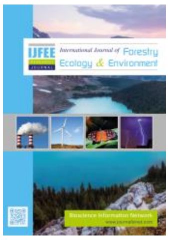
Published with Open Access at Journal BiNET
Vol. 04, Issue 01: 141-152
International Journal of Forestry, Ecology and Environment
Journal Home: https://www.journalbinet.com/ijfee-journal.html



Undergrowth phytodiversity index in exotic and indigenous tree plots in Hoteya forest range of Sakhipur upazila under Tangail forest division, Bangladesh

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Article received: 13.01.21; Revised: 09.04.21; First published online: 05 May, 2021.

ABSTRACT

This study was undertaken to know the species diversity of the monoculture plantations of exotic species Acacia auriculiformis and Eucalyptus camadulensis compared to indigenous species Shorea robusta and Mangifera indica. There are 12 sample plots (size 36x36 m) were selected from the study area following the purposive random sampling. A total of 720 quadrats (12 plots x 10 quadrats x 6 seasons) were placed in the sample plots to collect the undergrowth vegetation data over two years of 2010-11 following summer, monsoon and winter season. The average value of Shannon-Wiener diversity index was 2.65±0.16 and 3.28±0.13 that of Simpson's diversity index was 0.87±0.02 and 0.93±0.01 and that of Margalef's diversity index was 7.34±0.77 and 10.43±0.52 collectively in all exotic and indigenous plots, respectively. This scenario depicts that the extent of species diversity was higher in indigenous tree species plots than in exotic tree plots and the flora of the study area was highly diversified. The Shorea plots were richer in species diversity out of the four species categories of sampling plots. The index values of three diversity indices were significantly different for the exotic and indigenous tree plots, excluding Eucalyptus and Mangifera species plots, which mean the undergrowth species diversity of Eucalyptus and Mangifera species plots, were not significantly different. Adequate awareness building programs need to conduct among the local community and Bangladesh Forest Department to understand environmental degradation, the importance of conservation management of indigenous 'Sal' forest and significance of plant diversity in the village forest for future generations.

Key Words: *Shannon-Wiener diversity index, Phytodiversity, Monoculture, Exotic, Indigenous and Undergrowth*

Cite Article: Rahman, M. M., Khan, S. A., Hossain, G. M. and Rahim, M. A. (2021). Undergrowth phytodiversity index in exotic and indigenous tree plots in Hoteya forest range of Sakhipur upazila under Tangail forest division, Bangladesh. International Journal of Forestry, Ecology and Environment, 04(01), 141-152. **Crossref:** https://doi.org/10.18801/ijfee.040121.16

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EISSN: 2708-5430,

I. Introduction

In Bangladesh, plantation programs with exotic tree species prioritize both the public and private sectors. A priority program of fast-growing exotic tree species has recently been taken up to minimize the acute shortage of timber, fuel wood and contribute to poverty reduction in Bangladesh. Block or woodlot plantation includes fallow lands with degraded fertility, which is not suitable for agricultural production. A lot of plantation (afforestation and/or reforestation) programs with exotic tree species have shown success in Bangladesh (Hossain and Pasha, 2001; Ara et al., 1989) through proper choice of species, particularly regarding some exotics tree species plantations (i.e. *Acacia auriculiformis* and *Eucalyptus camaldulensis* is still under debate (Bouvet, 1998; Abbasi and Vinithan, 1997; Poore and Fries, 1985). The campaign of social forestry programs did facilitate plantation of exotic tree species in 1980's publicizing the planting of individual fast-growing exotic trees with higher timber value and fuel wood value. The previous research has stressed the potential advantages and environmental benefits of indigenous tree species plantations instead of exotic tree species (Piotto et al., 2010; Erskine et al., 2006; Lambert et al., 2005; Hartley, 2002). However, there is strong debate in the field on the impacts of exotic tree species plantation in comparison to indigenous tree species in different plantation programs. Jactel and Brockerhoff (2007) studied the advantages and impacts of mixed tree species plantations or polyculture over monoculture and their analysis depicted that the mixture of tree species in plantation might be more imperative because the effects of species diversity on herbivory (animals that feed on plants) were much better in mixed species forests condition comparison to taxonomically more distant tree species (Felton et al., 2016; Kibria and Anik, 2010; Hooper et al., 2005). Dogra et al. (2010) in study reviewed alien invasive plants and their impact on indigenous species diversity. The study mentioned that plant invasion is a threat to species diversity worldwide during the 21st century. Invasive species affect indigenous species diversity, soil dynamics and the economics of the agricultural ecosystem (Schierenbeck and Ellstrand, 2009; Pimentel et al., 2005).

