Research Article

LEAF LITTER DECOMPOSITION AND WEIGHT LOSS PATTERN OF FIVE TROPICAL TREE SPECIES

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ABSTRACT

Leaf litter decomposition in terrestrial ecosystems has a major role in recycling the nutrients to the soil. Various biotic (microorganisms) and abiotic (temperature, rainfall, humidity, seasonal variations) factors affect the rate of litter decomposition. This paper aims to compare leaf litter decomposition and weight loss pattern of five tropical tree species, and assess the effect of temperature and rainfall to the decomposition. A leaf litter bag method was used to assess the decomposition pattern for one year. Both decomposition rate constant (k), and weight loss were highest for *Mallotus philippensis* (% weight loss = 73.49; k = 0.33) and lowest for *Shorea robusta* (% weight loss = 54.01; k = 0.18). The study showed a significant positive correlation between decomposition rate constant (k) and temperature (p = 0.000; r = 0.54) and rainfall (p = 0.000; r = 0.51). The rate of leaf litter decomposition is primarily governed by biological organisms which in turn, get largely affected by climatic condition, especially temperature and precipitation, and litter quality. Thus, there is a need to analyze properties of leaf litter while using them as compost to get better production.

Keywords: Biogeochemistry, microorganism, ecosystem, *Mallotus philippensis*

INTRODUCTION

The dead plant materials such as leaves, bark, needles, and twigs etc. that have fallen to the ground is called litter. This detritus or dead organic material and its constituent nutrients are added to the top layer of soil which helps to increase soil fertility. Transfer of nutrients and energy from living biological components to the soil is clearly related to litter fall thus being initiation phase of nutrient recycling. In the cycling of such nutrient, the decomposition processes have a crucial role by releasing complex organic compound 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 term decomposition refers to the process of biological disintegration of dead organic materials whereby mineralization of complex organic compounds into simple inorganic forms takes place (Vitousek et al., 1994; Aerts & de caluwe, 1997; Saha et al., 2016). The process of decomposition is primarily carried out by bacteria and fungithus the rate of decomposition entirely depends on microbial activities which in turn, get affected by soil character and climatic condition in an area (Beg & McClaugherty, 2014). Also, the decomposition proceeds faster in intermediate water contents and anaerobic decomposition is less efficient than aerobic decomposition (Taylor & Jones, 1990). Moreover, Gautam & Mandal (2016) have also reported effect of disturbance on litter dynamics in moist tropical forest.

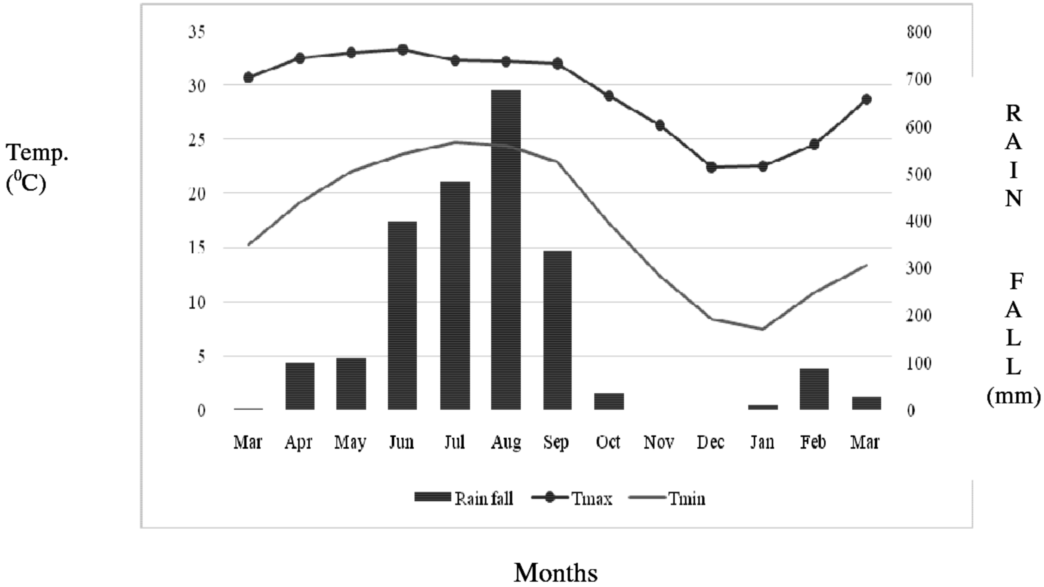
'Litter mass loss' or 'decay' is the sum of carbon dioxide release and discharge of compounds that contains both carbon compounds and nutrients (Brady & Weil, 2010). In general, three major factors viz. site environmental condition (particularly climate), litter quality and the soil biota play a crucial role on decomposition of leaf litter (Swift et al., 1979) andusually climate is known to be the dominant factor influencing litter decomposition followed by litter quality in determining decomposition process (Austin & Vitousek, 2000; Berg et al., 2014).

