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***MD. HASANUZZAMAN and MAHMOOD HOSSAIN*[1]**

LITTER PRODUCTION AND NUTRIENT RETURN THROUGH LEAF LITTER OF SELECTED CROPLAND AGROFOREST TREE SPECIES IN SOUTHWESTERN BANGLADESH

SUMMARY

Cropland agro forestry is an important production system in southwestern Bangladesh. *Swietenia macrophylla, Mangifera indica, Zizyphus jujuba, Litchi chinensis, Albizia saman, Artocarpus heterophyllus, Azadirachta indica, Melia azadirachta, Khaya anthotheca, Eucalyptus camaldulensis, Acacia auriculiformis* and *Dalbergia sissoo* are the common cropland agro forest tree species of this region and have been selected for this study. This study focused on litter production and estimation of nutrient return through leaf litter of the selected tree species. Five trees of individual species with average Diameter at Breast Height were selected and whole tree covering method was followed for the litter production experiment. Significant ($p<0.05$) differences in rate of litter production were observed among the studied tree species and *M. azadirachta* showed the highest rate (553 g/week) followed by *S. macrophylla* (525 g/week). The nutrients (N, P and K) concentration in leaf litter found to vary significantly ($p<0.05$) among the species. Highest concentration of nitrogen (13 mg/g) was detected in the leaf litter of *M. azadirachta* and highest concentration of phosphorus (8.70 mg/g) and potassium (43.61 mg/g) were observed for *A. indica*. The estimated highest amount of nitrogen (76 mg/kg), phosphorus (58 mg/kg) and K (229 mg/kg) can be returned from leaf litter of *K. anthotheca, A. saman* and *A. indica* respectively. Among the studied species, *M. azadirachta, A. indica, E. camaldulensis* and *D. sissoo* can be recommended as timber species; and *M. indica* and *Z. jujuba* can be recommended as fruit tree species for the cropland agro forest in the southwestern Bangladesh.

Keywords: Agro forestry, Cropland, Leaf litter, Litter production, Nutrients

INTRODUCTION

Bangladesh is a developing country where agriculture is the major economic activity (Zashimuddin 2004). About two-thirds of the total land area has been used for agricultural production. This country has the highest (964 per square kilometer) population density (BBS 2011) which results shrink of per capita land holding. Presently, the land holding is 0.045 ha/person which was 0.12 ha/person during 1975 (Ericksen *et al* 1997). This shrinkage in land holding exerts intense pressure on crop production and other types of land use. Farming communities are trying by all means to increase the land productivity through the application of chemical fertilizers, use of high yielding crop varieties which in

[1]MD. HASANUZZAMAN, (corresponding author: hasanfwt@gmail.com), MAHMOOD HOSSAIN, Forestry and Wood Technology Discipline, Life Science School, Khulna University, Khulna - 9208, Bangladesh.

turn impact on biodiversity (Hasanuzzaman *et al* 2006). Considering these circumstances, cropland agro forestry practices have shown their ability to hold sustainable agriculture and better environment as well (Dwivedi 1992, Ahmed 2001). *Azadirachta indica* (A. Juss.), *Melia azadirachta* (L.), *Eucalyptus camaldulensis* (Dehnh.), *Mangifera indica* (L.), *Artocarpus heterophyllus* (Lam.), *Dalbergia sissoo* (Roxb.), *Albizia saman* (F. Muell.), *Litchi chinensis* (Sonn.), *Zizyphus jujuba* (Mill.), *Swietenia macrophylla* (King), *Khaya anthotheca* (Welw.) and *Acacia auriculiformis* (A. Cunn. Ex Benth.) are the common tree species in the cropland agro forests and other type of agro forests of Bangladesh (Quddus 2001, Hasanuzzaman *et al* 2006, Zaman *et al* 2010, Alam *et al* 2012). But, these tree species have been planted in different agro forests without considering the issue of productivity, sustainability, environmental health and nutrient cycling.

