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Nutrient Leaching from Leaf Litter of Cropland Agroforest Tree Species of Bangladesh

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Abstract

Leaf litter is the main and quick source of organic matter and nutrient to the soil compared to other parts of litter. This study focused on the nutrients (N, P and K) leaching from leaf litter of *Melia azadirachta, Azadirachta indica, Eucalyptus camaldulensis, Swietenia macrophylla, Mangifera indica, Zizyphus jujuba, Litchi chinensis, Albizia saman, Artocarpus heterophyllus, Acacia auriculiformis, Dalbergia sissoo* and *Khaya anthotheca* as the common cropland agroforest tree species of Bangladesh. About (9 to 35) % of initial mass was lost, while Electric Conductivity (EC) and TDS (Total Dissolved Solid) of leaching water increased to (573 to 3,247) μS/cm and (401 to 2,307) mg/l respectively after 192 hours of leaching process. Mass loss (%) of leaf litter, EC and TDS of leaching water showed significant (ANOVA, $p<0.05$) curvilinear relationship with leaching time. Initial concentration of NH_4, PO_4 and K in leaching water was found to increase significantly ($p<0.05$) up to 48/72 hours and then remained almost constant at later stages (48/72 to 192 hours). Mass loss of leaves; EC, TDS, NH_4, PO_4 and K in leaching water was varied also significantly (ANOVA, $p<0.05$) among the studied tree species. All the tree species showed similar pattern of nutrients ($K>N>P$) release during the leaching process. The highest NH_4 (4,097 ppm) and potassium (8,904 ppm) concentration was found for *M. azadirachta* while the highest PO_4 (1,331 ppm) concentration was found for *E. camaldulensis* in the leaching water. Among the studied tree species, *M. azadirachta, A. indica, D. sissoo, E. camaldulensis* and *Z. jujuba* was selected as the best tree species with respect to nutrient leaching.

Key Words: bangladesh, cropland agroforestry, leaf litter, leaching, nutrients

Introduction

Cropland agroforestry is an important production system of Bangladesh. Farmers plant trees in the cropland agroforest for the production of timber, fodder, fuel wood, fruits, herbal medicines and also for the environmental and ecological benefits (Dwivedi 1992; Ahmed 2001; Ya 2002; Ahmed et al. 2004; Anon 2010). A wide variety of tree species (about 40 species) are practiced in cropland agroforest of Bangladesh (Aktar et al. 1992; Ahmed 2001; Anon 2006). Among these species, *Melia azadirachta*, *Azadirachta indica*, *Eucalyptus camaldulensis*, *Swietenia macrophylla*, *Mangifera indica*, *Zizyphus jujuba*, *Litchi chinensis*, *Albizia saman*, *Artocarpus heterophyllus*, *Acacia auriculiformis*, *Dalbergia sissoo* and *Khaya anthotheca* are common in the cropland agroforest of Bangladesh (Quddus 2001).

Trees and agricultural crops uptake nutrients from the same piece of land but trees usually uptake nutrients from comparatively deeper layers of soil (Hasanuzzaman et al. 2006). A portion of those nutrients are stored in plant biomass and a considerable amount of nutrients are returned back to the soil as litter and leaching from leaf litter. Litter

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acts as a source of organic matter and nutrients to the agricultural crops through the process of physical and microbial degradation activities i.e. leaching and decomposition of litter (Marschner 1995; Kimmins 2004; Mahmood et al. 2009; Hossain et al. 2011) which also improves the soil quality (Ngoran et al. 2006; Mahmood et al. 2009; Mahmood et al. 2010; Traidiati et al. 2011). Leaf litter is the main and quick source of organic matter and nutrient to the soil compared to other parts of litter which is available through the process of decomposition (Mason 1977; Park and Cho 2003; Hossain et al. 2011). The amount of nutrient addition varies from species to species (Marschner 1995; Jones 1998; Hasanuzzaman et al. 2006). This variation may be related to nutrients concentration in leaf and age of leaf; rate of nutrient uptake; nutrient retranslocation; growth and life form and characteristics of individual nutrients (Elevitch and Wilkinson 1998; Mahmood and Saberi 2007; Mahmood et al. 2009; Salehi et al. 2013). Appropriate tree species selection based on leaching of nutrients from leaf litter can be an issue in agroforestry practice. Some studies focused on the nutrient leaching from leaf litter of some tree species (Hasanuzzaman et al. 2006; Mahmood et al. 2009; Mahmood et al. 2010). But, there is not a complete study on nutrient leaching from leaf litter of all the species used in agroforestry practices in Bangladesh. Therefore, this study aimed to evaluate nutrient leaching from leaf litter of common agroforest tree species of Bangladesh. The information on nutrient leaching from leaf litter will draw peoples' interest to incorporate the nutrient return efficient tree species in agroforestry

