Journal of Tropical Agriculture 56 (2): 99-106, 2018

Litter dynamics in *Imperata cylindrica* grassland under culturally managed system in North East India

Karabi Pathak, Arun Jyoti Nath*, Ashesh Kumar Das and Mohan Bhar

Department of Ecology and Environmental Science, Assam University, Silchar 788011, Assam

Received 01 February 2018; received in revised form 17 September 2018 ; accepted 26 October 2018

Abstract

Imperata cylindrica is a dominant grass species in North East India and is traditionally managed in the family farms for socioeconomic purposes. However, little is known about its role on ecosystem dynamics and nutrient fluxes. The present study was undertaken in Barak Valley part of North East India to study the leaf, root and rhizome litter production, litter mass loss, litter chemistry and decomposition dynamics of leaf, root and rhizome litter, and pattern of nutrient release from the leaf, root and rhizome litter. The mean monthly surface and belowground litter production was recorded as 64 and 215 kg ha^{-1} respectively. The annual total litter production in *Imperata* grassland was 3344 kg ha^{-1}. The time required for 50% and 99% decomposition of litter residue was shorter for surface litter than the belowground litter. The concentration of N, P, K and C was more in surface litter than the belowground litter. Belowground litter returned more nutrients to soil system than surface system. *Imperata cylindrica* with slow decomposition of its belowground litter can help in soil organic matter build up in the long run, and therefore prove efficient in soil health conservation.

Keywords: *Imperata cylindrica,* Nutrient conservation, Nutrient returned, Root and rhizome litter, Surface litter.

Introduction

The importance of litter production has long been recognized because the majority of organic matter produced by plants through photosynthesis is returned to the soil as litter in the ecosystem. Litter fall may be either seasonal or a continuous process, and represents one of the most important pathways for the transfer of energy and material through its decomposition (Bargali et al., 2015). Litter decomposition plays a crucial role in regulating the nutrient budget of an ecosystem where vegetation depends directly on the recycling of nutrients contained in the plant detritus (Isaac and Nair, 2005). During this process plant nutrients become available for recycling within the ecosystem. Decomposition is regulated by soil organisms, environmental conditions and chemical nature of the litter. A slow rate of decomposition results in accumulation of organic matter and nutrient stocks in soil, while a faster rate helps to meet the plant uptake requirements (Isaac and Nair, 2005). Knowledge of these processes is crucial for generating ideas about the factors controlling rate of decay. Decomposition process plays an important role in maintaining soil fertility in terms of nutrient cycling and the formation of soil organic matter (Singh et al*.,* 2007; Guendehou et al*.,* 2014).

Several studies have been carried out worldwide from temperate to tropical forests, and in agroforestry systems including grasslands such as Savanna on litter dynamics. However, not much is known about litter dynamics of grasslands that are managed indigenously at community level. As *Imperata* grasslands are managed traditionally for monetary benefits in rural landscapes of Barak

*Author for correspondence: Phone: 91-9435598232, Email: arunjyotinath@gmail.com

Valley, North East India, the present study is an important approach to explore this grassland in terms of ecosystem dynamics and nutrient fluxes. Present study was framed to understand the litter production, composition and decay rates of *Imperata cylindrica* grasslands with the objectives of studying the following: (i) leaf, root and rhizome litter production, (ii) litter mass loss, (iii) litter chemistry and decomposition dynamics of leaf, root and rhizome litter, and (iv) pattern of nutrient release from the leaf, root and rhizome litter.

Materials and Methods

Study area

The field study was conducted in the Rosekandy area (24°41·310² N, 092°41·939² E) of Cachar district, Barak Valley, North East India. The climate of the area is subtropical warm and humid with an annual average rainfall of 2,226 mm, and the monthly average maximum and minimum temperatures are 30·5°C and 20·3°C, respectively (Nath et al., 2015). The major soils of the study area are inceptisols, and the soil of the experimental plots is classified as loamy skeletal mixed, hyperthermic family of typic dystrudepts (USDA, 1998). The broad physiographic position of the study area is steep foothills and moderately sloping (15–30% slope) terrain. The grasslands in the study area are dominated by *Imperata cylindrica*. The farming unit ranges in size from 0.25 to 1.5 ha and is managed traditionally at the individual farm level. Traditional management practices include annual harvesting and felling of other unwanted vegetation, building fire breaks, controlled burning, and tillage (only once in about 10 years when the soil becomes too compacted). Small growers harvest *Imperata* at the end of winter when the growth has senescenced. For the present study, a 1.2 ha area of the grassland was chosen.