Plant uptake nutrients for their growth and development and a portion of these nutrients are accumulated in plant body. Conversely, considerable amount of nutrients are returned to the soil through litter fall. Litter (leaves, bark, needles and twigs) improves the soil quality through adding the organic matter and nutrients to the soil (Ngoran *et al* 2006, Mahmood and Hoque 2008, Mahmood *et al* 2009, 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 Kang-Hyun 2003, Mahmood *et al* 2011). Litter from different tree species is mostly used as fuel in the developing countries like Bangladesh where majority people burn the litter as fuel (Hasanuzzaman *et al* 2014). Litter falls normally in small quantities throughout the year, but peak (up to 90%) fall was observed during the spring and early summer periods with long days, higher air temperature, limited availability of water, higher wind speed and lower air humidity (Rapp 1969, Arianoutsou 1989, Mahmood and Hoque 2008, Sanches *et al* 2008, Triadiati *et al* 2011). However, no attempt has been taken to screen or prioritized the tree species of the cropland agro forests and other types of agro forest on the basis of nutrient return capacity in the South Asian region as well as in Bangladesh. Therefore, this study aimed to prioritize the commonly planted tree species on the basis of litter production and amount of nutrient (N, P and K) return through litter fall. This finding will help to influence people in using leaf litter as manure rather than fuel and prioritizing the potential tree species for sustainable cropland agro forestry practices and other types of agro forestry practices in Bangladesh as well as other countries in the world.

MATERIAL AND METHODS

Description of the study area

Bangladesh is located between 20°34'-26°3' N; and 88°01'-92°41' E and bordered by the Bay of Bengal on the South and India on all other sides along with small part of Myanmar. 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 monthly average rainfall is 155 mm, the highest average rainfall (339 mm) occurs during the month of June to September and the lowest average rainfall (16 mm) occurs in the month of November to February of 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 highest (86%-88%) during the month of July to August and the lowest (72%-74%) during February to April.

Litter production

The total height (m) and DBH (Diameter at Breast Height) of *S. macrophylla, M. indica, Z. jujuba, L. chinensis, A. saman, A. heterophyllus, A. indica, M. azadirachta, K. anthotheca, E. camaldulensis, A. auriculiformis* and *D. sissoo* in the cropland agro forests of the study area were measured. Five individual of each species with average DBH were selected for litter production experiment. Whole tree covering method of litter production (Brown 1984) was followed for six months from November 2011 to April 2012 (end of dry month). Litter was collected on weekly basis and the collected litter was sorted into leaves, small branches, flowers, fruits and miscellaneous materials. The litter parts were then oven dried and weighted. The weekly rate of litter production was also calculated. Moreover, the length, width and leaf litter area of individual species were measured by using a leaf area meter (CI-202, CID, Inc, Washington, U.S.A.).

Nutrients in leaf litter

The oven-dried leaf litter samples of individual species were grounded, processed and acid digestion according to (Allen 1974). The digested sample extracts were processed according to (Weatherburn 1967) and (Timothy *et al* 1984) to measure nitrogen and phosphorus concentration in sample extracts respectively using UV-Visible Recording Spectrophotometer (U-2910, HITACHI, Japan). Potassium concentration in sample extracts was also measured by Flame photometer (PFP7, Jenway LTD, England). The amount of nutrient in leaf litter was estimated from mass of leaf litter and the concentrations of respective nutrients in leaf litter.

Statistical analysis

The weekly rate of litter production of the studied species were compared by one-way analysis of variance (ANOVA) followed by DMRT (Duncan Multiple Range Test) using SAS statistical software. The relationship among the rate of litter production and climatic factors (rainfall and wind speed) were evaluated by correlation analysis using SAS statistical software. Nutrients (N, P and K) concentration in leaf litter of different tree species was compared by one-way analysis of variance (ANOVA) using SAS statistical software.

RESULTS AND DISCUSSION

Leaf morphology

The highest range of leaf litter length (12.80 to 30.30 cm) and width (3.70 to 12.20 cm) were observed for *K. anthotheca* and the lowest values for length (2.20 to 6.10 cm) and width (1.30 to 3.50 cm) were measured for *A. saman*. Highest area (92.40 cm^2) of leaf litter was observed for *K. anthotheca* followed by *Mangifera indica* (77.55 cm^2), *A. heterophyllus* (59.93 cm^2) and the lowest (09.02 cm^2) was measured for *A. saman* (Table 1). The leaf morphology (size, shape, area etc.) found to vary among the species and this variation attributed to age, thickness of leaf and internal arrangement (midribs, margins, venations) of leaf/leaflets as well as environmental conditions and adaptation to different habitats (Cordell *et al* 1998, Lugo *et al* 2003, Lamers *et al* 2006).