In 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 the purposes of livestock bedding and farm yard manure (FYM) production. Thus decomposed leaf litters become 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 litter and their decomposition mechanism as some of the species are with complex structural biomolecules which do not decompose easily. In Nepal, only few studies have been made regarding the litter dynamics. Therefore, this study was done in tropical forest ecosystem in central Nepal to compare the leaf litter decomposition rate constant (k) values of five frequently used tropical tree species, and to analyze the effect of temperature and rainfall on their decomposition.

MATERIAL AND METHODS

Study area

The studywas carried out in tropical lowland (about 450 m altitude) of Hetauda, Makawanpur district, central Nepal. *Shorea robusta*, *Terminalia chebula*, *Terminalia bellirica*, *Mallotus philippensis*, *Ficus* spp., *Adina* *cordifolia*, *Acacia catechu*, *Dalbergia sissoo* are common species found in the study area. The experiment was set up in tropical climatic condition having mean monthlymaximum and minimum temperatureranging from 22.4⁰C to 33.3⁰C and 7.4⁰C to 24.7⁰C respectively during study period (March, 2018 to March, 2019). Likewise, the amount of rainfall ranged from 0 mm to 674.8 mm with the mean value158.45 mm. The temperature and rainfall variations in the study area during study period are shown in Figure 1.



Source: Department of hydrology and meteorology, 2019

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

Selection of species

A total five tree species widely used for animal bedding, fodder and composting in the study areabased on key informant interview with local farmers were selected for the analysis (Table 1).

Table 1. List of species selected for the study

S. N.	Species	Local name	Local uses
1.	*Shorea robusta* Gaertn.	Sal	Litter/compost
2.	*Ficus hookeri* Miq.	Nimaro	Fodder/compost
3.	*Mallotus philippensis* (Lam.) Mull. Arg.	Sindure	Litter/compost
4.	*Artocarpus lakoocha* Wall. exRoxb.	Badahar	Fodder/compost
5.	*Dillenia pentagyna*Roxb.	Tatari	Litter/compost

Methods

Decomposition of leaf litter of selected tree species was studied in the open land using a nylon bag technique (Gilbert & Bocock, 1960). Newly fallen leaves of the selected five species (*Shorea robusta*, *Ficus hookeri*, *Mallotus philippensis*, *Artocarpus lakoocha* and *Dillenia pentagyna*) were collected from the forest floor randomlyduring the peak litter fall period (March). The litter samples wereidentified based on morphological characters and oven dried at 70⁰C to a constant weight in the laboratory. For each species, 36 litter bags were prepared enclosing a 50g sample of oven dried leaves into a 25*25 cm sized 2 mm nylon mesh, which was small enough to prevent major losses of litter sample yet large enough to permit microbial activity, and placed at open area during March, 2018. Litter bags wereplaced separately in an open field in such manner that they were in contact with soil and care were taken not to disturb the floor vegetation. Three litter bags of each species were recovered randomly at monthly interval during March, 2018 to march, 2019. Then the samples were made free from dust and other unnecessary materials thenoven dried at 70⁰C and weighted. The climatic data (temperature and rain fall) were used from department of hydrology and meteorology. This study has focused on weight loss pattern to analyze decomposition though crude fibre is also an indicator of the leaf litter decomposition (Subedi et al., 2011).

Data Analysis

The decomposition rate constant was calculated using the exponential decay model of Olsen (1963) as -

$$X/Xo = e^{-kt}$$

where, X is the dry weight remaining at time t (year), Xo is the original dry weight of the litter and k is the decomposition rate coefficient. The data used for the calculation of decomposition rate constant was the mean value of weight remaining at each collection time.

The time required for half life(t_{50}) was calculated as

$$t_{50} = 0.693/k$$

Likewise, correlation analyses were used to examine the effect of temperature and precipitation of the study area to the decomposition rate as expressed by the value 'k'.

RESULTS AND DISCUSSION

Decomposition and weight loss pattern

Leaf litter decomposition is a complex method and consists of two simultaneous processes as a) the associated mineralization and humification of lignin, cellulose and other compounds through a series of actions by microorganisms and b) the leaching of soluble compounds into the soil whose carbon and nitrogen are gradually mineralized (Anderson, 1988).

