Jahangirnagar University J. Biol. Sci. **3**(2): 33-47, 2014 (December)

Effect of exotic tree plantation on floristic composition and phytodiversity of Rema-Kalenga wildlife sanctuary, Bangladesh

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Abstract

Effect of exotic tree plantation on floristic composition and phytodiversity status of Rema-Kalenga wildlife sanctuary of Bangladesh was studied. A total of 309 vascular plant species under 245 genera belonging to 83 families were found to constitute the vascular flora of the studied area. The maximum number of species (298) with the highest Shannon-Weiner diversity index value (3.882±0.090) was recorded from natural forest, which was followed by 194 and 165 plant species with 3.441±0.205 and 3.398±0.103 diversity index values recorded from *Tectona* and *Acacia* plantation sites respectively. The minimum number of plant species (142) with the lowest diversity index value (2.999±0.152) was recorded from *Eucalyptus* plantation site. The collected data on the selected forest sites of Rema-Kalenga wildlife sanctuary showed the trends of gradual decrease in floristic composition and phytodivesity status of three plantation sites (*Tectona* to *Acacia* to *Eucalyptus*) in respect to natural forest, which indicated that exotic tree plantations might have negative impact on floristic composition and phytodiversity of this semi-tropical forest area and the fast-growing exotic tree plantation of *Acacia* and *Eucalyptus* should be avoided for sustainable development of Rema-Kalenga wildlife sanctuary.

Key words: Fast-growing exotic tree plantation, floristic composition, phytodiversity, Rema-Kalenga wildlife sanctuary, Bangladesh.

INTRODUCTION

The global extent of plantation forests in 1990 is estimated to be around 135 million ha (FAO, 1993; Gauthier, 1991; Pandy, 1995). About 75% of these plantation forests are in temperate regions and about 25% in the tropics and subtropics; some 5% are found in Africa, a little more than 10% in each of the American continents, some 20% in the former USSR and around 25% in each of Asia-Pacific and Europe (Gauthier, 1991; Kanowski & Savill, 1992). Most plantation forests have been established as even-aged monoculture crops of tree species with the primary purpose of wood production (Evans, 1992). Around 90% of existing plantations have been established for the production of wood for industrial use and most of the remainder to produce wood for use as fuel or round wood. Some plantation forests are grown and managed, either primarily or jointly, for non-wood products such as betel leaf, medicinal plants or fodder. Fast-growing tree plantations, mainly *Acacia* and *Eucalyptus* are widespread in tropical countries (Bouillet & Bernhard-Reversat, 2001). In the 19th and 20th Centuries valuable timber species and fast growing tree species of Australian origin were introduced to facilitate the development of forestry in Bangladesh (Hossain & Pasha, 2001; Islam *et al*., 2003; Hossain, 2006). Last few decades some fast-growing exotic tree species like akashmoni (*Acacia auriculiformis* A. Cunn. ex. Benth.) and eucalyptus (*Eucalyptus camaldulensis*

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Hook.) have been planted in different areas of Bangladesh. Most of the original forest cover of Rema-Kalenga wildlife sanctuary has been removed or substantially altered through plantation programs or other anthropogenic activities. Plantation started in this region from 1922 and in early stage, the Forest Department started the plantation program by planting teak tree (*Tectona grandis* L.). Then they took several initiatives to extend natural forest in degraded and deforested areas. As a consequence they planted some fast-growing exotic tree species like *Acacia* and *Eucalyptus* in some areas of the sanctuary. Environmental impact of fast-growing tree plantations in the tropics has been a controversial topic. Some authors argued that these species exhaust soil water and nutrient resources, and prevent undergrowth vegetation and in further soil erosion and loss of fertility (Poore & Fries, 1985; Abbasi & Vinithan, 1997; Bouvet, 1998). The fast-growing exotic tree plantations are not suitable for local undergrowth vegetation (Hossain *et al*., 2002) as well as for soil nutritional quality (Prasad, 1988) and microbial growth (Hossain and Hossain, 2009). The previous studies conducted on this sanctuary were on taxonomy, ethnobotany, soil ecology etc. (Uddin *et al*., 2001; Uddin & Hassan, 2004; Hossain & Hossain, 2009). Data on the effects of different plantations on the vegetation in this area is still lacking. Therefore, the present investigation in this sanctuary was conducted to know the impacts of plantations of exotic tree species on the floristic composition and phytodiversity status of this area and to provide data that might be helpful for proper management plan and sustainable development of the sanctuary.

MATERIALS AND METHODS

The Rema-Kalenga wildlife sanctuary is located at Chunarughat thana of Habigonj district under the forest administration unit of Habigonj-2 forest range of Sylhet forest division (Fig. 1). Geographically, the study area is situated between 24°06′ to 24°14′N latitude and 91°34′ to 91°41′E longitude with about 67 m elevation at the highest peak (Rizvi, 1970). In 1982, this area was declared as a wildlife sanctuary through a Gazette Notification No. 11/For-68/89/882, Date 22/12/1981 by the Government under the Bangladesh Wildlife (Preservation) Order, 1973 (Amendment Act 1974) to provide for the preservation, conservation and management of wildlife in Bangladesh. The sanctuary falls under IUCN management category IV- habitat/species management area (Green, 1990). This area is under the bio-ecological zone-9b with broad zone ‘Sylhet Hills’ (Nishat *et. al.*, 2002). According to Bangladesh agro- ecological

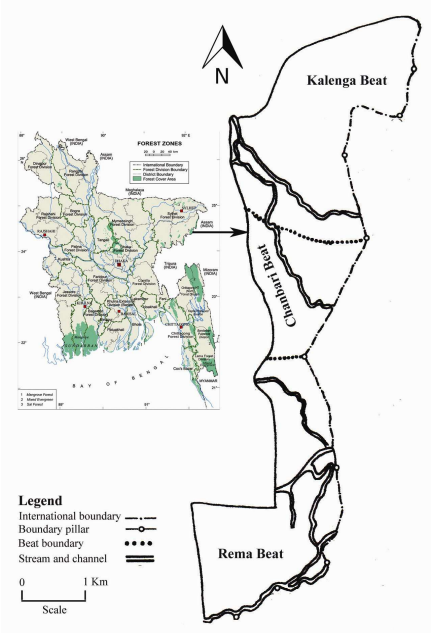

Fig. 1. Map of the Rema-Kalenga wildlife sanctuary.

zones, this area belongs to Region-29, 'Northern and Eastern Hills', sub-region-29c, 'Low hills and piedmont plains' (FAO, 1988). Current notified area of this sanctuary is 1795.54 ha. (Canonizado & Rahman, 1998). This forest area covers an area of low-medium high hills formed primarily from soft sandstones and classified as a mixed tropical evergreen forest (Champion, 1936). Sub-tropical monsoon climate exists in the study area with three distinct seasons, *viz*. summer, monsoon and winter. The mean minimum and maximum temperatures varied between 11.8°C and 33.2°C, relative humidity ranged from 71.5% to 87.5% and mean annual rainfall varied from 7.3 to 456.8 mm (Uddin and Hassan, 2004). The relief is characterized by a gently undulating to hilly topography and the soils are mainly sandy loam to silt clay with acidic in nature (Hossain, 2006).