Table 1 Leaf morphology of different cropland agro forest tree species in Southwestern Bangladesh

Name of species	Leaf Types	Leaf/Leaflet			
		Range of leaf length (cm)	Range of leaf width (cm)	Average leaf area (cm^2)	Average oven-dry weight (g)
Khaya anthotheca	Compound	12.80-30.30	3.70-12.20	92.40	1.02
Mangifera indica	Simple	12.30-31.00	3.40-6.00	77.55	0.94
Artocarpus heterophyllus	Simple	9.30-15.30	4.70-7.80	59.93	0.72
Eucalyptus camaldulensis	Simple	8.70-29.70	1.80-4.70	40.16	0.63
Swietenia macrophylla	Simple	5.30-16.30	2.00-5.20	57.26	0.62
Zizyphus jujuba	Simple	2.50-9.20	1.80-5.80	20.94	0.39
Acacia auriculiformis	Compound	11.90-18.30	1.80-3.70	34.90	0.32
Litchi chinensis	Simple	10.70-25.60	2.80-4.60	42.30	0.28
Dalbergia sissoo	Compound	2.90-7.70	1.70-6.50	12.89	0.17
Azadirachta indica	Simple	3.00-8.20	1.50-2.40	10.04	0.06
Melia azadirachta	Compound	2.30-9.10	1.30-3.20	10.83	0.06
Albizia saman	Compound	2.20-6.10	1.30-3.50	09.02	0.06

Litter production and nutrients in leaf litter

The amount of litter production, time period and duration of peak litter production found to vary with species. The highest amount (9.43 kg) of litter

production was observed for *K. anthotheca* followed by *S. macrophylla* (8.94 kg), *M. azadirachta* (7.82 kg), while lowest amount (5.35 kg) was found for *A. saman* (Figures 1 to 12). Significant ($p<0.05$) differences in rate of litter production was observed among the studied species and *M. azadirachta* showed the highest rate (553 g/week) of litter production followed by *S. macrophylla* (525 g/week), *K. anthotheca* (361 g/week) and the lowest rate (263 g/week) was reported for *Z. jujuba* (Figure 13). These variations in litter fall rates may be due to the variation in leaf litter morphology, age and crown architecture of tree species (Mahmood and Hoque 2008). It was identified that wind speed has significant ($p<0.05$) positive relationship with litter production but rain fall showed no significant ($p>0.05$) influence on it as the experiment was done during the dry season (Table 2). This could be the reason for getting no significant relationship among litter production and rainfall. However, Cornejo *et al* (1994); Barajas-Guzman and Alvarez-Sanchez (2003); Cleveland *et al* (2004) and Sanches *et al* (2008) reported that, rainfall and different climatic conditions (temperature, water availability, wind speed, air humidity etc.) directly influence the litter production dynamics. Among the litter parts, leaf litter contained the highest proportion (95%) for *A. indica* followed by *L. chinensis* (94%), *D. sissoo* (93%) and the lowest proportion (69%) was observed for *K. anthotheca* (Table 3). The proportion of litter parts found to vary and generally leaf litter contain 63% to 97% of total litter production which is species, age, size and site specific (Arianoutsou 1989, Mahmood and Hoque 2008, Sanches *et al* 2008, Tripathi *et al* 2009).

Table 2 Correlation among litter production, rainfall and wind speed

Name of species	Wind speed & litter production	Rainfall & litter production
Khaya anthotheca	r = 0.37, p = 0.07	r = 0.04, p = 0.86
Mangifera indica	r = 0.50, p = 0.01	r = 0.10, p = 0.64
Artocarpus heterophyllus	r = 0.33, p = 0.17	r = 0.16, p = 0.33
Eucalyptus camaldulensis	r = 0.74, p =.027	r = 0.22, p = 0.46
Swietenia macrophylla	r = 0.49, p = 0.04	r = 0.10, p = 0.70
Zizyphus jujuba	r = 0.50, p = 0.02	r = 0.07, p = 0.75
Acacia auriculiformis	r = 0.69, p = 0.04	r = 0.09, p = 0.70
Litchi chinensis	r = 0.16, p = 0.44	r = -0.02, p = 0.94
Dalbergia sissoo	r = 0.70, p = 0.01	r = 0.13, p = 0.30
Azadirachta indica	r = 0.49, p = 0.02	r = 0.12, p = 0.24
Melia azadirachta	r = 0.64, p = 0.01	r = 0.45, p = 0.11
Albizia saman	r = 0.62, p = 0.02	r = 0.20, p = 0.39