The dry matter loss in leaf litter of the selected species at monthly intervals was analyzed to assess the decomposition rate and the effect of temperature and rainfall on it. Comparatively the rate of weight loss of leaf litter of *F. hookeri*, *M. philippensis*, *A. lakoocha* and *D. pentagyna* was higher at the end of first month followed by a gradual mass loss for the subsequent days. However, the rate of weight loss of *S. robusta* was not higher during the first month as found in other species rather the rate was higher at the end of second month. The weight loss of leaf litter samples ranged from 54.01% (*S. robusta*) to 73.49% (*M. philippensis*) whereas the decomposition rate constant (k) valueswere ranged from 0.18 (*S. robusta*) to 0.33 (*M. philippensis*) and the half-lives (t_{50}) varied from 3.85 to 2.1 respectively (Table 2, Figure 2).

Table 2. Annual decomposition rate constant (k), half-life (t_{50}) for different species

S. N.	Species	Dry mass		
		k	Weight loss (%)	t_{50}
1.	*Shorea robusta*Gaertn.	0.18	54.01	3.85
2.	*Ficus hookeri*Miq.	0.24	65.58	2.89
3.	*Mallotus philippensis* (Lam.) Mull. Arg.	0.33	73.49	2.1
4.	*Artocarpus lakoocha* Wall. exRoxb.	0.29	70.53	2.39
5.	*Dillenia pentagyna*Roxb.	0.25	70.6	2.77

