PHYTOSOCIOLOGICAL STUDIES OF MANGROVE FORESTS OF CHAKARIA SUNDARBANS

Ansarul Karim
M. A. Aziz Khan

Phytosociological studies were made for the thirteen stands of Chakaria Sundarbans, Chittagong. Soil factors such as profile, texture, ground water table, pH and salinity were studied. Depending on the characteristic species four phytosociological zones were recognised which were related with the various ecological factors. Maximum soil salinity ranging from 10 mmhos to 33 mmhos were recorded in the *Avicennia - Sonneratia - Aegialitis* zone. In this zone water table ranges from few cm to 30 cm (11.8 in). Soil profile differentiation is not well marked. Soil is more silty than other zones. *Heritiera - Brugiiera* zone occur in the soil with least salinity conductivity ranging from 7.5 mmhos to 2.5 mmhos. Water table ranges from 100 cm (34.3 in) to 150 cm (59.1 in). Soil profile is differentiated into various horizons in this zone. In the field condition surface soil shows pH range from 6.2 to 7.5. The air dried soil shows a fall of pH value to 3.4 in some stands.

INTRODUCTION

Mangrove forests, locally known as Sundarbans, 'Para ban' in Chittagong play an important role as a direct source of timber, fuel, tannin, pulpwood and raw material for match industries. Besides, it also provides protection against tidal bores and cyclones. Due to its inherent property to build soil around its peculiar root system mangrove plants are planted in the new accretions along the coastal belt and offshore islands of Bangladesh for accelarating siltation and consolidating soil.

The existing mangrove forests of Bangladesh consisting of nearly 6103 sq km (2356 sq miles) is the largest in the world. Besides, about 400 sq km (154 sq miles) of mangrove forests have been planted in the new coastal formations so far. It has been planned to raise mangrove plantations in an area of about 4980 sq km (2000 sq miles) in the new formations of the Bay of Bengal (Anon. 1978). Increasing use of mangrove forest areas of Bangladesh for agriculture and fisheries has added an additional attraction for understanding this ecosystem. Chapman (1976) summarised the available literature on mangrove vegetation of the world. Descriptive accounts of mangrove forests of Sundarban of the Ganges and Brahmaputra delta were given earlier by Prain (1903) and later by Troup (1921), Curtis (1933) and Chowdhury (1960). Precise account on the description of vegetation of Chakaria Sundarbans were dealt by Puri (1960) and Chowdhury (1964). Cowan (1926) made an extensive study of the flora of of Chakaria Sundarbans. In recent times a preliminary study on the succession of species was done in the clearfelled areas of the Sundarbans by Khan *et al* (1971). On the basis of observation Das (1971) reviewed the vegetation and ecology of coastal belt of Bangladesh.

Chakaria Sundarbans is an isolated compact patch of mangrove forest with an area of about 8540 ha (21103 acre) which occurs along the delta of the Matamuhury in the district of Chittagong. In the past the area of the forest was about 18200 ha (44974 acre) (Cowan 1926). It is one of the oldest mangrove forests in the subcontinent (Chowdhury 1964). These forests were subjected to various human interferences for extension of agricultural land and collection of fuel, etc. As a result only a small patch of forest is left now in the interior where a few Sundri trees (*Heritiera fomes*) of about 21 m (70 ft) height can be seen as remnant of the old luxuriant vegetation.

No quantitative work on ecological studies of these forests has yet been done. The present study is an attempt to assess the phytosociological composition of the vegetation of Chakaria Sundarbans and to relate the variation of composition with various environmental factors so as to understand the casual ecological factors responsible for the distribution and abundance of various mangrove plants.

MATERIALS AND METHODS

Thirteen stands with the combination of various dominant plants were selected at random. Sampling of vegetation was done from January to April, 1977. Depending on the accessibility of the area and the size of the plant community five to ten quadrants, 2 m x 4 m each (6.6 ft X 13.1 ft) were, laid at random at 10 m (32.8 ft) intervals. Number of individuals of each species in each quadrant was noted. Dominance of each species was calculated by summing up the relative density and relative frequency of the species in each stand. Presence of grasses and climbers were noted.

Soil analysis : Soil profile colour was noted by visual observation. Ground water table was determined by boring the soil with a soil auger. Soil samples were collected from 0 to 150 mm (0 to 5.9 in) and was termed surface soil. Two other samples 150 mm to 600 mm (5.9 in to 23.6 in) and above were termed subsurface samples.