Sample collection and analysis: Plant samples were collected from four different types of standing forest sites, *viz*., natural forest, teak (*Tectona grandis* L.), acacia (*Acacia auriculiformis* A. Cunn. ex. Benth.) and eucalyptus (*Eucalyptus camaldulensis* Hook.) plantation forests sites during winter, summer and monsoon seasons from 2003 to 2005. Undergrowth plant samples of the selected sites were collected by standard quadrat method (Braun-Blanquet, 1932; Raunkiaer, 1934) and the quadrat size was determined as 10m×10m following species-area curve method (Braun-Blanquet, 1932). Collected plant specimens were properly processed using standard herbarium techniques (Hyland, 1972; Jain & Rao, 1977 and Alexiades, 1996). The specimens were identified through consulting with expert taxonomists, cross-checking with herbarium specimens preserved at JUH and Bangladesh National Herbarium (DACB); and also matching with different relevant taxonomic literatures, *viz.*, Hooker (1872-1897), Prain (1903), Uddin and Hassan (2004), Siddiqui *et al.* (2007) and Ahmed *et al.* (2008-2009).

Shannon-Wiener diversity index of the recorded undergrowth plants of different selected sites was calculated through the following formula described as Kent and Coker (1992).

$$\text{Shannon-Wiener Diversity Index } (H') = -\Sigma\, pi \ln pi$$

where,
pi = The proportion of individuals or the abundance of the ith species expressed as a proportion of total cover,
ln = Log base$_n$

RESULTS AND DISCUSSION

The collected data on the floristic composition and Shannon-Wiener diversity index of the undergrowth plant species of selected forest sites of Rema-Kalenga wildlife sanctuary have been presented in Tables 1 to 2 and Figs. 2 to 5. In this study, a total of 309 vascular plant species under 245 genera belonging to 83 families were identified as undergrowth species (Table 1). The maximum number of species (250; 80.91%) belonged to dicotyledons and it was followed by 47 (15.21%) and 12 (3.88%) species, respectively of monocotyledons and pteridophytes (Fig. 3). The highest number of species 100 (32.36%) were recorded as herb, which was followed by 93 (30.10%), 71 (22.98%) and 45 (14.56%) species, respectively of tree, shrub and climber respectively (Fig. 4).

In natural forest, a total of 304 plant species under 240 genera and 81 families were found (Fig. 2), of which 298 species under 237 genera of 79 families were recorded during monsoon season, 287 species under 234 genera of 75 families during winter season, whereas 245 species under 221 genera belonging to 69 families in summer season (Table 2). The values of Shannon-Wiener diversity index of the recorded undergrowth species of natural forest site varied between 3.960 and 3.784. The highest index value 3.960 was calculated during monsoon season which was followed by 3.901 and 3.784 recorded during winter and summer seasons, respectively (Fig. 5).

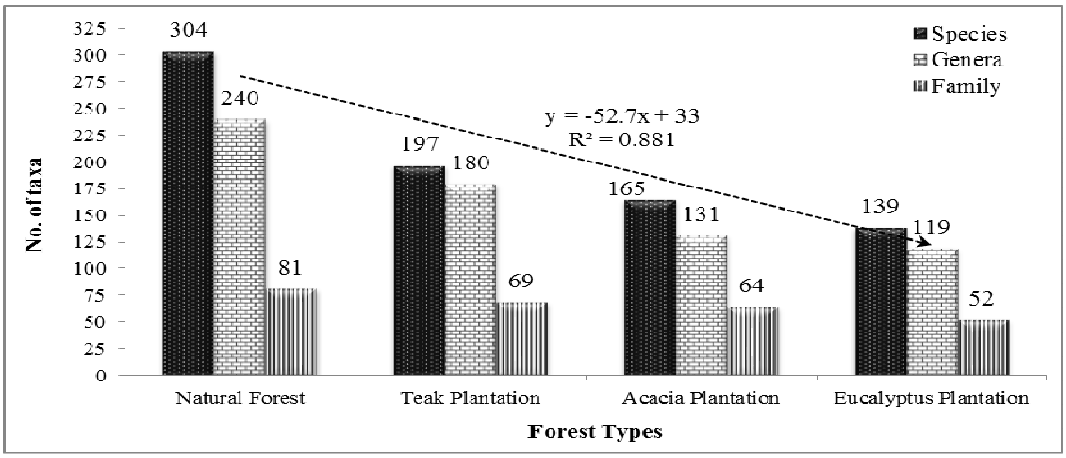

Fig. 2. Floristic composition of undergrowth plant species recorded from four types of forest sites of Rema-Kalenga wildlife sanctuary

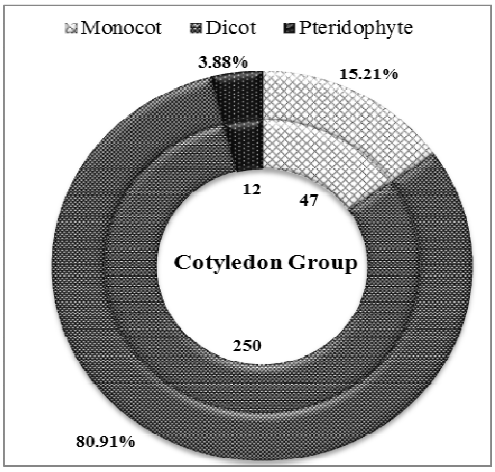

Fig. 3. Major groups of undergrowth plant species recorded from four types of forest sites of Rema-Kalenga wildlife sanctuary