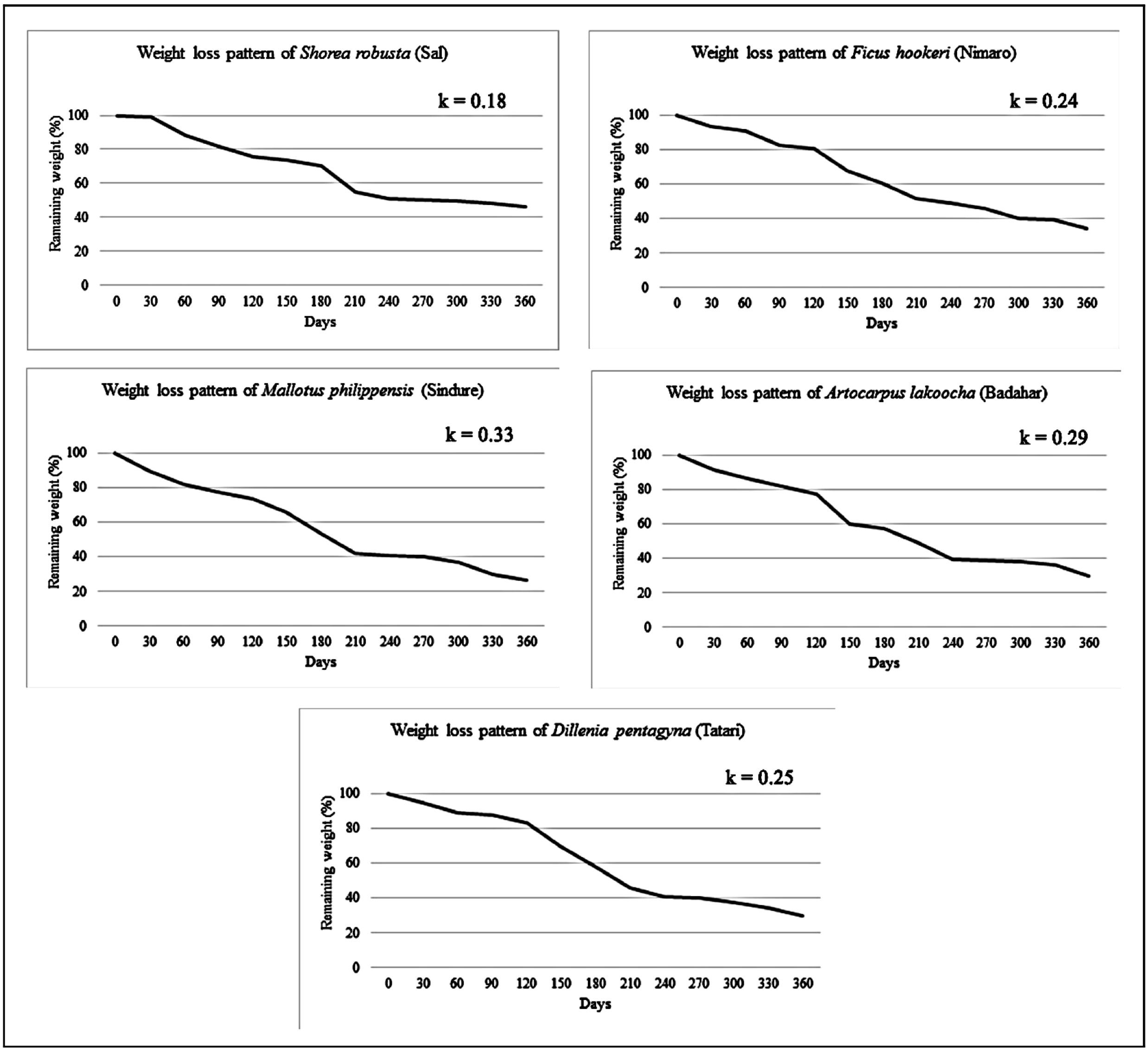


Figure 2. Weight loss pattern of leaf litter of selected species

Effect of temperature and precipitation on decomposition

The study showed a significant positive correlation between leaf litter decomposition and aerial temperature (p = 000; r = 0.54) (Figure 3). This positive relationship is perhaps due to pronounced microbial activity under favorable temperature and moisture conditions and accentuated leaching due to rainfall. Similar to the previous findingsof Hobbie (1996), Kirshbaum (2000), Bargali et al. (2015), Krishna & Mohan (2017), this study also reported temperature to be considered as a prime factor in determining the rate of litter decomposition as soil microbial activity rises exponentially with soil temperature (Kirshbaum, 1995).

Though environmental condition (particularly climate), litter quality and the soil biota play a crucial role on decomposition of leaf litter, Zhou et al. (2008); Bhalawe et al. (2013); Portillo-Estrada et al. (2016) concluded that the climatic factors controls the decomposition rate, in which mean annual temperature and annual actual evapotranspiration are dominant and mean annual precipitation is subordinate which is similar to the finding of this study. Similarly, Zhang et al. (2008) have also concluded that k-value increases with temperature, precipitation and nutrient concentration but single factor such as climate, litter quality and geographic variable can just act upon decomposition as combined factors. Likewise, Gautam & Mandal (2016) have concluded that there is reduction of litter fall due to disturbance like looping, litter removal, tree felling, grazing, and fire etc. thus causing degradation of soil quality of forest ecosystem, however, this study was carried out in an open area after collecting leaf litter from the forest so this study does not focus on amount of litter in forest floor.

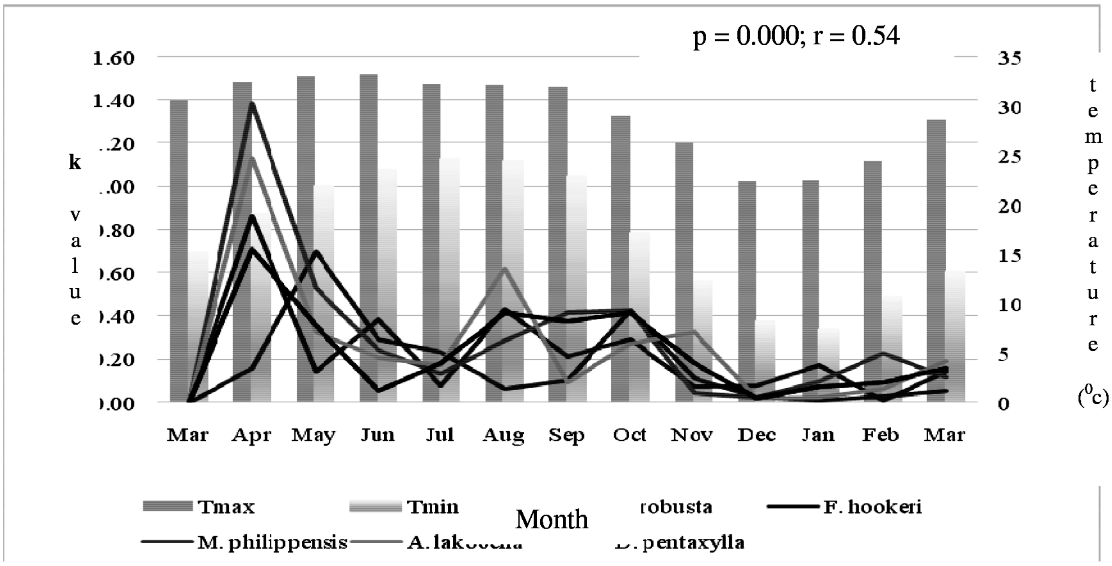


Figure 3. Effect of temperature on decomposition

Theresult also showed a significant positivecorrelationbetween decomposition constantand rainfall ($p = 0.000$; $r = 0.51$) (figure 10) thus indicating the role of temperature and precipitation to be prominent for decomposition rate in the study area.