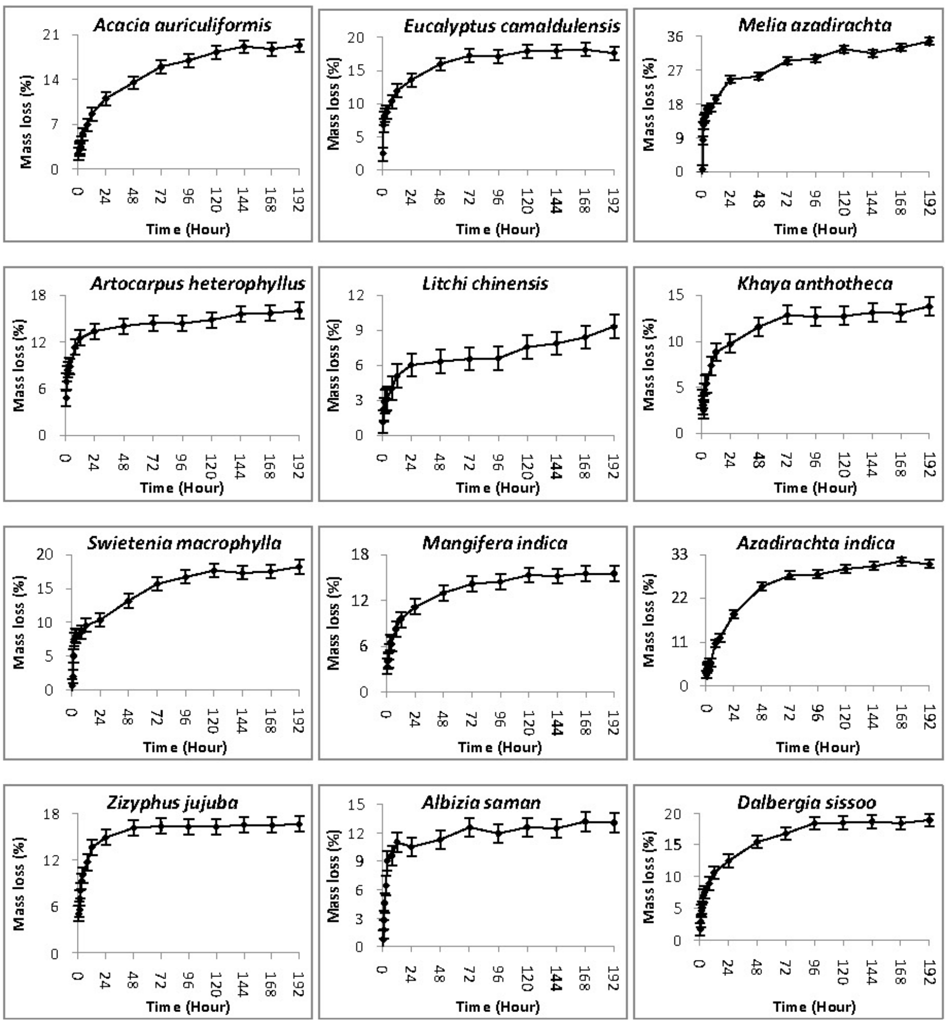

Fig. 1. Mass loss due to leaching process.

practices. So far, no attempt has been taken to screen or prioritized the agroforest tree species on the basis of nutrient return in the South Asian region as well as in Bangladesh. Therefore, this study aimed to evaluate the nutrient (N, P and K) leaching from leaf litter of the selected tree species. This finding will help to prioritize the tree species for cropland agroforest and other types of agroforestry practices in Bangladesh as well as other countries in the world.

Materials and Methods

Description of the study site

Southwestern Bangladesh is a low (< 10 m above mean sea level) flat, and fertile deltaic plain which is predominated by calcareous to noncalcareous alluvium soils (BBS 2004). Three districts (administrative unit) i.e. Khulna, Jessore and Satkhira were selected from southwestern Bangladesh, that lies between 22°44'-23°14' N and 89°01'-89°36' E. A tropical to subtropical monsoon climate characterizes this region with three distinct seasons i.e. summer (March–May), rainy (June–October), and winter (November–February). The annual average rainfall is 1,800±268 mm, while the monthly average rainfall is 155 mm. The highest monthly rainfall (339 mm) occurs during the month of June to September and the lowest monthly rainfall (16 mm) occurs in the month of November to February in the study area. January is the coldest month and May is the warmest month of the years. The mean annual temperature is 26°C with a range of 22–31°C (Kabir and Webb 2008). The average relative humidity is the high-