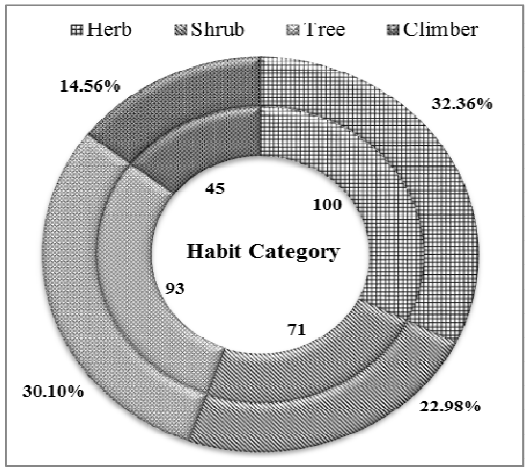

Fig. 4. Habit categories of undergrowth plant species recorded from four types of forest sites of Rema-Kalenga wildlife sanctuary

Table 1. Comprehensive checklist of vascular plant species recorded from four different types of forest sites of Rema-Kalenga wildlife sanctuary

Sl. No.	Scientific name	Family	Cotyledon	Habit
1.	*Abelmoschus moschatus* Medic.	Malvaceae	Dicot	Shrub
2.	*Abutilon indicum* (L.) Sweet	Malvaceae	Dicot	Shrub
3.	*Abrus precatorius* L.	Fabaceae	Dicot	Climber
4.	*Acacia auriculiformis* A. Cunn. *ex* Benth. & Hook.	Fabaceae	Dicot	Tree
5.	*Acacia mangium* Willd.	Fabaceae	Dicot	Tree
6.	*Acacia nilotica* (L.) Delile	Fabaceae	Dicot	Tree
7.	*Achyranthus aspera* L.	Acanthaceae	Dicot	Herb
8.	*Adhatoda zeylanica* Medikus	Acanthaceae	Dicot	Shrub
9.	*Adiantum phillippense* L.	Adiantaceae	Pteridophyte	Herb
10.	*Aegle marmelos* (L.) Corr.	Rutaceae	Dicot	Tree
11.	*Ageratum conyzoides* L.	Asteraceae	Dicot	Herb
12.	*Aglaonema hookerianum* Schott.	Araceae	Monocot	Herb
13.	*Albizia chinensis* (Osb.) Merr.	Fabaceae	Dicot	Herb
14.	*Albizia lebbeck* (L.) Benth. & Hook.	Fabaceae	Dicot	Herb
15.	*Albizia odorattisima* (L. f.) Benth.	Fabaceae	Dicot	Herb
16.	*Albizia procera* (Roxb.) Benth.	Fabaceae	Dicot	Herb
17.	*Aleuritopteris grisea* (Blanford) Panigrahi	Sinopteridaceae	Pteridophyte	Herb
18.	*Allophylus cobbe* (L.) Raeuschel	Sapindaceae	Dicot	Shrub
19.	*Alocasia auminata* Schott.	Araceae	Monocot	Herb
20.	*Alpinia allughas* (Retz.) Rose.	Zingiberaceae	Monocot	Herb
21.	*Alpinia galangal* (L.) Sw.	Zingiberaceae	Monocot	Herb
22.	*Alpinia malaceensis* (Burm. f.) Rose.	Zingiberaceae	Monocot	Herb
23.	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	Dicot	Tree
24.	*Alternanthera sesilis* (L.) R. Br. *ex* Roem. & Schult.	Amaranthaceae	Dicot	Herb
25.	*Amaranthus spinosus* L.	Amaranthaceae	Dicot	Herb
26.	*Amorphophallus bulbifer* (Roxb.) Blume	Araceae	Monocot	Herb
27.	*Ampelopteris prolifera* (Retz.) Copel.	Thelypteridaceae	Pteridophyte	Herb
28.	*Ampelocissus latifolia* (Roxb.) Planch.	Vitaceae	Dicot	Climber
29.	*Angiopteris evecta* (Forst) Hoffm.	Angiopteridaceae	Pteridophyte	Herb
30.	*Anisomeles ovata* R. Br.	Lamiaceae	Dicot	Herb
31.	*Anona reticulata* L.	Annonaceae	Dicot	Shrub
32.	*Anthocephalus chinensis* (Lamk.) A. Rich. *ex* Walp.	Rubiaceae	Dicot	Tree
33.	*Antidesma bunius* (L.) Spreng.	Euphorbiaceae	Dicot	Shrub
34.	*Antidesma ghaesembilla* Gaertn.	Euphorbiaceae	Dicot	Shrub
35.	*Aphanamixis polystachya* (Wall.) R. N. Parker	Meliaceae	Dicot	Tree
36.	*Aquilaria agallocha* Roxb.	Thymeliaceae	Dicot	Tree
37.	*Aporosa dioica* (Roxb.) Muell.-Arg.	Euphorbiaceae	Dicot	Shrub
38.	*Ardisia solanacea* (Poir.) Roxb.	Myrsinaceae	Dicot	Shrub
39.	*Argyreia nervosa* (Burm. f.) Boj.	Convolvulaceae	Dicot	Climber
40.	*Aristolochia tagal* Cham.	Aristolochiaceae	Dicot	Climber
41.	*Artocarpus chaplasha* Roxb.	Moraceae	Dicot	Tree
42.	*Artocarpus heterophyllus* Lamk.	Moraceae	Dicot	Tree
43.	*Artocarpus lacucha* Buch.-Ham.	Moraceae	Dicot	Tree
44.	*Atylosia scarabaeoides* (L.) Baker	Fabaceae	Dicot	Climber
45.	*Averrhoea carambola* L.	Averrhoaceae	Dicot	Tree
46.	*Axonopus compressus* (Sw.) P. Beauv.	Poaceae	Monoot	Herb
47.	*Azadirachta indica* A. Juss.	Meliaceae	Dicot	Tree
48.	*Baccaurea ramiflora* Lour.	Euphorbiaceae	Dicot	Tree
49.	*Bambusa tulda* Roxb.	Poaceae	Monocot	Tree

