Nutrients (N, P and K) dynamics associated with the leaf litter of two agroforestry tree species of Bangladesh

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***Eucalyptus camaldulensis* (Dehnh.) and *Swietenia macrophylla* (King.) are not native to Bangladesh, but they are widely used in agroforestry practices for their commercial values. Selection of tree species with efficient return of nutrients is a vital challenge in agroforestry practices to maintain the soil fertility for sustainable crop production. Therefore, a comparative study was conducted on nutrients (N, P and K) leaching from leaf litter of *E. camaldulensis* and *S. macrophylla* in laboratory condition. The initial dry weight of leaf litter of *E. camaldulensis* and *S. macrophylla* were significantly (p<0.05) decreased to 18% and 10%, respectively at the end of the experiment. *Eucalyptus camaldulensis* showed comparatively (*t*-test, p<0.05) higher rate of weight loss, conductivity and TDS (Total Dissolved Solid) of leached water. Comparatively, higher amount of N (48 µg g^{-1}) was released from leaf litter of *E. camaldulensis* whereas higher amount of P (0.8 µg g^{-1}) and K (23 mg g^{-1}) from *S. macrophylla*, leaf litter and both the species showed similar pattern of nutrient (K>N>P) release during the leaching process. Nutrients (N, P and K) concentration in leaf litter of these species showed significant (p<0.05) negative exponential curvilinear relationships with the weight loss. Result of this study suggests that *E. camaldulensis* is the best in terms of N return and *S. macrophylla* the best in terms of P and K return.**

Keywords: ***Eucalyptus camaldulensis*, *Swietenia macrophylla*, Leaching, Nutrient cycling**

Introduction

Chemical fertilizer is now commonly used in agricultural practices, but it becomes expensive and farmers are reducing its use due to negative environmental impacts (Good et al. 2004). In addition, access to fertilizer in developing nations is limited (Sanchez 2002). It is an important task to gain a better understanding how agricultural practices can be designed with low input of fertilizer. Maintenance of soil productivity is a critical issue in a tropical agroecosystems. Agroforestry practice is an important component of it. Tropical farmers use this practice for their dependence on organic residues as low cost and readily available nutrients for soil fertility management (Nair 1989, Kwabiah et al. 2001). To this regard, agroforestry got special impetus in tropical agriculture.

Farmers of the tropical region traditionally use variety of species composition in agroforestry practices. In Bangladesh, leguminous tree species are traditionally used in different agroforestry practices. Presently, farmers prefer *Eucalyptus camaldulensis* and *Swietenia macrophylla* due to their commercial values. Agroforestry being a people oriented program, farmer's preference should be acknowledged, but the performance of these species is needed to be scientifically assessed with due attention in terms of nutrient return efficiency for further promotion. However, nutrient return from a tree is influenced by quantity, quality (nutrient composition) and rate of leaching and decomposition of plant litter (Senevirante et al. 1998, Kwabiah et al. 2001). Leaf litter is the main and quick source of nutrient return to the soil compared to other litter components (Tukey 1970, Wetzel & Manny 1972, Mason 1977, Dahm 1981, Park & Hyun 2003). The present study aimed to assess the pattern of nutrients leaching (N, P and K) from the leaf litter of *E. camaldulensis* and *S. macrophylla* in laboratory condition.

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Materials and Methods

Leaf litter selection and leaching experiment

Bulk of yellowish senescent leaves of *E. camaldulensis* and *S. macrophylla* were collected during March 2007 (maximum leaf fall period). This period corresponds to dry season and no leaching was occurred from litter. Litter was air-dried at room temperature for one week. For each species, air-dried leaves were thoroughly mixed and weighted to two grams as an individual sample and thus a total of 42 samples were prepared. Each sample was placed at room temperature into individual beaker (500 ml) and 250 ml of distilled water was poured to each beaker and few drops of $HgCl_2$ solution (50 mg l^{-1} - McLachlan 1971, Otsuki & Wetzel 1974) were added in each beaker to prevent fungal decay. Five samples were kept into an oven at 80°C until constant weight to get the air-dry to oven-dry conversion weight.