The nutrients (N, P and K) concentration in leaf litter varied significantly ($p<0.05$) among the tree species. Highest nitrogen concentration (13 mg/g) was recorded from leaf litter of *M. azadirachta* followed by *E. camaldulensis* (12.28 mg/g) and *A. indica* (12.15 mg/g). Highest phosphorus concentration (8.70 mg/g) was detected from leaf litter of *A. indica* followed by *A. saman* (8.56 mg/g) and *M. azadirachta* (8.50 mg/g). Highest potassium concentration (43.61 mg/g) was observed in leaf litter of *A. indica* followed by *M. azadirachta* (39.53 mg/g) and *E. camaldulensis* (37.23 mg/g) (Table 4). Irrespectively, highest amount (76 mg/kg) of nitrogen can be added from leaf litter of *K. anthotheca* followed by *M. azadirachta* (72 mg/kg), *E. camaldulensis* (71 mg/kg). Highest amount (58 mg/kg) of phosphorus can be added from leaf litter of *A. saman* followed by *M. indica* (53 mg/kg), *M. azadirachta* (47 mg/kg). Moreover, highest amount (229 mg/kg) of potassium can be added from leaf litter of *A. indica* followed by *M. azadirachta* (219 mg/kg), *E. camaldulensis* (214 mg/kg) and the lowest amount of 58 mg/kg can be added from *A. saman.* The variation in nutrients concentration in the leaf litter of the studied species were found as the selected tree species were from different families with varying nature of nitrogen fixing capacity; rate of nutrient uptake and retranslocation; types of leaf shading characteristics (i.e. evergreen, semi evergreen, deciduous, semi deciduous etc.); growth and life form; characteristics of individual nutrients and soil physiochemical characteristics (Elevitch and Wilkinson 1998, Mahmood and Saberi 2007, Mahmood *et al* 2009, Ali *et al* 2013).

Table 3 Proportion (%) of litter parts of different cropland agro forest trees in southwestern Bangladesh

Name of species	Litter parts				
	Leaf litter (%)	Small branches, <2 cm in diameter (%)	Flowers (%)	Fruits (%)	Miscellaneo-us materials (%)
Khaya anthotheca	68.67	23.78	0.39	7.11	0.05
Swietenia macrophylla	71.86	17.06	0.67	10.32	0.06
Melia azadirachta	70.72	26.02	0.80	2.42	0.02
Artocarpus heterophyllus	88.75	4.95	1.59	4.57	0.12
Mangifera indica	92.17	3.83	3.02	0.93	0.03
Eucalyptus camaldulensis	83.05	8.53	2.50	5.29	0.17
Litchi chinensis	94.34	2.53	0.58	2.46	0.07
Dalbergia sissoo	93.34	2.90	1.55	2.14	0.04
Zizyphus jujuba	87.75	5.06	3.00	4.13	0.05
Acacia auriculiformis	88.76	4.62	2.36	4.17	0.06
Azadirachta indica	95.32	2.88	0.79	0.96	0.02
Albizia saman	89.84	4.44	0.82	4.78	0.11

The species specific variation in added amount of nutrients to soil may be attributed to the variation of amount of leaf litter production and concentration of respective nutrients in leaf litter. However, the estimated amount of nutrients can be added to the soil through the complex process of leaf litter decomposition (Mahmood and Hoque 2008). Among the studied species, *M. azadirachta, A. indica, E. camaldulensis* and *D. sissoo* can be recommended as timber species, and *M. indica* and *Z. jujuba* can be recommended as fruit tree species for the cropland agro forests on the basis of litter production and possible amount of nutrient return. Moreover, this priority list of species can be improved by considering the local demand and end product of these species.

Table 4 Nutrients in leaf litter of cropland agro forest tree species in southwestern Bangladesh

Name of Species	Nutrient concentration (mg/g)			Amount of returnable nutrient (mg/kg)		
	N	P	K	N	P	K
Melia azadirachta	13.00±4.10	8.50±3.50	39.53±3.30	71.91	47.01	218.64
Eucalyptus camaldulensis	12.28±1.60	8.10±1.10	37.23±1.30	70.53	46.52	213.81
Azadirachta indica	12.15±4.70	8.70±2.40	43.61±1.80	63.76	45.66	228.86
Albizia saman	12.00±2.40	8.56±5.10	33.15±2.10	57.74	57.74	57.74
Acacia auriculiformis	11.89±3.60	2.60±2.80	17.97±1.20	61.13	13.37	92.40
Zizyphus jujuba	11.87±7.50	5.74±6.50	36.70±21.50	63.19	30.56	195.37
Khaya anthotheca	11.66±3.50	2.65±1.50	17.73±1.50	75.52	17.16	114.83
Dalbergia sissoo	11.10±3.10	6.10±1.30	33.86±1.30	66.07	36.31	201.55
Mangifera indica	10.07±1.10	8.39±2.90	31.20±1.50	64.22	53.54	198.97
Swietenia macrophylla	9.02±3.50	4.88±4.10	18.61±0.60	57.93	31.37	119.52
Artocarpus heterophyllus	7.82±3.80	1.31±2.10	24.64±0.90	49.31	8.26	155.37
Litchi chinensis	4.33±3.20	1.17±0.40	22.51±0.90	27.73	7.49	144.17

