Dhaka Univ. J. Biol. Sci. **30**(3 CSI): 443-452, 2022 (June)
DOI: https://doi.org/10.3329/dujbs.v30i3.59036

EFFECTS OF EUCALYPTUS ON SOIL PROPERTIES AND LITTER DECOMPOSITION PROCESSES

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Key words: Eucalyptus, Plantation, Soil properties, Litter, Decomposition

Abstract

This study investigated the effect of plantation of exotic species Eucalyptus (*Eucalyptus* spp.) on the physico-chemical properties of soil by collecting field data and also on litter decomposition and nitrogen mineralization rates of the other selected species by following microcosm experimental design. Effects of Eucalyptus plantation on soil properties were studied by comparing soil properties of plots planted with Eucalyptus and other two species Acacia (*Acacia auriculiformis* A. Cunn. ex Benth.) and Lagerstroemia (*Lagerstroemia speciosa* (L.) Pers.) located at Madhupur, Tangail and Singra, Dinajpur, respectively. Effects of Eucalyptus litter on decomposition and nitrogen mineralization rates of litter of Axonopus (*Axonopus compressus* (Sw.) P. Beauv), Swietenia (*Swietenia mahagoni* (L.) Jacq.) and Teak *(Tectona grandis* L.f.) were studied by incubating leaf litter of these species with that of Eucalyptus at room temperature for 12 months. Results showed that soil moisture content was significantly lower in plot planted with Eucalyptus than that with Lagerstroemia. However, no significant difference appeared when soil moisture content was compared between Eucalyptus and Acacia indicating that plantation effects varied with the identity of species. Soil pH, total P (%) and organic C (%) contents were significantly lower in plots planted with Eucalyptus. Although mixing of leaf litter of Eucalyptus with that of *A. compressus*, *S. mahagoni* and *T. grandis* did not affect significantly, it affected mass loss rate of these three plant species significantly and such effect could be explained by the chemical composition of the litter used in the incubation study. Overall, the results of the present study indicated that plantation with Eucalyptus might have potential influence on altering soil properties and litter decomposition of other plant species, nevertheless, such effects varied with the species with whom the comparison was made.

Introduction

Plantation of Eucalyptus (*Eucalyptus* spp.) has created enormous concern worldwide due to its socioeconomic and environmental impacts[1,2]. Because of the nature of rapid growth and adaptation capability with wide range of environmental conditions, the genus has become a popular choice for introduction especially in the warmer parts of the

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world. However, plantation of this genus has been strongly criticized by some quarters because they are alleged to cause adverse effects on soil properties including depletion of nutrients and moisture(2). Introduction of exotics has also been criticized since they provide a relatively poor habitat for wildlife and plant biomass they produce are unpalatable to indigenous biotic communities including micro- and macro-fauna. Nevertheless, experimental data on the ecological impacts of Eucalyptus plantation have been limited, although such information is relevant for successful afforestation program as well as for better management and conservation of forests resources.

Bangladesh is one of the most densely populated countries in the world with limited natural forest area. Increased population, rapid industrialization and urbanization have created pressure on the natural forest ecosystems. In order to meet the increased demand of timber and other forest products as well as to implement reforestation program, the Department of Forestry introduced a number of fast growing plant species including Eucalyptus.(3). However, there has been debate on the long term effects of plantation of Eucalyptus on soil properties and ecosystem functions considering the environmental condition of Bangladesh.

Ecological investigation on the impacts of plantation of Eucalyptus has been hampered since it requires long term study to monitor the changes of soil properties due to plantation. Further, it becomes difficult to maintain a controlled experimental condition in the natural environment excluding the other potential factors that influence the soil properties. Therefore, the objectives of the present study were (i) to examine the effect of Eucalyptus plantation on the soil physico-chemical properties by collecting field data and also (ii) to investigate the effect of Eucalyptus leaf litter on the decomposition (mass loss) and nitrogen release rates of the leaf litter of other selected plant species following incubation of litter mixture in microcosm condition for a period of one year.

