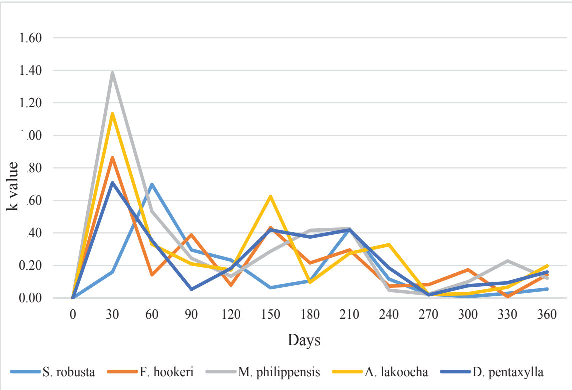

Figure 2: Leaf-liter decomposition rate-constant with respect to time

The decomposition rate-constant showed a significant positive correlation with the aerial temperature (p = 000; r = 0.54) and rainfall (p = 0.000; r = 0.51). Hasanuzzaman and Hossain (2014) reported the concentration of the nutrients to have decreased gradually at the end of the experiment in a dry season whereas there was decrease in the initial stage but increase at the end of the experiment in the wet season. On the contrary, Salinas *et al*. (2011) concluded the temperature to be overwhelmingly the most important driver. However, Wieder *et al*. (2009) concluded the positive correlation between precipitation and leaf-litter decomposition along with the temperature. Hence, the physico-chemical environment, litter quality and the composition of the decomposer community are the three leading features regulating litter decomposition (Dechaine *et al*., 2005).

Changes in nutrient concentration in decomposing litter

In general, there was a significant positive correlation (except *F. hookeri*) between the remaining weight and the C: N ratio (Table 3). Kim (2007) also concluded that the lower C : N ratio increased the rate of decomposition.

Table 3. Correlation between the remaining weight and the OM, N, P & K

Species	Value	OM	N	P	K	C:N
S. *robusta*	p	0.04	0.000	0.482	0.194	0.000
	r	0.58	-0.945	-0.214	-0.385	0.885
F. hookeri	p	0.27	0.302	0.315	0.915	0.216
	r	0.33	-0.311	-0.303	-0.033	0.368
M. philippensis	p	0.42	0.005	0.901	0.021	0.019
	r	0.25	-0.728	-0.039	-0.632	0.637
A. *lakoocha*	p	0.49	0.003	0.831	1.000	0.002
	r	0.21	-0.756	-0.066	0.000	0.773
D. pentagyna	p	0.92	0.001	0.231	0.168	0.048
	r	-0.03	-0.809	0.357	-0.407	0.556

Organic matter concentration

The percentage of the OM showed a positive correlation with the remaining weight in all the species except *D. pentagyna* which showed a slightly negative correlation (Figure 3a). However, there was no significant relationship (p>0.05) between the remaining weight and the OM except in the case of *S. robusta*. The value of the remaining OM at monthly intervals showed high fluctuation for *F. hookeri* followed by *M. philippensis*.

Nitrogen concentration

The initial N concentration of *A. lakoocha* (0.07%), was found to be the highest followed by *F. hookeri* and *M. philippensis* each having 0.062%. There was a continuous increase in N concentration (Figure 3b) of residual litter throughout the decomposition cycle in all the species, thus showing significant (p<0.05, except in the case of *F. hookeri*) inverse linear relationship. At the end of the study period, the N concentration was more than one and half times higher than the initial in the case of all the species except *F. hookeri* whose concentration was just slightly higher than that at the initial phase. Similar to the findings of this study, an increase in N concentration was observed by Bargali *et al*. (2015), Arslan *et al*. (2010) and Bargali *et al*. (2006). This might have resulted from microbes taking up inorganic N, *i.e.* fungal immobilization as microbes require nutrients like N and P for their growth, and they have to take sufficient N to use C containing materials (Bargali *et al*., 1993). Though there was an increasing pattern of nitrogen concentration during the study period, *F. hookeri* might provide mineralized N earlier than other species as this species showed less net change from the initial N content.

Phosphorus concentration

The initial P was found to be highest (0.145%) in *D. pentagyna* followed by *F. hookeri* (0.131%). Similar to the result of N, the correlation between the remaining weight and the P was slightly negative except in the case of *D. pentagyna* which showed a positive relationship with the remaining weight (Figure 3c). However, the relation was not significant for any of the species (p>0.05). This study showed that the net release of P was highest for *S. robusta* followed by *D. pentagyna*.