Table 1. Continued…

Sl. No.	Scientific name	Family	Cotyledon	Habit
50.	*Bauhinia purpurea* L.	Fabaceae	Dicot	Tree
51.	*Bauhinia variegata* L.	Fabaceae	Dicot	Tree
52.	*Blumea lacera* (Burm. f.) DC.	Asteraceae	Dicot	Herb
53.	*Boerhaavia diffusa* L.	Nyctaginaceae	Dicot	Herb
54.	*Bombax ceiba* Burm. f.	Bombacaceae	Dicot	Tree
55.	*Borreria articularis* (L. f.) Williams	Rubiaceae	Dicot	Herb
56.	*Breynia retusa* (Dennst.) Alston	Euphorbiaceae	Dicot	Shrub
57.	*Bridelia stipularis* (L.) Blume	Euphorbiaceae	Dicot	Shrub
58.	*Buettneria pilosa* Roxb.	Sterculiaceae	Dicot	Climber
59.	*Butea monosperma* (Lamk.) Taub.	Fabaceae	Dicot	Tree
60.	*Caesalpinia bonduc* (L.) Roxb.	Fabaceae	Dicot	Shrub
61.	*Calamus guruba* Buch.-Ham. *ex* Martius	Arecaceae	Monocot	Climber
62.	*Calamus tenuis* Roxb.	Arecaceae	Monocot	Climber
63.	*Calamus viminalis* Willd.	Arecaceae	Monocot	Climber
64.	*Callicarpa longifolia* Lamk.	Verbinaceae	Dicot	Shrub
65.	*Calotropis procera* (Ait.) R. Br.	Asclepiadaceae	Dicot	Shrub
66.	*Carex jackiana* Boott	Cyperaeae	Monocot	Herb
67.	*Careya arborea* Roxb.	Lecythidaceae	Dicot	Tree
68.	*Caryota urens* L.	Arecaceae	Monocot	Tree
69.	*Cassia fistula* L.	Fabaceae	Dicot	Tree
70.	*Caturnaregam spinosa* (Thumb.) Tirveng.	Rubiaceae	Dicot	Shrub
71.	*Senna occidentalis* Roxb.	Fabaceae	Dicot	Shrub
72.	*Cassia siamea* Lamk.	Fabaceae	Dicot	Tree
73.	*Senna sophera* (L.) Roxb.	Fabaceae	Dicot	Shrub
74.	*Senna tora* (L.) Roxb.	Fabaceae	Dicot	Herb
75.	*Castanopsis tribuloides* (Smith) A. DC.	Fagaceae	Dicot	Tree
76.	*Celosia argentea* L.	Amarnthaceae	Dicot	Herb
77.	*Centella asiatica* (L.) Urban	Hydrocotylidaceae	Dicot	Herb
78.	*Chickrassia tabularis* (A. Juss.) Wight & Am.	Meliaceae	Dicot	Tree
79.	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	Dicot	Herb
80.	*Cissus adnata* Roxb.	Vitaceae	Dicot	Climber
81.	*Cissus repens* Lamk.	Vitaceae	Dicot	Climber
82.	*Clausena heptaphylla* (Roxb.) Wight & Arn. *Ex* Steud.	Rutaceae	Dicot	Shrub
83.	*Clerodendrum viscossum* Vent.	Verbenaceae	Dicot	Shrub
84.	*Coccinia cordifolia* Cogn.	Cucurbitaceae	Dicot	Climber
85.	*Coffea bengalensis* Roxb. *ex* Schult.	Rubiaceae	Dicot	Shrub
86.	*Colocasia esculenta* (L.) Schott	Araceae	Monocot	Herb
87.	*Combretum acuminatum* Roxb.	Combretaceae	Dicot	Shrub
88.	*Commelina benghalensis* L.	Commelinaceae	Monocot	Herb
89.	*Costus speciosus* (Koenig *ex* Retz.) Smith	Costaceae	Monocot	Herb
90.	*Crataeva nurvala* Buch.-Ham.	Cappridaceae	Dicot	Tree
91.	*Crinum asiaticum* L.	Liliaceae	Monocot	Herb
92.	*Crotalaria pallida* Ait.	Fabaceae	Dicot	Herb
93.	*Croton banplandianum* Baill.	Euphorbiaceae	Dicot	Herb
94.	*Curcuma amada* Roxb.	Zingiberaceae	Monocot	Herb
95.	*Cyathia gigantean* (Wall. Ex Hook.) Holtt.	Cyathaceae	Ptidophyte	Tree
96.	*Cyperus kyllinga* Endl.	Cyperaceae	Monocot	Herb
97.	*Dactyloctenium aegepticum* (L.) P. Beauv.	Poaceae	Monocot	Herb
98.	*Daemonorops jenkinsianus* (Griff.) Martius	Arecaceae	Monocot	Climber
99.	*Dalbergia sisoo* Roxb.	Fabaceae	Dicot	Tree