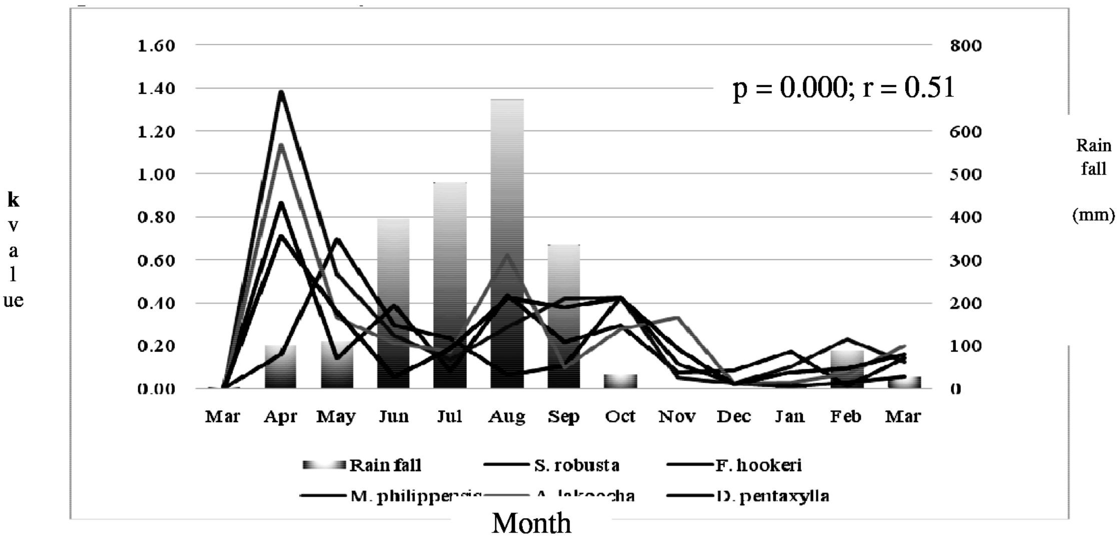


Figure 4. Effect of rainfall on decomposition

Similar to the finding of this study, Aber & Melillo (1982) reported the decomposition methods to be markedly affected by temperature, humidity and biotic features of the soil. Dechaine et al. (2005) also concluded the physico-chemical environment, litter quality and the composition of the decomposer community to be the leading features regulating litter decomposition.

Hasanuzzaman & Hossain (2014) reported the nutrients concentration to be decreased gradually at the end of the experiment in dry season whereas there was decreased in the initial stage but increased at the end of experiment in wet season. On the contrary, Salinas et al. (2010) concluded the temperature to be overwhelmingly the most important driver but they showed no direct relationship with rainfall. This might be due to change in relative humidity along elevation gradient in their study. However, similar to this study, Wieder et al. (2009) concluded the positive correlation between precipitation and leaf litter decomposition. Hirobe et al. (2004) also reported a great variation in decomposition pattern among fifteen species in the same climatic condition due to variability in litter quality. Likewise, Subedi & Bhatta (2010) have also reported moisture content and temperature to be the determining factor during leaf litter decomposition and residue mineralization.

Thus, the leaf litter decomposition is a very important factor in recycling nutrient to increase the soil fertility which, in fact, gets affected by a variety of factors including litter quality, duration, soil microbial activities, climatic factors etc. Moreover, mass loss or decomposition is the one and only route to release bound molecules in the form of complex chemicals to the simple and usable forms. So just collecting the leaf litter from the forest and using them as an immediate source of soil nutrient is questionable. In fact, the decomposition process is highly governed by climatic factors along with microbial activities and litter quality.

CONCLUSION

During a year-long litter decomposition experiment, the decomposition and weight loss rate started greatly for four species by the end of first month and then continued with a consistent manner whereas *Shorea robusta* got decomposed highly at the end of second month. Based on the present study, it can be concluded that the rate of decomposition differs from species to species even in the same environmental condition due to variation of leaf litter chemistry. The decomposition rate of *Mallotus philippensis* was highest followed by *Artocarpus lakoocha* whereas the rate of decomposition of *Shorea robusta* was the lowest. Decomposition is a complex procedure heavily influenced by biotic and abiotic factors. Findings of this study have shown the significant positive relationship between decomposition rate constant, and temperature, and rainfall pattern. Thus *Mallotus philippensis* and *Artocarpus lakoocha* provide nutrition earlier than *Shorea robusta,* meaning, multiple factors should be considered while selecting tree species for composting.

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