



**NUTRIENT DYNAMICS IN SOIL ASSOCIATED WITH LEAF LITTER
OF *Shorea robusta* Gaertn. f. IN MADHUPUR SAL FOREST OF
BANGLADESH**

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KUS:18/13: 031018

Manuscript received: October 03, 2018

Accepted: September 04, 2019

Abstract: Litter plays an important role in nutrient cycling in forest ecosystem. Nutrients are released from litter through leaching, and decomposition process and readily available nutrients are obtained through leaching process. *Shorea robusta* forest is a tropical deciduous forest and shed their leaves during the dry season. In the vicinity, poor people usually collect this litter from the forest to meet household demand for fuel. Thus, a considerable amount of nutrients is lost from this system. However, some nutrients from those leaves is possible to harvest through leaching technique before use as fuel. Therefore, to quantify this nutrient Leaf litter production and leaf litter standing crop were estimated in the Modhupur Sal forest. In addition, mass loss and nutrients (nitrogen, potassium and phosphorus) release through leaching were observed over 192 hours through leaching process in the laboratory. Mean leaf litter production was found 12.94 ± 0.65 g/m²/day during the litter shedding period was estimated to and the mean leaf litter standing crop was found 89.20 ± 9.77 g/m². About 10% of initial mass was lost after 48 hours of leaching process. Moreover, initial concentration of nitrogen and phosphorus was sharply decreased to 65 µg/g and 42 µg/g respectively after 24 hours and initial concentration (38 µg/g) of potassium was sharply decreased to 5 µg/g after 12 hours. About 25%, 45% and 92% of initial N, P and K content, respectively can be extracted through leaching process.

Keywords: Leaching, mass loss, nutrient cycling, *Shorea robusta*

Introduction

Shorea robusta Gaertn. f. is a indigenous deciduous tree species and found in Dhaka, Gazipur, Mynensingh, Tangail, Dinajpur and Comilla districts of Bangladesh (Alam et al., 2008). Sal forests are the only natural forest in the central and northern parts of Bangladesh where the vast majority of the population live. Sal is the dominant species of the Sal forest (about 90%). The other common trees are *Butea monosperma*, *Adina cordifolia*, *Dillenia pentagyna*, *Albizzia procera*, *Terminalia* spp, *Lagerstroemia parviflora*, etc.. During the dry season, this species shed their leaves and the local poor people usually collect the leaf litter from the forest floor. In developing countries, the local inhabitants normally use senescent leaves as a source of fuel. However, as the senescent leaves contain some organic and inorganic nutrients, burning it implies the total loss of most nutrients in to the atmosphere. A portion of nutrients can be harvested from leaf litter using leaching technique and the local poor can use the leached nutrients as liquid fertilizer in the homestead vegetable garden or in other agricultural

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DOI: <https://doi.org/10.53808/KUS.2019.16.1and2.1813-L>

practices. Moreover, local poor can still use the leached leaf litter as fuel after air-drying. By using the liquid fertilizer in their home gardens, local farmers can get the ecological as well as economic benefit.

Chemical fertilizer is now being commonly used in agricultural practices, but it is expensive and has negative environmental impacts (Good et al., 2004). In addition, access to fertilizer in developing nations is limited (Sanchez, 2002) either due to lower availability or being expensive. Moreover, in some countries unscrupulous traders may create artificial fertilizer crisis during peak seasons to get high value, as in happened in Bangladesh in 2008 (Jahiruddin et al., 2009). Tropical farmers often use organic residues as low cost and readily available nutrients for soil fertility management (Nair, 1984; Kwabiah et al., 2001).

Leaching of soluble organic substances is ~~the~~ ^{first} step of decomposition which has influence on subsequent decomposition process (Mahmood et al., 2014; Prescott, 2005). Leaching provides better and faster information on nutrient cycling (Gallardo & Merino, 1993; Prescott, 2005). However, fewer studies have addressed the use of leached substances as a readily available nutrient source especially for those crops normally harvested within 6 months (Gindaba, et al., 2004; Mahmood et al., 2009; Mahmood et al., 2011; Nyberg et al. 2002; Tietema & Wessel 1994). Therefore, it can be possible to fulfill a portion of chemical fertilizer demand for the agricultural practices as it supply essential nutrients commonly obtained from chemical fertilizers. In this view, this study was carried out to estimate the leaf litter production and litter standing crop and to quantify the amount of nutrient released and nutrient release pattern through leaf litter of Sal.