Rahman (2001) conducted a study on plant diversity and soil nutrient status of central Sal forests of Bangladesh but did not found a prominent influence of soil properties on overall phytodiversity and species richness. He finds out several causes for the reduction of phytodiversity and gradation of soil quality in Sal forests. The plantation of indigenous plant species has always been the essential source of timber, fruits, food, fodder, fuel, bamboo, canes, medicines etc., though the land-use changes have altered the vegetation of village forest and indigenous Sal forests of Bangladesh. In other studies, a good number of people and stakeholders have raised their opinion against the plantation of exotic tree species like *A. auriculiformis* and *E. camaldulensis* in plantation programs and claim that these exotic species are damaging our ecosystems, losing plant diversity (Hossain et al., 2002) although these public opinions were not supported by proper evidence (Hossain, 2003). In Bangladesh, research on agroforestry, poverty alleviation, socio-economic impacts of social forestry, ecology, phytodiversity and soil nutrient status of 'Sal' tract and performance of exotic plantation has been carried out by several researchers like Rahman et al. (2016), Hossain et al. (2010), Rahman et al. (2010), Ali (2009), Rahman (2001) and Islam (1998). Few research were conducted in different areas of this country on undergrowth species composition (Malaker et al., 2010; Al-Amin et al., 2004; Ahmed; 1996) and also in the country's central deciduous Sal forest areas (Rahman, 2009; Khan et al., 2007; Rahman, 2001; Green, 1981). Some other studies on plantation programs have been conducted in central Sal (*Shorea robusta*) forest areas of Bangladesh (Alam et al., 2008; Haque, 2007; Motiur, 2006; Kabir and Ahmed, 2005). Rahman (2001) worked on soil properties, forest ecology and plant diversity of central Sal forests of Bangladesh. However, previous studies did not give proper attention to the remote areas like Sakhipur of Tangail to know and compare the status of the phytodiversity in the Sal forest and the monoculture woodlots established in private lands in and around the Sal forest areas of Sakhipur region. The study's objectives were to investigate the comparative status of phytodiversity indices of the undergrowth in exotic and indigenous tree plots of the study area.

II. Materials and Methods

Description of the study area

The Sakhipur upazila occupies 435 km^2, including 191 km^2 forest area (BBS, 2012). Sakhipur is situated 80 km north of the capital city Dhaka. It is located between 24°11´and 24°26´ north latitudes; and between 90°04´ and 90°18´ east longitudes (Figure 01). The study region falls under sub-tropical

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EISSN: 2708-5430,

monsoon where found three distinct seasons, namely summer, which covered March to mid June, monsoon which covered mid June to mid October and the winter which covered mid October to February. In the study area, the mean annual rainfall ranges from minimum 1126 to maximum of 2748 mm and the mean annual temperature from minimum of 20.25°C to maximum of 31.48°C. This tropical climate condition is characterized by a distinct rainy season (April to October) and a dry season (November to March). The relative humidity varies between 69 and 86%, the duration of sunshine ranges average from 5-9 hours and average maximum wind speed was 87 km/hour (NWRD/CEGIS, 2015). The soils of this area have a moderate to strong acidic reaction. Usually, there are three prominent soil types observed in Sakhipur areas, *viz*., deep red brown terrace soils, shallow red-brown terrace soil and brown mottled terrace soils (Richards and Hassan, 1988). About half of the Sal forests land is covered by deep red-brown terrace soil. The soils are moderate to strongly acidic with pH 5.0-5.5 (UNDP/FAO, 1988).

Sampling and data collection

Since the study focused on evaluating phytodiversity status in the exotic and indigenous sample plots, we consulted with the local Forest Department officials, NGOs and local people to find out the sample plots as of research objectives. Finally, *Acacia*, *Shorea, Eucalyptus* and *Mangifera* dominant species-area were identified and 12 sample plots were selected following purposive random sampling (Figure 01). These 12 sample plots located in public and private land were composed of 3 *Acacia auriculiformis* plots, 3 *Shorea robusta* plots, 3 *Eucalyptus camaldulensis* plots and 3 *Mangifera indica* plots. Each sample plot size (36 m x 36 m = 0.132 ha) was considered in connection to research objectives (Figure 01). The exotic species *Acacia auriculiformis* occupied the plantation's major percentage at Sakhipur upazila of Tangail district, but the *Eucalyptus camadulensis* plantations and *Swietenia macrophylla* were very less in that area. Furthermore, Sakhipur is dominated by indigenous *Shorea robusta* forest, considered true plots for research objectives.

