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Undergrowth Species Composition of the Exotic and Indigenous Tree Plotsin Deciduous Forest Area of Hoteya Forest Range of Tangail District, Bangladesh

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Abstract: This study was conducted to assess the impacts of monoculture of exotic tree species on the species composition and status of undergrowths in relation to that of indigenous tree species and to provide the baseline data on the undergrowth species of the plantation forests of exotic and indigenous tree species. This study reports 116 undergrowth species belonging to 97 genera and 52 families of vascular plants from the tree plots of exotic *Acacia auriculiformis* A. Cunn. ex Benth. and *Eucalyptus camaldulensis* Dehnh. and 150 undergrowth speciesunder 122 genera and 56 families from those of indigenous *Shorea robusta* Roxb. and *Mangifera indica* L. of Hoteya Forest Range of Tangail district. Most of the 182 undergrowth species, found in exotic and indigenous tree plots together, were Angiosperms (±95%) and only ±5% were Pteridophytes. 63.74% of these species were herbs, 25.82% trees and 10.44% shrubs. In exotic tree plots, the undergrowths of 86, 87 and 76 species, and in indigenous tree plots, the undergrowths of 118, 113 and 111 species were found in summer-, monsoon- and winter seasons, respectively. In *S. robusta*-, *A. auriculiformis*-, *E. camaldulensis*-, and *M. indica* tree plots, a total of 93, 69, 61 and 42 species were found in summer; 90, 77, 55, and 46 species in monsoon; and 82, 68, 39 and 51 species in winter seasons, respectively. In exotic tree plots, *Axonopus compressus* (Sw.) P. Beauv. was found in highest relative density and frequency and *Cyperus iria* L. in highest relative abundance, whereas, in indigenous tree plots, *A. compressus* was found in highest relative density and abundance, and *Clerodendrum infortunatum* L. in highest relative frequency. Species number and density were significantly different among the plots of *A. auriculiformis*, *S. robusta*, *M. indica* and *E. camaldulensis*. This study concludes that, indigenous tree plots harbor the higher number of species (18.68%) than the exotic tree plots, considering all types of plant species and all seasons and the number of uncommon species was relatively higher in indigenous tree plots than that in exotic tree plots. It proves that plantations of indigenous tree species are relatively better in harboring better species richness and diversity. The data provided by this study will be useful in biodiversity conservation and in appropriate selection of tree species for better plantation programs. This study suggests for preferring the indigenous species for plantation programs in forested and fertile land areas; and exotic species for that in the degraded or barren areas with strict maintenance of the natural condition.

Keywords: Undergrowth, Exotic, Indigenous, *Acacia*, *Shorea*, Plot

1. Background

Exotic species are the non-natives that grow outside their natural ranges and dispersal potential (Randall, 1996). Many of the exotic tree species had been introduced to new habitats by humans (Ridenour and Callaway, 2001 and Dogra *et al.*, 2010) due to economic reasons, especially commercial timber production (Hossain and Pasha, 2001; Bhagwat *et al.*, 2012; Mukul *et al.*, 2006), their efficient dispersal capacities, large reproductive output, and greater tolerance to a broad range of environmental conditions (Campbell, 2005).

Indigenous species are those that grow in an area only naturally, i.e., without any human intervention since many years or over a geologic time. Such species growing in their natural ranges and dispersal potential has the positive role on food security and in bringing economic, environmental and social benefits.

Both the exotic and indigenous timber yielding species are being used in creating the plantation forests or intensively managed forest stands artificially with the primary purpose of wood production (Evans, 1999). Various plantation or reforestation and afforestation programs with exotic tree species have shown success (Hossain and Pasha, 2001; Ara *et al*., 1989). In contrast, the exotic plant species can be invasive when they are deliberately or intentionally planted outside their natural range into new areas where they are able to establish themselves and quickly invade and out-compete native plant species for resources (Randall, 1996; Williamson, 1996 and Akter and Zuberi, 2009). Recent research has emphasized on the potential advantages of plantation with indigenous species instead of exotic species (Erskine *et al*., 2006; Hartley, 2002; Lambert *et al*., 2005; Piotto *et al*., 2010), however, there is a strong debate on the impacts of using exotic versus indigenous tree species in plantation programs.

In Bangladesh, two exotic species, *A. auriculiformis* and *E. camaldulensis*, are most commonly used in various reforestation and afforestation programsbecause of their fast growing characteristics and production of high volumes of biomass within a short time frame, short rotation, non-palatability to grazing animals and ability to thrive in poor soils. In this country, plantation programs with exotic tree species are getting priority in both public and private sectors. But, the choice of the species is still under debate. Some public opinions have also been raised against the cultivation of exotic species like *A. auriculiformis* and *E. camaldulensis* in plantation programs claiming that these species have a damaging impact on the ecosystems, though such opinion is not backed by sufficient scientific information and research or field experiments (Hossain, 2003). Some studies on the growth performance and impacts of the exotic species have been conducted by different authors (Chowdhury, 1982; Das, 1982; Hossain *et al*., 1998; Hoque, 1977; Davidson and Das, 1985; Amin *et al*., 1995 and Elahi, 2006 and 2008). However, the existing research on exotic species in Bangladesh is still very limited in terms of detailed investigations of their effects on native ecosystems (Akter and Zuberi, 2009; Barua *et al*., 2001; Hossain and Pasha, 2001; Hossain, 2003 and Islam *et al*., 2003). Detailed and quantitative investigations of exotics in biogeographic and ecological aspects, including their impacts on formation of the understories, are still scarce (Biswas *et al*., 2007, 2012; Islam *et al*., 1999).

On the other hand, though much of the biodiversity harbored in the forests resides in undergrowth vegetation and data on undergrowth species ofthe forests help us to have an idea on the actual species richness and diversity existing under their canopy cover, studies on undergrowth species in forested areas and impacts of plantations with exotic versus indigenous tree species on the undergrowths are still scarce, especially in Bangladesh. Some studies on undergrowth species composition in different areas of this country (Ahmed; 1996; Al-Amin *et al*., 2004; Malaker *et al*., 2010) including the deciduous 'Sal' (*S. robusta*) forest areas of Modhupur-Mymensingh-Gazipur region (Green, 1981; Rahman, 2001, 2009; Khan*et al*., 2007) have been conducted. However, no study included an integrated and comparative inventory on the composition of undergrowth species in exotic and indigenous tree plots of this country.

The Hoteya Forest Range of Tangail district, one of the forest areas that harborthe typical deciduous forests of *S. robusta* as well as the massive plantations of exotic tree species, isan appropriate area for conducting a comparative study on undergrowth composition in exotic and indigenous tree plots. The objectives of this study were to assess the impacts of monoculture of exotic tree species on the species composition and status of undergrowths in relation to that of indigenous tree species and to provide the baseline data on the undergrowth species of the plantation forests of exotic and indigenous tree species that might be useful in biodiversity conservation and appropriate selection of tree species for massive plantation programs.