Sample collection and measurements

Three replicates of samples were collected at 0, 1, 2, 3, 4, 8, 12, 24, 36, 48, 72 and 96 hours of intervals and the collected samples were ringed by distilled water and oven-dried at 80°C to constant weight. The mass loss (%) due to the leaching process was calculated from the differences between initial and final oven-dried weights and was expressed as a percentage of initial loss. The rate of mass loss was obtained by dividing mass loss (%) with the leaching time. Conductivity (µS cm^{-1}), total dissolve solid (TDS - mg l^{-1}) of leaching water sample were measured by a conductivity and TDS meter manufactured by 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 Weatherburm (1967) and Timothy et al. (1984), respectively using UV-Visible Recording Spectrophotometer (Shimadzu UV-160A, Japan). Potassium concentration in leaf extracts at different time intervals were measured by Atomic Absorption Spectrophotometer (Perkin Elmer 4100, USA). The nutrient amounts released from leaf litters were calculated as differences between initial and final absolute amounts and also expressed as percentage of initial amounts.

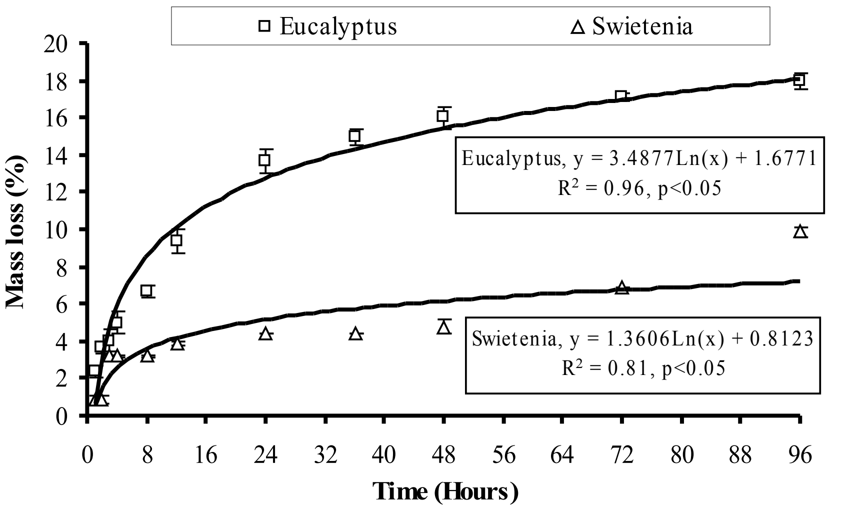

Fig. 1 - Mass loss (%) of leaf litter of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

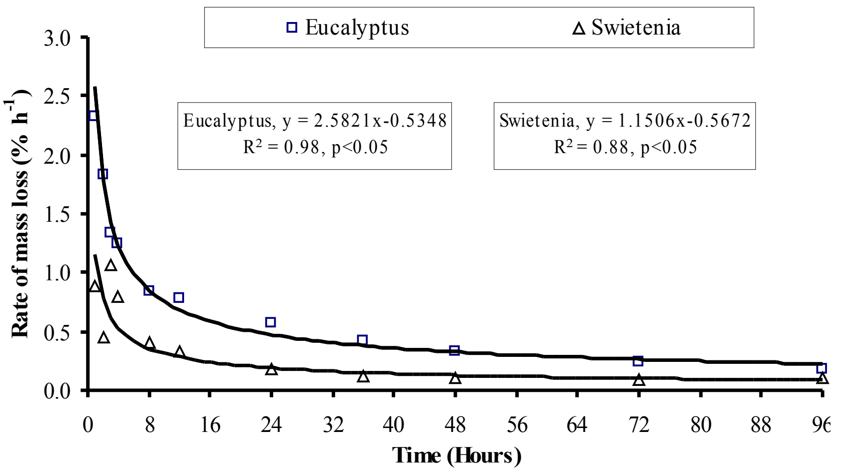

Fig. 2 - Mass loss rate (% h^{-1}) of leaf litter of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