The soil pH was determined by a glass electrode pH meter, both in the field moist condition and air dried condition from a 1:1 soil water suspension. Conductivity was determined by a conductivity meter from a 1 : 2 soil : water extract. Soil particle size was also determined.

RESULTS AND DISCUSSIONS

Phytosociological analysis : The dominance of species in each stand has been shown in Table 1. It shows that the main species of the Chakaria Sundarbans comprise of *Avicennia alba, Avicennia officinalis, Avicennia sp., Sonneratia apetala, Sonneratia alba, Aegialitis rotundifolia, Dalbergia spinosa, Ceriops roxburghiana, Excoecaria agallocha, Bruguieara gymnorhiza,* and *Heritiera fomes*. *Phoenix palludosa* is the only palm tree found in these forests. *Acanthus ilicifolius* is a shrub and *Acrostichum aurium* is the only fern which occur as undergrowths. The woody slender creepers in these forests are *Derris scandens* and *Brownlowia lanceolata*. Grasses like *Oryza coarctata* and *Imperata cylindrica* are frequent in the low lying areas. Figure 1 shows zona-

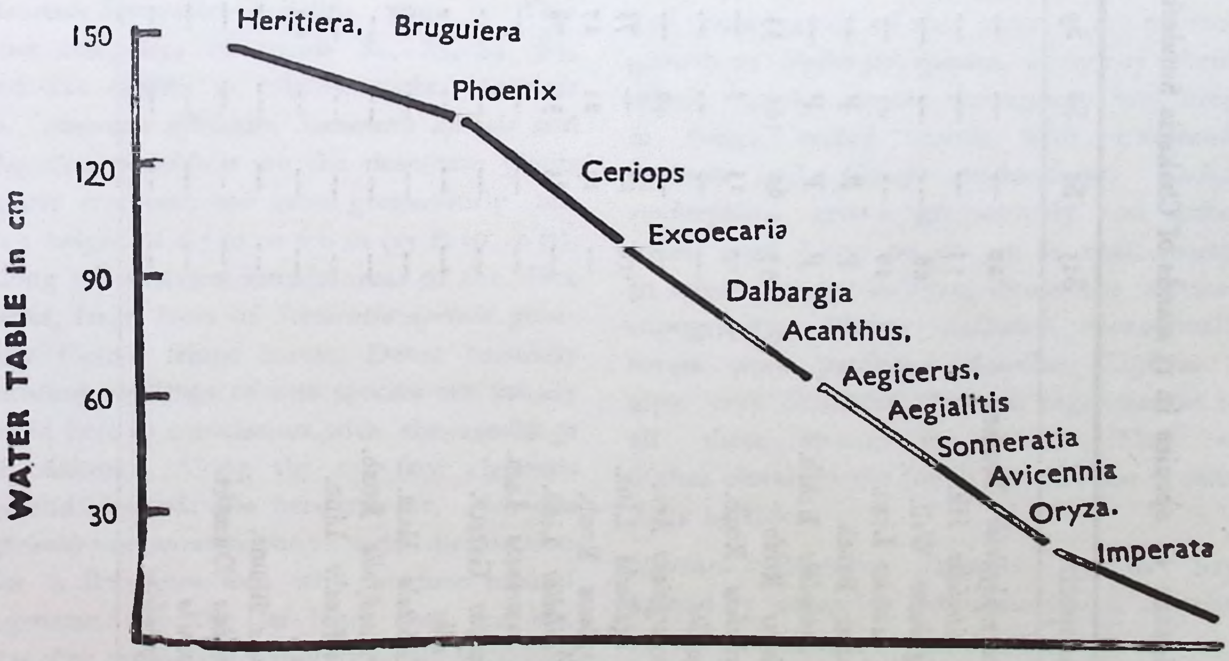

Figure 1. Hypothetical model of relation between the vegetation zones and water table elevation complex.