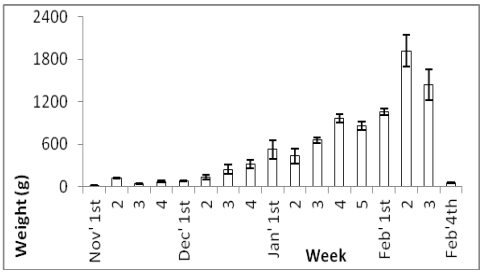


Figure 1 Litter production of *Swietenia macrophylla*

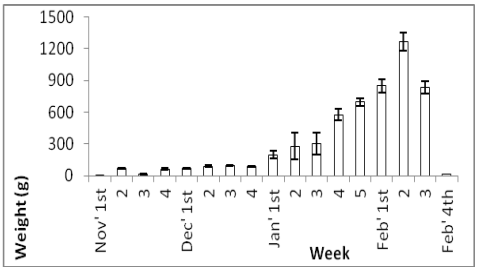


Figure 2 Litter production of *Azadirachta indica*

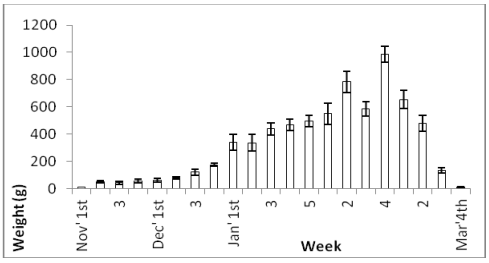


Figure 3 Litter production of *Eucalyptus camaldulensis*

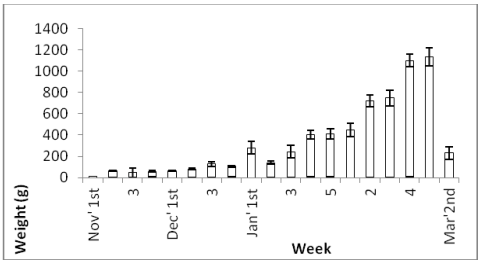


Figure 4 Litter production of *Dalbergia sissoo*

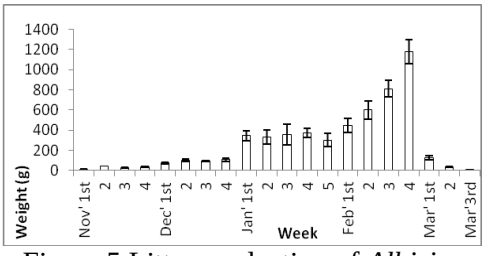


Figure 5 Litter production of *Albizia saman*

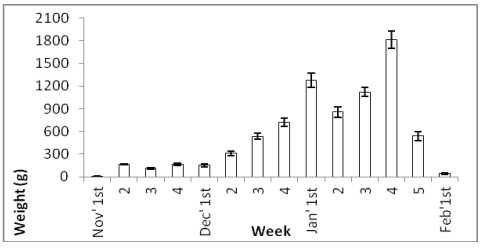


Figure 6 Litter production of *Melia azadirachta*

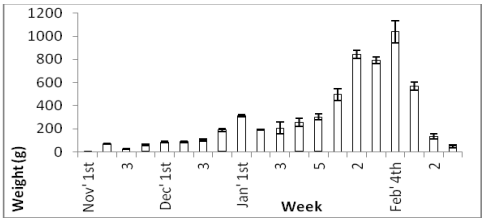


Figure 7 Litter production of *Acacia auriculiformis*

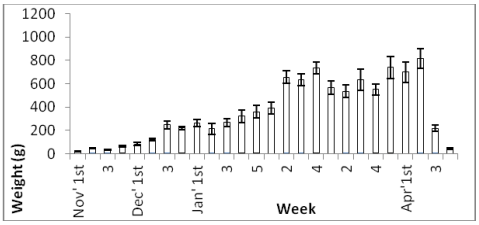


Figure 8 Litter production of *Khaya anthotheca*

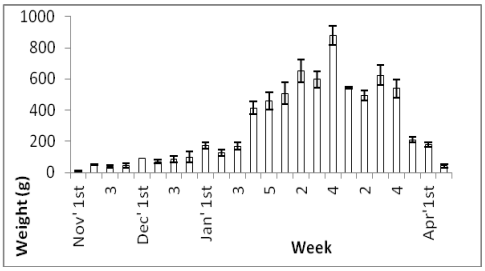


Figure 9 Litter production of *Artocarpus heterophyllus*

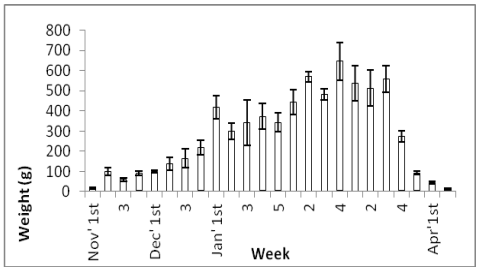


Figure 10 Litter production of *Litchi chinensis*

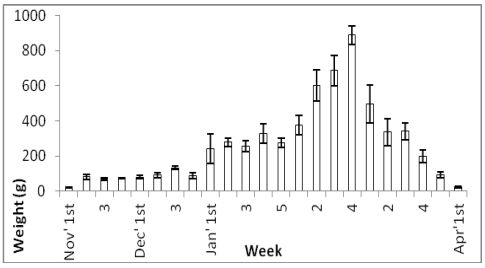
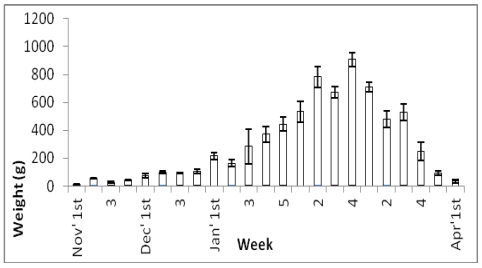


Figure 11 Litter production of *Zizyphus jujuba*



12 Litter production of *Mangifera indica*

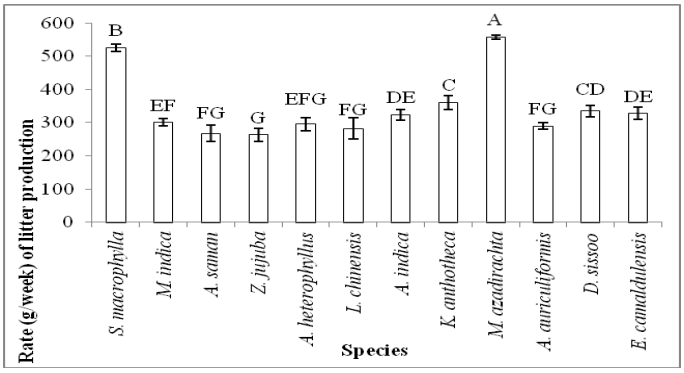


Figure 13 Rate (g/week) of litter production of cropland agroforest tree species in southwestern Bangladesh. Means with similar letter are not significantly ($p>0.05$) different

CONCLUSIONS

Litter can contributes a significant role in nutrient cycling and primary productivity in any cropland agro forest ecosystem. On the contrary, different high yielding varieties of agricultural crops have increased the indiscriminate use of fertilizers in the croplands which leads the negative effect on the environment. Therefore, species selection in cropland and other form of agro forest on the basis of nutrient return can reduce the use of chemical fertilizer, which in turn improves the soil quality and soil health.