Litter production

Aboveground (AG) litter production (surface litter) was studied at monthly intervals from randomly laid five quadrants (50 cm x 50 cm) in *Imperata* grasslands. Belowground (BG) litter i.e., root and rhizome litter were sampled from another five quadrants (50 cm x 50 cm) laid near to the quadrants used for AG litter production study. The BG litter was studied with a soil core (inner diameter: 5.5cm) up to 25 cm soil depth at monthly intervals. Soil samples collected were brought to the laboratory and washed carefully to remove the adhered soil with roots and rhizomes. Identification of BG litter (dead rhizome and root) was carried out by visualizing their black to brown colors (Anderson and Ingram, 1993). The samples of surface and BG litter collected from the grasslands were oven dried at 70^0 C up to constant weight to obtain the biomass. Surface and BG litter production were calculated with the following formulae:

Litter production =

$$[\text{litter content}_{\text{nth month}} - \text{litter content}_{(n-1)\text{th month}}] + \text{Decay}_{\text{nth month}}$$

Litter decomposition

Air dried AG and BG litter weighing 5 g were placed in 15 cm x 15 cm nylon litter bags (1 mm mesh size) and 60 such bags were prepared for each litter type of *Imperata* grassland. Litter bags enclosing AG and BG plant parts were placed under the densely grown *Imperata* vegetation. Subsequently, 5 litter bags were removed at monthly intervals from the ground of grassland until 95% decomposition was observed. The residual material from the sampled litter bags was separated carefully from the adhering soil particles using a small brush. The litter samples from each bag were oven dried at 70 ^{0}C until they reached a constant weight. Monthly mass loss (g $month^{-1}$) from decomposing litter was determined from the difference between the mass of litter remaining in the litter bags in a particular month, and the mass of litter in the litterbags in the previous month.

Mass loss over time

Mass loss over time was computed using the negative exponential decay model (Olson, 1963).

$$X / X_0 = \exp(-kt),$$

where, X is the weight remaining at time t, X_0 the initial weight, exp the base of natural logarithm, k

the decay rate coefficient and *t* the time (year). The time required for 50% (t_{50}) and 99% (t_{99}) decay was calculated as $t_{50} = 0.693/k$ and $t_{99} = 5/k$.

Litter nutrient content

Samples of initial litter and those retrieved during the sampling periods were ground in a Wiley mill for chemical analysis. The ash content was determined by igniting 1 g of powdered litter sample at 550 ^{0}C for 6 hours in a muffle furnace. A total of 50% of the ash free mass was calculated as the carbon (C) content (Allen et al., 1989). Total nitrogen (N) and total phosphorus (P) was determined by semi-micro Kjeldahl and molybdenum blue method respectively (Allen et al., 1989). Potassium (K) was determined flame photometrically (Systronics 121) after tri-acid digestion (1:5:0.5; perchloric acid, nitric acid and sulphuric acid) (Allen et al., 1989). The total stock of N, P and K was calculated by multiplying the concentration (%) with that of dry matter content. Absolute amount of nutrient in the litter bag was calculated as,

$(C/C_0) \times (X/X_0) \times 100$

where, C is the nutrient concentration in the litter samples at the time of sampling, C_0 is the nutrient concentration of the initial litter, X is the mass of dry matter at the time of sampling and X_0 is the initial dry mass of the litter sample.