Materials and Methods

Collection and analysis of soil samples for physico-chemical properties: In order to study the effect of plantation of Eucalyptus on soil properties, two sites one in Madhupur, Tangail and another one in Singra, Dinajpur were selected where plantation of Eucalyptus was done in plot adjacent to the plot that was planted with Acacia (*Acacia auriculiformis* A. Cunn. ex Benth.) and Lagerstroemia (*Lagerstroemia speciosa* (L.) Pers.), respectively. Area of the planted plots was about 50 decimal with nearly 500 mature trees of minimum 10 years old. Study sites were selected from two different geographical locations and climatic conditions to examine whether the effect of Eucalyptus plantation was similar in different environmental conditions. For each plantation, soil samples were collected from three locations which were 50 m away from each other. Soil samples were collected at three different depths 0-10, 10-20 and 20-30 cm in each location and kept in air tight polythene bags to avoid loss of soil moisture. Thus, a total of 36 soil samples (2 sites x 2 plantations × 3 depths × 3 replicates) were collected from the fields for analysis.

Soil pH was determined in suspension made with distilled water (2 : 1, v : w) using a pH meter (Hanna pH meter, pHeP). Electrical conductivity was determined with the help of a conductivity meter by using suspension with the ration of 5 : 1 (v : w). Soil moisture content was measured by weight loss after drying 10 g fresh soil at 80°C for 24 h. Soil available N was determined by following the Kjeldahl method after extraction with 1 N KCl solution(4). Total P (%) was determined following the digestion of dry leaf sample with HNO_3 and $HClO_4$. After digestion, P was determined by following Venado-molybdate yellow color method using a spectrophotometer at 440 nm (5). Organic C was determined by Walkley and Black method(4).

Leaf sample collection and experiment design for litter decomposition: Fresh leaves of Eucalyptus (*Eucalyptus camaldulensis* Dehnh.), Axonopus (*Axonopus compressus* (Sw.) P. Beauv.), Mahagoni (*Swietenia mahagoni* (L.) Jacq.*)* and Teak (*Tectona grandis* L.f.) were collected from the campus of the University of Dhaka. Leaves were dried at 70^{0}C for 24 h before using in incubation and chemical analysis. Leaves were cut into pieces of about 2 cm in size. Then, 500 g soil was collected from the Botanical garden at the University of Dhaka and kept in a plastic pot of half litre in volume. Each 1 g leaves of Axonopus, Swietenia and Tectona was added separately with soil kept in the pot. These pots were considered as single litter treatments. Then, for mixing treatments, each 500 mg leaf of Eucalyptus was mixed separately with the same amount of leaf of Axonopus, Swietenia and Teak making total amount of leaf 1 g for each mixing treatment. Leaves were then mixed well with soil using forceps. For each treatment, three replicates were used. Thus, a total of 54 pots (6 treatments x 3 replicates x 3 incubation times) were used. Pots were covered with sterilized polythene bag to avoid contamination. Leaf litter was incubated for 12 months at room temperature. Autoclaved water was added to the pot in such a way that all pots received similar amount throughout the period of incubation. Samples were collected destructively after 4 months, 8 months and 12 months for the analysis of mass loss rate and amount of available N released from leaf litter into soil. On the day before collection of samples, the undecomposed leaf litter was collected from the pot and rinsed thoroughly with distilled water to remove soil adhered to leaf. Litter was then oven-dried at 80^{0}C for 24 hours before taking weight and conducting analysis.

Chemical analysis of leaf: Leaf litter of the four selected species were analyzed for N, P, Phenol and tannin contents. Fresh leaves were dried at 60^{0}C for 24 hours. Total N in leaf was determined by using 0.2 g leaf following the Kjeldahl method (6). Leaf P was determined by following the colorimetric method. Phenolic compounds and tannins were determined from 0.2 g leaf sample by following the methods described by Bärlocher and Graça(7).

Determination of mass loss and N mineralization rate: Mass loss rate was determined by subtracting mass of litter obtained after incubation from the initial mass before incubation and then expressed in percentage. Amount of mineralized N was calculated by deducing available nitrogen content determined before incubation from that determined after incubation(8). Both mass loss rate and mineralized N contents in soil were determined at 4, 8 and 12 months after incubation at room temperature.

Statistical analysis: Two-way ANOVA was done to clarify the effect of plantation (Eucalyptus versus other species) and vertical depth (10 cm, 20 cm and 30 cm) on the soil properties. Same statistical approach was also applied for the determination of litter decomposition rate and mineralized N content in soil after incubation with the selected litter after incubation. Tukey-Kramer HSD was done to test the level of significance among the means.