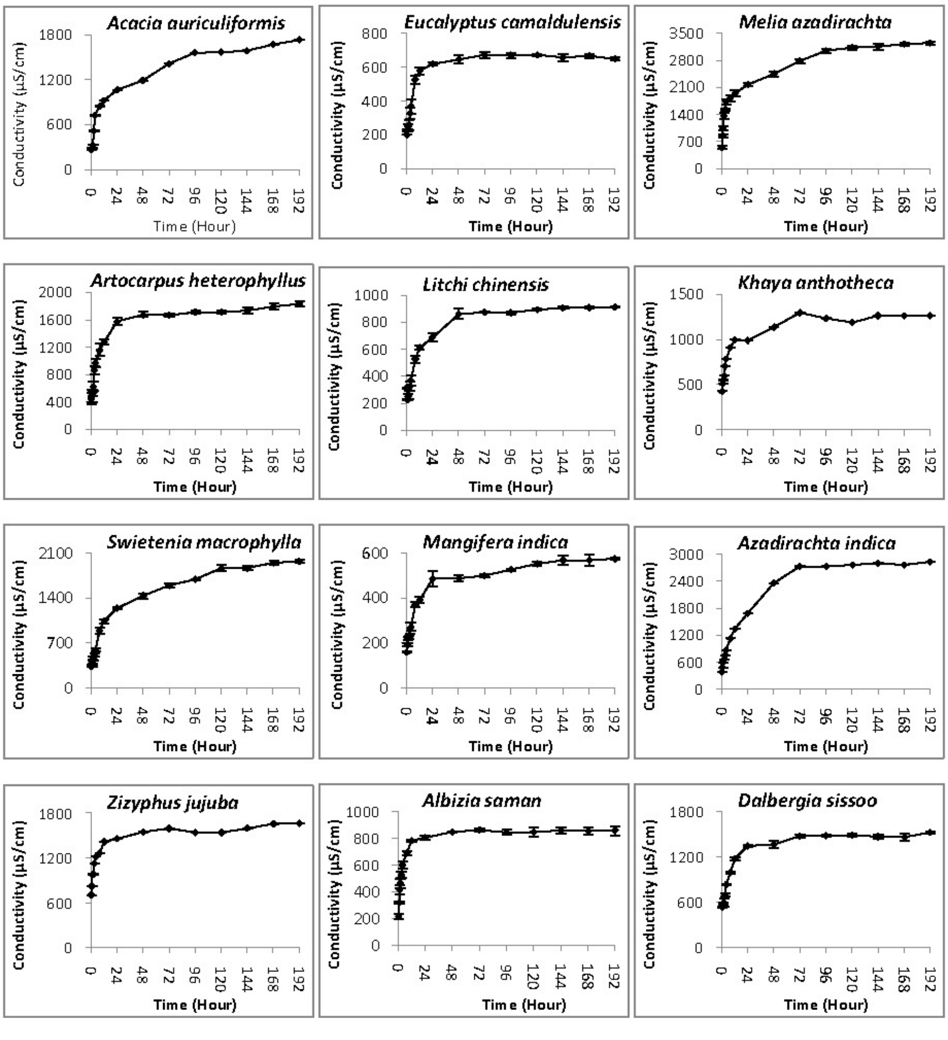

Fig. 2. Electrical conductivity (EC) of leaching water during the leaching process.

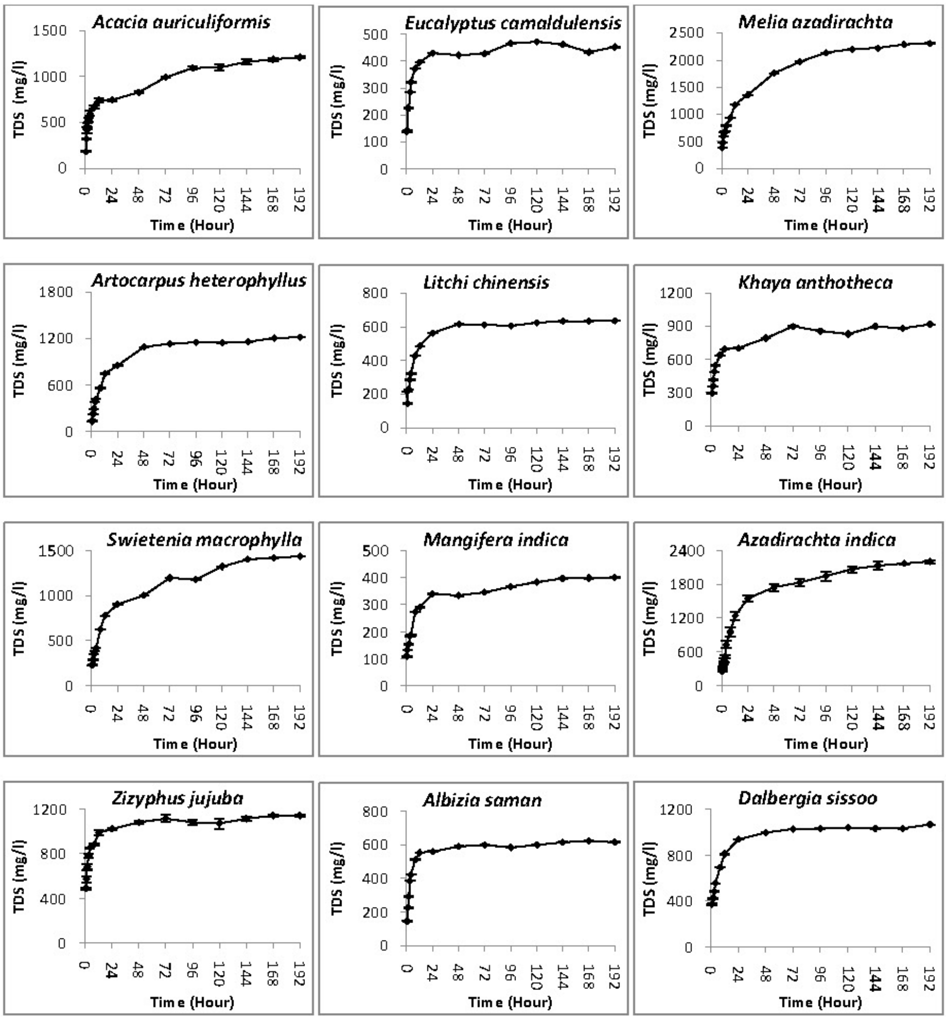

Fig. 3. Total Dissolved Solid (TDS) of leaching water during the leaching process.