Table 1. Dominance of species in 13 stands of Chakaria Sunderbans

	Name of the species	S15	S1	S8	S9	S7	S12	S6	S3	S5	S4	S10	S2	S13
1.	*Bruguiera caryophylloide* Blume.	20	—	—	—	—	—	—	—	—	—	—	—	—
2.	*Paramygnea citrifolia* Hk.	57	—	—	—	—	—	—	—	—	—	—	—	—
3.	*Sarcolobus globosus* Wall.	28	—	—	—	—	—	—	—	—	—	—	—	—
4.	*Acrostichum aureum* Linn.	10	—	—	—	—	—	—	—	—	—	—	—	—
5.	*Derris scandens* Benth.	P	P	P	—	—	—	—	—	—	—	—	—	—
6.	*Brownlowia lanceolata* Benth.	P	P	P	—	—	—	P	—	—	—	—	—	—
7.	*Heritiera fomes* Roxb.	57	60	105	33	—	—	—	-	—	—	—	—	—
8.	*Phoenix palludosa* Roxb.	—	15	3	—	103	—	—	—	—	—	—	—	—
9.	*Tamarix gallica*	—	—	—	—	9	—	—	—	—	—	—	—	—
10.	*Ceriops roxburghiana* Arn.	—	—	40	—	37	147	35	—	—	—	—	—	—
11.	*Excoecaria agallocha* Linn.	16	25	—	75	37	17	71	—	—	—	—	—	—
12.	*Dalbergia spinosa* Roxb.	—	13	22	17	—	20	30	—	—	—	—	—	—
13.	*Acanthus ilicifolius* Linn.	—	83	30	78	—	14	35	—	48	45	—	8	—
14.	*Rhizophora mucronata* Lam.	—	—	—	—	—	—	—	4	—	—	—	—	—
15.	*Aegicerus majus* Gaertn.	—	—	—	—	—	—	—	58	—	—	—	9	—
16.	*Sonneratia alba*	—	—	—	—	—	—	—	4	—	—	—	—	—
17.	*Sonneratia apetala* Ham.	—	—	—	—	—	—	—	—	78	12	—	—	—
18.	*Aegialitis rotundifolia* Roxb.	—	—	—	—	—	—	—	84	36	32	116	10	—
19.	*Avicennia officinalis* Linn.	—	—	—	—	—	—	14	11	18	16	—	105	—
20.	*Avicennia* sp	—	—	—	—	—	—	—	—	18	1	11	8	—
21.	*Avicennia alba* Blume.	—	—	—	—	—	—	—	47	7	10	74	62	—
22.	*Suaeda martima* Dumort.	—	—	—	—	—	—	—	—	—	—	P	—	P
23.	*Oryza coarctata*	—	—	—	—	—	—	—	—	P	—	—	—	P
24.	*Imperata cylindrica*	—	—	—	—	—	—	—	—	P	—	—	—	P

S—Stand, P—Present.

tion of vegetation. In these zones certain species tend to occur in association with other species. The composition of species in each zone is different from the other. It appears that the plant species which is dominant in one zone, is either absent or rare in other zones. On the basis of characteristic species composition the following phytosociological zones can be recognised.

Grass zone : This zone is composed of grasses, mostly *Imperata cylindrica* and *Oryza coarctata.* They occur as pure patches of grassland on the soft fresh deposits. The whole area of this zone is subjected to frequent tidal inundation and remain submerged for the greater part of the day.

Avicennia-Sonneratia - Aegialitis **zone :** This zone comprises of stands S2, S3, S4, S5, and S10 (Table 1). *Avicennia alba, Avicennia* sp., *Avicennia officinalis, Sonneratia apetala* and *Aegialitis rotundifolia* are the dominant plants mostly evergreen and grow gregariously upto a height of 4.5 m to 6.0 m (15 ft to 20 ft). Along the shelving muddy areas of the river banks, large trees of *Sonneratia apetala* generally form a fringe forest. Dense naturally occuring seedlings of this species are usually found here in association with the seedlings of *Avicennia.* Along the sea face *Avicennia* sp, and *Avicennia alba* predominate. *Avicennia officinalis* var *tomentosa* shows wide distribution but it flourishes well with profuse natural regeneration in the flat basin near the sea. *Aegialitis rotundifolia*, a straight small deciduous tree of 3 m to 3.5 m (9.8 ft to 11.5 ft) height form a second storey along with *Avicennia* and *Sonneratia.* It occurs in abundance in the flat basins where tidal water accumulates. *Aegicerous majus,* a nectar producing plant is an associate of the *Avicennia* and *Aegialitis* communities. *Rhizophora mucranata* with stilt root is also found occassionally in this zone. All the species present in this zone produce pneumatophores. *Aegialitis rotundifolia* forms a dense mat of thin fibrous roots in the soil. *Acanthus ilicifiolius,* a spiny shrub, grows profusely where substratum is exposed to sunlight. The forest floor in this zone is inundated by the diurnal tides and most of the time the area remains waterlogged. Banik* made similar observation.