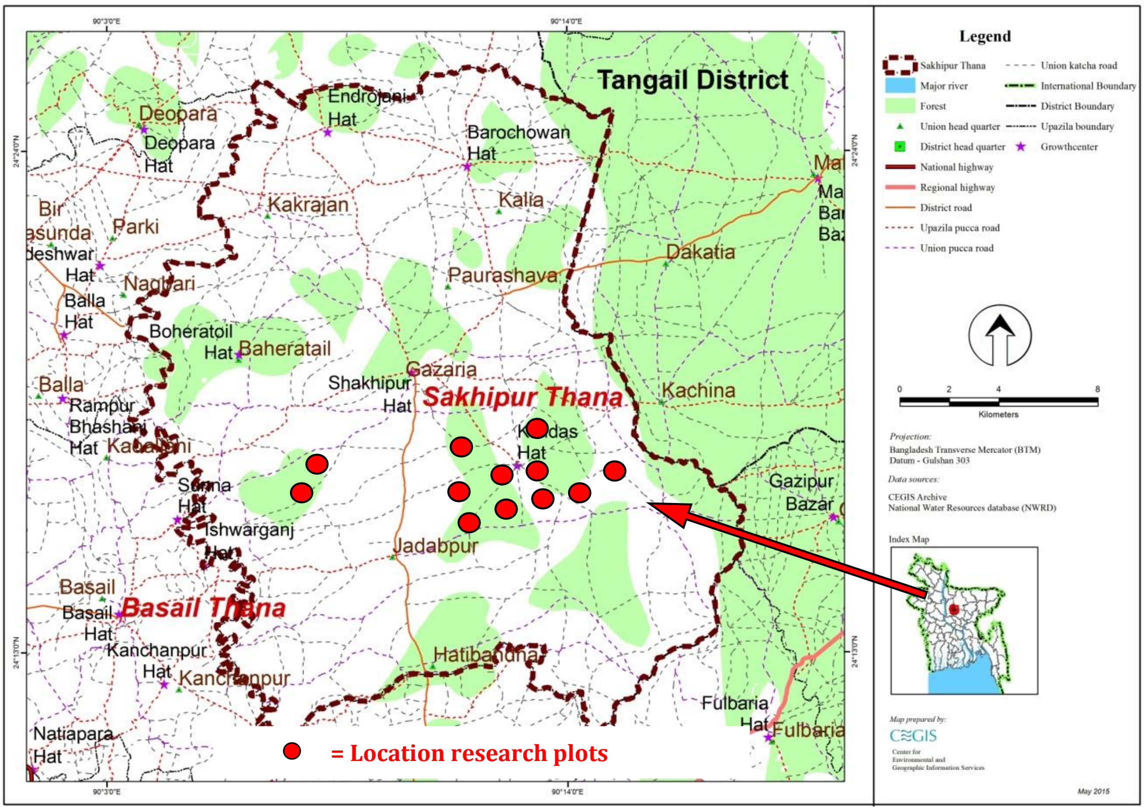

Figure 01. Location of research plots in the study area, Sakhipur, Tangail (CEGIS, 2015)

The summer, monsoon and winter seasons were considered for data collection. The undergrowth survey was done for 2 years (2010-2011) in April, July and November, which covered summer, monsoon and winter seasons, respectively. Transect method was applied to survey the selected plots of the study area to assess the ecological status of the undergrowth. Hence, the transect line was laid out across the sample plots and necessary number of quadrats were placed systematically. To determine the standard size of the quadrate, the 'Species Area Curve (SAC)' (Braun-Blanquet, 1964;

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Cain, 1938) was prepared first. Based on SAC data, the 4m x 4m size was the convenient quadrate size for collecting the undergrowth data. To assess undergrowth species diversity data were collected following the quadrat method (Raunkiaer, 1934; Braun-Blanquet, 1932). In each sample plot, 10 quadrats were placed systematically following transect line. Thus for undergrowth vegetation survey, the data were collected from a total of 720 quadrats (12 plots x 10 quadrats x 6 seasons) (covering two percent of total area) from these sample plots in 6 seasons over two years of 2010-11, which represent 2% of the total sample plot areas.