2. Methods

Study area: The study area Hoteya Forest Range, located in between 24°11´and 24°26´ north latitudes and 90°04´ and 90°18´ east longitudes, is situated in Sakhipur forest area (191 sq. Km.) under the Tangail Forest Division, 80 Km north from Dhaka. This area is a part of Madhupur tract of 'Sal' forest. The floristic composition, wildlife and forest characteristics of this area are almost similar to that of other parts of Madhupur 'Sal' forests. 70% to 75% trees of this forest areabelong to *S. robusta* which is associated with other tree species, such as *Terminalia bellirica* (Gaertn.) Roxb.*, Albizia procera* (Roxb.) Benth.*, Lagerstroemia speciosa* (L.) Pers. And *Ficus* spp. The study area was selected following the information of Forest Department and field reconnaissance survey.

Specimen collection and identification: Field data and representative plant specimens were collected over a period of two years, ranging from April 2010 to November 2011, and in three seasons, *viz*., a hot, humid summer from March to June, a less hot, rainy monsoon season from June to October; and a cool and dry winter from October to March. The quadrat method (Braun-Blanquet, 1932; Raunkiaer, 1934) following the determination of the standard size of the quadrat (4m x 4m) by 'Species Area Curve' (Cain, 1938; Braun-Blanquet, 1964) was applied in collecting the field data and plant specimens. Following the standard herbarium techniques (Hyland, 1972; Jain and Raw, 1977), the freshly collected representative specimens were processed and pressed in the field station and dried and preserved in Jahangirnagar University Herbarium (JUH). Besides the author's own collections, the herbarium specimens previously collected from Bhawal-Madhupur tract of Bangladesh by different collectors and deposited at JUH and

Bangladesh National Herbarium (DACB) were also examined.

Identification of all plant specimens was confirmed through consultation with the experienced Plant Taxonomists of JUH and DACB, matching the specimens with authentically identified herbarium specimens housed at DACB, JUH and Dhaka University Salar Khan Herbarium (DUSH), clear type images available in the websites of different international herbaria, and taxonomic descriptions and keys available in standard taxonomic literatures (e.g., Hooker, 1872-1897; Prain, 1903; Nasir and Ali, 1980-2005; Wu, *et al*., 1995-2013; Watson *et al*., 2011; Flora of North America Editorial Committee, 1993-2014). The original and updated nomenclatural information was incorporated following Index Kewensis, recent taxonomic publications and the nomenclatural data bases (e.g., IPNI, 2008 and TROPICOS, 2010).

Data analysis: Data were analyzed using SPSS software (version 16.0). One way ANOVA (DMRT) was used to test the significant differences ($P<0.05$) for marginal means of variables. Density, relative density, frequency, relative frequency, abundance and relative abundance of the plant species were estimated calculating the relevant formulae available in Mueller-Dombois and Ellenberg (1974) and Shukla and Chandal (1980).

3. Results and Discussion

Species composition: During this study, a total of 116 undergrowth species belonging to 97 genera and 52 families of vascular plants were found in the tree plots of exotic *A. auriculiformis* and *E. camaldulensis*, whereas, 150 undergrowth species belonging to122 genera and 56 families in the tree plots of indigenous *S. robusta* and *M. indica* in the deciduous forest area of Hoteya Forest Range. Based on these results, this study reports the occurance of a relatively lower number of undergrowth species (18.68%) in the exotic tree plots of *A. auriculiformis* and *E. camaldulensis* in respect to that in the indigenous tree plots of *S. robusta* and *M. indica* in the study areain summer-, monsoon- and winter-seasons, whether considering all undergrowth species or the seedlings and saplings of the tree species (referred as ‘undergrowth tree species’ in this article) only (Table 2; Figure 1). The results of this study also indicate that the number of uncommon species was relatively lower in the exotic tree plots than that in the indigenous tree plots facing similar extent of ecological and anthropogenic stresses (Table 1). Moreover, the rare orchid species *Gastrodia zeylanica* Schltr. and *Geodorum densiflorum* (Lamk.) Schltr. were found to grow in indigenous plots but no orchid was observed in exotic tree plots. These scenarios indicate that plantations of indigenous tree species are relatively better than that of the exotic tree species in harboring better richness of undergrowth species, consistent with Montagnini *et al*. (1995).

Among the tree plots of exotic and indigenous species, the *S. robusta* plots were found to harbor the maximum number of undergrowth species in each of the summer-, monsoon- and winter seasons, which was followed by that of *A. auriculiformis*, *E. camaldulensis* and *M. indica*, whether the undergrowths of all or only of tree species are considered (Figure 2).

Table 1. *Checklist of undergrowth plant species recorded from the deciduous forest area of Hoteya Forest Range under Sakhipur upazila of Tangail district.*

Scientific name	Familyname	Habit	Plant group*	Exoticplot	Indigenous plot	Voucher Specimen
Acacia auriculiformis Benth.	Leguminosae	Tree	D	√	√	MR-1
Aegle marmelos L.	Rutaceae	Tree	D	√	√	MR-54
Ageratum conyzoides (L.) L.	Compositae	Herb	D		√	MR-54
Albizia lebbeck (L.) Benth.	Leguminosae	Tree	D	√	√	MR-179
Albizia procera (Roxb.) Benth.	Mimosaceae	Tree	D	√	√	MR-56
Alstonia scholaris (L.) R. Br.	Apocynaceae	Tree	D	√	√	MR-43
Alternanthera sessilis (L.) R. Br. ex DC.	Amaranthaceae	Herb	D	√	√	MR-89
Ampelocissus barbata (Wall.) Planch.	Vitaceae	Herb	D	√	√	MR-154
Ampelocissus latifolia (Roxb.) Planch.	Vitaceae	Herb	D		√	MR-41
Andrographis paniculata (Burm. f.) Wall. ex Nees	Acanthaceae	Herb	D	√	√	MR-80
Anisomeles indica (L.) Kuntze.	Lamiaceae	Herb	D	√		MR-49
Antidesma acidum Retz.	Euphorbiaceae	Tree	D	√	√	MR-52
Antidesma ghaesembilla Gaertn.	Euphorbiaceae	Tree	D	√	√	MR-31
Artocarpus chama Buch.-Ham.	Moracerae	Tree	D	√	√	MR-148
Artocarpus heterophyllus Lam.	Moraceae	Tree	D	√	√	MR-58
Axonopus compressus (Sw.) P. Beauv.	Poaceae	Herb	M	√	√	MR-5
Azadirachta indica A. Juss.	Meliaceae	Tree	D	√	√	MR-59
Bambusa balcooa Roxb.	Poaceae	Shrub	D		√	MR-180
Bauhinia racemosa Lamk.	Caesalpiniaceae	Tree	D		√	MR-147
Blumea flava DC.	Asteraceae	Herb	D		√	MR-111
Blumea lacera (Burm. f.) DC.	Asteraceae	Herb	D		√	MR-40
Bombax ceiba L.	Bombacaceae	Tree	D	√	√	MR-84
Borassus flabellifer L.	Arecaceae	Tree	M	√	√	MR-7
Bridelia retusa (L.) A. juss.	Euphorbiaceae	Tree	D	√	√	MR-108
Butea monosperma (Lam.) Taub.	Caesalpiniaceae	Tree	D	√	√	MR-86
Calamus guruba Buch.-Ham. ex Mart.	Arecaceae	Shrub	D		√	MR-44
Canscora decussata (Roxb.) Roem. & Schult	Gentiaceae	Herb	D	√		MR-94