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REFERENCES

Alam, MK, Basak, SR, Alam, S. (2012) *Khaya Anthotheca* (WELW.) C. DC. (Melliaceae) – An exotic species in Bangladesh. *Bangladesh J. Plant Taxon* 19: 95-97.

Ahmed, MFU. **(**2001) Agro forestry in Bangladesh with special reference to northern Bangladesh. In: Haq MF, Hasan MK, Asaduzzaman SM, Ali MY (eds), *Development of agro forestry research in Bangladesh.*Bangladesh: Proceedings of a national workshop on agro forestry research, 16-17 September, Gazipur. pp 1−10.

Allen, SE. (1974) Chemical analysis of ecological materials. Oxford: Blackwell Scientific Publications.

Ali, S, Neda, G, Manyam, S. (2013) Soil nutrient status, nutrient return and retranslocation in poplar species and clones in northern Iran. *iForest* (early view), doi:10.3832/ifor 0976-006.

Arianoutsou, M. (1989) Timing of litter production in a maquis ecosystem of North-Eastern Greece. *Acta Oecologica/ Oecologia Plantarum* 10: 1-8.

Barajas-Guzman, G, Alvarez-Sanchez, J. (2003) The relationships between litter fauna and rates of litter decomposition in a tropical rain forest. *Appl. Soil Ecol.,* 24: 91-100. Doi:10:1016/S0929-1393(03)00069-6.

BBS (Bangladesh Bureau of Statistics) (2011) *Population & Housing Census 2011 Preliminary Results*. Dhaka: Statistics Division. Ministry of Planning.

BBS (Bangladesh Bureau of Statistics) (2004) *Statistical Pocket Book of Bangladesh*. Dhaka: Statistics Division. Ministry of Planning.