Dalbergia - Ceriops - Excoecaria **zone :** Stands S12, S9, S7 and S6 represent this zone. The characteristic of this zone is the profuse growth of *Dalbergia spinosa,* a thorny shrub which grows almost throughout the area. It forms mixed stands with *Excoecaria agallocha* and *Ceriops roxburghiana. Ceriops roxburghiana* grows gregariously and either forms pure forest or occurs as understorey. In relatively dry habitat, due to the elevated topography, *Phoenix palludosa* occassionally forms pure patches. *Acanthus ilicifolius* is also very common. Natural regeneration of all these species is common. Due to higher elevation the forest floor is not flooded daily by tides.

Heritiera - Bruguiera **zone :** Stands S15, S8 and S1 comprise this zone which consists of the maximum number of species.

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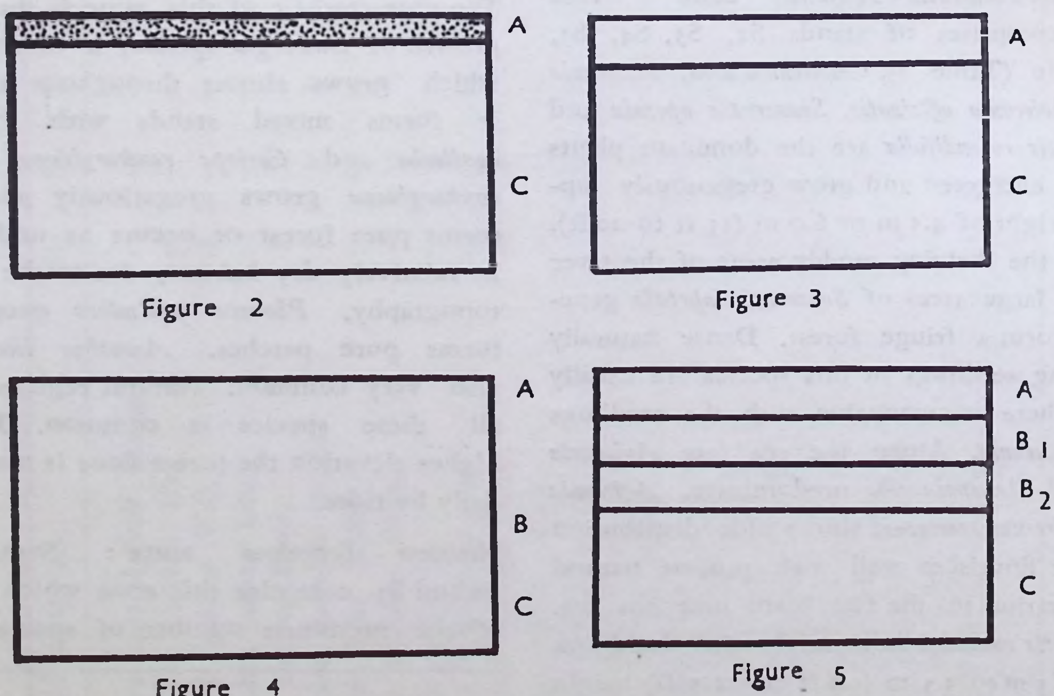
* *Personal communication*

Heretiera fomes occurs in association with *Exocoecaria agallocha*, *Bruguiera gymnorhiza* and *Ceriops roxburghiana*. Sometimes monodominant plant community of *Heritiera fomes* can be seen in certain localities. The whole forest floor is intermittently flooded during spring tide. The growth of *Heritiera fomes* is uniformly luxuriant. Sometimes it forms a multistoried forest attaining a height of about 15 m (49 ft). It occurs in association with *Bruguiera caryophylloide* , *Paramygnia citrifolia* and *Sarcolobus globosus* in the elevated areas. The fern *Acrostichum aureum* grows in abundance as an undergrowth in this zone. *Brownloiwia lanceolata* and *Derris scandens* are the slender creepers found in association with *Heritiera fomes*.