Scientific name	Familyname	Habit	Plant group*	Exoticplot	Indigenous plot	Voucher Specimen
Careya arborea Roxb.	Lythraceae	Tree	D	√	√	MR-11
Careya herbacea Roxb.	Lythraceae	Herb	D		√	MR-112
Cassia fistula L.	Caesalpiniaceae	Tree	D		√	MR-113
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	Shrub	D		√	MR-2
Centella asiatica (L.) Urb.	Apiaceae	Herb	D	√	√	MR-71
Centrosema pubescens Benth.	Leguminosae	Herb	D	√		MR-114
Cheilanthes belangeri (Bory) C. Chr.	Sinopteridaceae	Fern	P	√	√	MR-4
Cheilanthes tenuifolia (Burm. f.) Sw.	Sinopteridaceae	Fern	P		√	MR-171
Chloris virgata Sw.	Poaceae	Herb	M			MR-153
Chrysopogon aciculatus (Retz.) Trin.	Poaceae	Herb	D	√		MR-79
Clerodendrum infortunatum L.	Lamiaceae	Herb	D	√	√	MR-6
Coccinia grandis (L.) Voigt	Cucurbitaceae	Herb	D	√	√	MR-105
Colocasia esculenta (L.) Schott	Araceae	Herb	M	√	√	MR-92
Commelina erecta L.	Commelinaceae	Herb	M	√	√	MR-115
Commelina nudiflora L.	Commelinaceae	Herb	M		√	MR-34
Corchorus capsularis L.	Tiliaceae	Herb	D	√		MR-149
Crinum latifolium L.	Liliaceae	Herb	M		√	MR-168
Curculigo orchioides Gaertn.	Hypoxidaceae	Herb	M	√	√	MR-33
Curcuma caesia Roxb.	Zizingiberaceae	Herb	M	√	√	MR-142
Curcuma domestica Valeton	Zizingiberaceae	Herb	M		√	MR-172
Curcuma zedoaria (Christm.) Roscoe	Zinzigiberaceae	Herb	M	√	√	MR-32
Cynodon dactylon (L.) Pers.	Poaceae	Herb	M	√	√	MR-73
Cyperus haspan L.	Cyperaceae	Herb	M		√	MR-155
Cyperus iria L.	Cyperaceae	Herb	M	√	√	MR-116
Cyperus rotundus L.	Cyperaceae	Herb	M	√	√	MR-27
Dentella repens (L.) J. R. Forst. & G. Forst.	Rubiaceae	Herb	D	√		MR-119
Derris trifoliata Lour.	Fabaceae	Herb	D		√	MR-157
Desmodium gangeticum (L.) DC.	Fabaceae	Herb	D		√	MR-165
Desmodium gyroides (Roxb. ex Link) DC.	Fabaceae	Herb	D	√	√	MR-117
Desmodium motorium (Houtt.) Merr.	Fabaceae	Herb	D		√	MR-87
Desmodium pulchellum (L). Benth.	Fabaceae	Shrub	D	√	√	MR-118
Desmodium triflorum (L.) DC.	Fabaceae	Herb	D	√	√	MR-20
Digitaria sanguinalis (L.) Scop.	Poaceae	Herb	M	√	√	MR-162
Dillenia pentagyna Roxb.	Dilleniaceae	Tree	D		√	MR-109
Dioscorea belophylla (Prain) Voigt ex Heines	Dioscoreaceae	Herb	M	√	√	MR-35
Dioscorea bulbifera L.	Dioscoreaceae	Herb	M	√	√	MR-169
Dioscorea hamiltonii Hook. f.	Dioscoreaceae	Herb	M	√	√	MR-19
Dioscorea pentaphylla L.	Dioscoreaceae	Herb	M	√	√	MR-67
Dioscorea triphylla L.	Dioscoreaceae	Herb	M	√	√	MR-120
Dysolobium pilosum (J. G. Klein ex Willd.) Maréchal	Fabaceae	Herb	D		√	MR-167
Echinochloa colonum (L.) Link.	Poacaeae	Herb	D	√		MR-159
Eclipta prostrata (L.) L.	Asteraceae	Herb	D	√		MR-46
Elephantopus scaber L.	Asteraceae	Herb	D	√	√	MR-78
Eleusine indica (L.) Gaertn.	Poaceae	Herb	M	√		MR-182
Eragrostis tenella (L.) P. Beauv. ex Roem. & Schult.	Poacaeae	Herb	M	√	√	MR-102
Eragrostis unioloides (Retz.) Nees ex Steud.	Poaceae	Herb	M		√	MR-121
Eriocaulon sexangulare L.	Eriocaulaceae	Herb	M	√	√	MR-122
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Tree	D	√		MR-76
Eupatorium odoratum L.	Asteraceae	Shrub	D	√	√	MR-3
Euphorbia hirta L.	Euphorbiaceae	Herb	D		√	MR-166
Evolvulus nummularius (L.) L.	Convolvulaceae	Herb	D	√	√	MR-62
Ficus hispida L. f.	Moraceae	Tree	D	√	√	MR-66
Ficus religiosa L.	Moraceae	Tree	D		√	MR-106
Fimbristylis miliacea (L.) Vahl	Cyperaceae	Herb	D	√		MR-181
Flacourtia indica (Burm. f.) Merr.	Flacourtiaceae	Shrub	D		√	MR-12
Flemingia strobilifera (L.) R. Br.	Fabaceae	Herb	D		√	MR-124
Fleurya interrupta (L.) Gaudich.	Urticaceae	Herb	D			MR-150
Floscopa scandens Lour.	Commelinaceae	Herb	M		√	MR-82
Garuga pinnata Roxb.	Burseracerae	Tree	D		√	MR-125
Gastrodia zeylanica Schltr.	Orchidaceae	Herb	M		√	MR-128
Geodorum densiflorum (Lamk.) Schltr.	Orchidaceae	Herb	M		√	MR-81
Glochidion heyneanum (Wight & Arn.) Wight	Euphorbiaceae	Shrub	D		√	MR-156
Glycosmis pentaphylla (Retz.) A. DC.	Rutaceae	Shrub	D		√	MR-173
Gmelina arborea Roxb. ex Sm.	Verbenaceae	Tree	D	√		MR-75