Results and Discussion

Effects of Eucalyptus plantation on soil properties: Two-way ANOVA statistics on the effects of plantation (Eucalyptus versus other species), depth (10, 20 and 30 cm) and their interactions on soil properties are shown in Fig. 1. When compared between plantations of Eucalyptus and Lagerstroemia, it was found that soil moisture content was significantly affected by plantation ($p = 0.0001$) and interaction between plantation and depth ($p = 0.0477$). Mean soil moisture (%) content was almost three times higher in plot planted with Lagerstroemia than that of Eucalyptus. When effects of plantation of Eucalyptus was compared with that of Acacia, no significant effect appeared indicating that potentials of altering soil moisture by these two species were comparable. Data also revealed that soil moisture content gradually increased with the increase of soil depth irrespective of plantations types.

Data of the present study showed significant effects of plantation with Eucalyptus on soil moisture content although the effect depended on the identity of the species i.e. with which species the effect of Eucalyptus plantation was compared. Significantly lower soil moisture content in plot planted with Eucalyptus than that of Lagerstroemia might be related with several factors including structure of leaf and growth behavior of plant. Since, in both sites, Eucalyptus was compared with Acacia and Lagerstroemia grown in adjacent plots, the difference appeared in soil moisture between the two species might be reasonably attributed to the difference in water uptake by plants and or microclimatic changes due to difference in canopy coverage. Lagerstroemia has dense canopy coverage compared to that of Eucalyptus which has narrow leaf structure. The higher soil moisture content in plot planted with Lagerstroemia might be related with the fact that this species required less amount of water than Eucalyptus. Data that revealed no significant difference in soil moisture content between plots planted with Eucalyptus and Acacia indicated that both species were comparable in terms of water use due to similar canopy coverage. Overall, present study indicated that Eucalyptus species could deplete more soil moisture content than other species. The fast growing nature of these species could exert greater uptake of moisture for maintaining their fast growth. The result was consistent with other studies those reported that Eucalyptus root systems absorbed more water than the other species[1]. Eucalyptus leaf is vertically arranged but that of Lagerstroemia is horizontally arranged and bigger in size which interrupt the sun light to penetrate protecting evaporation.