Specimen collection and identification

Identification of all plant specimens collected from Sakhipur, Tangail has been confirmed through consultation with the experienced plant taxonomists of Plant Systematics and Biodiversity Laboratory, Department of Botany, JU and BNH. Moreover, matching the specimens with (i) authentically identified herbarium specimens housed at BNH, Dhaka University Salar Khan Herbarium and Jahangirnagar University Herbarium (JUH), (ii) clear type images available in the websites of different international herbaria, and (iii) taxonomic descriptions and keys available in standard taxonomic literature (Hooker, 1872-1897; Prain, 1903; Nasir and Ali, 1980-2005; Wu et al., 1995-2013; Siddiqui et al., 2007-2008; Ahmed et al., 2008-2009; Watson et al., 2011; Flora of North America Editorial Committee, 1993-2014). Using the standard herbarium techniques (Jain and Rao, 1977; Hyland, 1972), the freshly collected specimens were processed correctly, pressed and properly managed in the field and later on, dried and preserved at JUH, maintained in Plant Systematics and Biodiversity Laboratory, Department of Botany, JU.

Data analysis

SPSS software (version 16.0) was used for data analysis. To test for significant differences ($P<0.05$), the one way ANOVA (DMRT) tool was used to determine marginal means of variables. Besides, data were also analyzed through Microsoft Excel.

Shannon-Weiner diversity index

The Shannon-Weiner Diversity Index (Shannon and Wiener, 1963) is one of several diversity indices used to measure species diversity. It takes into account the number of species and evenness of the species. This index was calculated from the following formula given by Magurran (1988):

Shannon-Wiener Diversity Index (H) $= -\Sigma\ (n/N)\ \text{In}\ (n/N)$
$= -\Sigma\ pi\ \text{In}\ pi$

Where,

Pi= n/N = Proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover.
n= number of individuals of a particular species.
N= total number of individuals of all species.
In= log base; In other words, *Pi* is the proportion of the i^{th} species and the number of all individuals of all species (*ni/N)*.

The standard range of Shannon-Weiner Diversity Index is 1-4. The highest value of Shannon-Wiener Diversity Index value indicates highly diversified area and lowest value indicates low diversified vegetation.

Simpson diversity index

Simpson's Diversity Index (Simpson, 1949) is one of the diversity indices used to measure species diversity. This diversity index was calculated using the following formula:

$D = \Sigma\ (n / N)2$ or $D= D = \Sigma(Pi)^2$

Where,

D= Simpson's diversity index
n= number of individuals of a particular species
N= total number of individuals of all species.
pi is the same as for the Shannon-Wiener information function.

It can range between 0 and 1, where 0 is infinite diversity, and 1 is the least diverse an ecosystem can possibly be (i.e. only one species present). With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. After measuring the Simpson index (D), its reciprocal 1-D is considered to measure the biodiversity index. So that the higher value indicates higher diversity and lower value indicates lower diversity.

Margalef's diversity index of species richness

Margalef's index was used as a simple measure of species diversity (Margalef, 1958). It is calculated from the total number of species present and the abundance or total number of individuals. The higher the index value, the greater the diversity. The Margalef index measures species richness (Magurran, 2004). This index was calculated using the following formula:

Margalef's index = (S – 1) / In N

Where

S= Total number of species
N= Total number of individuals in the sample
In= natural logarithm

For Margalef index there is a sub estimation of the index. Species richness is the number of different species in a given area. Usually, the species richness was calculated to determine the sensitivity of these ecosystems and their resident species. The number of species per sample is a measure of richness. The more species present in a sample, the 'richer' the sample is.

III. Results and Discussion

Sakhipur is a part of the Madhupur Sal tract, due to which its plant species composition is almost similar to that of other parts of this tract. The Sal forest of Sakhipur is composed of few scattered and degraded patches. *Shorea robusta* is dominant in Sal forest, representing 70% to 75% of the forest trees and associated with other tree species and medicinal plants (Khan, 1990). Besides, the *Shorea* trees, *Acacia*, *Eucalyptus, Swietenia*, *Artocarpus., Mangifera and Albizia* are commonly found in the area's village forests, though *Acacia* is dominant. Rahman et al. (2016) recorded 182 plant species under 150 genera and 56 families, of which 47, 19 and 116 species were classified as trees, shrubs and herbs, respectively. The research also revealed that the exotic tree plots comprised 19% less species compared to indigenous plots. This study has assessed the plant diversity of the monoculture of exotic species *Acacia auriculiformis* and *Eucalyptus camaldulensis* compared to the plantation of indigenous species *Shorea robusta* and *Mangifera indica* in research plots in 'Sal' forest area of Sakhipur area.