Scientific name	Familyname	Habit	Plant group*	Exoticplot	Indigenous plot	Voucher Specimen
Hedyotis scabra Wall. ex Kurz	Rubiaceae	Herb	D	√	√	MR-126
Hemidesmus indicus (L.) R. Br.	Asclepiadaceae	Herb	D	√	√	MR-30
Holarrhena pubescens Wall. ex G. Don	Apocynaceae	Tree	D	√	√	MR-8
Hymenodictyon excelsum (Roxb.) DC.	Rubiaceae	Tree	D		√	MR-37
Hyptis suaveolens (L.) Poit.	Lamiaceae	Herb	D	√	√	MR-129
Ichnocarpus frutescens (L.) W. T. Aiton	Apocynaceae	Herb	D	√	√	MR-21
Imperata cylindrica var. *major* (Nees) C. E. Hubb.	Poaceae	Herb	M	√	√	MR-22
Jasminum scandens (Retz.) Vahl	Oleaceae	Shrub	D		√	MR-163
Justicia diffusa Willd.	Acanthaceae	Herb	D	√	√	MR-132
Kyllinga nemoralis (J. R. Forst. & G. Forst.) Dandy ex Hutch. & Dalziel	Cyperaceae	Herb	M	√	√	MR-90
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	Tree	D	√	√	MR-45
Leucas aspera (Willd.) Link.	Lamiaceae	Herb	D	√	√	MR-133
Leucas indica (L.) R. Br. ex Sm.	Lamiaceae	Herb	D	√	√	MR-70
Lindernia ciliata (Colsm.) Pennell	Scrophulariaceae	Herb	D	√	√	MR-130
Lindernia crustacea (L.) F. Muell.	Scrophulariaceae	Herb	D	√	√	MR-25
Litsea atrata S. K. Lee	Lauraceae	Tree	D		√	MR-174
Litsea glutinosa (Lour.) C. B. Rob.	Lauraceae	Tree	D	√	√	MR-14
Ludwigia hyssopifolia (G. Don) Exell	Onagraceae	Herb	D	√	√	MR-136
Lygodium flexuosum (L.) Sw.	Lygodiaceae	Herb	P	√	√	MR-16
Lygodium yunnanense Ching	Lygodiaceae	Herb	P	√	√	MR-135
Mangifera indica L.	Anacardiaceae	Tree	D		√	MR-101
Melia azedarach L.	Meliaceae	Tree	D	√	√	MR-74
Melocanna bambusoides Trin.	Sterculiaceae	Shrub	M		√	MR-134
Microcos paniculata L.	Tiliaceae	Tree	D		√	MR-127
Microlepia strigosa (Thunb.) C. Presl	Dennstaedtiaceae	Fern	P		√	MR-137
Mikania cordata (Burm. f.) B. L. Rob.	Asteraceae	Herb	D	√	√	MR-61
Miliusa velutina (Dunal) Hook. f. & Thomson	Annonaceae	Tree	D	√	√	MR-50
Mimosa himalayna Gamble	Mimosaceae	Shrub	D	√	√	MR-85
Mimosa pudica L.	Mimosaceae	Herb	D	√	√	MR-23
Modhica trilobata Roxb.	Cucurbitaceae	Herb	D	√	√	MR-175
Mucuna pruriens (L.) DC.	Fabaceae	Herb	D	√	√	MR-104
Mukia maderaspatana (L.) M. Roem.	Cucurbitaceae	Herb	D		√	MR-97
Murdannia edulis (Stokes) Faden	Commelinaceae	Herb	M		√	MR-99
Nelsonia canescens (Lamk.) Spreng.	Acanthaceae	Herb	D		√	MR-107
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Tree	D	√	√	MR-143
Neonauclea sessilifolia (Roxb.) Merr.	Rubiaceae	Tree	D		√	MR-51
Ocimum gratissimum L.	Lamiaceae	Shrub	D		√	MR-145
Oldenlandia corymbosa L.	Rubiaceae	Herb	D	√		MR-151
Oplismenus compositus (L.) P. Beauv.	Poaceae	Herb	M	√		MR-158
Panicum vicinus F. M. Bailey	Poaceae	Herb	M	√	√	MR-26
Paspalidum punctatum (Brum) A. Camus	Poaceae	Herb	D	√		MR-139
Paspalum scrobiculatum L.	Poaceae	Herb	D		√	MR-15
Phaseolus aconitifolius Jacq.	Fabaceae	Herb	D		√	MR-176
Phaulopsis imbricata (Forssk.) Sweet Hort.	Acanthaceae	Herb	D	√	√	MR-60
Phoenix acaulis Roxb.	Arecaceae	Shrub	M	√	√	MR-36
Phoenix sylvestris Roxb.	Arecaceae	Tree	M		√	MR-96
Phyllanthus embelica L.	Euphorbiaceae	Tree	D	√	√	MR-55
Phyllanthus reticulatus Poir.	Euphorbiaceae	Shrub	D	√	√	MR-13
Phyllanthus urinaria L.	Euphorbiaceae	Herb	D	√	√	MR-103
Pogostemon auricularius (L.) Hassk.	Lamiaceae	Herb	D	√		MR-164
Polygala chinensis L.	Polygalaceae	Herb	D	√		MR-131
Pteris ensiformis Burm. f.	Pteridaceae	Fern	P	√	√	MR-144
Pterygota alata (Roxb.) R. Br.	Sterculiaceae	Tree	D	√		MR-64
Pueraria phaseoloides (Roxb.) Benth.	Leguminosae	Herb	D	√	√	MR-146
Randia uliginosa (Retz.) Poir.	Rubiaceae	Tree	D	√	√	MR-42
Rhaphidophora hookeri Schott	Araceae	Herb	M		√	MR-63
Riedlea corchorifolia (L.) DC.	Sterculiaceae	Herb	D	√		MR-138
Rungia pectinata (L.) Nees	Acanthaceae	Herb	D	√	√	MR-17
Sarcolobus sp. R. Br.	Asclepiadaceae	Herb	D		√	MR-68
Scleria levis Retz.	Cyperaceae	Herb	M		√	MR-48
Scoparia dulcis L.	Cyperaceae	Herb	D	√	√	MR-95
Selaginella ciliaris (Retz.) Spring	Selaginellaceae	Fern	P	√	√	MR-88
Selaginellavaginata Spring	Selaginellaceae	Fern	P		√	MR-177
Semecarpus anacardium L. f.	Anacardiaceae	Tree	D		√	MR-57
Senna sophera (L.) Roxb.	Caesalpiniaceae	Herb	D		√	MR-98