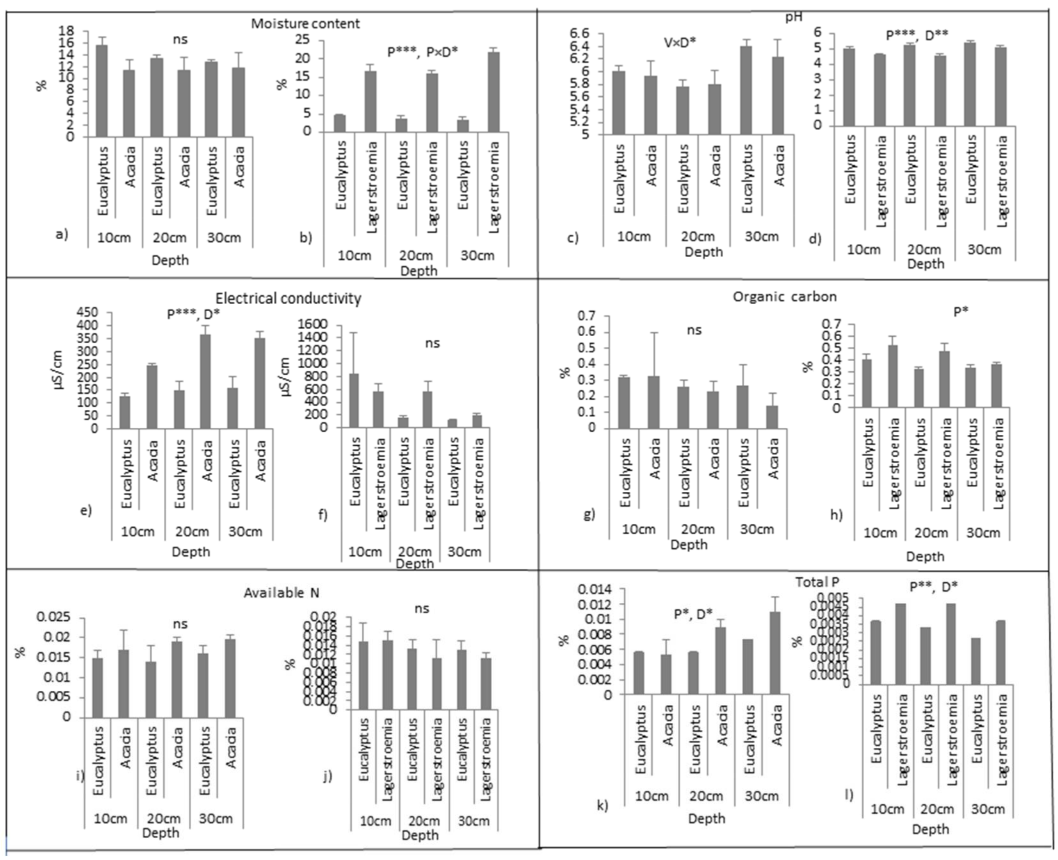

Fig. 1. Effects of plantation of Eucalyptus in comparison with that of Acacia and Lagerstroemia planted in adjacent plots located at Madhupur, Tangail and Singra, Dinajpur, respectively on the physico-chemical properties of soil. P: Plantation (Eucalyptus versus Acacia or Lagerstroemia); D: Depth (10, 20 and 30 cm). * and *** indicate significant at $p < 0.05$ and $p<0.0001$, respectively.

Soil pH was significantly affected by plantation ($p = 0.0001$) and depth ($p = 0.0029$) when comparison was done between Eucalyptus and Lagerstroemia although no significant difference appeared between Eucalyptus and Acacia plantations (Fig. 1). Soil pH was lower in plantation with Lagerstroemia than Eucalyptus. Soil pH increased with the increase of depth in both plots planted with Eucalyptus and Acacia. The lower soil pH observed in plot planted with Lagerstroemia could be related with soil organic C content which was higher in this soil perhaps due to greater amount of leaf fall. The organic content is often responsible for the acidic condition in soil[3].

Soil electrical conductivity was significantly affected by plantation ($p = 0.0001$) and depth ($p = 0.0483$) when plantation of Eucalyptus and Acacia was compared, although no significant difference appeared between Eucalyptus and Lagerstroemia plantations. Soil electrical conductivity increased with the increase of depth in Eucalyptus plantation and the value was higher in soil under the plantation with Lagerstroemia than that with Eucalyptus. When comparison was made between Eucalyptus and Acacia plantations, soil electrical conductivity decreased with the increase of soil depth in both plantations. The lower value of electrical conductivity in soil planted with Eucalyptus indicated that plantation with Eucalyptus has the potentials to reduce nutrient availability in soil through change in electrical conductivity[9].

Soil organic C content was significantly ($p = 0.0268$) higher in plots planted with Lagerstroemia than that with Eucalyptus. Relatively larger leaf size and dense canopy structure of Lagerstroemia might have contributed to higher organic C content through litter fall in soil than that was planted with Eucalyptus. Results obtained were thus in agreement with the findings of other studies that soil organic C in Eucalyptus plantation forest was significantly lower than in the natural forest soil[10,11].

Although soil available N showed no significant difference between plantations, total P content showed significant difference with the highest value in plots planted with Acacia and Lagerstroemia than that with Eucalyptus. Lower soil P content in plots planted with Eucalyptus indicated the potentials of Eucalyptus vegetation in uptaking more soil P than other species. The fast growing nature of Eucalyptus could exert the greater demand for nutrients[12]. Relatively lower concentration of soil P was found in the forest of Eucalyptus plantation in Botswana[13]. Furthermore, concentration of available P in the soil of Eucalyptus plantation was very low in Ethiopia[14].

Chemical composition of leaf litter and soil used in the decomposition study: Leaf litter of the four plant species used in the incubation study showed a significant difference in total N, phenol and tannin contents (Fig. 2). Leaf N content was higher in Axonopus (0.92 ± 0.04) and lower in Eucalyptus (0.72 ± 0.01). However, the highest phenol and tannin contents were found in Mahagony. Although not statistically significant, Eucalyptus leaf litter showed the lowest P (%) content. Axonopus showed the lowest phenol and tannin contents (0.29 ± 0.02). All these results indicated that leaf litter of Axonopus was of good quality and that of Eucalyptus and Mahagony were of poor quality since N and P contents in leaf litter are considered as nutrient elements while phenol and tannin contents are as defense chemicals during litter decomposition[9]. Soil used for the incubation of leaf litter was characterized as pH 7.0, electrical conductivity 53.7 μS/cm, moisture content 20.35%, total N 0.117% and total P 0.062%.