Results and Discussion

The mean monthly AG and BG litter production were recorded as 64 and 215 kg ha^{-1} respectively. The highest surface litter production was estimated as 112 kg ha^{-1}in the month of September. Figure 1 shows that there was no surface litter production in the month of March. The monthly BG litter production ranged from 70-352 kg ha^{-1}. BG litter production started to decline from September and attained a value of 70 kg ha^{-1}in January. The annual total litter production in *Imperata* grassland was estimated as 3344 kg ha^{-1} (Table 1). BG litter contributed >50% of the total litter mass produced for any month of the year. BG litter contributed 100% of the litter production for the month of March. The highest allocation by surface litter was about 48% for the months of September and October.

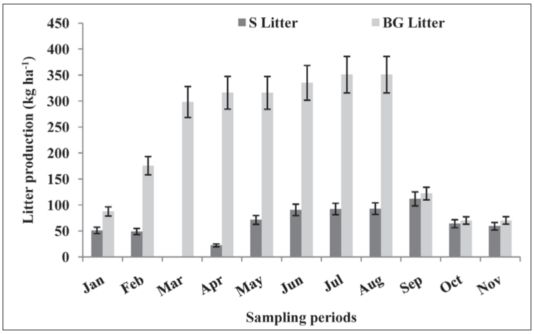

Figure 1. Annual surface litter production (kg ha^{-1}) in grassland of *Imperata cylindrica*.
Error bar represents standard error of the mean.

The climate of North East India is characterized heavy rainfall. Rainfall and wind might have influenced the standing dead mass to bent leeward and leaf tearing that may potentially cause standing dead mass to loss (de Langre, 2008). Based on plant dynamics of *Imperata* grasses, standing dead

Table 1. Total litter production and nutrient returned to soil in *Imperata* grassland

	Litter type	Litter production kg ha^{-1}yr^{-1}	Total kg ha^{-1}yr^{-1}
Total litter production	Surface	763	3343
	BG	2580	
Total N returned	Surface	7.6	30
	BG	22.4	
Ave P returned	Surface	1	3
	BG	2	
Exchangeable K^+ returned	Surface	2.4	9
	BG	6.7	

biomass loss as litter fall is the only source of surface litter production. The fire management strategy of the grassland also impacted on surface litter when it burnt all above ground litter in March (Pathak et al., 2017). Harvesting prior to fire also caused removal of all live and dead biomass from the grassland leading to the least possibility of surface litter production during March. However, in the aftermath of fire, *Imperata* regeneration started and simultaneously surface litter started to accumulate when standing dead biomass began to increase slowly.

The monthly average surface litter production of 64 kg ha^{-1} observed in the present study is comparable with 63-116 kg ha^{-1} from the semi arid grasslands of South Africa (Snyman, 2005). Litter production of the present study was lower than the production of 750 kg ha^{-1} from semi-arid *Astrebla pectinata* grassland in Australia (Ingram, 2003). Monthly litter production in the semi-arid Rift Valley Province of Kenya was 925 kg ha^{-1} (Ekaya and Kinyamario, 2001). Such differences in the surface litter production can be attributed to differences in site condition, climate, plant morphology and the prevailing management systems. In *I. cylindrica* root and rhizome litter production was 3.8 times higher than the surface litter production. Similarly, Steinakar and Willson (2005) observed that in Northern grasslands roots accounted for 80-90% of total litter production.

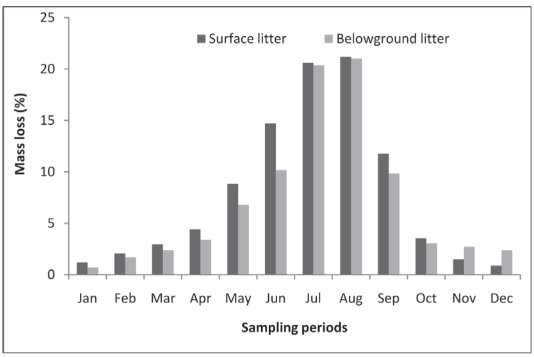

Figure 2. Annual mass loss (%) of surface litter and below ground litter over time of *Imperata cylindrica*.