Scientific name	Familyname	Habit	Plant group*	Exoticplot	Indigenous plot	Voucher Specimen
Senna tora (L.) Roxb.	Caesalpiniaceae	Herb	D		√	MR-178
Shorea robusta Roxb.	Dipterocarpaceae	Tree	D	√	√	MR-10
Sida acuta Burm. f.	Malvaceae	Shrub	D		√	MR-100
Sida rhombifolia L.	Malvaceae	Herb	D		√	MR-152
Smilax ovalifolia Roxb.	Smilaceae	Herb	D	√	√	MR-38
Spatholobus roxburghii Benth.	Fabaceae	Herb	D		√	MR-29
Spermacoce articularis L. f.	Rubiaceae	Herb	D	√	√	MR-69
Spilanthes acmella (L.) L.	Asteraceae	Herb	D		√	MR-161
Sporobolus diandrus (Retz.) P. Beauv.	Poaceae	Herb	M	√		MR-72
Sterculia villosa Roxb.	Sterculiaceae	Tree	D		√	MR-140
Streblus asper Lour.	Moraceae	Tree	D	√	√	MR-9
Synedrella nodiflora (L.) Gaertn.	Asteraceae	Herb	D	√	√	MR-123
Syzygium fruticosum DC.	Myrtaceae	Tree	D	√	√	MR-47
Tamarindus indica L.	Caesalpiniaceae	Tree	D		√	MR-160
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Tree	D	√	√	MR-24
Thespesia lampas (Cav.) Dalzell & A. Gibson	Malvaceae	Shrub	D		√	MR-83
Triumfetta rhomboidea Jacq.	Tiliaceae	Shrub	D	√	√	MR-65
Typhonium trilobatum (L.) Schott	Araceae	Herb	M	√	√	MR-91
Uraria lagopodioides (L.) DC.	Fabaceae	Herb	D	√		MR-141
Urena lobata L.	Malvaceae	Herb	D	√	√	MR-77
Vangueria spinosa Roxb.	Rubiaceae	Shrub	D	√	√	MR-110
Vernonia cinerea (L.) Less.	Asteraceae	Herb	D	√	√	MR-39
Vitex peduncularis Wall. ex Schauer in A. DC.	Vitaceae	Tree	D		√	MR-170
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	Tree	D	√	√	MR-28
Zehneria japonica (Thunb.) H. Y. Liu	Cucurbitaceae	Herb	D		√	MR-53
Ziziphus rugosa Lam.	Rhamnaceae	Shrub	D	√	√	MR-18

*D=Dycotyledon; M=Monocotyledon; P=Pteridophyta.

The potential reasons of finding the better species richness in *S. robusta* plots include less human interferences and more wild condition. The finding of relatively less number of species in *E. camaldulensis* plots in respect to that of *S. robusta* and *A. auriculiformis* might be due to less humus cover and more human interferences there. The reasons of occurrence of less number of undergrowth species in *M. indica* plots include deeper shade under most of the canopy of profusely branched trees and frequent human disturbances etc. in contrast to relatively light shade under the mostly dispersed or narrow canopies and less human interferences in other tree plots.

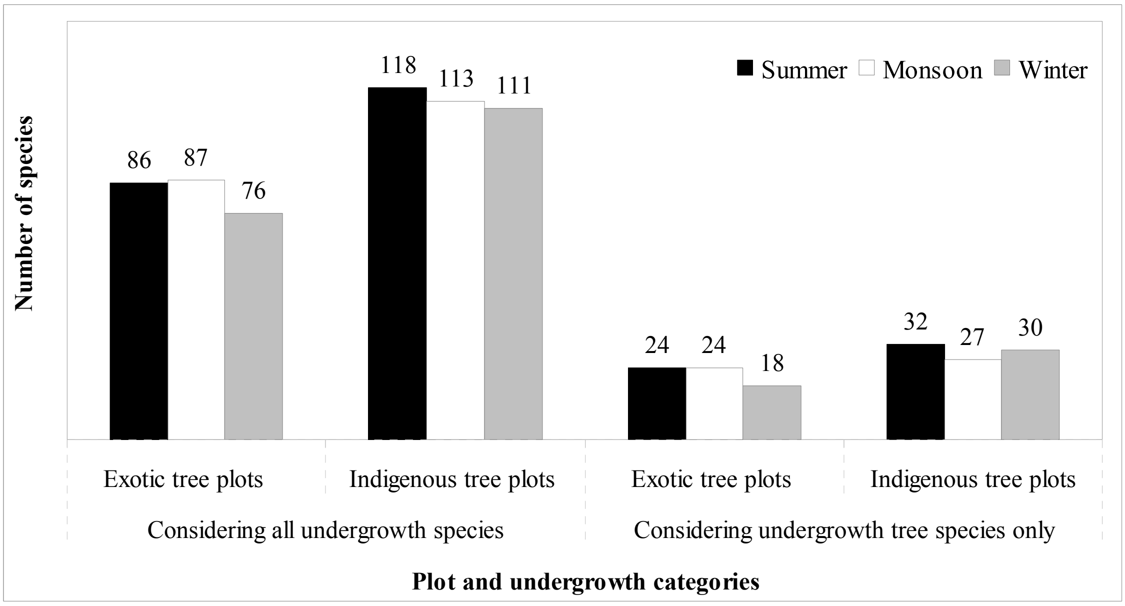

Figure 1. *Species composition in exotic and indigenous plots in summer-, monsoon- and winter seasons.*

In *A. auriculiformis* plots, the maximum number of undergrowth species was recorded during monsoon season, in *E. camaldulensis*- and *S. robusta* plots, during summer season, whereas, in *M. indica* plots, in winter season (Figure 2), which indicate the seasonal variation in growth performance and diversification of the undergrowth species in these tree plots. The occurrence of herbaceous plant species, especially grasses and sedges, was found to fluctuate along with the seasonal changes in a year. This phenemenon is desirable, since the availability of soil moisture, precipitation and temperature etc. plays a major role on the development and sustenance of the associated vegetation in the tree plots.

During summer season, the herbaceous species *A. conyzoides, A. compressus, C. odorata, C. dactylon, C. rotundus, D. triflorum, C. odorata, C. infortunatum, D. triflorum* and *D. hamiltonii* etc. were found to dominate in the exotic and indigenous tree plots. During moonson season, *C. zedoarea, C. dactylon, S. articularis, P. vicinus, E. nummularius, I. frutescens, L. ciliate, L. hyssopifolia, R. pectinata* and *X. spinosa*etc. and during winter season, *A. compressus, C. infortunatum, C. rotundus, D. triflorum, D. belophylla, C. orchioides, C. zedoaria, C. dactylon, E. nummularius* and *H. scabra* etc. were recorded as the dominating herbaceous undergrowth species in the tree plots studied. The habit categories of the undergrowths of the study area show that the herbs were highest in number and percentage than trees and shrubs (Table 2) in exotic and indigenous plots. The same status of habit categories was found when the undergrowths of all research plots were calculated.