Shannon-Weiner diversity index

Considering all undergrowth species of all sample plots, Shannon-Wiener diversity index (H) values were found to vary between 1.47 and 2.27, where the highest value 2.27 was recorded from Shorea plots monsoon season and the lowest value 1.47 from *Eucalyptus* plots during winter season. The highest mean value (2.25±0.02) of Shannon-Wiener diversity index was found in *Shorea* plots, which was followed by the index values 1.75±0.09, 1.72±0.09, and 1.60±0.11 recorded from *Acacia, Mangifera* and *Eucalyptus* plots, respectively (Table 01). The average value 2.19±0.09 of Shannon-Wiener diversity index was recorded as the highest for indigenous plots, whereas the lowest value 1.77±0.11 was recorded for exotic plots (Table 01). Therefore, Shannon-Wiener diversity index data calculated for four types of plots showed the following trend in four types of sample plots**-***Shorea* >*Acacia* >*Mangifera* >*Eucalyptus* plots. On the other hand, considering only the seedling and saplings of tree species as the undergrowth, the highest mean value 1.11±0.05 was recorded from *Shorea* plots, which was followed by 0.95±0.15, 0.76±0.10 and 0.70±0.04, recorded from *Eucalyptus*, *Mangifera* and *Acacia* plots, respectively (Table 01). The highest mean value 1.23±0.08 was found in indigenous plots and the lowest mean value 0.77±0.11 was found in exotic plots (Table 02). Shannon-Wiener diversity index's mean values calculated for the seedling and saplings of all tree species as undergrowth growing in all of four selected plots showed the following sequence in terms of index values**-** *Shorea* > *Eucalyptus*>*Mangifera* >*Acacia* plots.

Table 01. Shannon-Wiener diversity index (H) of different exotic and indigenous plots during summer, monsoon and winter seasons in Sakhipur, Tangail.

Seasons	All undergrowth species				Undergrowth tree species only			
	Acacia plots	*Eucalyptus* plots	*Shorea* plots	*Mangifera* plots	*Acacia* plots	*Eucalyptus* plots	*Shorea* plots	*Mangifera* plots
Summer	1.86	1.67	2.24	1.79	0.75	0.78	1.08	0.87
Monsoon	1.69	1.67	2.27	1.63	0.69	0.99	1.08	0.72
Winter	1.72	1.47	2.25	1.75	0.67	1.07	1.17	0.68
Average	1.75	1.60	2.25	1.72	0.70	0.95	1.11	0.76
±SD	±0.09	±0.11	±0.02	±0.09	±0.04	±0.15	±0.05	±0.10

Table 02. Shannon-Wiener diversity index (H) in exotic and indigenous plots during summer, monsoon and winter seasons in Sakhipur, Tangail.

Seasons	All undergrowth species		Undergrowth tree species only	
	Exotic plots	Indigenous plots	Exotic plots	Indigenous plots
Summer	1.89	2.28	0.90	1.14
Monsoon	1.74	2.11	0.73	1.27
Winter	1.68	2.18	0.68	1.29
Average	1.77	2.19	0.77	1.23
±SD	±0.11	±0.09	±0.11	±0.08

The Shannon-Wiener diversity index's values showed that the flora of the study area was highly diversified and the extent of phytodiversity was higher in indigenous, especially in Sal (Shorea) forest area than in exotic species plantation areas. The Shannon-Wiener diversity index value (1.75±0.09) found in the study area's *Acacia plots* was much less than the value 6.07 reported by Chowdhury and Huda (2002) for the *Acacia* plots in the forests of Bangladesh. The findings of average Shannon-Wiener index value (2.19±0.09) for all indigenous plots seems similar to that of Roy et al. (2011), but the value found for exotic tree plots (1.77±0.11) was less with their index value (2.73) reported for natural degraded 'Sal' forest in Modhupur. The findings of average Shannon-Wiener index value (2.19±0.09) for all indigenous plots and that (2.25±0.02) from *Shorea* plots seem lower than the index value (3.23) reported by Kumari and Biswas (2003) from Selakui Sal forest of India and that (3.29) reported by Kumar et al. (2006) from secondary Sal forests of Garo Hills of India. The Shannon-Wiener index value (1.60±0.11) found in *Eucalyptus* plots was notably higher than that (0.59) reported by Tyynela (2001) for *Eucalyptus camaldulensis* woodlots in north-east Zimbabwe. All values of the Shannon-Wiener index found in the research plots seem similar to the index value reported by Sapkota et al. (2009) from Sal forest in Nepal (2.29), Dutta and Devi (2013) from Sal (*Shorea robusta* Gaertn.) forest of Assam, north-east India (2.32) and Chaturvedi and Raghubanshi (2014) Sal forest of India (2.26). The study results on species diversity depicted that indigenous tree plots, especially the *Shorea* plots, are rich in species diversity than the tree plots of exotic species supported by Montagnini et al. (2005). Moderately high diversity of plants (trees, shrubs and herbs) were found in the indigenous *Shorea* forests, though the areas were facing human settlement, encroachment, leaf litter collection, over-exploitation, illegal tree felling and multifarious anthropogenic activities.