Imperata leaves are persistent in nature and remains standing even after senescence (Yonekura et al., 2010). This caused less surface litter production indicating higher allocation of litter from dead root and rhizomes. *Imperata* grasses are relatively shallow rooted plants and the roots are prone to be affected by fire (Pathak et al., 2017). Post fire effect might have killed roots and rhizomes leading to high BG litter production during March to August. Moreover, root phenology is also an important factor that drives litter production (McCormack et al., 2014). The high root and rhizome production during growth period of *Imperata* may potentially pose competitive disadvantage for some roots and rhizomes in acquiring available resources i.e., water and nutrients. Hence that may cause a greater supply of root and rhizome litter during April to August.

AG and BG litter mass loss in *Imperata* grasslands pertaining to the periodical disappearance are depicted in Figure 2. Total mass loss increased with progress of time but the monthly mass loss was not uniform. Comparatively higher mass loss occurred during the period of July to September in surface litter and 66-83% of total surface mass loss occurred during this period (Figure. 2). The mean monthly surface mass loss over the study period was 14%. Similarly greater BG mass loss occurred during the period July to September with highest intensity during August (38-39%) (Figure 2). Weight loss expressed as a percentage of the original dry weight, decreased exponentially with time (Figure 3). As represented in Figure 3, the equations for surface litter may be given as $Y = 147.38e^{-0.006x}$, $R^2 = 0.8897$ (Figure 3A); and $Y = 181.59e^{-0.009x}$, $R^2 = 0.8774$ (Figure 3B) for BG litter. Annual decay constant (k), half life ($t_{0.50}$) and time for 99% loss of dry weight ($t_{0.99}$) of surface and BG litter are presented in Table 2. Data also revealed that time required for 50% and 99% decomposition of litter residue was shorter for AG than in BG litter (Table 2). Initial litter chemistry viz., concentration of N, P, K and C was more in AG than in BG litter. However, C:N ratio and N:P ratio was more in BG litter (Table 3).

Table 2. Annual decay rate of surface and below ground (BG) litter of *Imperata*

Litter type		Decomposition rate constant *k* (year^{-1})	50% decomposition time (t_{50}) (days)	99% decomposition time (t_{99}) (days)
Imperata cylindrica	Surface	2.63	94.9	693.5
	Below ground (BG)	1.73	146	1051.2

Table 3. Initial litter chemistry and stochiometric ratios of *Imperata* litter

Litter type		N (%)	P (%)	K (%)	C (%)	C:N	N:P
Imperata cylindrica	Surface	0.7	0.07	0.59	47	68	10
	Belowground	0.6	0.04	0.5	46	77	15

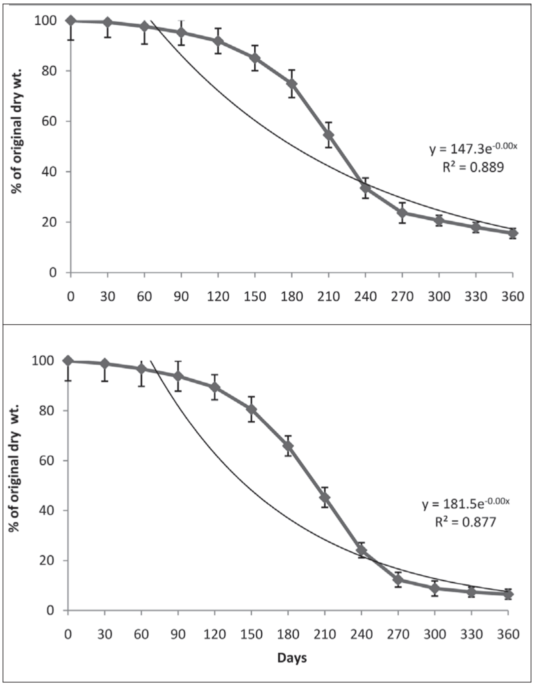

Figure 3. Decomposition of (A) surface litter and (B) belowground litter *Imperatacylindrica.*
Error bar represents standard error of the mean