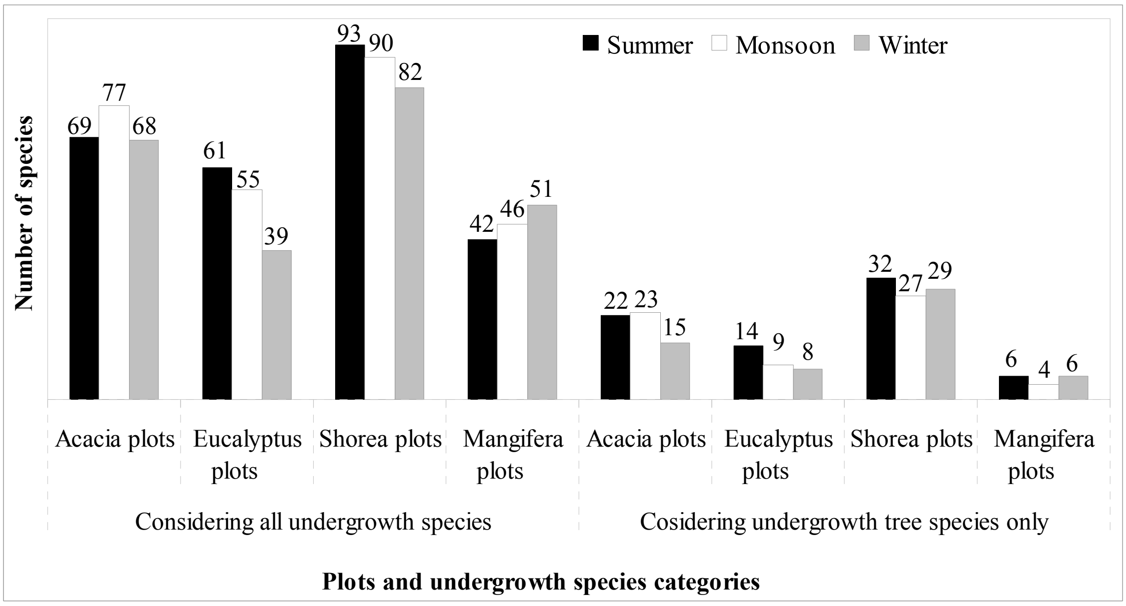

Figure 2. *Species composition in different tree plots in summer, monsoon and winter seasons.*

During this study, all together 182 species under 150 genera belonging to 56 families of vascular plant were found as undergrowths in the tree plots of exotic *A. auriculiformis* and *E. camaldulensis* and indigenous *S. robusta* and *M. indica* of the study area (Tables 1 & 2). Out of these species, 133 were dycotyledons, 41 were monocotyledons and the rest eight were pteridophytes. These taxonomic enumeration of the undergrowth species occurring in the study area seems higher in respect to that reported by Uddin and Rahman (1999), Rashid and Mia (2001), Uddin (2002) and Malaker *et al*. (2010) etc. considering the size of area.

Table 2. *Habit categories of the plant species found in exotic and indigenous plots.*

Habit	Species in exotic plots	Species in indigenous plots	Species in all plots
Tree	32 (45%)	42 (28%)	47 (26%)
Shrub	11 (9%)	18 (12%)	19 (11%)
Herb	73 (46%)	90 (60%)	116 (63%)
Total	116 (100%)	150 (100%)	182 (100%)

On the other hand, irrespective of the size of area, it seems lower to that reported by Uddin and Rahman (1999), Uddin (2002), Uddin and Hassan (2010), Arefin *et al.* (2011), and Uddin and Hassan (2012) etc. and consistent to that reported by Malaker *et al*. (2010), Rahman and Hassan (1995) and Rahman and Uddin (1997) etc., though a realistic comparision in species enumeration between two or more floristic areas requires homogeneity in size and type of the areas, sampling, strategy and procedure of specimens collection and frequency and intensiveness of the field visits etc.

Density and relative density: Thehighest average value of undergrowth density was found in *M. Indica* plots (387052±106848 per ha), which was followed by *E. camaldulensis* (342135±145009 per ha), *A. auriculiformis* (222465±102954 per ha) and *S. robusta* (68429±8872 per ha) plots, when all undergrowth species were considered (Figure 3). In *M. indica* plots, the individual number of few species, especially of grasses and sedges, was higher in respect to that of other plots, whereas, in the tree plots of *A. auriculiformis* and *S. robusta*, the individual number of undergrowth tree seedlings and saplings were higher than that of *M. indica* and *E. camaldulensis* tree plots. On the other hand, the tree plots of *A. auriculiformis* were found to house relatively more individuals of herbs, especially of grasses and sedges, and undergrowth tree seedling and sapling in respect to those of *S. robusta* plots. As the consequence, the average value of undergrowth density in exotic tree plots (262292±117188 per ha) was found to be higher than that (174583±41384 per ha) recorded for indigenous tree plots. *A. auriculiformis* plots housed relatively higher density of the undergrowths than *S. robusta* plots (Figure 3). During this study most of the exotic tree plots were found to be dominated by the individuals of small herbaceous species, especially of grasses and sedges, in respect to the indigenous plots due to which relatively more plant individuals were found inexotic plots. The occurrence of lower density of undergrowth species in *S. robusta* plots in each season in relation to other tree plotsis consistent with Sapkota *et al*. (2009). The data on plant density in the 14 year old *Acacia* and *Eucalyptus* plots recorded by Thapliyal (2002) seem much higher than that recorded by this study, which might be possible because higher number of individuals of herbaceous species like those of grasses and sedgescan occur per hectare land.

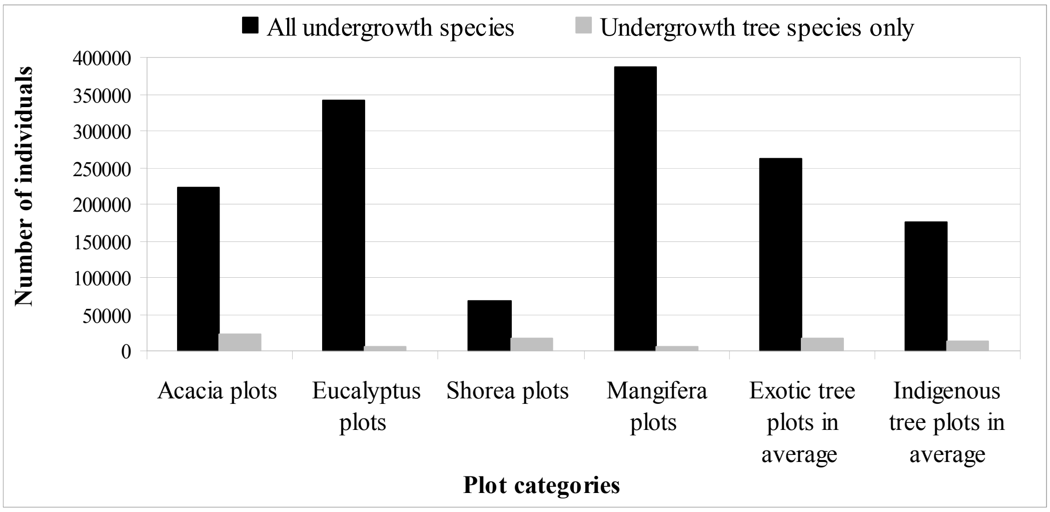

Figure 3. *Status of undergrowth density per hectare in different tree plots.*

Among three seasons, the highest value of density (485271 per ha) was found during winter in *E. camaldulensis* plots and the lowest value during summer in *S. robusta* plots (59536 per ha), when all undergrowth species were considered (Figure 4). In case of undergrowth tree seedling and sapling only, the highest density was found in winter (30958 per ha) in *A. auriculiformis* plots and the lowest in summer in *M. indica* (1479 per ha) plots (Figure 4). The records of this study on the density of all undergrowth species including the seedlings and saplings of tree species are much lower than that reported by Islam (2004) from *S. robusta* forests of Madhupur protected area. On the other hand, the data on undergrowth tree seedling and sapling are higher than Rahman (2009)'s record on the density of woody undergrowth species in *S. robusta* forests of Gazipur. It is notable that the *S. robusta* forests of Gazipur and the study area are not protected like that of Madhupur where better wild conditions exist and conservation measures were functional.