Environmental relations : Results on soil analysis (Table 2) shows that characteristic profile occurs under each phytosociological zone and is much related with the depth of water table. Figure 1 shows the hypothetical model of relations of vegetation zones with the depth of water table and soil elevation. The low lying areas where water table is very near the ground surface and which remains submerged for the maximum period and receive fresh silt deposit each year do not show any differentiation of profile excepting a light brown cover of slime above the grey horizon (Fig. 2). These fresh deposits can hardly sustain any woody vegetation. Only grass community occurs in this soil. With the increase of elevation the depth



Figures 2—5, Stages of soil profile differenciation,

Table 2. Rsults of soil analysis and dominant plant in 13 stands of Chakaria Sundarbans

Stand No.	Dominant sp.	Soil–profile colour	Soil texture		Water table depth (cm)	Soil PH				Soil Conductivity	
			S	SS		Surface		Sub-surface		Surface	Sub-surface
						F	D	F	D		
1	2	3	4	5	6	7	8	9	10	11	12
S 13	*Oryza* *Imperata*	A-Greyish brown B1-Nil B2-Nil C-Grey	Silt loam	Silt loam	30	7.3	7.0	6.5	5.0	9.7	11.0
S 2	*Avicennia officenalis* *Avicennia alba*	A-Greyish brown B1-Nil B2-Nil C-Grey	Silt	Silt	30	7.0	5.0	7.6	4.3	33.1	30.4
S 10	*Aegialitis* *Avicennia alba*	A-Brown B1-Nil B2-Nil C-Grey	Silt loam	Silty clay loam	45	7.5	6.5	6.3	6.3	14.6	22.0
S 4	*Sonneratia*	A-Brown B1-Nil B2-Nil C-Grey	Silt	Silt loam	30	7.0	5.6	6.4	5.5	13.6	10.1
S 3	*Aegialitis* *Aegicerus majus*	A-Greyish brown B1-Nil B2-Nil C-Grey	Silt loam	Silt loam	45	7.3	5.2	6.5	3.3	11.5	10.6
S 5	*Acanthus*	A-Greyish brown B1-Nil B2-Nil C-Grey	Silt	Silt loam	75	6.9	6.3	6.9	5.5	13.6	13.1

Continued

1	2	3	4	5	6	7	8	9	10	11	12
S 6	*Excoecaria agallocha*	A-Brown B1-Red mottledbrown B2-Nil C-Grey	Silt	Clay loam	110	6.9	6.6	6.6	4.4	12.7	7.6
S 12	*Ceriops roxburghiana*	A-Greyish brown B1-Red mottled brown B2-Yellow mottled grey C-Grey	Silty clay loam	Silty clay	125	6.8	6.6	6.5	4.0	9.6	11.0
S 9	*Excoecaria Acanthus*	A-Greyish brown B1-Red mottled brown B2-Red mottled greyish brown C-Grey	Silt loam	Silt loam	100	6.3	6.3	6.6	4.1	7.2	10.5
S 7	*Phoenix paltudosa*	A-Light brown B1-Nil B2-Red mottled grey C-Grey	Clay	Silt clay loam	135	6.5	6.3	6.7	6.5	10.5	6.0

Continued

1	2	3	4	5	6	7	8	9	10	11	12
S 1	*Heritiera* *Acanthus*	A-Brown B1-Red mottled brown B2-Red & yellow mottled grey C-Grey	Clay	Silt clay loam	105	6.2	6.3	6.5	5.6	7.5	7.5
S 8	*Heritiera*	A-Brown B-Nil B2-Red mottled middle grey C-Grey	Silt loam	Silty clay	140	6.3	6.2	6.6	4.1	3.5	7.2
S 15	*Heritiera* *Paramygnea*	A-Dark brown B1-Red mottled brown B2-Red & yellow mottled grey C-Grey	Clay	Silty clay loam	150	6.4	6.0	5.5	5.1	5.0	2.5