The various tools to manage grasslands also impact on litter turnover or decomposition (Snyman, 2005). Decomposition is the obvious phenomenon of litter life which begins soon after its fall. Litter layer on the soil surface acts as an output input system, receiving inputs of organic matter and nutrients from the vegetation, losing biomass by decomposition and supplying nutrients to the mineral soil and roots (Das and Chaturvedi, 2006). Numerous studies have established that several ecological factors regulate the process of decomposition and positively correlate with temperature and rainfall of the region (Austin, 2002; Gholz et al., 2000; Meentemeyer, 1978). In the present study, litter loss was comparatively high in the wettest and hottest months. However, BG litter was slower in decomposition. Decomposition of root and rhizome litter in *Imperata* grasslands were 1.5 times slower than the leaf litter in the present study. Freschet et al. (2013) also found that root decomposes 2.8 times slower than the leaf litter derived from same species. This indicated that the complex and harder root and rhizomes prevented access to the decomposing microorganisms (Rogers, 2002). There was a significant positive relationship between litter quality and decomposition for the most complex community (Smith and Bradford, 2003).

Complex dynamics of N mobilization and immobilization in surface and BG litter of *Imperata* grassland was observed. The pattern of N release was biphasic. An accumulation phase of N in surface litter during 90 to 180 days of decomposition was

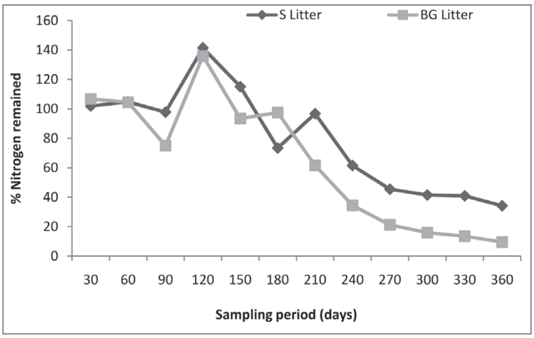

Figure 4. Changes in nitrogen concentration over time in surface and below ground (BG) litter of *Imperata cylindrica*

recognized (Figure 4). N in the remaining mass of decomposing AG litter after 90% of decomposition was 16%. For BG litter, N content increased in first 30 days of decomposition (Figure 4). Second accumulation phase was observed during 90-120 days of decomposition and succeeding N mobilization was observed during 210 and 360 days of decomposition. The N content in the remaining mass of 90 % decomposing BG litter was 18 %.

P in surface litter initially declined and later increased in two phases during 90-120 days and 150-210 days (Figure 5). The pattern of release of K in all the litter types from the decomposing mass revealed that the loss of K occurred at all the stages of decomposition. K in the remaining mass of decomposing litter after 360 days was the highest in surface litter (4%) followed by BG litter (1.4%) (Figure 6). The C:N ratio declined throughout the decomposition process in AG litter (Figure 7). It

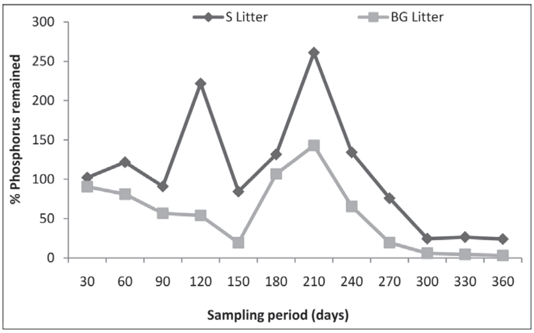

Figure 5. Phosphorus decomposition over time in surface and below ground (BG) litter of *Imperata cylindrica.*

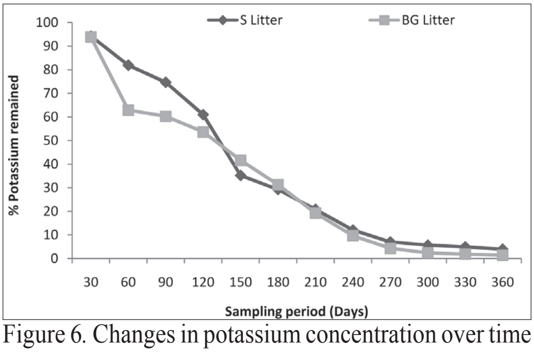

Figure 6. Changes in potassium concentration over time in surface and below ground (BG) litter of *Imperata cylindrica.*