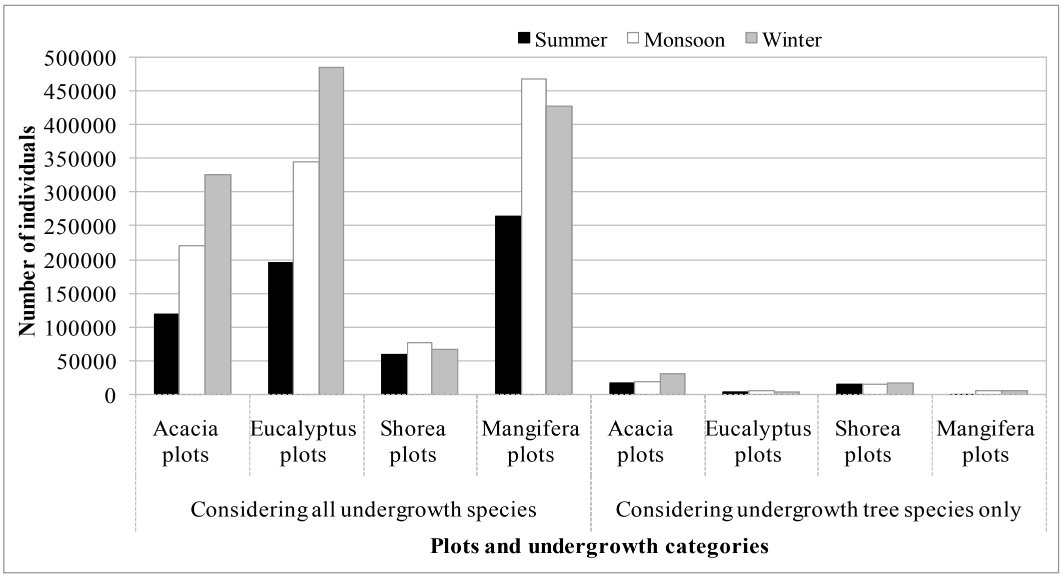

Figure 4. *Status of undergrowth density per hectare in different tree plots in summer, monsoon and winter seasons.*

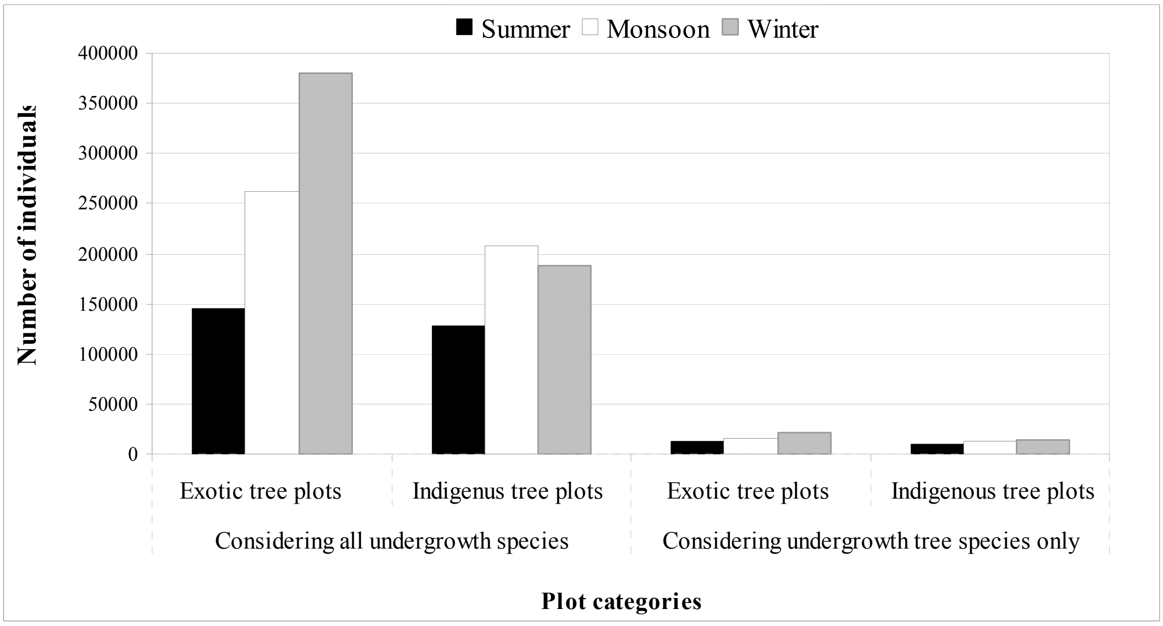

Figure 5. *Status of undergrowth density per hectare in exotic and indigenous tree plots in summer, monsoon and winter seasons.*

Considering all undergrowth species it can be concluded that the average undergrowth plant density was higher in exotic tree plots than that in indigenous plots (Figure 5). The highest value (21875 per ha) was found during winter season in exotic tree plots and the lowest (10625 per ha) during summer season in indigenous tree plots (Figure 5).

The highest relative density in exotic tree plots was recorded for *A. compressus* (23.35%), which was followed by *S. articularis*, *D. triflorum*, *C. odorata* and *A. auriculiformis* etc. and in indigenous tree plots, it was recorded also for *A. compressus* (16.33%), but followed by *D. triflorum*, *S. articularis*, *C. dactylon* and *C. rotundus* etc., when all undergrowth species were considered. When only the undergrowth tree seedling and sapling were considered, the relative density in exotic plots were found to be highest for *A. auriculiformis* (77.17%), followed by *S. robusta*, *A. indica*, *H. antidysentarica* and *L. glutinosa* etc. In indigenous plots, it was found to be highest for *S. robusta* (54.28%), followed by *A. ghaesembilla*, *A. auriculiformis*, *L. glutinosa* and *H. antidysenterica* etc. The seedlings and saplings of *A. auriculiformis* and *S. robusta*in some undisturbed tree plotswere found to form a dense layer of vegetation that might be the potential reason of finding higher relative density for these two tree species. The finding of relative density for *S. robusta* and *L. glutinosa* in *S. robusta* tree plots is consistent with Islam (2004).