Table 1. Continued…

Sl. No.	Scientific name	Family	Cotyledon	Habit
100.	*Dalbergia spinosa* Roxb.	Fabaceae	Dicot	Shrub
101.	*Dalbergia stipulacea* Roxb.	Fabaceae	Dicot	Shrub
102.	*Datura metel* L.	Solanaceae	Dicot	Herb
103.	*Delonix regia* Rafin.	Fabaceae	Dicot	Tree
104.	*Dentella repens* (L.) J. R. & G. Forst.	Rubiaceae	Dicot	Herb
105.	*Derris elliptica* (Wall.) Benth.	Fabaceae	Dicot	Climber
106.	*Derris robusta* (Roxb. *ex* DC.) Benth.	Fabaceae	Dicot	Climber
107.	*Desmodium leguminosarum*	Fabaceae	Dicot	Herb
108.	*Desmodium triflorum* (L.) DC.	Fabaceae	Dicot	Herb
109.	*Desmos chinensis* Lour.	Annonaceae	Dicot	Climber
110.	*Dicranopteris linearis* (Burm. f.) Underw.	Gleicheniaceae	Pteridophyte	Herb
111.	*Dillenia indica* L.	Dilleniaceae	Dicot	Tree
112.	*Dillenia pentagyna* Roxb.	Dilleniaceae	Dicot	Tree
113.	*Dioscorea alata* L.	Dioscoreaceae	Monocot	Climber
114.	*Dioscorea belophylla* (Prain) Voigt *ex* Haines	Dioscoreaceae	Monocot	Climber
115.	*Dioscorea bulbifera* L.	Dioscoreaceae	Monocot	Climber
116.	*Dioscorea pentaphylla* L.	Dioscoreaceae	Monocot	Climber
117.	*Diospyros peregrine* Guerke	Ebenaceae	Dicot	Tree
118.	*Diplazium esculentum* (Retz.) Sw.	Athyriaceae	Pteridophyte	Herb
119.	*Dipterocarpus turbinatus* Roxb.	Dipterocarpaceae	Dicot	Tree
120.	*Dracaena spicata* Roxb.	Liliaceae	Monocot	Herb
121.	*Duabanga grandiflora* (Roxb. *ex* DC.) Walp.	Onneratiaceae	Dicot	Tree
122.	*Eclipta alba* (L.) Hassk.	Asteraceae	Dicot	Herb
123.	*Elaeocarpus floribundus* Blume	Elaeocarpaceae	Dicot	Tree
124.	*Elaeocarpus robustus* Roxb.	Elaeocarpaceae	Dicot	Tree
125.	*Elephantopous scaber* L.	Asteraceae	Dicot	Herb
126.	*Elusine indica* (L.) Gaertn.	Poaceae	Monocot	Herb
127.	*Emilia sonchifolia* (L.) DC.	Asteraceae	Dicot	Herb
128.	*Entada phaseoloides* (L.) Merr.	Fabaceae	Dicot	Climber
129.	*Eragrostis tenella* (L.) P. Beauv. *ex* Roem. & Schult.	Poaceae	Monocot	Herb
130.	*Erythrina ovalifolia* Roxb.	Fabaceae	Dicot	Tree
131.	*Erythrina variegata* L.	Fabaceae	Dicot	Tree
132.	*Eucalyptus camadulensis* Dehnhardt	Myrtaceae	Dicot	Tree
133.	*Eupatorium odoratum* L.	Asteraceae	Dicot	Shrub
134.	*Euphorbia hirta* L.	Euphorbiaceae	Dicot	Herb
135.	*Evolvulus numularius* (L.) L.	Convolvulaceae	Dicot	Herb
136.	*Ficus benghalensis* L.	Moraceae	Dicot	Tree
137.	*Ficus bnjamina* L.	Moraceae	Dicot	Tree
138.	*Ficus hirta* Vahl	Moraceae	Dicot	Tree
139.	*Ficus hispida* L. f.	Moraceae	Dicot	Tree
140.	*Ficus racemosa* L.	Moraceae	Dicot	Tree
141.	*Ficus religiosa* L.	Moraceae	Dicot	Tree
142.	*Ficus semicordata* Buch.-Ham. *ex* Smith	Moraceae	Dicot	Tree
143.	*Fimbristylis dichotoma* (L.) Vahl	Cyperaceae	Monocot	Herb
144.	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae	Monocot	Herb
145.	*Flacourtia indica* (Burm. f.) Merr.	Flacourtiaceae	Dicot	Shrub
146.	*Flacourtia jangomas* (Lour.) Raeusch.	Flacourtiaceae	Dicot	Tree
147.	*Flemingia bracteata* (Roxb.) Wight	Fabaceae	Dicot	Shrub
148.	*Floscopa scandans* Lour.	Commelinaceae	Monocot	Herb
149.	*Garcinia cowa* Roxb. *ex* DC.	Cluceaceae	Dicot	Tree

Table 1. Continued…

Sl. No.	Scientific name	Family	Cotyledon	Habit
150.	*Garcinia xanthochymus* Hook. f. *ex* T. Anders.	Cluceaceae	Dicot	Tree
151.	*Globba marantina* L.	Zingiberaceae	Monocot	Herb
152.	*Glochidion lanceolarium* (Roxb.) Voigt	Euphorbiaceae	Dicot	Shrub
153.	*Glochidion multiloculare* (Roxb. *ex* Willd.) Muell.-Arg.	Euphorbiaceae	Dicot	Shrub
154.	*Glycosmis pentaphylla* (Retz.) A. DC.	Rutaceae	Dicot	Shrub
155.	*Gmelina arborea* Roxb.	Verbenaceae	Dicot	Tree
156.	*Gnaphalium luteo-alba* L.	Asteraceae	Dicot	Herb
157.	*Grewia asiatica* L.	Tiliaceae	Dicot	Shrub
158.	*Grewia serrulata* DC.	Tiliaceae	Dicot	Shrub
159.	*Guazuma tomentosa*	Sterculiaceae	Dicot	Shrub
160.	*Hedyotis scandens* Roxb.	Rubiaceae	Dicot	Climber
161.	*Heliotropium indicum* L.	Boraginaceae	Dicot	Herb
162.	*Hemidesmus indicus* (L.) R. Br.	Asclepiadaceae	Dicot	Climber
163.	*Holarrhena antidysenterica* (L.) Wall. *ex* Decne.	Asclepiadaceae	Dicot	Shrub
164.	*Homalomena aromatica* (Roxb. *ex* Sim) Schott.	Araceae	Monocot	Herb
165.	*Hydnocarpus kurzii* (King) Warb.	Flacourtiaceae	Dicot	Tree
166.	*Hyptis suaveolens* (L.) Poit.	Lamiaceae	Dicot	Herb
167.	*Ichnocarpus frutescens* (L.) R. Br.	Apocynaceae	Dicot	Climber
168.	*Ilex godajam* Colebr.	Aquifoliaceae	Dicot	Tree
169.	*Imperata cylindrical* (L.) P. Beav.	Poaceae	Monocot	Herb
170.	*Ipomoea fistulosa* Mart. Ex Choisy	Convolvulaceae	Dicot	Shrub
171.	*Ixora arborea* Roxb. ex Smith	Rubiaceae	Dicot	Shrub
172.	*Ixora spectabilis* Wall. Ex Don	Rubiaceae	Dicot	Shrub
173.	*Ixora undulata* Roxb.	Rubiaceae	Dicot	Shrub
174.	*Jasminum multiflorum* (Burm. f.) Andr.	Oleaceae	Dicot	Shrub
175.	*Jasminum sambac* Ait.	Oleaceae	Dicot	Shrub
176.	*Justicia diffusa* Willd.	Acanthaceae	Dicot	Herb
177.	*Lagerstroemia speciosa* L. Pers.	Lythraceae	Dicot	Tree
178.	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Dicot	Tree
179.	*Lantana camara* L.	Verbenaceae	Dicot	Shrub
180.	*Laportea crenulata* Gaud.	Urticaceae	Dicot	Climber
181.	*Leea acuminate* (Burm. f.) Merr.	Leaceae	Dicot	Shrub
182.	*Leea robusta* Roxb.	Leaceae	Dicot	Shrub
183.	*Leucaena leucocephala* (Lamk.) DC. Wit.	Fabaceae	Dicot	Tree
184.	*Leucas aspera* (Willd.) Link.	Lamiaceae	Dicot	Herb
185.	*Leucas lavendulifolia* Smith.	Lamiaceae	Dicot	Herb
186.	*Lindernia procumbens* (Krocker) Philcox	Scrophulariaceae	Dicot	Herb
187.	*Lippia nodiflora* (L.) Rich.	Verbenaceae	Dicot	Herb
188.	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	Dicot	Tree
189.	*Lycopodium* sp.	Lycopodiaceae	Pteridophyte	Climber
190.	*Lygodium flexuosum* (L.) Sw.	LygodIaceae	Pteridophyte	Climber
191.	*Macaranga denticulate* (Blume) Muell.-Arg.	Euphorbiaceae	Dicot	Tree
192.	*Maesa montana* A. DC.	Myrsinaceae	Dicot	Shrub
193.	*Madhuca indica* (L.) Rich.	Sapotaceae	Dicot	Tree
194.	*Mallotus philippnsis* (Lamk.) Muell.-Arg.	Euphorbiaceae	Dicot	Shrub
195.	*Mangifera indica* L.	Anacardiaceae	Dicot	Tree
196.	*Mangifera sylvatica* Roxb.	Anacardiaceae	Dicot	Tree
197.	*Manihot esculenta* Crantz.	Euphorbiaceae	Dicot	Tree
198.	*Melastoma malabathrium* Roxb.	Melastomaceae	Dicot	Shrub
199.	*Melia sempervirens* (L.) sw.	Meliaceae	Dicot	Tree