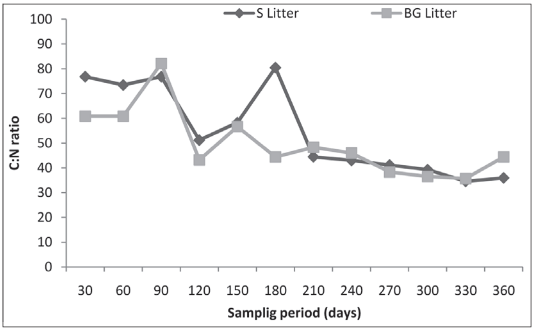

Figure 7. Changes in C :N ratios over time in surface and below ground (BG) litter of *Imperata cylindrica*

reduced to 35 after 360 days although it was observed to increase during 60-90 days and 120-150 days of decomposition.

Leaf litter had comparitively lower C:N ratio than root and rhizome litter. The leaf, root and rhizome litter having higher N and lower C:N ratio showed faster decomposition rate compared with litter with lower N and higher C:N ratio (Table 1 for decay constants). Initial N (Meentemeyer and Berg, 1986; Isaac and Nair, 2006) and C:N ratio (Swift et al.,1979) has been well correlated with the weight loss. The slower decomposition of leaf litter of *Imperata cylindrica* may lead to soil organic matter accumulation in the long run and can be expected to be more efficient than root and rhizome litters in soil organic matter conservation. AG litter returned 7.6 kg $ha^{-1}yr^{-1}$ of total N to soil, whereas BG litter returned 22.4 kg $ha^{-1}yr^{-1}$ (Table 1). Total N returned to soil through litter was estimated as 30 kg $ha^{-1}yr^{-1}$. Average P returned in soil through AG and BG litter were estimated as 1 kg $ha^{-1}yr^{-1}$ and 2 kg $ha^{-1}yr^{-1}$respectively. Exchangeable K^+ returned to soil through AG and BG litter was 2.4 kg $ha^{-1}yr^{-1}$ and 6.7 kg $ha^{-1}yr^{-1}$ respectively (Table 1).

From the present study the following conclusions were drawn (i) root and rhizome litter production is higher than surface litter production in *Imperata* grassland, (ii) surface litter decomposes faster than root and rhizome litter, (iii) of the total annual nutrient flux, nitrogen was returned in the highest quantity followed by potassium and phosphorus and

(v) *Imperata cylindrica* with slow decomposition of its below ground litter is likely to lead soil organic matter build up in the long run and therefore be more efficient in soil health conservation.

References

Allen, S.E., Grimshaw, H.W., Parkinson, J.A., and Quarnby, C. 1989. Chemical Analysis of Ecological Materials, Blackwell Scientific Publications, Oxford.

Anderson, J.M. and Ingram, J.S.I. eds. 1993. Tropical soil biology and fertility: A handbook of methods. 2nd Edn. CAB International, Wallingford, UK.

Austin, A.T. 2002. Differential effects of precipitation on production and decomposition along a rainfall gradient in Hawaii. Ecol. 83: 328–338.

Bargali, S.S., Shula, K., Singh, L., Ghosh, L. and Lakhera, M.L. 2015. Leaf litter decomposition and nutrient dynamics in four tree species of dry deciduous forest. Trop. Ecol. 56: 191-200.

Das, D.K. and Chaturvedi, O.P. 2006. *Bambusa bambos* (L.) Voss plantation in eastern India: I. Culm recruitment, dry matter dynamics and carbon flux. J. Bamboo Rattan 5:47-59.

De Langre E. (2008) Effects of Wind on Plants. Annu. Rev. Fluid Mech. 40:141–68.