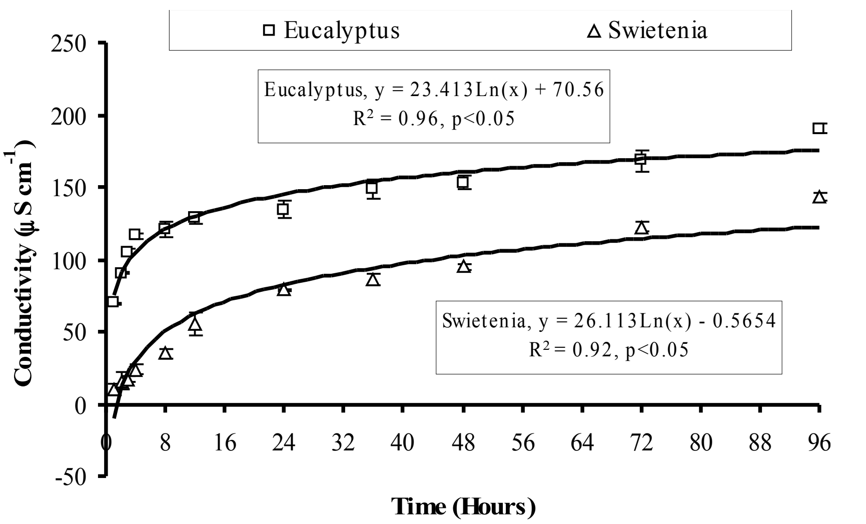

Fig. 3 - Conductivity (µS cm^{-1}) in leaching water samples of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

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 analysis of variance using SAS 6.12 statistical software. Rate of mass loss, conductivity, TDS and nutrients (N, P and K) concentration in leaf litter between two species were compared by unpaired *t*-test using SPSS (11.5) Statistical Software. For each species relationships among the mass loss and nutrients (N, P and K) concentration with leaching time were calculated.

Results

The initial dry mass of leaf litter of *E. camaldulensis* and *S. macrophylla* were significantly ($p<0.05$) decreased to 13.6% and 4.37% after 24 hours; 18% and 10%, after 96 hours respectively (Fig. 1) and comparatively (*t*-test, $p<0.05$) higher rate of mass loss was observed for *E. camaldulensis* (Fig. 2). Conductivity and TDS of leaching water of both the species were significantly ($p<0.05$) increased at the end of the experiment and comparatively (*t*-test, $p<0.05$) higher conductivity and TDS were observed for *E. camaldulensis* (Fig. 3, Fig. 4). Mass loss of leaf litter, conductivity and TDS of leaching water of both the species showed significant ($p<0.05$) positive logarithmic relationships with the leaching time (Fig. 1, Fig. 3, Fig. 4).

Initial concentrations of N, P and K in leaf litter of *E. camaldulensis* were significantly ($p<0.05$) decreased from 120 µg g^{-1}, 2.15 µg g^{-1}, and 21.76 mg g^{-1} to 75.09 µg g^{-1}, 1.65 µg g^{-1} and 5.14 mg g^{-1}, respectively after 24 hours. Similarly, N, P, and K concentration in leaf litter of *S. macrophylla* were significantly ($p<0.05$) decreased from 90.98 µg g^{-1}, 2.09 µg g^{-1}, and 27.75 mg g^{-1} to 65.51 µg g^{-1}, 1.43 µg g^{-1} and 12.5 mg g^{-1}, respectively after 24 hours (Fig. 5, Fig. 7). And after 96 hours, 40%, 32% and 89% of the initial amount of N, P and K was lost for E. *camaldulensis*, whereas 43%, 38% and 85% for S *macrophylla* (Tab. 1).

Comparatively (*t*-test, $p<0.05$) higher concentrations of N was observed in leaf litter of *E. camaldulensis* (Fig. 5), whereas higher concentrations of K was observed in *S. macrophylla* (Fig. 7) throughout the leaching process, but these species contained similar (*t*-test, $p > 0.05$) concentration of P (Fig. 6). Higher amount of N (48 µg g^{-1}) was released from leaf litter of *E. camaldulensis* whereas higher amount of P (0.8 µg g^{-1}) and K (23 mg g^{-1}) was released from *S. macrophylla* and both the species showed similar pattern of nutrient (K>N>P) release during the leaching process (Tab. 1). Nutrients (N, P and K) concentration in leaf litter of these species showed significant ($p<0.05$) negative logarithmic relationships with the mass loss (Tab. 2).