Simpson diversity index (1-D)

Simpson's diversity index (1-D) was found to be varied from 0.83 to 0.94 when all undergrowth species of all research plots are considered. The highest value 0.94 was recorded from *Shorea* plots in most of the seasons and the lowest value 0.83 was recorded from *Eucalyptus* plots during winter season. The highest average value 0.94±0.00 of Simpson's index was recorded from *Shorea* plots, which was followed by 0.88±0.02 recorded from both *Acacia* and *Mangifera* plots and 0.85±0.02 recorded from *Eucalyptus* plots. The mean value 0.93±0.01 of Simpson's index of all indigenous plots was found to be higher than that (0.87±0.02) of all exotic plots (Table 03). Considering Simpson's diversity index values found in all four types of plots showed the following sequence- *Shorea* >*Acacia*>*Mangifera*>*Eucalyptus* plots. On the other hand, only considering the undergrowth tree species, the highest mean value 0.75±0.09 was recorded from *Eucalyptus* plots that were followed by 0.60±0.04 and 0.52±0.15 were recorded from *Shorea* and *Mangifera* plots, respectively, whereas the lowest mean value 0.34±0.07 was recorded from *Acacia* plots. The highest mean value 0.67±0.06 was found in indigenous plots and the lowest mean value 0.41±0.09 was found in exotic plots (Table 03).

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Therefore, the available data regarding Simpson's diversity index of four selected plots showed the following sequence as**-** *Eucalyptus*> *Shorea*>*Mangifera*>*Acacia* plots.

Table 03. Simpson diversity index (1-D) of different exotic and indigenous plots during summer, monsoon and winter seasons in Sakhipur, Tangail.

Seasons	All undergrowth species				Undergrowth tree species only			
	Acacia plots	*Eucalyptus* plots	*Shorea* plots	*Mangifera* plots	*Acacia* plots	*Eucalyptus* plots	*Shorea* plots	*Mangifera* plots
Summer	0.90	0.87	0.94	0.90	0.43	0.85	0.57	0.64
Monsoon	0.86	0.86	0.94	0.86	0.31	0.67	0.57	0.58
Winter	0.87	0.83	0.94	0.88	0.29	0.74	0.64	0.35
Average ±SD	0.88 ±0.02	0.85 ±0.02	0.94 ±0.00	0.88 ±0.02	0.34 ±0.07	0.75 ±0.09	0.60 ±0.04	0.52 ±0.15

Table 04. Simpson diversity index (1-D) in exotic and indigenous plots during summer, monsoon and winter seasons in Sakhipur, Tangail.

Seasons	All undergrowth species		Undergrowth tree species only	
	Exotic plots	Indigenous plots	Exotic plots	Indigenous plots
Summer	0.90	0.94	0.51	0.61
Monsoon	0.86	0.92	0.40	0.69
Winter	0.86	0.93	0.34	0.72
Average ±SD	0.87 ±0.02	0.93 ±0.01	0.41 ±0.09	0.67 ±0.06

In all exotic and indigenous plots, the average Simpson's diversity index (1-D) were 0.87±0.02 and 0.93±0.01 respectively, whereas 0.88±0.02, 0.85±0.02, 0.94±0.00 and 0.88±0.02 in *Acacia, Eucalyptus, Shorea* and *Mangifera* plots respectively considering all undergrowth species (Table 04). Nearly similar results were also found by Chowdhury and Huda (2002) from the *Acacia* plots in forests of Bangladesh (0.97) and Das and Sarker (2014) from *Acacia auriculiformis* plots in Bhawal 'Sal' forest (0.71). All values of Simpson's diversity index found in the study plots were higher than the index value reported by Sapkota et al. (2009) from 'Sal' forest in Nepal (0.56), Gupta and Kumar (2014) from northern Indian 'Sal' forest (0.18) and Dutta and Devi (2013) from 'Sal' (*Shorea robusta*) forest of Assam, north-east India (0.15).