Table 1. Continued…

Sl. No.	Scientific name	Family	Cotyledon	Habit
200.	*Melilotus alba* Desr.	Fabaceae	Dicot	Shrub
201.	*Merremia hirta* (L.) Merr.	Convolvulaceae	Dicot	Climber
202.	*Mesua ferrea* L.	Clauciaceae	Dicot	Tree
203.	*Microcos paniculata* L.	Tiliaceae	Dicot	Shrub
204.	*Micromelum minutum* (Forst. f.) Wight. & Arn.	Rutaceae	Dicot	Shrub
205.	*Mikania cordata* (Burm. f.) B. L. Roxb.	Asteraceae	Dicot	Climber
206.	*Mimosa pudica* L.	Fabaceae	Dicot	Herb
207.	*Mimusops elengi* L	Sapotaceae	Dicot	Tree
208.	*Moghania latifolia* (Benth.) Mukherjee	Fabaceae	Dicot	Shrub
209.	*Morinda angustifolia* Roxb.	Rubiaceae	Dicot	Shrub
210.	*Mucuna imbricata* (DC.) Baker	Fabaceae	Dicot	Climber
211.	*Mucuna pruriens* (L.) DC.	Fabaceae	Dicot	Climber
212.	*Murdannia nudiflora* (L.) Brenan	Commelinaceae	Monocot	Herb
213.	*Musa ornata* Roxb	Musaceae	Monocot	Herb
214.	*Mussanda roxburghii* Hook. f.	Rubiaceae	Dicot	Shrub
215.	*Mycetia longifolia* (Wall.) O. Kuntze.	Rubiaceae	Dicot	Shrub
216.	*Nelsonia canescens* (Lamk.) Spreng.	Acanthaceae	Dicot	Herb
217.	*Nerium indicum* Mill.	Apocynaceae	Dicot	Tree
218.	*Ocimum sanctum* L.	Lamiaceae	Dicot	Herb
219.	*Oldenlandia corymbosa* L.	Rubiaceae	Dicot	Herb
220.	*Ophiorrhiza mugna* L.	Rubiaceae	Dicot	Herb
221.	*Oroxylum indicum* (L.) Kurz.	Bignoniaceae	Dicot	Tree
222.	*Oxalis corniculata* L.	Oxalidaceae	Dicot	Herb
223.	*Paederia foetida* L.	Rubiaceae	Dicot	Climber
224.	*Pandanus foetidus* Roxb.	Pandanaceae	Monocot	Shrub
225.	*Panicum repens* L.	Poaceae	Monocot	Herb
226.	*Passiflora foetida* L.	Passifloraceae	Dicot	Herb
227.	*Peperomia pellucida* (L.) H. B. & K.	Piperaceae	Dicot	Herb
228.	*Peristrophe bicalyculata* (Retz.) Nees	Acanthaceae	Dicot	Herb
229.	*Persicaria hydropiper* (L.) Spach	Polygonaceae	Dicot	Herb
230.	*Persicaria orientalis* (L.) Spach	Polygonaceae	Dicot	Herb
231.	*Phlogacanthus thyrsiflorus* Nees.	Acanthaceae	Dicot	Shrub
232.	*Phyllanthus embelica* L.	Euphorbiaceae	Dicot	Tree
233.	*Phyllanthus niruri* L.	Euphorbiaceae	Dicot	Herb
234.	*Phyllanthus reticulatus* Poir	Euphorbiaceae	Dicot	Shrub
235.	*Physalis minima* L.	Solanaceae	Dicot	Herb
236.	*Piper longum* L.	Piperaceae	Dicot	Climber
237.	*Piper sylvaticum* Roxb.	Piperaceae	Dicot	Climber
238.	*Polyalthia longifolia* (Sonn.) Thw.	Annonaceae	Dicot	Tree
239.	*Premna corymbosa* Rott. & Willd.	Verbenaceae	Dicot	Shrub
240.	*Premna esculenta* Roxb.	Verbenaceae	Dicot	Shrub
241.	*Proniferium nudatum* (Roxb. ex Griff.) Holtt.	Thelypteridaceae	Pteridophyte	Herb
242.	*Psidium guajava* L.	Myrtaceae	Dicot	Tree
243.	*Pterygota alata* (Roxb.) R. Br.	Sterculiaceae	Dicot	Tree
244.	*Pteris vittata* L.	Pteridaceae	Pteridophyte	Herb
245.	*Pterospermum acerifolium* (L.) Willd.	Sterculiaceae	Dicot	Tree
246.	*Pterospermum semisegittatum* Buch.-Ham. *ex* Roxb.	Sterculiaceae	Dicot	Tree
247.	*Quercus spicata* Smith	Fagaceae	Dicot	Tree
248.	*Rauwolfia sarpentina* (L.) Benth. *ex* Kurz.	Apocynaceae	Dicot	Herb
249.	*Ricinus communis* L.	Euphorbiaceae	Dicot	Shrub