Brown, MS. (1984) Mangrove leaf litter production and dynamics. In: Snedaker SC, Snedaker JG (eds). *The Mangrove Ecosystem: Research Methods.* Paris: UNESCO. pp. 231-238.

Cleveland, C, Townsend, AR, Constance, BC, Ley, RE, Schmidt, SK. (2004) Soil microbial dynamics in Costa Rica: Seasonal and biogeochemical constraints. *Biotropica* 36:184-195.

Cordell, S, Goldstein, G, Mueller-Dombois, D, Webb, D, Vitousek, PM. (1998) Physiological and morphological variation in Metrosideros Polymorpha, a dominant Hawaiian tree species, along an altitudinal gradient: the role of phenotypic plasticity. *Oecologia* 113:188-196.

Cornejo, FH, Varela, A, Wright, SJ. (1994) Tropical forest litter decomposition under seasonal drought: Nutrient release, fungi and bacteria. *Oikos* 70: 183-190.

Dwivedi, AP. (1992) *Agro forestry Principles and Practices.* India: Oxford & IBH Publishing co. pvt. Ltd, New Delhi. pp.48-227.

Elevitch, C, Wilkinson, K. (1998) Nitrogen fixing trees: Multipurpose pioneers. Available at http://Agroforestry.net/pubs/NFTs.html [accessed 05 September 2013].

Ericksen, NJ, Ahmad, QK, Chowdhury, AR. (1997) *Socio-economic Implications of Climate Change for Bangladesh.* Bangladesh Unnayan Parishad. Dhaka. Available at http://academic.research.microsoft.com/paper/4946231.aspx. [accessed 05 November 2013].

Hasanuzzaman, Md, Mahmood, H, Lemon, SH, Islam, MN. (2006) Nutrients (P, K and Na) leaching from leaf litter of *Dalbergia Sissoo* (Roxb.). *Pakistan Journal of Forestry* 56: 22-29.

Hasanuzzaman, Md, Mahmood, H, Saroar, M. (2014). Floristic composition and management of cropland agro forest in southwestern Bangladesh. *Journal of Forestry Research*. DOI-10.1007/s11676-014-0451-4.

Kabir, ME, Webb, EL. (2008) Can homegardens conserve biodiversity in Bangladesh? *Biotropica* 40: 95–103

Lamers, JPA, Khamzina, A, Worbes, M. (2006) The analysis of physiological and morphological attributes of 10 tree species for early determination of their suitability to afforest degraded landscapes in the Aral Sea Basin of Uzbekistan. *Elsevier* 221: 249-259.

Lugo, AE, Figueroa, JC, Alayon, M. (2003) Bio-Leaf Mahogany: Genetics, Ecology and Management. *Springer* 432pp.

Mahmood, H, Hoque, AKF. (2008) Litter production and decomposition in mangrove- A review. *Indian Journal of Forestry* 3: 227-238

Mahmood, H, Saberi, O. (2007) Micro-nutrient contents of field grown seedlings, saplings and trees of a mangrove species, Bruguiera parviflora (Wight and Arnold) in the Kuala Selangor nature park, Malaysia. *Indian Forester* 133: 1057-1062.

Mahmood, H, Limon, SH, Rahman, MS, Azad, AK, Islam, MS, Khairuzzaman, M. (2009) Nutrients (N, P and K) dynamics associated with the leaf litter of two agro forestry tree species of Bangladesh. *iForest* 2: 183-186.

Mahmood, H, Siddique, MRH, Rahman, MS, Hossain, MZ, Hasan, MM. (2011) Nutrient dynamics associated with leaf litter decomposition of three agro forestry tree species (*Azadirachta indica, Dalbergia sissoo* and *Melia azadirachta)* of Bangladesh. *Journal of Forestry Research* 22: 577-582.

Mason, FC. (1977) *Decomposition.* The Institute of Biology's Studies in Biology no. 74. London: Edward Arnold Limited. 219 p.

Ngoran, A, Zakra, N, Ballo, K, Kouamé, C, Zapata, F, Hofman, G, Van, CO. (2006) Litter decomposition of *Acacia auriculiformis* Cunn. Ex Benth. and *Acacia mangium* Willd. under coconut trees on quaternary sandy soils in Ivory Coast. *Biology and Fertility of Soils* 43: 102-106

Park, S, Kang-Hyun, C. (2003) Nutrient leaching from leaf litter of emergent macrophyte *(Zizania latifolia*) and the effects of water temperature on the leaching process. *Korean J. Biologi. Sci.* 7: 289-294.

Quddus, MA. (2001) The cropland agro forestry experiences of the village and farm forestry project in northwest Bangladesh. Bangladesh: Paper presented at the *National workshop on agro forestry*, Gazipur, 16-17 September 2001, pp 229-239.