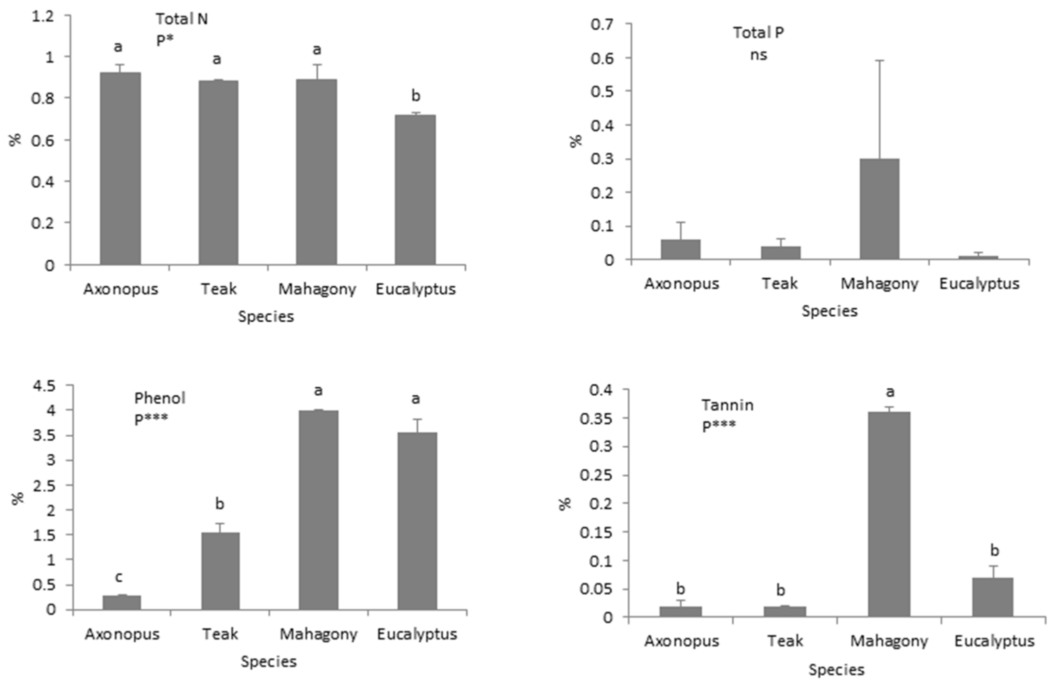

Fig. 2. Total N, P, phenol and tannin contents of the leaf litter of Eucalyptus, Axonopus, Mahagony, and Teak collected from the campus of the University of Dhaka. * and *** indicate significant difference at p < 0.05 and p < 0.0001, respectively.

Litter decomposition rate and mineralized N content in soil: ANOVA statistics revealed that mass loss rate was significantly affected by litter species ($p = 0.0001$), incubation time ($p = 0.0001$) and their interaction ($p = 0.0009$) whereas soil N content was significantly affected only by incubation time ($p = 0.0071$) but not by litter species ($F = 0.14$, $p = 0.99$) and their interactions. Mass loss rate of *A. compressus, S. mahagony* and *T. grandis* was reduced when litter of Eucalyptus was mixed (Fig. 3). Mass loss rate increased significantly from the initial time till 12 months across all types of litter mixing treatments. Soil N content gradually decreased with time across all litter mixing treatments indicating immobilization of nitrogen (Fig. 4).

Differences in the effect of Eucalyptus litter on the mass loss rate of other litter species could be attributed to the difference in chemical composition of Eucalyptus litter. When Eucalyptus litter was added with the litter of Swietenia, then mass loss rate of this species decreased significantly across all measurements. Similar trend was observed in case of Axonopus leaf litter. Both leaf N and P contents were higher in the leaf litter of