Species having dominance value of 50 or more are shown in the Table

S–Surface, F–Field moist soil
SS–Sub-surface, D–Air dry soil

of water table increases, the substratum looses water due to evapo-transpiration and the soil becomes compact ; this condition is conducive to the growth of woody vegetation. *Avicennia alba, Avicennia* sp. and *Sonneratia apetala* predominate in this relatively stabilized but immature soil. Afterwards *Aegialitis rotundifolia* becomes associated with these species. When the soil remains exposed to the air for a considerable period of time during the low tide, oxidation takes place and thus a shallow brown 'A' horizon develops over the grey coloured 'C' horizon. *Dalbergia spinosa* and *Excoecaria agallocha* communities occur in such half matured soil (Fig. 3). With further elevation, the layer of soil which comes in contact with the atmospheric oxygen increases. Thus thickness of brown 'A' horizon is increased. *Ceriops roxburghiana* either in pure patches or in association with *Delheagio spinosa* occurs in such soil. *Phoenix palludosa* occurs in almost pure patches where the horizon differentiation is considerably well marked by a brown 'A' horizon and a poorly developed red mottled 'B' horizon (Fig. 4). Maximum differentiation of soil profile was found in the *Heritiera - Bruguiera* zone. Due to high elevation and least flooding by tide the substratum in this zone remains exposed to air for the maximum period of time. Leaching is facilitated due to increased depth of water table in this zone. This might have favoured soil maturation process and led to differentiation of brown 'A' horizon, red mottled 'B' horizon and sometimes yellow mottled 'B2' horizon over the grey coloured 'C' horizon (Fig. 5).

Soil in these forests varies from silty loam to silt and sometimes clayey. In *Avicennia - Sonneratia - Aegialitis* zone soil is more silty while in the *Heritiera - Bruguiera* zone it is more clayey.

The soil pH is also highly variable. The pH of soil in the *Avicennia - Sonneratia - Aegialitis* zone is slightly alkaline to neutral and varies from 7.5 to 7. Soil is mild acidic in the *Heritiera* zone and the pH varies from 6.2 to 6.4. Soil in *Dalbergia - Ceriops– Excoecaria* zone is nearly neutral to very weakly acidic and the pH varies from 6.9 to 6.5. It is remarkable that intense acidity was developed in most of the soil when it was air dried. This fall of pH may be the result of accumulation of sulphides under anaerobic condition and their oxidation to free sulphuric acid under aerobic condition (Hart 1959). Potential acid layer is very near to the surface in the *Avicennea - Aegilitis* zone, but in the field condition this accumulation of acid is prevented due to frequent inundation of this zone by tidal water. In *Heritiera - Bruguiera* zone potential acid layer lies below 0.91 m (3 ft). It is probable that improved drainage condition of the soil in this zone might have favoured leaching of the acid producing substances from the root zone.

Conductivity of soil extract (Table 2) reveals that *Avicennea - Sonneratia - Aegilitis* zone occur in the highly saline soil while *Heritiera-Bruguiera* zone occurs in the least saline soil. This indicates that *Avicennia, Sonneratia* and *Aegealitis* are most salt tolerant species while *Heritiera* and *Bruguiera* are not. *Dalbergia - Ceriops - Excoecaria* zone occur in the intermediate condition.

From the foregoing discussion it is apparent that multiplicity of interacting ecological factors influence the species pattern. Here the pattern of species distribution is influenced by such phenomenon as water table and soil salinity which, in turn, are affected by topography. Soil texture also influences the dominance of various plant species in these forests. Correlation between profile differentiation and characteristic plant communities as revealed in the present study suggests that profile differentiation also has an important role in maintaining the pattern of vegetation. Whether this factor has got any determining influence on the pattern and distribution needs further study but it can be said that differentiation of profile is a manifestation of interactions of various ecological factors and also have an effect on plant growth.

The study also reveals that presence of acid layer, which quickly oxidizes to sulphuric acid if exposed and dried, stands a threat to the use of these soils for various development works that expose this layer to the atmosphere. Clearing of vegetation and excavation of earth may bring up this acid layer though this acid layer lies far below the soil surface. Construction of dams may also create an waterlogged condition by hindering the normal drainage patt ern resulting in deficiency of oxygen in the substratum. This condition in the root zone may also hinder the root respiration resulting in the death of the plant. However, the effect of toxic substances produced by the fall of pH and anaerobic condition created by waterlogged condition on the plant need further study.

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Ansarul Karim, Assistant Professor and M. A. Aziz Khan, Professor, Department of Botany, University of Chittagong, Bangladesh