Rapp, M. (1969) Production de litiere et apport au sol d'elements mineraux dans deux ecosysteme mediterraneens: La foret de Quercus ilex L. et la garrigue de *Quercus coccifera* L. *Acta Oecologica/ Oecologia Plantarum* 1: 151-164.

Sanches, L, Valentini, CMA, Junior, OBP, Nogueira, JS, Vourlities, GL, Biudes, MS, Silva, CJ, Bambi, P, Lobo, FA. (2008) Seasonal and interannual litter dynamics of a tropical semideciduous forest of the southern Amazone Basin, Brazil. *Journal of Geophysical Research 113.* G04007, doi:10:1029/2007JG000593.

Timothy, RP, Yoshiaki, M, Carol, ML. (1984) A manual of chemical and biological methods for seawater analysis. Oxford: Pergamon press.

Triadiati, S, Tjitrosemito, E, Sundarsono, G, Qayim, I, Leuschner, C. (2011) Litterfall production and leaf-litter decomposition at natural forest and Cacao agro forestry in Central Sulawesi, Indonesia. *Asian journal of Biological Sciences*, 4:221-234.

Tripathi, OP, Pandey, HN, Tripathi, RS. (2009) Litter production, decomposition and physic-chemical properties of soil in developed agro forestry systems of Meghalaya, Northeast India. *African Journal of Plant Science* 3: 160-167.

Weatherburm, MW. (1967) Phenol-hypochlorite reaction for determination of ammonia. *Analytical Chemistry* 39: 971-974.

Zaman, S, Siddique, SS, Katoh, M. (2010) Structure and Diversity of Homegarden Agro forestry in Thakurgaon District, Bangladesh. *The Open Forest Science Journal* 3:38-44.

Zashimuddin, M. (2004) Community forestry for poverty reduction in Bangladesh. In: Sim HC, Appanah S, Lu WM (eds), *Can community forestry make money*? Proceedings of the regional workshop on forest for poverty reduction, 1-2 September, Beijing, China. Available at www.fao.org./docrep/007/ad511e/ad511 e00.htm#Contents. [accessed 05 November 2013].

MD. HASANUZZAMAN and MAHMOOD HOSSAIN

PRODUKCIJA STELJE I NADOKNADA HRANLJIVIH MATERIJA KROZ LISNI OTPAD ODABRANIH AGROŠUMARSKIH VRSTA U JUGOZAPADNOM BANGLADEŠU

SAŽETAK

Agrošumarstvo predstavlja važan dio sistema proizvodnje u jugozapadnom Bangladešu. *Swietenia macrophylla, Mangifera indica, Zizyphus jujuba, Litchi chinensis, Albizia saman, Artocarpus heterophyllus, Azadirachta indica, Melia azadirachta, Khaya anthotheca, Eucalyptus camaldulensis, Acacia auriculiformis i Dalbergia sissoo* su karakteristične vrste drveća zastupljene u ovom regionu i kao takve odabrane za naše istraživanje. Ova studija se bavi proizvodnjom zelenog otpada i procjenom hranljivih materija kod lisnog komposta (šumske stelje) kod određenih vrsta drveća. Za eksperiment proizvodnje otpada odabrano je pet vrsta drveća sa prosječnim vrijednostima prečnika na prsnoj visini i primjenjena je metoda procjene kompletne biomase drveta. Uočene su značajne razlike ($p<0.05$) u proizvodnji organskih materija kod različitih vrsta drveća, tako da je najveća stopa zabilježena kod *M. azadirachta* (553 g/nedeljno), a odmah slijedi S. macrophylla (525 g/nedeljno). Koncentracija hranljivih materija (N, P i K) u lisnom otpadu značajno varira ($p<0.05$). Najveća koncentracija azota (13 mg / g) je pronađena kod lisnog otpada *M. Azadirachta*, a najveća koncentracija fosfora (8.70 mg/g) i kalijuma (43.61 mg/g) su pronađene kod *A. indica*. Izračunato je da najveća količina azota (76 mg/kg), fosfora (58 mg/kg) i K (229 mg/kg) može da se nadoknadi iz lisnog otpada *K. anthotheca, A. Samana i A. Indica*. Od ispitivanih vrsta, *M. azadirachta, A. indica, E. camaldulensis i D. sissoo* se mogu preporučiti kao vrste drveća dok se *M. Indica i Z. jujuba* se mogu preporučiti kao voćne vrste pogodne za agrošumarstvo u jugozapadnom Bangladešu.

Ključne riječi: agrošumarstvo, njiva, lisni otpad, proizvodnja otpada, proizvodnja hranljivih materija