Margalef's index of species richness

When all undergrowth species were considered in analysis, the values of Margalef index varied between 3.54 and 9.85, where the highest value 9.85 was recorded from *Shorea* plots during summer season and the lowest value 3.54 from *Eucalyptus* plots during winter season. The highest mean value of Margalef index 9.22±0.65 was recorded from *Shorea* plots, which was followed by 6.66±0.54, 4.94±1.30 and 4.32±0.35 recorded from *Acacia*, *Eucalyptus* and *Mangifera* plots, respectively. The average value 10.43±0.52 of Margalef index recorded for indigenous plots was higher than that (7.34±0.77) recorded for exotic plots (Table 05). Margalef index's values found in four types of plots showed the following sequence- *Shorea*>*Acacia*>*Eucalyptus*>*Mangifera*>plots. On the contrary, considering the undergrowth tree species i.e., the seedlings and saplings of tree species only, the highest mean value 3.51±0.33 was recorded from *Shorea* plots, which was followed by 2.29±0.59, 1.53±0.57 and 0.78±0.22 recorded from *Acacia*, *Eucalyptus* and *Mangifera* plots, respectively. The highest mean value 3.50±0.35 was found in indigenous plots and the lowest mean value 2.49±0.48 was found in exotic plots (Table 05). Margalef index's values found in four types of plots showed the following sequence**-***Shorea*> *Acacia*> *Eucalyptus*>*Mangifera*>plots.

In all exotic and indigenous plots, the average Margalef's index were 7.34±0.77 and 10.43±0.52 respectively, whereas 6.66±0.54, 4.94±1.30, 9.22±0.65 and 4.32±0.35 in *Acacia, Eucalyptus, Shorea* and *Mangifera* plots, respectively considering all undergrowth plant species (Table 06). The average value of Margalef's index shows that the study area's vegetation was highly diversified, where the phytodiversity was higher in indigenous and *Shorea* tree plots than that of exotic and *Acacia* tree plots. The average Margalef's index value found in the indigenous tree plots (10.43±0.52) or *Shorea* plots (9.22±0.65) of the study area is higher than that reported by Sapkota et al. (2009) from 'Sal' (*Shorea*

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robusta) forest in Nepal (5.18), Kibria and Anik (2010) from homestead village forest of Northern Part of Bangladesh (5.11), Roy et al. (2011) from natural degraded 'Sal' forest in Modhupur (2.54) and Chaturvedi and Raghubanshi (2014) from 'Sal' forest of India (7.96). The Margalef's index value found in *Acacia* plots (6.66±0.54) of the study area is higher than (4.6) reported by Das and Sarker (2014) from old *Acacia auriculiformis* plots in Bhawal 'Sal' forest.

Table 05. Margalef's index of different exotic and indigenous plots during summer, monsoon and winter seasons in Sakhipur, Tangail.

Seasons	All undergrowth species				Undergrowth tree species only			
	***Acacia* plots**	***Eucalyptus* plots**	***Shorea* plots**	***Mangifera* plots**	***Acacia* plots**	***Eucalyptus* plots**	***Shorea* plots**	***Mangifera* plots**
Summer	6.77	6.10	9.85	4.04	2.59	2.19	3.88	1.01
Monsoon	7.13	5.19	9.27	4.20	2.67	1.25	3.23	0.56
Winter	6.07	3.54	8.54	4.71	1.61	1.15	3.43	0.77
Average	6.66	4.94	9.22	4.32	2.29	1.53	3.51	0.78
±SD	±0.54	±1.30	±0.65	±0.35	±0.59	±0.57	±0.33	±0.22

Table 06. Margalef's index in exotic and indigenous plots during summer, monsoon and winter seasons in Sakhipur, Tangail.

Seasons	All undergrowth species		Undergrowth tree species only	
	Exotic plots	**Indigenous plots**	**Exotic plots**	**Indigenous plots**
Summer	7.89	11.03	2.80	3.86
Monsoon	7.66	10.18	2.74	3.16
Winter	6.46	10.09	1.94	3.48
Average	7.34	10.43	2.49	3.50
±SD	±0.77	±0.52	±0.48	±0.35

The results of species diversity based on three diversity indices depicts that indigenous tree plots, especially the *Shorea* plots, are rich in species diversity than exotic species plots, supported by Montagnini et al. (2005). Moderately high diversity of plants (i.e. trees, shrubs and herbs) were found in the indigenous *Shorea* forests, though the areas were facing human settlement, encroachment, leaf-litter collection, over-exploitation, illegal tree felling and multifarious anthropogenic activities. Species diversity in Sal forests of Sakhipur areas contributes to the local people's economy by supplying foods, fodder, fuel wood, medicines, and other non-timber forest products (NTFPs).