Potassium concentration

The remaining P concentration with time was more or less similar for all the species. The initial concentration was highest in *F. hookeri* (21.159%) followed by *A. lakoocha* (5.295). The amount of P was found to have dramatically decreased during the first month for all the species and increased in the second month and again decreased in the third month (see Figure 3d). The rate slightly fluctuated again at the last two months of the study period. The net release of P was highest in *F. hookeri* followed by *A. lakoocha*.

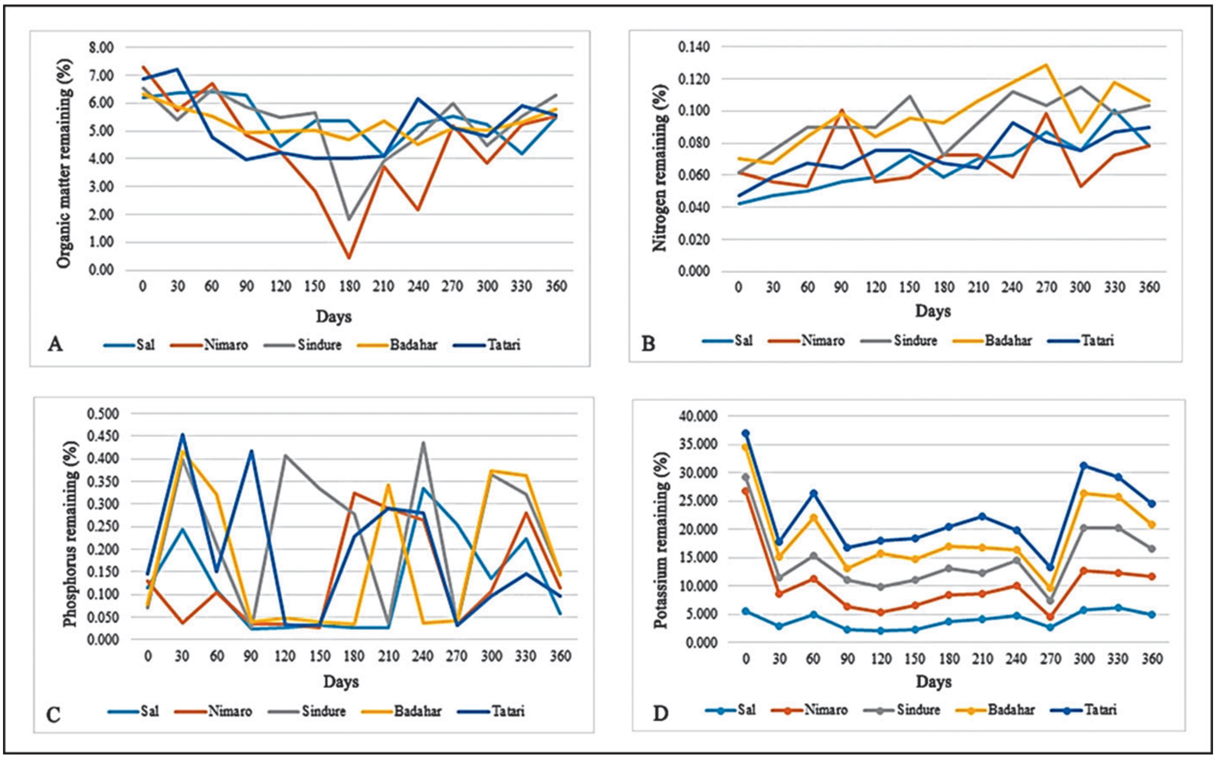

Figure 3a: Remaining OM (%) with time; Figure 3b: Remaining N (%) with time; Figure 3c: Remaining P (%) with time; and Figure 3d: Remaining K (%) with time

Conclusion

Based on the present study, it can be concluded that the rate of decomposition of *M. philippensis* is highest followed by *A. lakoocha* whereas the rate of decomposition of *S. robusta* is lowest. Decomposition is a complex procedure heavily influenced by biotic and abiotic factors. Both decomposition rate-constant and weight loss were highest for *M. philippensis* (% weight loss = 73.49; k = 0.33) and lowest for *S. robusta* (% weight loss = 54.01; k = 0.18). In general, the weight remaining was strongly negatively correlated with N and P concentrations but slightly negatively correlated with K concentration. However, there was a strong positive correlation between the remaining OM and C : N ratio for all the species. The study showed that there was no net release of N during the one-year study period, thus indicating none of the species to be the immediate source for N to the soil. However, the net P release was highest for *S. robusta* followed by *D. pentagyna* while the net K release was highest in *F. hookeri* followed by *A. lakoocha*.

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