Table 1. Relationship among mass loss of leaf litter, electrical conductivity (EC) and total dissolved solid (TDS) of leaching water and leaching time of selected cropland agroforest tree species

Name of species	Mass loss Vs Leaching time Relationship (Regression coefficient and *F*-value)	EC Vs Leaching time Relationship (Regression coefficient and *F*-value)	TDS Vs Leaching time Relationship (Regression coefficient and *F*-value)
M. azadirachta	R^2=0.74, F=39.00	R^2=0.76, F=48.31	R^2=0.83, F=69.12
A. indica	R^2=0.81, F=58.87	R^2=0.78, F=49.04	R^2=0.77, F=46.85
D. sissoo	R^2=0.75, F=42.20	R^2=0.63, F=24.34	R^2=0.63, F=24.19
S. macrophylla	R^2=0.76, F=44.80	R^2=0.83, F=66.39	R^2=0.83, F=67.86
E. camaldulensis	R^2=0.70, F=32.08	R^2=0.52, F=15.47	R^2=0.49, F=13.70
A. heterophyllus	R^2=0.67, F=28.21	R^2=0.64, F=24.59	R^2=0.71, F=33.62
M. indica	R^2=0.76, F=43.89	R^2=0.71, F=34.79	R^2=0.69, F=31.82
Z. jujuba	R^2=0.58, F=19.50	R^2=0.59, F=20.23	R^2=0.57, F=18.33
K. anthotheca	R^2=0.72, F=36.54	R^2=0.65, F=25.79	R^2=0.67, F=27.86
A. auriculiformis	R^2=0.84, F=76.22	R^2=0.80, F=55.26	R^2=0.81, F=58.31
A. saman	R^2=0.52, F=14.99	R^2=0.48, F=12.79	R^2=0.47, F=12.64
L. chinensis	R^2=0.83, F=66.05	R^2=0.70, F=32.13	R^2=0.61, F=22.03

Table 2. Significant test of mass loss of leaf litter, EC and TDS of leaching water at different time intervals

Name of species	Mass loss (%)	EC (μS/cm)	TDS (mg/l)
M. azadirachta	$F=4.14$, $p<0.0507$	$F=82.76$, $p<0.0001$	$F=50.38$, $p<0.0001$
A. indica	$F=5.28$, $p<0.0287$	$F=42.06$, $p<0.0001$	$F=43.16$, $p<0.0001$
D. sissoo	$F=6.93$, $p<0.0132$	$F=105.74$, $p<0.0001$	$F=96.30$, $p<0.0001$
S. macrophylla	$F=7.16$, $p<0.0119$	$F=46.43$, $p<0.0001$	$F=43.58$, $p<0.0001$
E. camaldulensis	$F=6.67$, $p<0.0149$	$F=77.78$, $p<0.0001$	$F=79.53$, $p<0.0001$
A. heterophyllus	$F=6.94$, $p<0.0132$	$F=81.34$, $p<0.0001$	$F=40.89$, $p<0.0001$
M. indica	$F=7.46$, $p<0.0105$	$F=67.57$, $p<0.0001$	$F=49.74$, $p<0.0001$
Z. jujuba	$F=6.70$, $p<0.0147$	$F=249.68$, $p<0.0001$	$F=230.66$, $p<0.0001$
K. anthotheca	$F=7.90$, $p<0.0086$	$F=125.99$, $p<0.0001$	$F=108.49$, $p<0.0001$
A. auriculiformis	$F=7.24$, $p<0.0115$	$F=46.19$, $p<0.0001$	$F=70.28$, $p<0.0001$
A. saman	$F=7.82$, $p<0.0089$	$F=114.83$, $p<0.0001$	$F=77.56$, $p<0.0001$
L. chinensis	$F=9.17$, $p<0.0050$	$F=58.72$, $p<0.0001$	$F=64.70$, $p<0.0001$

Table 3. Significant test of NH_4, PO_4 and K concentration of leaching water at different time intervals

Name of species	NH_4 (ppm)	PO_4 (ppm)	K (ppm)
M. azadirachta	$F=28.33$, $p<0.0001$	$F=98.28$, $p<0.0001$	$F=63.09$, $p<0.0001$
A. indica	$F=28.41$, $p<0.0001$	$F=111.10$, $p<0.0001$	$F=57.63$, $p<0.0001$
D. sissoo	$F=31.71$, $p<0.0001$	$F=52.06$, $p<0.0001$	$F=58.54$, $p<0.0001$
S. macrophylla	$F=34.09$, $p<0.0001$	$F=95.60$, $p<0.0001$	$F=72.31$, $p<0.0001$
E. camaldulensis	$F=40.67$, $p<0.0001$	$F=43.59$, $p<0.0001$	$F=119.96$, $p<0.0001$
A. heterophyllus	$F=38.06$, $p<0.0001$	$F=108.51$, $p<0.0001$	$F=92.10$, $p<0.0001$
M. indica	$F=33.65$, $p<0.0001$	$F=62.77$, $p<0.0001$	$F=79.54$, $p<0.0001$
Z. jujuba	$F=49.39$, $p<0.0001$	$F=57.22$, $p<0.0001$	$F=67.80$, $p<0.0001$
K. anthotheca	$F=46.48$, $p<0.0001$	$F=106.22$, $p<0.0001$	$F=77.15$, $p<0.0001$
A. auriculiformis	$F=52.60$, $p<0.0001$	$F=62.03$, $p<0.0001$	$F=67.79$, $p<0.0001$
A. saman	$F=48.23$, $p<0.0001$	$F=116.61$, $p<0.0001$	$F=95.82$, $p<0.0001$
L. chinensis	$F=43.57$, $p<0.0001$	$F=62.64$, $p<0.0001$	$F=99.82$, $p<0.0001$

est (86%-88%) during the month of July to August and the lowest (72%-74%) during February to April.

Leaf litter collection and leaching experiment

Yellowish senescence leaves were picked from *M. azadirachta, A. indica, E. camaldulensis, S. macrophylla, M. indica, Z. jujuba, L. chinensis, A. saman, A. heterophyllus, A. auriculiformis, D. sissoo* and *K. anthotheca* during March and April, 2013. The collected leaves were air-dried at room temperature for one week. Leaf discs (r = 0.80 cm) were prepared for leaves with higher leaf area (>34 cm^2). Leaves/leaf discs were thoroughly mixed and accurately weighted to 5 g of leaves as individual sample. A total of 90 samples were prepared of each species. Eighty five samples were placed into individual beaker (500 mL) and 200 mL

Table 4. Significant test of mass loss of leaf litter, EC, TDS, NH_4, PO_4 and K concentration of leaching water among the studied tree species

Parameter	Tabulated F 5% level	Significant level Pr > F
Mass loss (%) of leaf litter	F=33.76	0.0001
EC (μS/cm) of leaching water	F=48.46	0.0001
TDS (mg/l) of leaching water	F=35.50	0.0001
NH_4 concentration (ppm) of leaching water	F=19.11	0.0001
PO_4 concentration (ppm) of leaching water	F=36.71	0.0001
K concentration (ppm) of leaching water	F=43.71	0.0001

of distilled water was added to each beaker and few drops of $HgCl_2$ solution (50 mg/L) were added to each beaker to prevent fungal decay (Ibrahima et al. 2008; Mahmood et al. 2009). The beakers were kept at room temperature and covered with polyethylene sheets; and the experiment was conducted for 192 hours. Five samples for each species were kept into the oven at 80°C for four days to get air-dry to oven-dry weight conversion ratio.

Sample collection and measurements

Five samples of each species were collected at 0.5, 1, 1.5, 2, 2.5, 3, 4, 8, 12, 24, 48, 72, 96, 120, 144, 168 and 192 hours, respectively. The collected samples were oven dried at 80°C for 4 days. Mass loss due to leaching was calculated from the difference between initial and final oven-dried mass of the sample and the rate of mass loss was also calculated from the mass loss and the respective leaching time. Electric conductivity (μS/cm) and total dissolve solid (TDS) (mg/l) of leaching water samples at different time intervals were measured at the same time of sample collection by an Electric conductivity meter (EC-470L, Istek, Inc., Korea).

Nutrients measurement in leaf litter

Ammonium (NH_4) and phosphate (PO_4) concentration in leaching water were measured according to

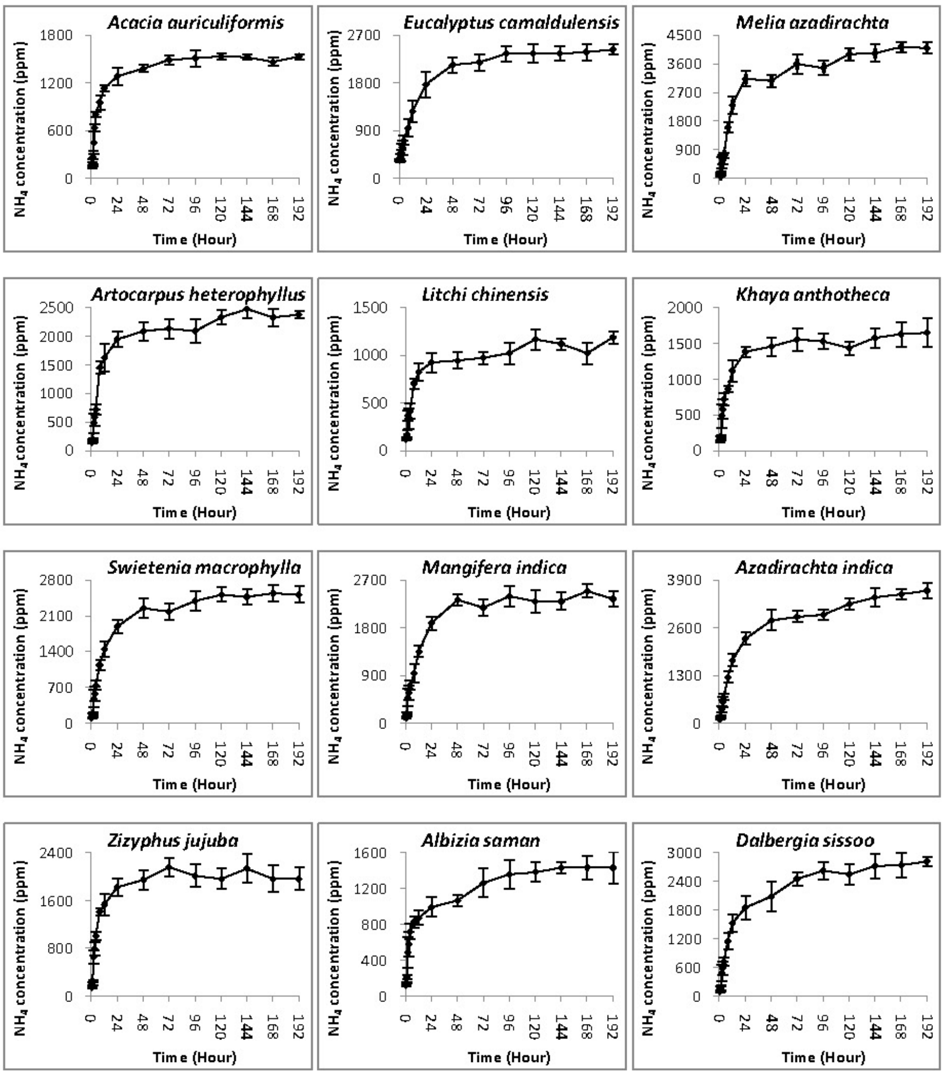

Fig. 4. NH_4 concentration (ppm) in leaching water during the leaching process.

Weatherburm (1967) and Timothy et al. (1984), respectively using UV-Visible Recording Spectrophotometer (HITACHI U-2910, Japan). Potassium concentration in leaching water samples were measured by Flame photometer (PFP7, Jenway LTD, England).

Statistical analysis

Mass loss (%) due to leaching was transformed to arcsine and analysis of variance (ANOVA) was calculated to compare the mass loss among the species using SAS 6.12 statistical software. Electric Conductivity (EC) and Total Dissolve Solid (TDS) of leached water samples and NH_4, PO_4 and K concentration in leaching water at different time interval were compared by ANOVA using SAS 6.12 statistical software. The relationship among mass loss, EC and TDS of leaching water and leaching time were calculated by using SPSS (17) statistical software.

Results (and Discussion)

Mass loss during the leaching process

The highest (34.64%) mass loss was observed for *M. azadirachta* followed by *A. indica* (30.53%), *A. auriculiformis* (19.26%) and the lowest (9.34%) was found for *L. chinensis* at the end of the experiment (Fig. 1). The highest (3,247 µS/cm) EC was observed for *M. azadirachta* fol-

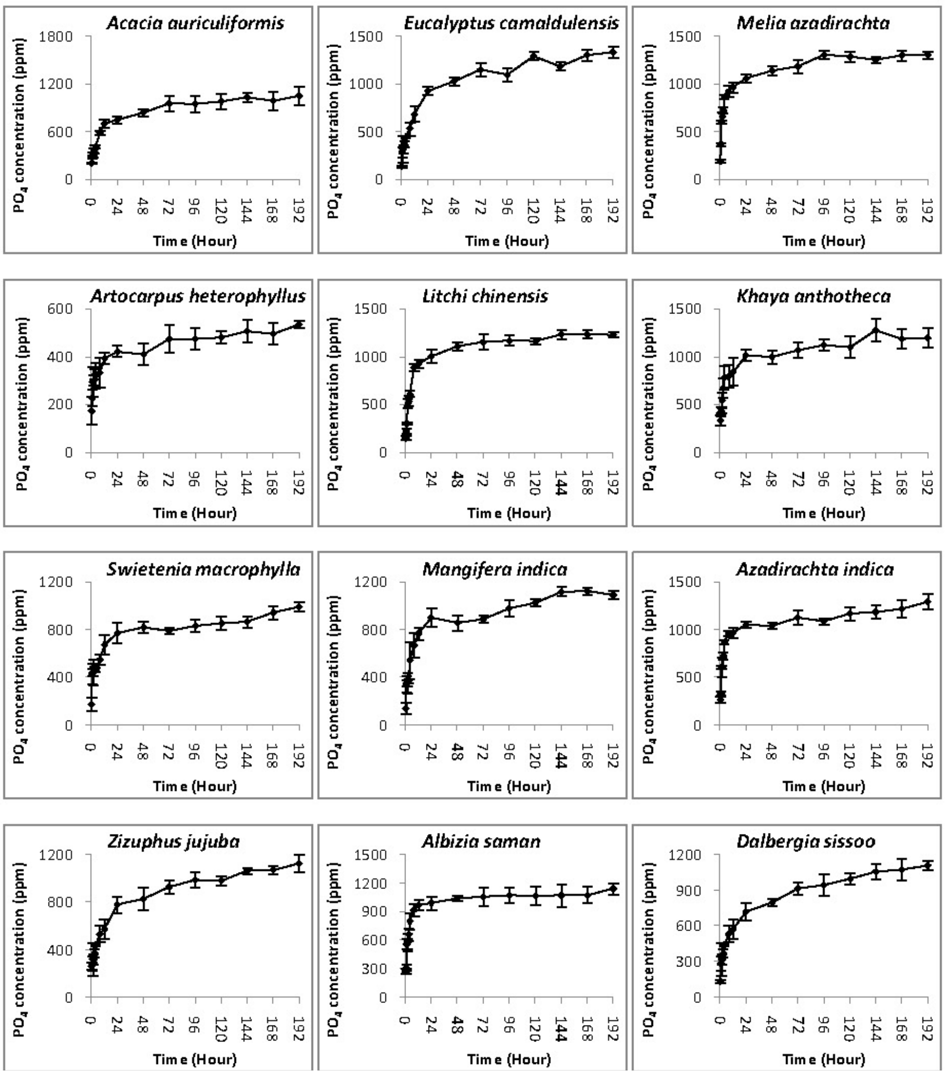

Fig. 5. PO_4 concentration (ppm) in leaching water during the leaching process.

lowed by *A. indica* (2,834 µS/cm), *A. heterophyllus* (1,836 µS/cm) and the lowest (573 µS/cm) was observed for *M. indica* (Fig. 2). The highest (2,308 mg/l) TDS was observed for *M. azadirachta* followed by *A. indica* (2,202 mg/l), *S. macrophylla* (1,434 mg/l) and the lowest (401 mg/l) was observed for *M. indica* (Fig. 3). The mass loss, EC and TDS showed significant (ANOVA, $p < 0.05$) positive curvilinear relationship with the leaching time (Table 1). Mass loss of leaves, EC and TDS of leaching water was found to vary significantly (ANOVA, $p < 0.05$) at different time intervals for individual species (Table 2). Moreover, mass loss of leaf litter, EC and TDS of leaching water was varied significantly (ANOVA, $p < 0.05$) among the studied tree species (Table 4). The differences in mass loss of leaves during the leaching experiment may be due to the variable concentration of different soluble inorganic and organic substances and morphological characteristics of leaf (Nykvist 1963; Taylor and Parkinson 1988; Saini 1989; Ibrahima et al. 1995). The higher amount of mass loss of leaves emphasizes the potentiality of species to provide readily available organic and inorganic compounds (Wetzel 1995). Irrespectively, the positive linear relationship between weight loss of leaf litter, EC and TDS of leaching water with leaching time (Table 1) indicated the weight loss of leaf litter could be the result of leaching of cations and other soluble organic substances, which in-

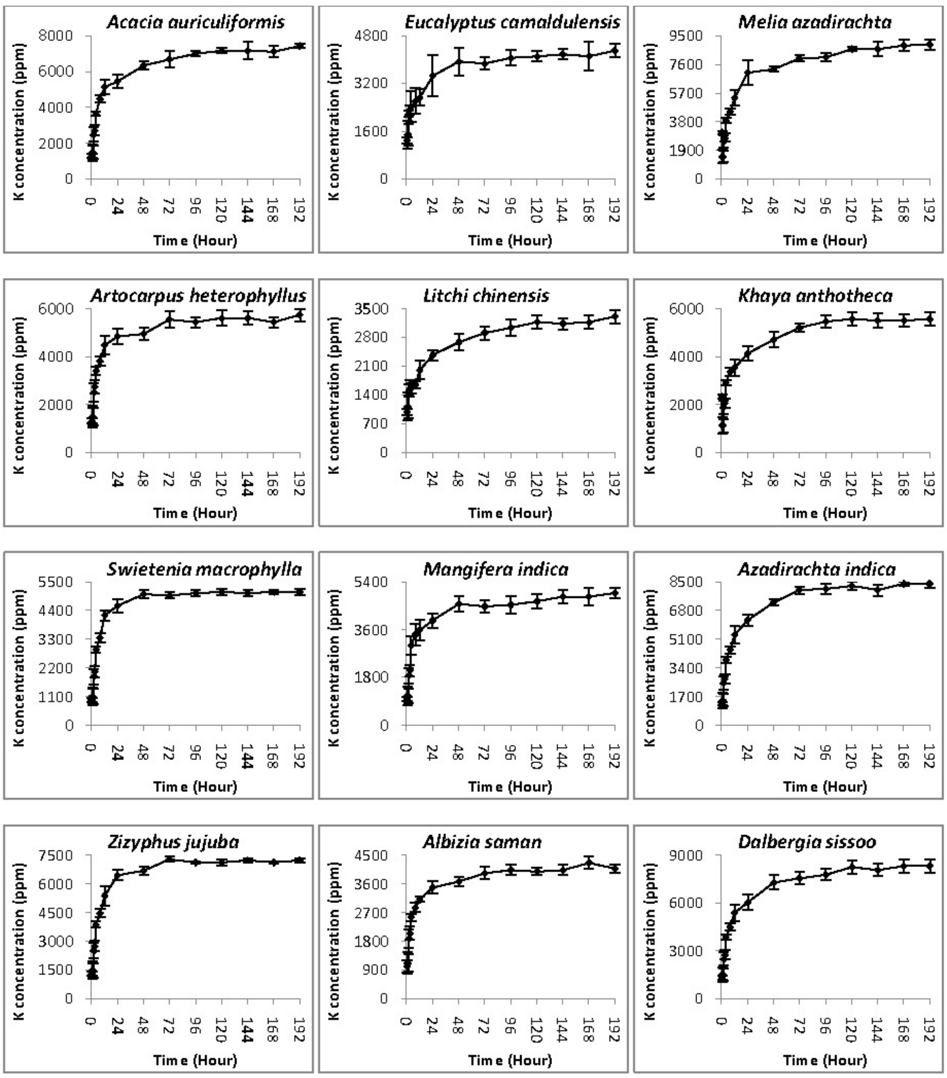

Fig. 6. Potassium concentration (ppm) in leaching water during the leaching process.

creased with time (Allen 1974). Similarly, Park and CH (2003); Hasanuzzaman et al. (2006) and Mahmood et al. (2009) reported that the rate of weight loss, subsequent loss of inorganic and organic substance from leaf litter varies with time.

Nutrients at different stages of leaching process

The highest concentration (4,097 ppm) of NH_4 was found in leaching water of *M. azadirachta* followed by *A. indica* (3,612 ppm), *D. sissoo* (2,812 ppm) and the lowest (1,188 ppm) was found for *L. chinensis* (Fig. 4). Highest concentration (1,331 ppm) of PO_4 was detected in leaching water of *E. camaldulensis* followed by *M. azadirachta* (1,303 ppm), *A. indica* (1,289 ppm) and the lowest (536 ppm) was found for *A. heterophyllus* (Fig. 5). Moreover, highest concentration (8,904 ppm) of K in leaching water was found for *M. azadirachta* followed by *A. indica* (8,366 ppm), *D. sissoo* (8,306 ppm) and the lowest (3,308 ppm) was found for *L. chinensis* (Fig. 6). NH_4, PO_4 and K concentration of leaching water at different time intervals was found to vary significantly (ANOVA, $p<0.05$) for individual species (Table 3). Moreover, NH_4, PO_4 and K concentration of leaching water was varied significantly (ANOVA, $p<0.05$) among the studied tree species (Table 4). The result of the study showed that $K>NH_4>PO_4$ (concentration) in the leaching water. Nutrients (NH_4, PO_4 and K) showed different rate of leaching among the studied tree species, as they were from different families with varying rate of nutrient uptake; growth and life form; site variability and nutrients involvement in structural properties of respective plant cell (Marschner 1995; Elevitch and Wilkinson 1998; Mahmood and Saberi 2007; Mahmood et al. 2009). The variation of nutrients (NH_4, PO_4 and K) concentration in leaching water of the studied tree species during the leaching process (Table 3) may depend on the initial concentration of nutrients in leaf (Ibrahima et al. 1995; Mahmood et al. 2009). The leaching of nutrients varied with the characteristics of nutrients and involvement in structural compound of leaf (Meyer et al. 1973; Mahmood et al. 2009). Initial concentration of NH_4 and PO_4 in leaching water was found to increase significantly ($p<0.05$) up to 72 hours and then remained almost constant at later stages (72 to 192 hours) (Figs. 4, 5). While the initial concentration of K in leaching water was found to increased significantly ($p<0.05$) up to 48 hours and then remained almost constant at later stages (48 to 192 hours) (Fig. 6). K is highly mobile in plant and accumulated in physiologically active tissues (leaves, buds and roots) (Marschner 1995). While nitrogen is an important part of compounds that regulate plant growth and development and found in the leaves (chlorophyll), grain, plant tissue and roots of plants (DeFelice 1993; Smil 2000). Phosphorus is most abundant in meristematic tissue and accumulated in the reproductive components (seeds and fruits) (Meyer et al. 1973) and leaf contained lower amount of P. These could be the reason of initial rapid increase in K concentration compared to NH_4 and PO_4 in leaching water (Marschner 1995; Mahmood et al. 2009). The significant positive curvilinear relationship among nutrients and leaching time explains the nutrient concentration increases with leaching time. Leaching is the preliminary stage of litter decomposition and it ceases at certain stage (Mason 1977), this could be the reason for observing positive curvilinear relationship with the mass loss of leaf and nutrients concentration in leaching water with longer leaching time.

The finding of this study reveals that the amount of nutrients addition to the soil through leaching of leaf litter will be an important phenomenon for agroforestry practices especially in the tropical and subtropical regions. Among the studied tree species *M. azadirachta, A. indica, D. sissoo and E. camaldulensis* have been prioritized for cropland agroforestry as well as other agroforestry practices in Bangladesh.

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