Field observations showed that the *Acacia* and *Eucalyptus* plots did not support the undergrowth vegetation supported by the natural *Shorea* forests. It indicates that the monoculture of exotic tree species may negatively affect the species richness and diversity of the undergrowth species. It was found that, when the large numbers of individuals of many dominant species were associated with rare species with few individuals, then the species diversity appears high. In the exotic tree plots, the number of grass and sedge individuals was found much higher than indigenous tree plots and as a result, the values of diversity indices for the exotic tree plots were increased. However, the data analysis excluding the grass and sedge individuals showed that the diversity indices for exotic tree species were much lower than that of indigenous plots. In the study areas, it was seen that the old tree plots provide favorable habitat for numerous indigenous species, including the undergrowth. In the study sites, the micro-climatic differences in temperature, light and air were happened due to canopy structure that are occupied by *Shorea robusta*, which has a positive effect on vegetation growth and establishment.

In Sakhipur Sal forest areas, numerous anthropogenic pressures including human settlement, urbanization and industrialization, irresponsible plantation forestry activities with exotic tree species, over-exploitation, lack of appropriate management systems and protection measures, absence of enough wildness in the habitats and lack of adequate public awareness etc., are responsible for decreasing plant species diversity and species richness there. Local peoples and workers have also reported negative vegetation patterns and structural changes due to forest degradation, deforestation, and reforestation activities. Different management systems operated in the study area's woodlots and forests were an important reason for the internal variation in species richness for the exotic and

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indigenous sites. Some woodlot tree growers weed out seedlings of indigenous or associate species, but other growers encouraged such species' growth. In some cases, fire was allowed to pass through the indigenous stands (*Shorea robusta*) as a weed control method and add ashes into soil, supported by Tyynela (2001). The field observation during the study also suggested that if the above stresses or factors remain active, then the plant diversity existing in the study area might be lost. In the study area, some species occurred in either plantation forest or natural forest only and constituted different species composition there. It noted that most of the plantation forest of the study area was comparatively disturbed. However, few were in controlled or wilderness conditions and these undisturbed woodlot plots showed more species diversity and regeneration status which is positively remarkable in Hoteya forest range of Sakhipur areas of Bangladesh. Uemura (1994) reported that, the species diversity of understory vegetation in different environments vary with light condition. In the monoculture plantation, the trees were planted with more or less similar gaps owing to which a homogeneous canopy was formed. Whereas in case of Sal forest, the trees were naturally scattered in position, owing to which a homogeneous canopy was not formed. Thus, the penetration and falling of solar light on the ground of exotic and indigenous tree plots were different, and undergrowth regeneration has been affected differently. Thick, leathery and phyllodic leaves of this exotic species (*Acacia auriculiformis*) and their dense canopy may also affect the number, growth and development of the undergrowth plant species (Ahmed, 1996). The natural recruitment density is frequently disturbed or damaged due to clearing of forest floor, human interference, grazing/trampling, and leaf litter collection (Kotiluoto and Makandi, 2004) and these stresses were found operating in most of the research plots of the study area.

IV. Conclusion

Most of the terrestrial biodiversity harbored in the forests resides in undergrowth vegetation and data on undergrowth species of the forests help us to have an idea of the actual species diversity existing under their canopy cover, undergrowth species diversity is higher in indigenous tree plots than in exotic tree plots. The monoculture of exotic tree species fails to ensure the sustainability of plant diversity. Detailed investigations on the effect of exotics tree species in ecological aspects and their impacts on the formation of the undergrowth are not available. Nevertheless, the studies on forest undergrowth species and the impacts of exotic versus indigenous tree species plantation on the undergrowth are inadequate in our country. Published information and research articles on the species composition and diversity in plantation of exotic species plots and indigenous forests on the Sakhipur areas of Tangail are not available. This study gives an insight into the plant diversity of monoculture of exotic tree species plots and indigenous research plots. The indigenous research plots, especially the *Shorea* plots, harbor higher number of species than the exotic species research plots in all seasons and the number of uncommon species is relatively higher in indigenous tree plots than that in exotic tree plots facing similar extent of ecological and anthropogenic stresses. In this context, detailed comparative studies on phytodiversity studies in the monoculture of exotic tree species versus indigenous tree species plots need to be conducted to understand much better required for conservation of plant diversity for sustainable development.

Acknowledgment

The authors thank Bangladesh Forest Department for permits to work in the forest of Tangail forest division and also Bangladesh National Herbarium, Dhaka, to support the study.

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