Discussion

Significant positive logarithmic relationships among the leaching time and mass loss, conductivity and TDS (Fig. 1, Fig. 3, and Fig. 4) indicate that water soluble organic and inorganic substances are leached from leaf litter, and ceased with the increasing leaching time. Park & Hyun (2003), Kongkon et al. (2006) and Hasan et al. (2006) 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 eight hours (Fig. 2) may be due to initial rapid loss of soluble inorganic and organic substances (Tukey 1970). The average rate of mass loss of *E. camaldulensis* and *S. macrophylla* leaf litter of the present study were 0.92% hr^{-1} and 0.41% hr^{-1}, respectively, which were higher than *Acacia auriculiformis* (0.25% hr^{-1}), *Vitex madiensis* (0.25% hr^{-1}), *Syzygium guineese* var. *guineese* (0.03% hr^{-1} - Kongkon et al. 2006, Ibrahima et al. 2008) and lower than *Melia azedarach* (1.15% hr^{-1} - Hasan et al. 2006). 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 (Nykvist 1963, Taylor & Parkinson 1988, 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 and K concentration in the leaf litter of *E. camaldulensis* and *S. macrophylla* during the leaching process (Fig. 5 and Fig. 7) may depend on their initial concentration (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 (Tab. 1) from leaf litter. The significant negative logarithmic relationship among elements (N, P and K) concentration, leaching

Tab. 1 - Absolute amount of nutrients released from leaf litter during the leaching process. Values in the parenthesis indicate released nutrient amounts expressed as percentage of initial nutrient amount.

Species	Nitrogen ($\mu g\ g^{-1}$)	Phosphorus ($\mu g\ g^{-1}$)	Potassium ($mg\ g^{-1}$)
E. camaldulensis	48 (40)	0.70 (32)	19.26 (89)
S. macrophylla	40 (43)	0.80 (38)	23.42 (85)

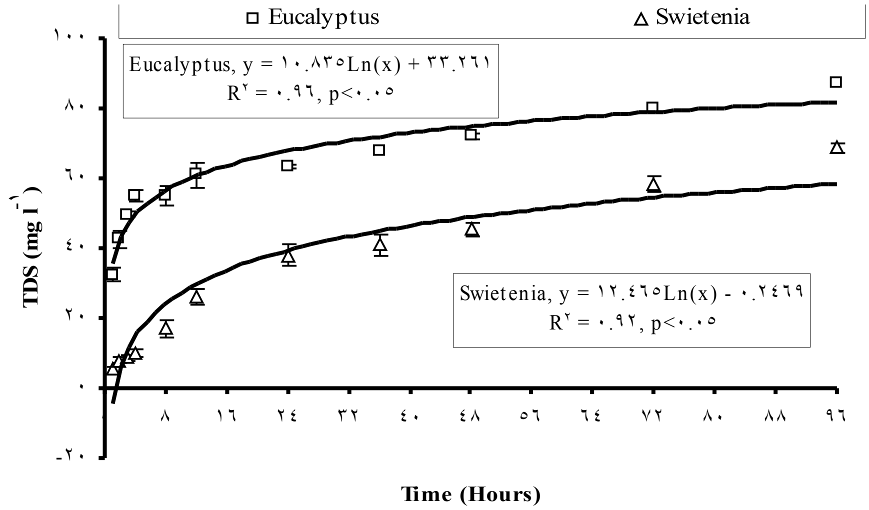

Fig. 4 - Total dissolve solid (mg l^{-1}) in leaching water samples of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

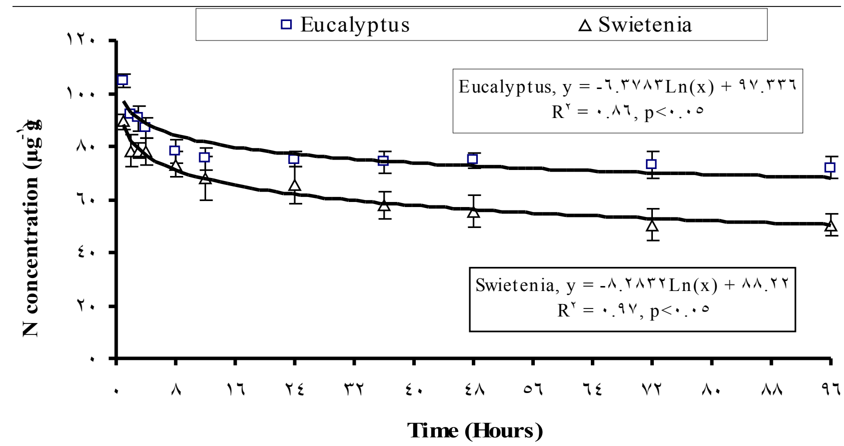

Fig. 5 - Nitrogen concentration ($\mu g\ g^{-1}$) in leaf litter of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