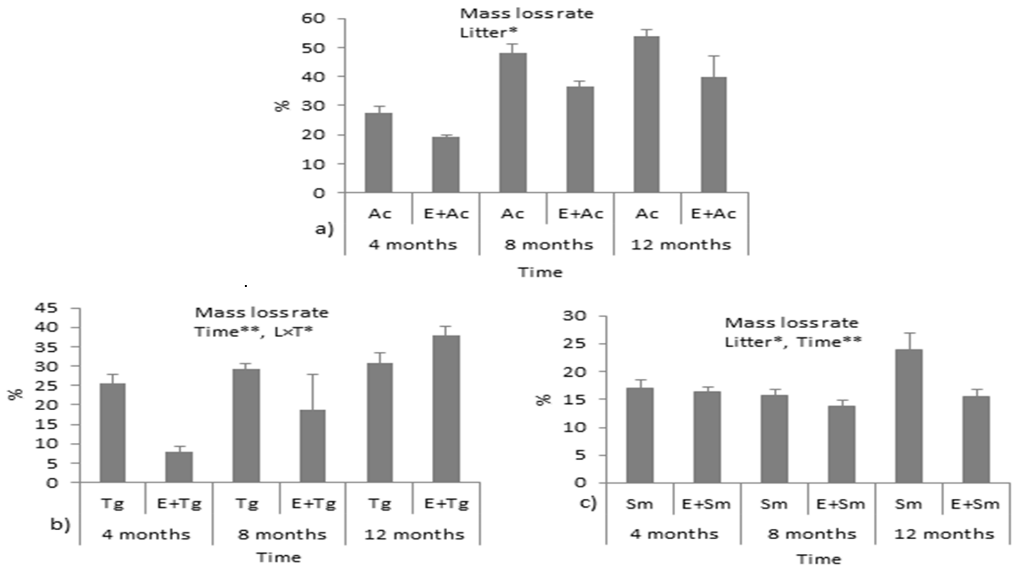

Fig. 3. Mass loss rate (%) of litter of a) Axonopus (Ac), b) Teak (Tg), and c) Mahagoni (Sm) during incubation with and without Eucalyptus (E) leaf litter. L: Litter species; T: Time of incubation and D: Depth. * and ** indicate significant at $p<0.05$ and $p<0.01$, respectively.

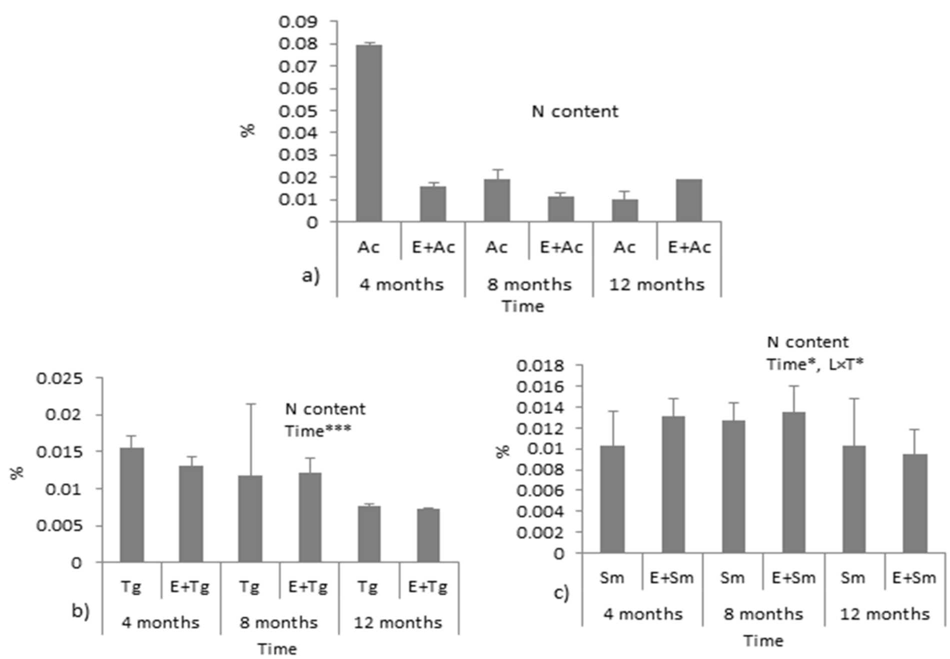

Fig. 4. Mineralized N content (%) of litter of (a) Axonopus (Ac), (b) Teak (Tg), and (c) Mahagoni (Sm) during incubation with and without Eucalyptus (E) leaf litter. L: Litter species; T: Time of incubation and D: Depth. *and *** indicate significant at $p<0.05$ and $p < 0.0001$, respectively.

Axonopus and lower in Eucalyptus. Mixing of Eucalyptus leaf litter resulted decreased mass loss rate in Axonopus, Swietenia and Teak species. Litter decomposition is done by the activities of the microbial communities[6]. Rate of microbial function depends on substrate quality like N and P contents[15]. Thus, plantation with Eucalyptus has the potentials to influence litter decomposition rate of other indigenous plant species in ecosystem. Overall, the results of the present study indicated that plantation with Eucalyptus might potentially influence soil properties including moisture, organic carbon and P contents although the effects were species specific i.e. with which species it was compared. Results also suggested that plantation with Eucalyptus influenced decomposition rate (e.g. mass loss rate) of other plant species in ecosystem through mixing with litter. Therefore, ecological consequences should be considered while plantation has to be done with Eucalyptus.

Acknowledgement

The authors of this study are thankful to the University of Dhaka for allocating research grants provided by Bangladesh University Grants Commission to conduct this piece of work during the fiscal year 2014-2015.

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(Manuscript received: 15 March, 2021; accepted: 27 July, 2021)