Materials and Methods

Leaf litter selection and leaching experiment: Bulk of freshly fallen senescent leaves of *S. robusta* were collected from Modhupur Sal forest of Tangail district during dry season (February) when the maximum leaf fall took place. Litter was air-dried at room temperature for a week. The air-dried leaves were mixed thoroughly and a total of 33 samples of 5 gm each were prepared. Each sample was placed at room temperature into individual beaker (500 ml) and 200 ml of distilled water was poured in each beaker and few drops (0.2-0.3 ml) of HgCl₂ solution (50 mg l⁻¹) (McLachlan, 1971; Otsuki & Wetzel, 1974) were added in each beaker to prevent fungal decay. Three samples were kept in an oven at 80 °C until constant weight to obtain the air-dry to oven-dry conversion weight.

Sample collection and measurement: Three replicates of samples were collected at 1, 2, 3, 6, 12, 24, 48, 72, 120 and 192 hours of intervals and the collected samples were rinsed by distilled water and oven-dried at 80 °C to constant weight. The mass loss (%) due to the leaching was calculated from the differences between initial and final oven-dried weights and was expressed as a percentage of initial weight. The rate of mass loss was obtained by dividing mass lost (%) with the leaching time. Conductivity ($\mu\text{S cm}^{-1}$), total dissolve solid (mg L^{-1}) of leached water sample were measured by a conductivity and TDS meter (Ciba-Corning Diagnostic Ltd., England).

Nutrients measurement in leaf litter: The leaf samples were processed and acid digested according to Allen (1974). Nitrogen (N) and phosphorus (P) concentration in sample extracts were measured according to Weather burm (1967) and Timothy et al., (1984), respectively using UV-Visible Recording Spectrophotometer (Shimadzu UV-160A, Japan). Potassium (K) concentration in leaf extracts at different time intervals were measured by Flame photometer (PFP7, Jenway LTD, England). The nutrient amounts released from leaf litters were calculated as differences between initial and final absolute amounts and also expressed as percentage of initial value.

Statistical analysis: The rate of mass loss and nutrients (N, P and K) concentration in leaf litter of each species at different time intervals was compared by one-way ANOVA analysis followed by Duncan Multiple Range Test (DMRT) of variance using SAS 6.12 statistical software.

Estimation of leaf litter and leaf litter standing crop: Estimation of leaf litter production was conducted during the peak litter fall time in the Modhupur forest of Tangail District using temporary sample plots (litter trap) of 2 m x 2 m. The leaf litter inside the traps were collected daily (24 hours' interval) for 15 days and oven-dried at 80 °C until constant weight. Moreover, twenty temporary sample plots of 2 m x 2 m were set randomly on the forest floor to estimate the leaf litter standing crops.

Quantification of leached nutrients: Amount of leaf litter standing crop was calculated as area basis. The initial and final nutrients (N, P and K) concentration will be multiplied with the total amount of leaf litter standing crop to get the harvestable amount of leaching nutrients.

Results

The initial dry mass of leaf litter of *Shorea robusta* was significantly ($p < 0.05$) decrease to 10% after 48 hours and showed similar percentage of loss at the end of the experiment (Fig-1). Conductivity and TDS of leaching water showed similar trend with leaching time. Conductivity and TDS of leaching water were significantly ($p < 0.05$) increased to 907 $\mu\text{S cm}^{-1}$ and 438 mg l^{-1} after 48 hours and showed similar values up to the end of the experiment. Moreover, mass loss, conductivity and TDS showed significant positive curvilinear (Logarithmic) relationship with the leaching time and the regression co-efficient values for conductivity and TDS were $R^2 = 0.95$, $R^2 = 0.98$ and $R^2 = 0.98$, respectively (Fig:1-3).