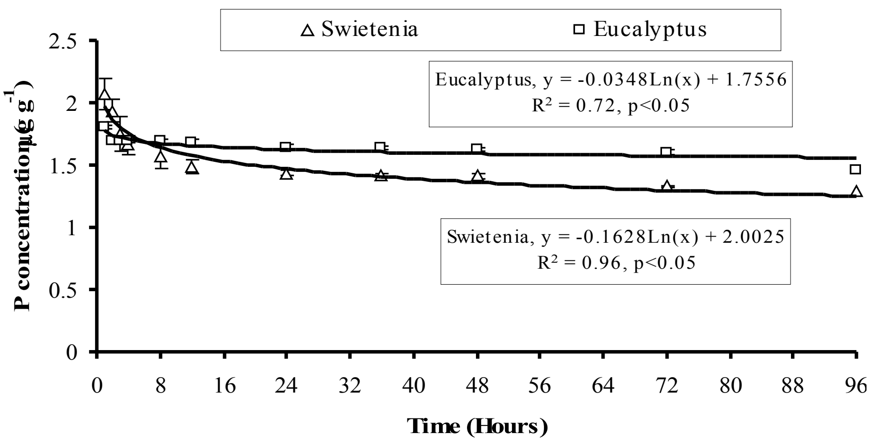

Fig. 6 - Phosphorus concentration ($\mu g\ g^{-1}$) in leaf litter of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

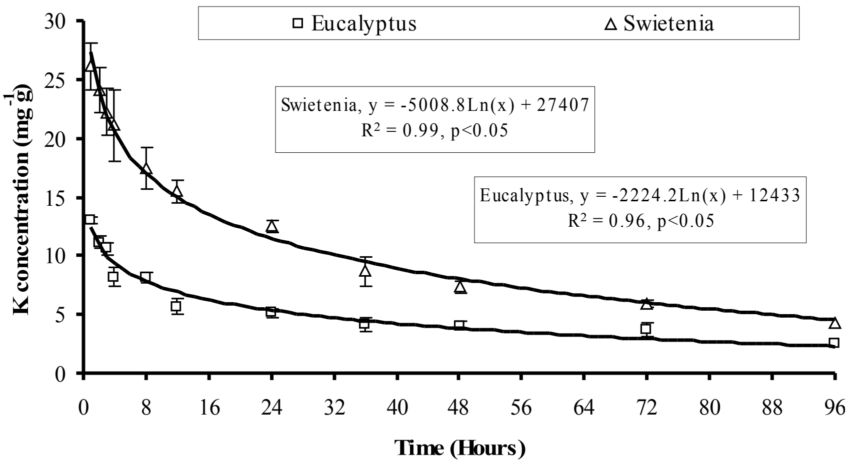

Fig. 7 - Potassium concentration (mg g^{-1}) in leaf litter of *Eucalyptus camaldulensis* and *Swietenia macrophylla* at different time intervals.

Tab. 2 - Relationships among the mass loss and nutrients concentration of leaf litter throughout the leaching experiment.

Species	Negative exponential curvilinear relationships among mass loss and nutrients		
	N	P	K
E. camaldulensis	Y = -6.3783Ln(x) + 97.34, R^2 = 0.86	Y = -0.0348Ln(x) + 1.7556, R^2 = 0.72	Y = -2224.2Ln(x) + 12433, R^2 = 0.96
S. macrophylla	Y = -8.2832Ln(x) + 88.22, R^2 = 0.97	Y = -0.1628Ln(x) + 2.0025, R^2 = 0.86	Y = -5008.8Ln(x) + 24407 R^2 = 0.86

time and mass loss of leaf litter (Tab. 2, Fig. 5, Fig. 7) explains that mass loss of leaf litter is associated with the release of these elements.

Conclusion

The amount of nutrients added to the soil through the leaching and decomposition process of plant litter may contribute to the sustainability of soil fertility, which becoming an important phenomenon for agroforestry practices. Among the considered species, *E. camaldulensis* was found to be the best in terms of nitrogen return and *S. macrophylla* the best in terms of phosphorous and potassium return with respect to leaching.

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