The results of DMRT (Duncan's Multiple Range Test) analysis showed that species number and density were significantly different between the tree plots of *A. auriculiformis*, *S. robusta* and *M. indica* or *E. Camaldulensis* but not significantly different when only the *M. indica*- and *E. camaldulensis* plots were considered. These parameters were significantly different when only the tree plots of two indigenous or two exotic species were considered (Table 3).

Table 3. *The results of DMRT analysis on different parameters of species composition and density in four types of research plots in Sakhipur, Tangail.*

Plot type	No. of species	Density
A. auriculiformis	71.3333b	355.6667ab
E. camaldulensis	51.6667a	547.3333c
S. robusta	88.3333c	109.6667a
M. indica	46.3333a	619.0000c

Note: Values in the same column that do not share common letters are significantly different at 5% (α=0.05) level among the plots after DMRT.

Frequency and Relative Frequency: In case of all undergrowth species, *A. compressus* was found in highest frequency and relative frequency (70.74%; 7.46%), which was followed by *S. articularis*, *A. auriculiformis*, *C. infortunatum* and *C. odorata* etc. in exotic tree plots, whereas, in indigenous tree plots, *C. infortunatum* was found in highest frequency and relative frequency (64.07%; 5.02%), which was followed by *S. robusta*, *C. zedoaria*, *I. frutescens* and *D. hamiltonii* etc. The finding of relative frequency for *C. infortunatum* and *I. frutescens* is in consistent with Islam (2004). In exotic tree plots, the value of frequency and relative frequency recorded for *C. pubescens*, *C. iria*, *F.miliacea*, *M. trilobata* and *P. ensiformis* etc, and in indigenous tree plots, for *M. azadirach*, *M. trilobata*, *R. hookeri*, *Sarcolobus* sp. and *Z. japonica* etc. were comparatively lower.

In case of undergrowth tree seedling and sapling, the frequency and relative frequency in exotic tree plots was found to be highest for *A. auriculiformis* (65.37%; 37.24%), followed by *S. robusta*, *L. glutinosa*, *A. indica* and *H. antidysentarica*, whereas, in indigenous tree plots, it was recorded for *S. robusta* (63.15%; 20.48%), followed by *A. ghaesembilla*, *L. glutinosa, C. arborea* and *H. excelsum* etc. The relative frequency recorded here for *S. robusta* and *L. glutinosa* seems somewhat higher than the findings of Islam

(2004). In exotic tree plots, *B. ceiba*, *A. lebbeck*, *A. marmelos*, *A. scholaris* and *R. dumetorum* etc., and in indigenous tree plots, *M. azadirach*, *L. salicifolia*, *B. flabellifer*, *N. sessilifolia* and *M. paniculata* etc. were found with less frequency and relative frequency.

Abundance and Relative Abundance: Whenall undergrowth plant species were considered, *C. iria* was found in highest abundance and relative abundance (329; 13.39%), which was followed by *A. compressus*, *S. articularis*, *D. triflorum* and *C. dactylon* etc. in exotic tree plots, whereas, in indigenous plots, *A. compressus* was found to be most abundant and in highest relative abundance, which was followed by *D. triflorum*, *C. dactylon*, *S. articularis* and *A. conyzoides*etc. In exotic tree plots, *P. phascoloides*, *B. flabellifer*, *C. arborea*, *L. coromandelica* and *S. ovalifolia* etc. and in indigenous plots, *A. scholaris*, *D. pentagyna*, *G. pinnata*, *Z. japonica* and *N. cadamba* etc. were found to occur in less abundance and relative abundance.

On the other hand, when only the undergrowth tree seedling and sapling were considered, *A. auriculiformis* was found in highest abundance and relative abundance (32; 19.78%), which was followed by *A. indica*, *H. antidysentarica*, *P.emblica* and *E. camaldulensis* etc. in exotic tree plots, whereas, in indigenous tree plots, *S. robusta* was found in highest abundance and relative abundance (18; 12.72%), which was followed by *A. auriculiformis*, *P. emblica*, *H. antidysenterica* and *P. sylvestris*etc. The data on relative abundance of *S. robusta* in Madhupur area recorded by Islam (2004) and Rahman (2009) are higher and that of *P. emblica* recorded by Islam (2004) is lower than the data of this study. In exotic tree plots, *B. flabellifer*, *L. coromandelica*, *C. arborea*, *G. arborea* and *F. hispida* etc., and in indigenous tree plots, *D. pentagyna*, *A. scholaris*, *B. ceiba*, *B. monosperma* and *Z. rhetsa* etc. were found in less abundance and relative abundance.

In the study area, some key factors were found to affect the occurrence and distribution of undergrowth species in the tree plots of exotic and indigenus species in different magnitudes. The undergrowth plant species, especially in most of the exotic tree plots, were found to be disturbed by the anthropogenic factors like clear felling, fuel wood collcetion, leaf litter collection, cattle grazing, firing, and making pathways arbitrarily by the local people etc. and abiotic factors like shade, rainfall, temperature and soil moisture and humidity etc. Different management systems functional in the study area were also the important reasons for high internal variation in species richness in exotic and indigenous tree plots. Some tree growers weed out almost all seedlings of indigenous or associate species, but others allowed thier natural regeneration. In some cases, fire was passed through the indigenous stands (*S. robusta*) as a weed control method, supported by Tyynela (2001).

4. Conclusions

This study concludes that the exotic tree plots of the study area harbored 18.68% less species in comparison to indigenous plots. The species composition of exotic tree plots was lower than that of indigenous plots in summer-, monsoon- and winter seasons. *S. robusta* tree plots were found to house highest number of undergrowth species and *M. indica* tree plots the lowest in all seasons. *A. auriculiformis* and *S. robusta* were found with highest relative density respectively in exotic and indigenous tree plots. The herbaceous species *A. compressus* and *C. iria* were found with highest relative frequency and highest relative abundance, respectively in exotic- and indigenous tree plots. The impacts of different key factors on the occurrence and distribution of undergrowth species in the tree plots of exotic and indigenous species were not uniform. This study provides an insight into the impacts of monoculture of exotic species on the status of undergrowths in a deciduous forest area of central Bangladesh. Further comparative studies involving more parameters are necessary to elucidate the exact impacts of massive monoculture of exotic tree species in this country. This study suggests for preferring the indigenous species for plantation programs in forested and fertile land areas and exotic species for that in the degraded or barren areas with strict maintenance of the natural condition. The data of this study will help in adopting effective attempts for biodiversity conservation and in appropriate selection of tree species for better plantation programs there and in similar other areas of Bangladesh.

Authors' Contribution

All authors conceived the study and contributed to the interpretation and discussion of the results. All authors helped to analysed the field data and draft the manuscript. All authors read and approved the final manuscript.

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