Ekaya, W.N. and Kinyamario, J.J. 2001. Production and decomposition of plant tiller in an arid rangeland of Kenya. Afr. J. Range For. Sci., 18: 125–129

Freschet, T.G., Cornwell, W.K., Wardle, D.A., Elumeeva, T.G., Liu, W., Jackson, B.G., Onipchenko, V.G., Soudzilovskaia, N.A., Tao, J. and Cornelissen, J.H.C. 2013. Linking litter decomposition of above- and below-ground organs to plant–soil feedbacks worldwide. J. Ecol. 101:943–952.

Gholz, H.L., Wedin, D.A., Smitherman, S.M., Harmon, M.E. and Parton, W.J. 2000 Long- term dynamics of pine and hardwood litter in contrasting environments: toward a global model of decomposition. Global Change Biol. 6:751–765.

Guendehou, G.H.S., Liski, J., Tuomi, M., Moudachirou, M., Sinsin, B. and Mäkipää, R. 2014. Decomposition and changes in chemical composition of leaf litter of five dominant tree species in a West African tropical forest. Trop. Ecol. 55: 207-220.

Isaac, S.R. and Nair, M.A. 2006. Litter dynamics in six multipurpose trees in a homegarden in Southern Kerala, India. Agrofor. Syst. 67: 203-213.

Ingram, L.J. 2003. Growth, nutrient cycling and grazing of three perennial Tussock grasses of the Pilbara Region of northwestern Australia. Ph D Thesis, Department of Botany, University of Western Australia 279 pp

McCormack, M.L., Adams, T.S., Smithwick, E.A.H. and Eissenstat, D.M. 2014. Variability in root production, phenology, and turnover rate among 12 temperate tree species. Ecology 8:2224–2235.

Meentemeyer, V. and Berg 1978. Macroclimate and lignin control of litter decomposition rates. Ecology 59:465–472.

Meentemeyer V., B. 1986. Regional variation in rate of mass loss of *Pinus sylvestris* needle litter in Swedish pine forests as influenced by climate and litter quality. Scand. J. Forest. Res. 1:167–180.

Nath, A.J, Lal, R. and Das, A.K. 2015. Ethnopedology and soil properties in bamboo *Bambusa* sp.) based agroforestry system in North East India. Catena 135: 92–99.

Olson, J.S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecology 44: 322-331.

Pathak, K., Nath, A.J., Sileshi, G.W., Lal, R. and Das, A.K. 2017. Annual burning enhances biomass production and nutrient cycling in degraded *Imperata* grasslands. Land Degrad. Develop. 28: 1763–1771.

Rogers, M.H. 2002. Litterfall, decomposition and nutrient release in a lowland tropical rain forest, Morobe Province, Papua New Guinea. J. Trop. Ecol. 18: 449-456.

Singh, L., Singh, A., Bargali, S.S., and Upadhyay, V.P. 2007. Leaf litter decomposition and nutrient release pattern in multipurpose tree species of central India. J. Basic Applied Biol. 1:14-21.

Snyman, H.A. 2005. Influence of fire on litter production and root and litter turnover in a semiarid grassland of South Africa, S. Afr. J. Bot. 71(2): 145–153.

Steinakar, D. and WiIlson, S.D. 2005. Below ground litter contributions to nitrogen cycling at a northern grassland–forest boundary. Ecology 86(10): 2825–2833.

Smith, V.C. and Bradford, M.A. 2003. Do non-additive effects on decomposition in litter- mix experiments result from differences in resource quality between litters? Oikos 102 (2): 235–242.

Swift, M. J., Heal O. W. and Anderson, J. M. 1979. Decomposition in Terrestrial Ecosystem. University of California Press, Berkeley, CA. USDA. 1998.

Keys to soil taxonomy. In USDA handbook, 8th edn. Soil Survey Staff: Washington, DC.

Yonekura, Y., Ohta, S., Kiyono, Y., Ahsa, D., Morisada, K., Tanaka, N., Kanzaki, M. 2010. Changes in soil carbon stocks after deforestation and subsequent establishment of "*Imperata*" grassland in the Asian humid tropics. Plant Soil 329:495–507.