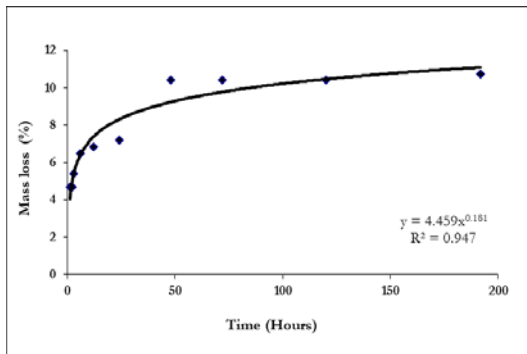


Fig. 1: Mass loss (%) of leaf litter of *Shorea robusta* during the leaching process.

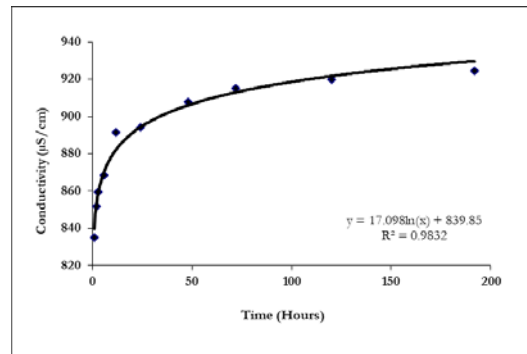


Fig. 2: Conductivity ($\mu\text{S cm}^{-1}$) of leaching water samples of leaf litter of *Shorea robusta*

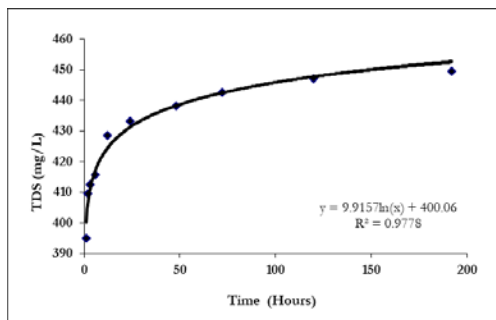


Fig. 3: TDS (mg L^{-1}) of leaching water samples of leaf litter of *Shorea robusta*

The concentration of N, P and K in leaf litter of *S. robusta* was significantly ($p < 0.05$) decrease from $83 \mu\text{g g}^{-1}$, $68 \mu\text{g g}^{-1}$ and $38 \mu\text{g g}^{-1}$ to $65 \mu\text{g g}^{-1}$, $42 \mu\text{g g}^{-1}$ and $5 \mu\text{g g}^{-1}$ respectively after 24 hours. Nitrogen, P and K concentration in leaf litter showed significant ($p < 0.05$) negative curvilinear relationship with leaching time (Fig- 4-6).

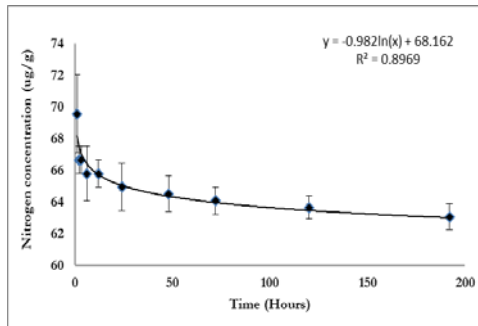


Fig. 4: Nitrogen concentration ($\mu\text{g g}^{-1}$) in leaf litter of *Shorea robusta* at different time intervals

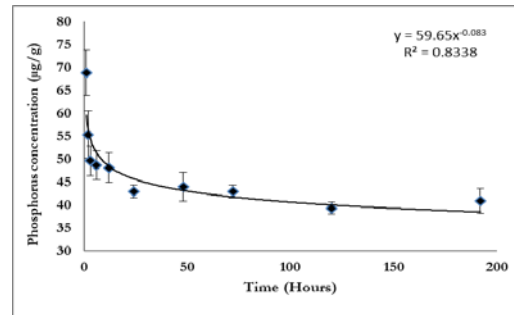


Fig. 5: Phosphorus concentration ($\mu\text{g g}^{-1}$) in leaf litter of *Shorea robusta* at different time intervals

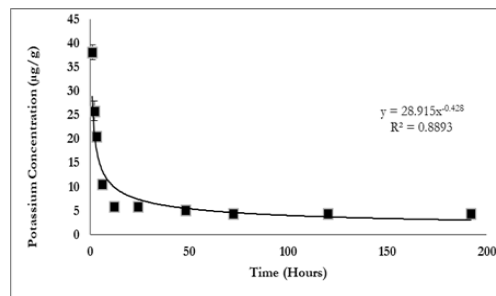


Fig 6: Potassium concentration ($\mu\text{g g}^{-1}$) in leaf litter of *Shorea robusta* at different time intervals

The initial concentration of NH_4 , PO_4 and K in leaching water were increased to 0.82, 102 and 79 ppm, respectively, but rapid increase of NH_4 and PO_4 concentration in leaching water was found after 24 hours, while K concentration sharply increase after 12 hours. Nutrients in leaching water showed significant positive curvilinear relationship with leaching time.

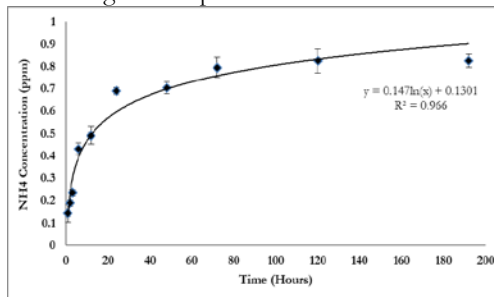


Fig. 7: NH_4 concentration (ppm) of leaching water of *Shorea robusta* leaf litter at different time intervals

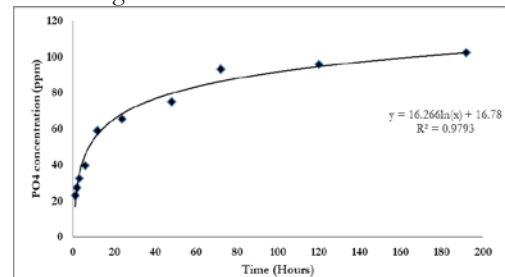


Fig. 8: PO_4 concentration (ppm) of leaching water of *Shorea robusta* leaf litter at different time intervals

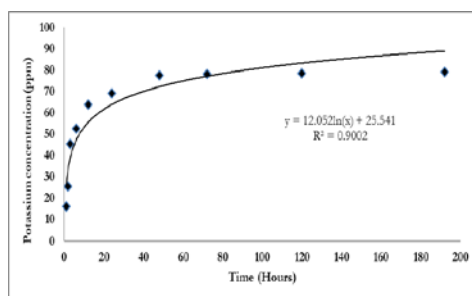


Fig. 9: Potassium concentration (ppm) of leaching water of *Shorea robusta* leaf litter at different time intervals

Leaf litter standing crops and nutritional quantity. Mean daily amount of leaf litter production during the leaf-shedding period was estimated to $12.94 \pm 0.65 \text{ g m}^{-2} \text{ day}^{-1}$ and the mean amount of leaf litter standing crop was $89.20 \pm 9.77 \text{ g m}^{-2}$. Nitrogen, P and K concentrations in leaf litter standing crop were 64.02 , 46.08 and $3.14 \text{ } \mu\text{g g}^{-1}$ respectively and the amount of nutrient stock on forest floor as leaf litter standing crops was $5.709 \pm 0.625 \text{ mg m}^{-2}$, $4.103 \pm 0.449 \text{ mg m}^{-2}$ and $0.268 \pm 0.029 \text{ mg m}^{-2}$, respectively. However, it was estimated that $0.270 \pm 0.013 \text{ mg m}^{-2}$, $0.462 \pm 0.023 \text{ mg m}^{-2}$ and $0.668 \pm 0.033 \text{ mg m}^{-2}$ of N, P and K, respectively can be harvested from leaf litter of *S. robusta* during the leaf shedding period (Table 1).

Table 1: Initial and final concentration of nutrients in leaf litter and harvestable amount of nutrients from leaf litter

	Nutrient concentration ($\mu\text{g g}^{-1}$)			Nutrient amount (mg m^{-2})		
	N	P	K	N	P	K
Initial concentration	83.3	75.45	56.12	1.086 ± 0.054	0.971 ± 0.049	0.725 ± 0.036
Final concentration after 192 hours of leaching experiment	63.05	39.32	4.37	0.816 ± 0.041	0.509 ± 0.026	0.057 ± 0.003
Harvestable amount of nutrients from leaf litter				0.270 ± 0.013	0.462 ± 0.023	0.668 ± 0.033

Discussion

Significant positive curvilinear relationships among the leaching time and mass loss, conductivity and TDS (Fig.1-3) indicate that water-soluble organic and inorganic substances are leached from leaf litter, and ceased the leaching process with the increasing time. Park & Hyun (2003); Kongkon et al., (2006); Hasan et al., (2006); Mahmood et al., (2010); Hasanuzzaman & Mahmood (2014); Limon et al., (2016) reported similar relationships among leaching time and mass loss of leaf litter, conductivity and TDS of leaching water. The higher rate of mass loss up to 48 hours (Fig. 1) may be due to initial rapid loss of soluble inorganic and organic substances (Limon et al., 2016). The average rate of mass loss of *S. robusta* leaf litter of the present study was only $0.05\% \text{ hr}^{-1}$, which was higher than *Syzygium guineense* var. *guineense* ($0.03\% \text{ hr}^{-1}$) (Ibrahima et al., 2008) but very lower than *Melia azedarach* ($1.15\% \text{ hr}^{-1}$) (Hasan et al., 2006), *E. camaldulensis* ($0.92\% \text{ hr}^{-1}$) and *S. macrophylla* ($0.41\% \text{ hr}^{-1}$) (Mahmood et al., 2009), *Acacia auriculiformis* ($0.25\% \text{ hr}^{-1}$) (Kongkon et al., 2006), *Vitex madiensis* ($0.25\% \text{ hr}^{-1}$), *Syzygium guineense* var. *guineense* ($0.03\% \text{ hr}^{-1}$) (Ibrahima et al., 2008). The observed differences in the mass loss rate among different species may be due to the variation in the concentration of different soluble inorganic and organic substances, the physical, chemical and morphological characteristics of leaf litter (Saini, 1989; Ibrahima et al., 1995). Moreover, the higher rate of mass loss also emphasizes the

potentiality of species to provide readily available organic and inorganic compounds for microbiota (Wetzel, 1995). The significant variation of N, P and K concentration in the leaf litter of different species during the leaching process may depend on their initial concentration (Mahmood et al. 2010; Tukey, 1970), characteristics, mobility, and involvement in structural properties of the respective plant cell (Meyer et al., 1973). Potassium (K) is highly mobile compared to N and P and at the same time K is not structurally bounded (Marschner, 1995). This could be the reason for observing higher amount of K release (Table 1) from leaf litter followed by P and N. The significant negative curvilinear relationship among elements (N, P and K) concentration, leaching time and mass loss of leaf litter explains that mass loss of leaf litter is associated with the release of these elements.

Conclusion

Leaf litter of *S. robusta* was susceptible to leaching within 192 hours and about 25%, 45% and 92% of initial N, P and K content, respectively can be extracted through leaching process. Thus, a considerable amount of nutrients can be harvested and can be utilized for agricultural purpose before burning this litter as fuel for cooking purpose. In this study, only leaching amount was measured but for getting knowledge about total amount of nutrient release from this species we need to carry out research on decomposition process.

Acknowledgement

The authors thankfully acknowledges the logistic support and continuous adherences from Forestry and Wood Technology Discipline, Khulna University, Khulna and Forest Department, Government of Bangladesh. This research was financially supported by the University Grant Commission, Bangladesh.

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