Table 1. Continued…

Sl. No.	Scientific name	Family	Cotyledon	Habit
250.	*Rorippa indica* (L.) Hiern	Brassicaceae	Dicot	Herb
251.	*Ruellia tuberosa* L.	Acanthaceae	Dicot	Herb
252.	*Saccharum spontaneum* L.	Poaceae	Monocot	Herb
253.	*Scleria levis* Retz.	Cyperaceae	Monocot	Herb
254.	*Scoparia dulcis* L.	Scrophulariaceae	Dicot	Herb
255.	*Selaginella vaginata* Spring	Selaginellaceae	Pteridophyte	Herb
256.	*Shorea robusta* Gaertn.	Dipterocarpaceae	Dicot	Tree
257.	*Sida acuta* Burm. f.	Malvaceae	Dicot	Shrub
258.	*Sida cordata* (Burm. f.) Borss.	Malvaceae	Dicot	Herb
259.	*Sida cordifolia* L.	Malvaceae	Dicot	Herb
260.	*Smilax prolifera* Roxb.	Smilacaceae	Monocot	Climber
261.	*Smilax zylanica* L.	Smilacaceae	Monocot	Climber
262.	*Solanum indicum* L.	Solanaceae	Dicot	Shrub
263.	*Solanum nigram* L.	Solanaceae	Dicot	Herb
264.	*Solanum torvum* Swartz	Solanaceae	Dicot	Shrub
265.	*Spatholobus roxburghii* Benth.	Fabaceae	Dicot	Climber
266.	*Spondias pinnata* (L. f.) Kurz.	Acanthaceae	Dicot	Tree
267.	*Stemona tuberosa* Lour.	Stemonaceae	Monocot	Climber
268.	*Stephania japonica* (Thunb.) Miers	Menispermaceae	Dicot	Climber
269.	*Sterculia vilosa* Roxb.	Sterculiaceae	Dicot	Tree
270.	*Steudnera colocasioides* Hook. f.	Araceae	Monocot	Herb
271.	*Streblus asper* Lour.	Moraceae	Dicot	Tree
272.	*Suregada multiflora* (A. Juss.) Baill.	Euphorbiaceae	Dicot	Shrub
273.	*Swietenia mahagoni* Jacq.	Meliaceae	Dicot	Tree
274.	*Swintonia floribunda* Griff.	Anacardiaceae	Dicot	Tree
275.	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae	Dicot	Herb
276.	*Syzygium cumini* (L.) Skeels	Myrtaceae	Dicot	Tree
277.	*Syzygium fruticosa* DC.	Myrtaceae	Dicot	Tree
278.	*Syzygium operculatum* (Roxb.) Niedz.	Myrtaceae	Dicot	Tree
279.	*Tabernaemontana recurva* Roxb.	Apocynaceae	Dicot	Shrub
280.	*Tamarindus indica* L.	Fabaceae	Dicot	Tree
281.	*Tectona grandis* L.	Verbenaceae	Dicot	Tree
282.	*Tephrosia purpurea* (L.) Pers.	Fabaceae	Dicot	Shrub
283.	*Terminalia arjuna* (Roxb. *ex* DC.) Wight & Arn.	Combretaceae	Dicot	Tree
284.	*Terminalia belerica* (Gaertn.) Roxb.	Combretaceae	Dicot	Tree
285.	*Terminalia capata* L.	Combretaceae	Dicot	Tree
286.	*Terminalia chebula* Retz.	Combretaceae	Dicot	Tree
287.	*Tetrastigma agustifolium* (Roxb.) Planch.	Vitaceae	Dicot	Climber
288.	*Thunbergia grandiflora* (Roxb. *ex* Rottler) Roxb.	Acanthaceae	Dicot	Climber
289.	*Thysanolaena maxima* (Roxb.) O. Kuntze	Poaceae	Monocot	Herb
290.	*Tinospora crispa* (L.) Hook. f. & Thorns.	Menispermaceae	Dicot	Climber
291.	*Trema orientalis* (L.) Blume	Ulmaceae	Dicot	Tree
292.	*Trewia nodiflora* L.	Euphorbiaceae	Dicot	Tree
293.	*Tridex procumbens* L.	Asteraceae	Dicot	Herb
294.	*Tylophora indica* (Burm. f.) Merr.	Asclepiadaceae	Dicot	Climber
295.	*Typhonium trilobatum* (L.) Schott.	Araceae	Monocot	Herb
296.	*Urena lobata* L.	Malvaceae	Dicot	Shrub
297.	*Urena sinuata* L.	Malvaceae	Dicot	Shrub
298.	*Vernonia cinerea* (L.) Less.	Asteraceae	Dicot	Herb
299.	*Vetiveria zizaniodes* (L.) Nash	Poaceae	Monocot	Herb

Table 1. Continued…

Sl. No.	Scientific name	Family	Cotyledon	Habit
300.	*Vitex nigundo* L.	Verbenaceae	Dicot	Shrub
301.	*Vitis trifolia* L.	Vitaceae	Dicot	Climber
302.	*Willoughdeia edulis* Roxb.	Apocynaceae	Dicot	Climber
303.	*Xanthium indicum* Koen. *ex* Roxb.	Asteraceae	Dicot	Shrub
304.	*Xeromphis spinosa* (Thunb.) Keay	Rubiaceae	Dicot	Shrub
305.	*Xylia dolabiformis* Benth.	Fabaceae	Dicot	Tree
306.	*Zanthoxyllum rhetsa* (Roxb.) DC.	Rutaceae	Dicot	Tree
307.	*Ziziphus mauritiana* Lamk.	Rhamnaceae	Dicot	Tree
308.	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae	Dicot	Shrub
309.	*Ziziphus rugosa* Lamk.	Rhamnaceae	Dicot	Shrub

