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Regeneration diversity of mangrove species inside *Sonneratia apetala* plantations along the coastal belt of Bangladesh

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ABSTRACT

Large scale coastal plantations with Sonneratia apetala[1] have been established by the Forest Department along the coastline of Bangladesh since 1966. A study was conducted to assess the present stocking and growth performance of this species and status of naturally regenerated mangrove species inside S. apetala plantations. The study was carried out from 17-42 years old S. apetala stands at 20 small islands (chars) of 4 major locations namely Rangabali (Patuakhali), Char Kukri-Mukri (Bhola), Sitakundu (Chittagong) and Hatiya (Noakhali) of Bangladesh. The data on tree density, height and diameter were recorded from originally planted S. apetala plantations. The data on naturally regenerated mangrove species (seedlings, saplings, poles and trees) were also counted from afforested S. apetala plantations. The density of afforested S. apetala per hectare area was ranged between 311-2178 trees, tree height ranged between 6.37-20.66m and diameter at breast height (dbh) ranged between 17.32-34.02cm at different chars. Totals of 6, 9, 6 and 1 different regenerated mangrove species were found to occur naturally inside S, apetala plantations at Rangabali, Char Kukri-Mukri, Sitakundu and Hatiya sites respectively. The most abundant regenerated species was Excoecaria agallocha in all sites. Others important species were Heritiera fomes, Avicennia officinalis, Bruguiera sexangula at Rangabali; Aegiceras corniculatum, A. officinalis, H. fomes, