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MASS LOSS AND NUTRIENT DYNAMICS ASSOCIATED WITH GREEN LEAF LEACHING OF CROPLAND AGROFOREST TREE SPECIES OF BANGLADESH

SUMMARY

Nutrients leaching from green leaves can contribute a major role in cycling and supply of nutrient to the agricultural crops in any agroforestry system. This study focused on the nutrients (N, P and K) leaching from green leaves of *Acacia auriculiformis, Eucalyptus camaldulensis, Mangifera indica, Artocarpus heterophyllus*, *Litchi chinensis*, *Khaya anthotheca* and *Swietenia macrophylla* as the common cropland agroforest tree species of Bangladesh. Green leaves of the selected species were leached in deionized water and the experiment was continued up to 192 hours. Mass loss (%) of green leaves, Electrical Conductivity (EC) and Total Dissolved Solid (TDS) of leaching water of each species showed significant ($p<0.05$) curvilinear relationship with leaching time. Initial concentration of NH_4, PO_4 and K in leaching water of green leaves of individual species was found to increase significantly ($p<0.05$) up to 72 hours and remained almost constant at the later stages. All the tree species showed similar pattern $K>NH_4>PO_4$ of nutrients release during the leaching process. The highest concentration of 3,242 ppm NH_4 was observed for *S. macrophylla*, highest concentration of 1,934 ppm PO_4 was detected for *L. chinensis* and highest concentration of 9,258 ppm potassium was found for *A. auriculiformis*. This study showed that *E. camaldulensis* was the best in terms of nutrient return through green leaves leaching process followed by *A. auriculiformis* and *L. chinensis*.

Keywords: Agroforestry, Bangladesh, Cropland, Green leaf, Leaching, Nutrients

INTRODUCTION

Trees and agricultural crops uptake nutrients from the same piece of land but trees uptake nutrients from comparatively deeper layers of soil. 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 green leaf (Kumar *et al.* 2010; Hasanuzzaman *et al.* 2014a). Litter acts as a source of organic matter as well as nutrients to the agricultural crops through the process of mechanical and

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microbial breakdown activities i.e. leaching and decomposition of litter (Marschner, 1995; Kimmins, 2004; Mahmood *et al.* 2011; Hasanuzzaman *et al.* 2014bc). Green leaves of cropland agroforest trees are harvested through different tending operations usually used as fuel in the under developed countries like Bangladesh, which can contribute a major role in biogeochemical cycling of nutrients (Hocking and Islam, 1994; Hasanuzzaman *et al.* 2014d). The green leaves fallen down on the cropland agroforest, dried in the open sunlight and may contribute to supply nutrients to the agricultural crops during the precipitation (Eaton *et al.* 1973; Chowdhury, 1997; Hossain *et al.* 1988; Mahmood *et al.* 2004; Wood *et al.* 2005; Mahmood *et al.* 2010). The nature of nutrient supply through leaching process found to vary from species to species and leaching time (Marschner, 1995; Jones, 1998; Hasanuzzaman *et al.* 2014b). Moreover, this variation may be related to nutrients concentration in leaf; rate of nutrient uptake; growth and life form and characteristics of individual nutrients (Elevitch and Wilkinson, 1998; Mahmood and Saberi, 2007; Mahmood *et al.* 2009; Ali *et al.* 2013). Selection of appropriate tree species is an issue in agroforestry practice (Hasanuzzaman *et al.* 2006; Hasanuzzaman *et al.* 2014be). The information on nutrient return efficient tree species will draw peoples' interest to incorporate them in agroforestry practices. So far, no attempt has been taken to screen and prioritized the agroforest tree species on the basis of nutrient return. Present study aimed to evaluate the nutrient (N, P and K) leaching from green leaf of *Acacia auriculiformis, Eucalyptus camaldulensis, Mangifera indica, Artocarpus heterophyllus, Litchi chinensis, Khaya anthotheca* and *Swietenia macrophylla*

MATERIAL 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 that lies between 22°44'-23°14' N and 89°01'-89°36' E at southwestern Bangladesh. 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 around 1,800±268 mm with 155 mm of monthly average rainfall. The mean annual temperature is 26 °C with a range of 22–31 °C. January is the coldest month and May is the warmest month of the years (Hasanuzzaman *et al.* 2014c). The average relative humidity is the highest (86%-88%) during the month of July to August and the lowest (72%-74%) during February to April.

Collection of green leaves and leaching experiment. Two kg of green leaves were picked from individual species of *Acacia auriculiformis, Eucalyptus camaldulensis, Mangifera indica, Artocarpus heterophyllus, Litchi chinensis, Khaya anthotheca* and *Swietenia macrophylla* during March and April, 2013 from the existing cropland agroforests of the study site. During that period, all the studied tree species flushes the new leaves which contain higher concentration of nutrients compared to other period. Moreover, this period is the driest period (almost no rainfall) in Bangladesh. Therefore, no leaching occurs in the green leaves on the trees. 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) of all the studied species. 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. The dust particles on individual leaf surface were removed through soft brushing and then rinsed in to deionized water for a few seconds (Turner and Broekhuizen, 1992; Kumar *et al.* 2010). 85samples were placed into individual beaker (500 ml) and 200 ml of deionized 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 the experiment was conducted for 192 hours. Five samples of each species were kept into the oven at 80 °C for four days to get air-dry to oven-dry conversion weight 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 (Mahmood *et al.* 2013). 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 (EC) and total dissolve solid (TDS) of leaching water at different time intervals were measured at the same time of sample collection by an Electric conductivity meter (EC-470L, Istek, Inc., Korea). About 100 ml of leaching water at different time interval was collected for each species for further analysis.

Nutrients in leaching water. Ammonium (NH_4) and phosphate (PO_4) concentration in leaching water were measured according to 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), Total Dissolve Solid (TDS), NH_4, PO_4 and K concentration in leaching water at different time interval of the studied species were compared by ANOVA using SAS 6.12 statistical software. Moreover, relationships 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. Mass loss of leaf samples, EC and TDS of leaching water was found to vary significantly ($p<0.05$) among the studied tree species and time. The highest (24.95%) mass loss of green leaf samples was observed for *S. macrophylla* followed by *K. anthotheca* (22.47%) and the lowest (09.83%) was found for *L. chinensis* at the end of the experiment (Figure 1).

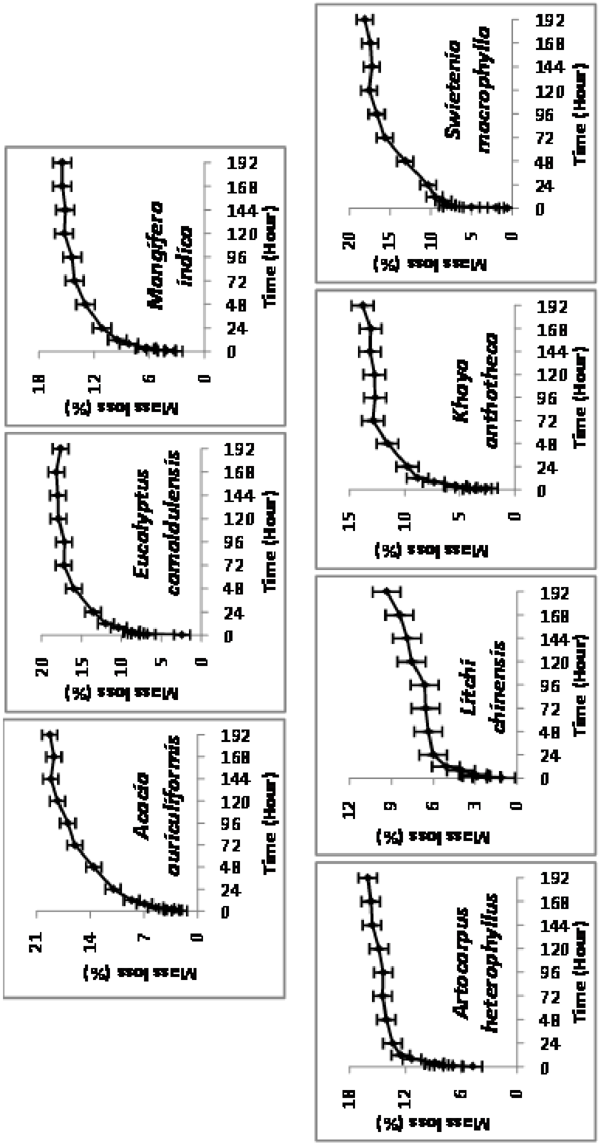

Figure 1. Mass loss (%) at different time of leaching process

The highest EC of 2,037 µS/cm was observed for *K. anthotheca* followed by *A. auriculiformis* (2,032 µS/cm) and the lowest of 892 µS/cm was observed for *M. indica* (Figure 2).

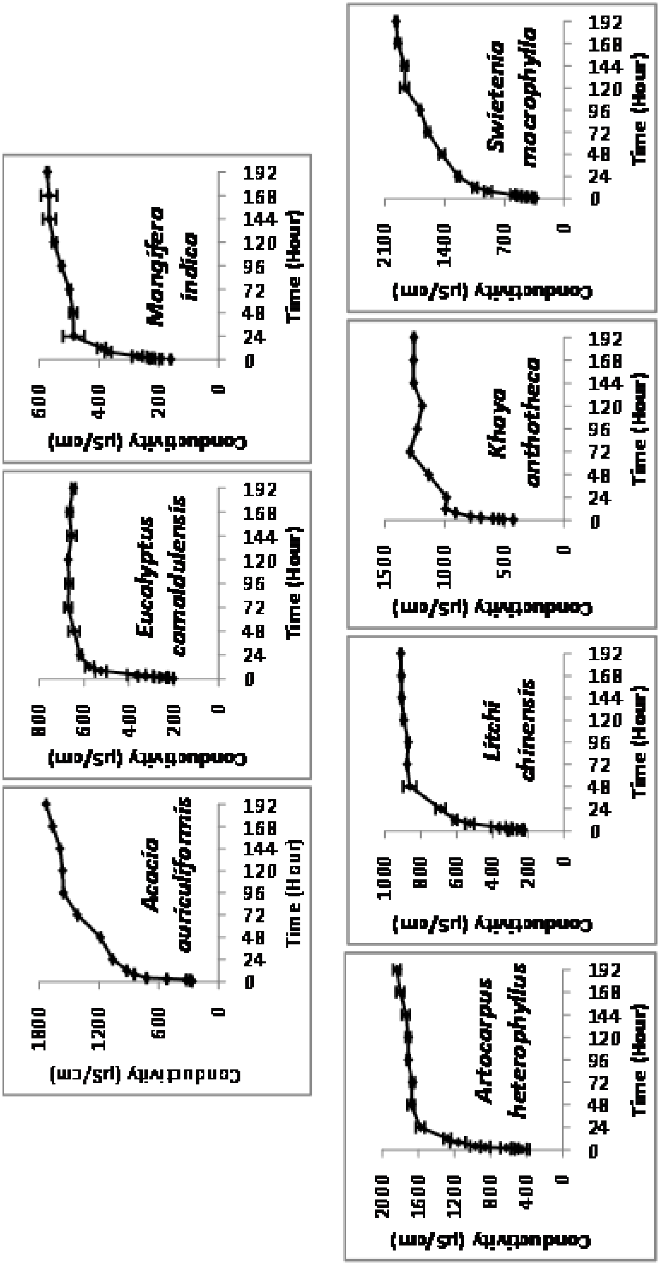

Figure 2. Electrical conductivity (µS/cm) of leaching water at different time of leaching process

The highest TDS of 1,700 mg/l was observed for *K. anthotheca* followed by *A. auriculiformis* (1,603 mg/l) and the lowest of 625 mg/l was observed for *M. indica* (Figure 3).

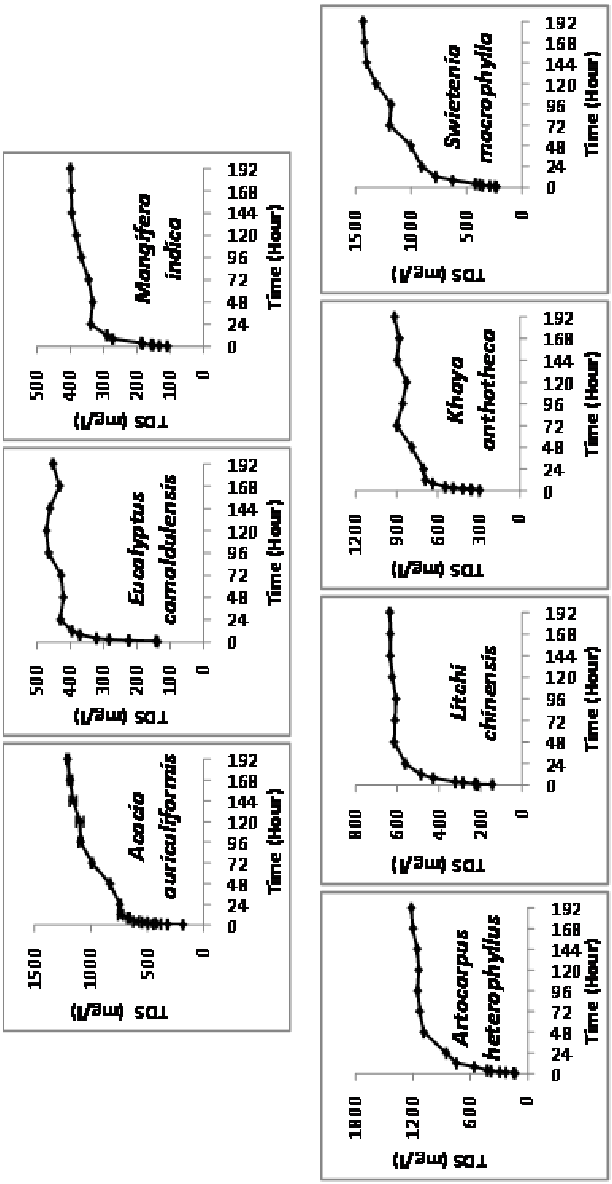

Figure 3. Total Dissolved Solid (mg/l) of leaching water at different time of leaching process

The mass loss, EC and TDS showed significant ($p<0.05$) positive curvilinear relationship with the leaching time (Table 1).

Table 1. Relationship among mass loss of green leaf, 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)
S. macrophylla	Y=3.46ln(x)+6.15; R^2=0.81, *F*=59.50	Y=316.2ln(x)+282.7; R^2=0.82, *F*=64.97	Y=238.5ln(x)+156.5; R^2=0.79, *F*=53.81
E. camaldulensis	Y=2.68ln(x)+6.59; R^2=0.77, *F*=46.12	Y=164.2ln(x)+204.6; R^2=0.75, *F*=42.20	Y=110.2ln(x)+175.9; R^2=0.73, *F*=37.28
A. heterophyllus	Y=2.17ln(x)+4.12; R^2=0.82, *F*=64.01	Y=253.9ln(x)+562.7; R^2=0.64, *F*=24.59	Y=217.3ln(x)+169.1; R^2=0.75, *F*=41.71
M. indica	Y=2.17ln(x)+5.61; R^2=0.70, *F*=32.31	Y=135.2ln(x)+187.4; R^2=0.74, *F*=39.61	Y=82.17ln(x)+192.2; R^2=0.67, *F*=28.83
K. anthotheca	Y=3.12ln(x)+5.59; R^2=0.77, *F*=47.69	Y=314.4ln(x)+467.8; R^2=0.73, *F*=38.57	Y=229.4ln(x)+315.0; R^2=0.87, *F*=96.19
A. auriculiformis	Y=2.85ln(x)+1.95; R^2=0.80, *F*=54.54	Y=344.7ln(x)+252.1; R^2=0.75, *F*=41.26	Y=227.8ln(x)+306.1; R^2=0.84, *F*=74.94
L. chinensis	Y=1.45ln(x)+1.15; R^2=0.87, *F*=91.71	Y=177.6ln(x)+195.5; R^2=0.79, *F*=53.55	Y=124.3ln(x)+169.9; R^2=0.78, *F*=49.92

The differences in mass loss of green leaves during the leaching process may be due to the variable concentration of different soluble inorganic and organic substances and morphological characteristics of leaf (Taylor and Parkinson, 1988; Saini, 1989; Ibrahima *et al.* 1995; Mahmood *et al.* 2013). 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 curvilinear relationship between weight loss of green leaf, EC and TDS of leaching water with the leaching time indicated the weight loss of leaf litter could be the result of leaching of cations and other soluble organic substances, which increased with time (Mahmood *et al.* 2009, 2013).

Nutrients at different stages of leaching process

Ammonium, PO_4 and K concentration in leaching water of individual species was found to vary significantly ($p<0.05$) with time and species. The highest concentration of 3,242 ppm of NH_4 was found in leaching water of *S. macrophylla* followed by *E. camaldulensis* (3,030 ppm) and the lowest of 1,424 ppm was found for *L. chinensis* (Figure 4). Highest concentration of 1,934 ppm of PO_4 was detected in leaching water of *L. chinensis* followed by *E. camaldulensis (*1,806 ppm) and the lowest of 325 ppm was found for *A. heterophyllus* (Figure 5). Comparatively higher concentration (9,258 ppm) of K was observed in leaching water of *A. auriculiformis* followed by *K. anthotheca* (7,167 ppm) and the lowest of 4,410 ppm was measured for *L. chinensis* (Fig. 6).

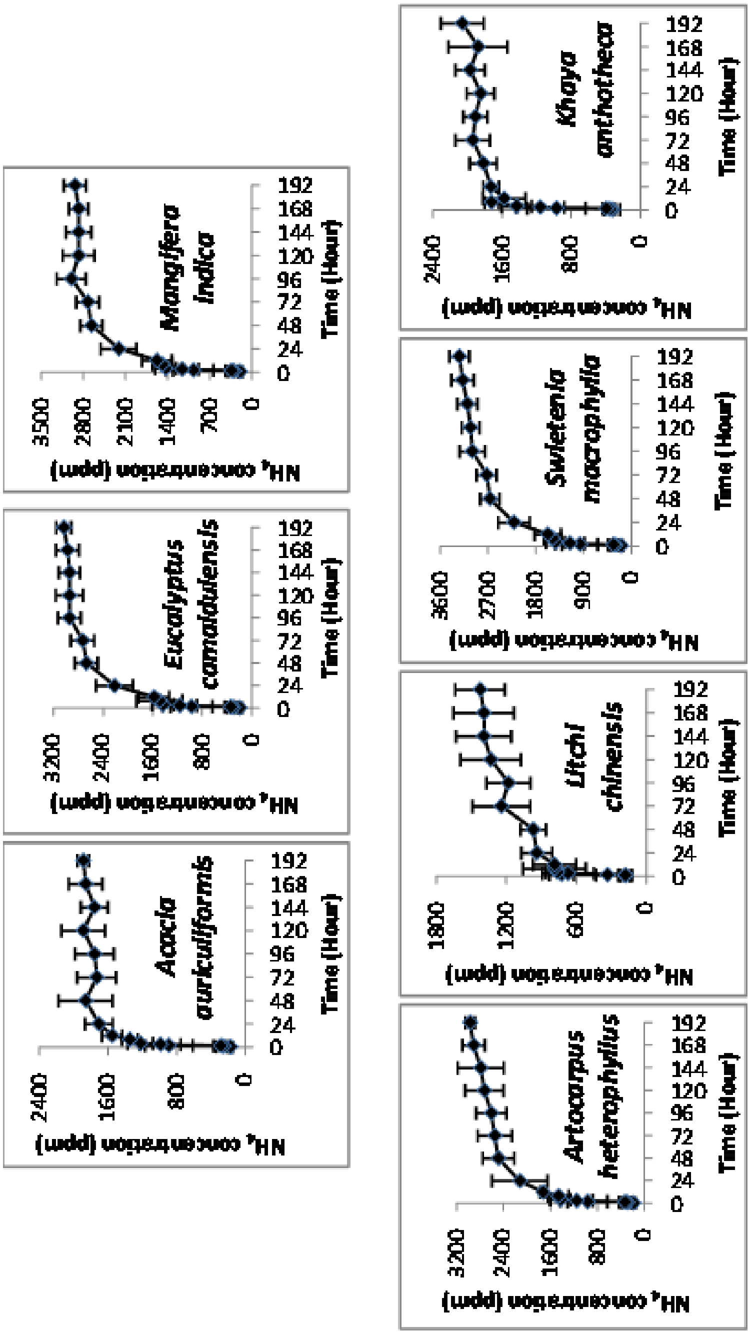

Figure 4. NH_4 concentration (ppm) in leaching water at different time of leaching process

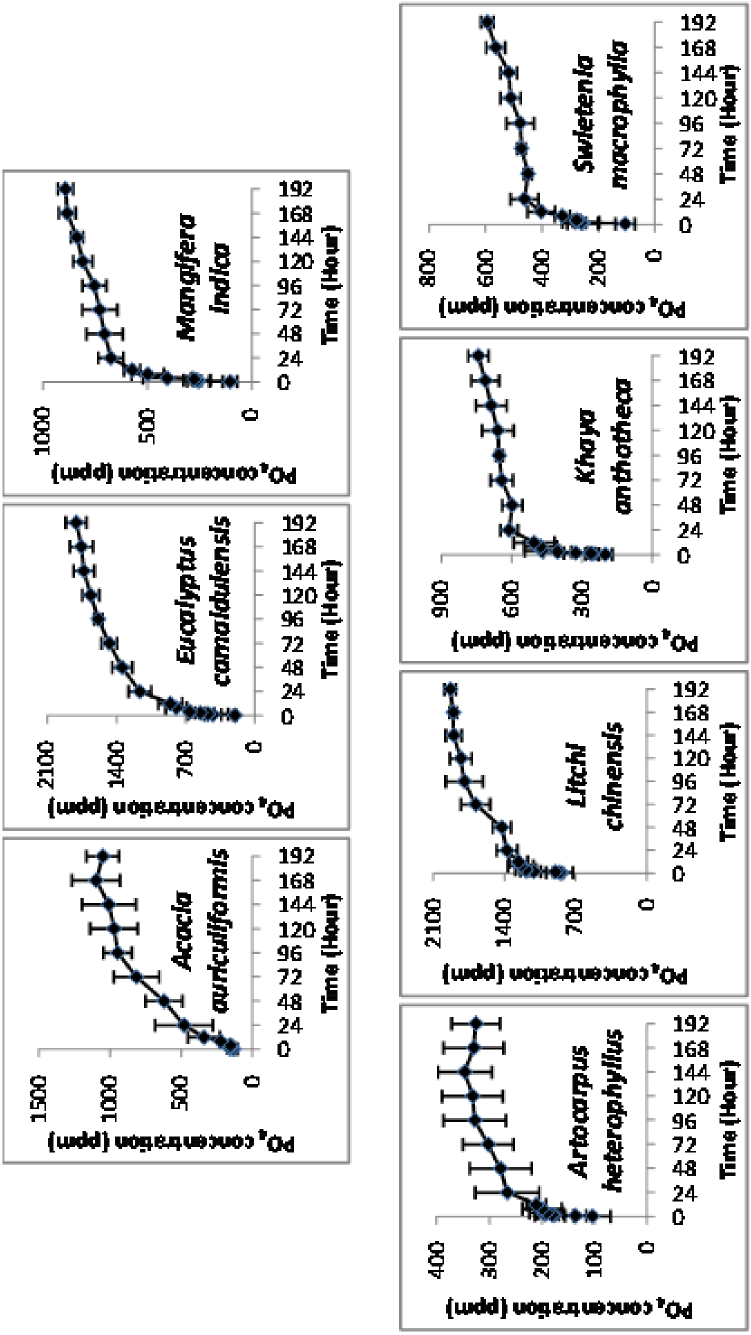

Figure 5. Phosphate concentration (ppm) in leaching water at different time of leaching process

Higher concentration of K was leached from the leaf followed by NH_4 and PO_4 for all the studied tree species (Figures 4 - 6). The variation in nutrients (NH_4, PO_4 and K) concentration in leaching water of the studied species may depend on their initial concentration in leaf (Ibrahima *et al.* 1995; Mahmood *et al.* 2009; 2013). Moreover, the leaching of nutrients varies with the characteristics of nutrients and their involvement in structural compound of leaf (Meyer *et al.* 1973). 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) (Figures 4 and 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) (Figure 6).

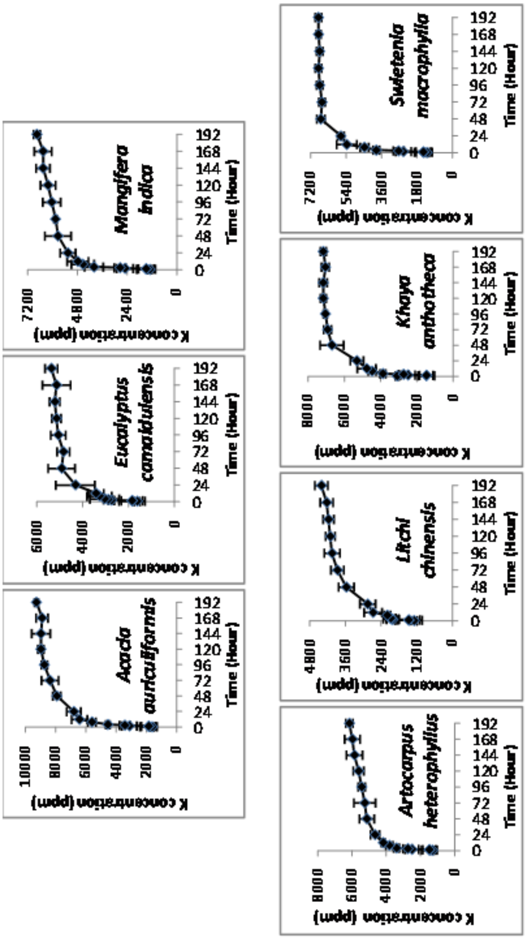

Figure 6 Potassium concentration (ppm) in leaching water at different time of leaching process

K is highly mobile and accumulated in physiologically active tissues (leaves, buds and roots) (Marschner, 1995). Nitrogen is an important compound of leaf (chlorophyll), grain, plant tissue and roots of plants and structurally bound with cell wall (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 comparatively lower concentration. These could be the reason for observing initial rapid increase of K concentration in leaching water compared to NH_4 and PO_4 (Marschner, 1995; Mahmood *et al.* 2009).

CONCLUSIONS

This study showed that *E. camaldulensis* was the best in terms of nutrient return through leaching process from green leaves followed by *A. auriculiformis* and *L. chinensis*. The present finding has given an idea on nutrient return capacity of tree species through leaching mechanism associated with green leaves. This finding will help in species selection in agroforestry practices as well as motivate people to use green leaf as manure rather than fuel.

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MD. HASANUZZAMAN, MAHMOOD HOSSAIN, S.M. RUBAIOT ABDULLAH, MD. AL-AMIN SHAIKH, MD. ZIAUL HAQUE, SHAMIMA NASRIN

GUBITAK MASE I DINAMIKA HRANLJIVIH SASTOJAKA USLIJED RAZLAGANJA ZELENOG LIŠĆA KOD VRSTA DRVETA SA POLJOPRIVREDNOG ZEMLJIŠTA U AGRO-ŠUMAMA BANGLADEŠA

SAŽETAK

Hranljivi sastojci koji se oslobađaju razgradnjom zelenog lišća može da ima veliku ulogu u ciklusu i stvaranju hranljivih sastojaka za poljoprivredne usjeve u bilo kojem agro-šumskom sistemu. Ovaj rad je usmjeren na nutriente (N, P i K) koji nastaju raspadanjem zelenog lišća *Acacia auriculiformis, Eucalyptus camaldulensis, Mangifera indica, Artocarpus heterophyllus, Litchi chinensis, Khaya anthotheca* i *Swietenia macrophylla* kao čestih vrsta drveta poljoprivrednog zemljišta agro-šuma u Bangladešu. Zeleno lišće odabranih vrsta se rastvara u dejonizovanoj vodi i eksperiment je vršen u periodu do 192 sata. Gubitak mase (%) zelenog lišća, električna provodljivost (EC) i ukupan sadržaj čvrste rastvorene materije (TDS) vode rastvora za svaku vrstu je pokazala značajan ($p<0,05$) krivolinijski odnos sa vremenom razlaganja. Otkriveno je da se početna koncentracija NH_4, PO_4 i K kod vodenog rastvora zelenog lišća pojedinačnih vrsta značajno povećava ($p<0,05$) do 72. sata i ostaje gotovo konstantna u narednim fazama. Sve tri vrste drveća su pokazale sličnu šemu $K>NH_4>PO_4$ oslobađanja hranljivih sastojaka tokom postupka raspadanja. Najveća koncentracija 3,242 ppm NH_4 je primijećena kod *S. macrophylla*, najveća konentracija 1,934 ppm PO_4 je otkrivena kod *L. chinensis* i najveća koncentracija 9,258 ppm kalijuma je otkrivena kod *A. auriculiformis*. Ovo istraživanje je pokazalo da je *E. camaldulensis* najbolji u smislu povrata hranljivih sastojaka kroz proces razgradnje zelenog lišća, a zatim slijede *A. auriculiformis* i *L. chinensis*.

Ključne riječi: Agrošumarstvo, Bangladeš, poljoprivredno zemljište, zeleno lišće, razlaganje, hranljivi sastojci