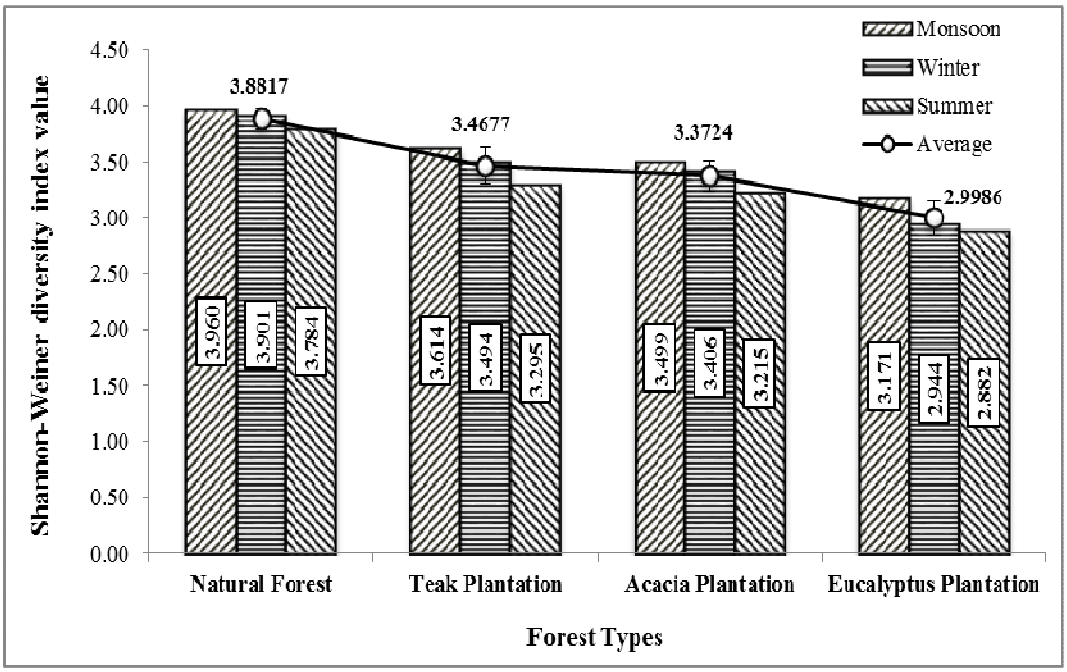

Fig. 5. Shannon-Weiner diversity index values recorded from different selected forest sites of Rema-Kalenga wildlife sanctuary

In plantation forest, the highest number of 194 plant species under 178 genera and 67 families were recorded from *Tectona* plantation site during monsoon season, which was followed by 164 plant species under 131 genera and 63 families were recorded from *Acacia* plantation site during the same season, whereas the lowest number of 105 plant species belonging to 86 genera and 45 families were recorded from *Eucalyptus* plantation site during summer season (Table 2). In *Tectona* plantation forest, the highest Shannon-Wiener index value 3.614 was calculated during monsoon season which was followed by 3.494 and 3.215 found during winter and summer seasons, respectively (Table 2; Fig. 5). In *Acacia* plantation forest, the highest index value 3.496 was recorded during monsoon

season which was followed by 3.406 and 3.291 recorded during winter and summer seasons, respectively. Similarly, In *Eucalyptus* plantation forest, the highest index value 3.171 was recorded during monsoon season which was followed by 2.944 and 2.882 were recorded during winter and summer seasons, respectively (Table 2; Fig. 5).

Table 2. Floristic composition and Shannon-Weiner diversity index values recorded from four different types of forest sites of Rema-Kalenga wildlife sanctuary

Name of the Site	Season	Floristic composition			Diversity Index
		No. of family	No. of genera	No. of species	
Natural forest	Monsoon	79	237	298	3.960
	Winter	75	234	287	3.901
	Summer	69	221	245	3.784
	Total	81	240	304	-
	Average	74.33	197.33	276.67	3.88±0.090
***Tectona* plantation**	Monsoon	67	178	194	3.614
	Winter	59	136	159	3.494
	Summer	52	94	124	3.215
	Total	69	180	197	-
	Average	59.33	136.00	159.00	3.441±0.205
***Acacia* plantation**	Monsoon	63	131	164	3.496
	Winter	56	127	152	3.406
	Summer	49	115	130	3.291
	Total	64	131	165	-
	Average	56.00	124.33	148.67	3.398±0.103
***Eucalyptus* plantation**	Monsoon	52	119	138	3.171
	Winter	48	103	126	2.944
	Summer	45	86	105	2.882
	Total	52	119	139	-
	Average	48.33	102.67	123.00	2.999±0.152

The average number of taxa and their diversity index values recorded from four different types of forest sites during three different seasons were found to decrease by different sites of plantation forests in the sequence from Natural forest to *Tectona* plantation to *Acacia* plantation to *Eucalyptus* plantation forest. Similarly, the number of plant taxa and Shannon-Wiener diversity index values varied among the studied seasons and found to show the trends of gradual decrease from monsoon to winter to summer seasons.

The number of undergrowth plant taxa as well as the phytodiversity index values was found to be the highest in natural forest site which was followed by *Tectona* and *Acacia* plantation sites and the lowest in *Eucalyptus* plantation site (Fig. 2 and Fig. 5). The finding of lower number of undergrowth species in the plantation of fast-growing exotic tree species is supported by that of Hossain *et al.* (2002) The occurrence of lower number of undergrowth species in the plantation forest of fast-growing exotic tree species

(Hossain *et al.*, 2002) that due to thick, leathery, flattened and expanded leaves of exotic plants were degrade slowly and ultimately the soil of their habitat become hard and unfertile. The finding of natural forests harboring the maximum species diversity index in their comparatively stable ecosystem in respect to any other plantation forest ecosystem is supported by Narayan *et al.* (1994) because they stated that higher values of diversity showed greater stability of the community. *Eucalyptus* plantation depressed the forest species more than other plantation either fast-growing *Acacia* or slow-growing *Tectona* plantation. Due to allelopathy *Eucalyptus* plantation is often regarded as damaging for the environment (Poore & Fries, 1985) which was also shown by Lisanework & Michelsen (1993), Souto *et al*. (1995), Bernhard-Reversat (1999), Reigosa *et al*. (1999). Moreover, the floristic composition and phytodiversity of fast-growing plantation forests in tropical regions have been reduced through the losing of fertility of top soil. The finding of *Acacia* and *Eucalyptus* plantations sites of the study area harboring fewer indigenous plant species and less species diversity is supported by the findings of Hossain & Hossain (2009), Bouvet (1998), Abbasi & Vinithan (1997).

The present findings concluded that any kind of plantations, either of fast-growing *Acacia* or *Eucalyptus* or slow-growing *Tectona* species in this semi-tropical region might affect the species composition and diversity of local forests. Fast-growing exotic tree plantations of *Acacia* and *Eucalyptus* affected the floristic composition and phytodiversity as well as on the environment more than that of *Tectona* plantation. Therefore, it might be suggested that monoculture plantations especially for the fast-growing exotic species like *Acacia*, *Eucalyptus* are not suitable for local forest plant species in the semi-tropical region of Rema-Kalenga wildlife sanctuary. These types of fast-growing species may be selected for plantation in unfertile barren lands or less fertile grasslands, because they grow well in those types of habitats without any care and supplementary nourishment (Hossain *et al*., 2002). So, the fast-growing exotic tree plantation of *Acacia* and *Eucalyptus* should be avoided for future sustainable management and development of Rema-Kalenga wildlife sanctuary.

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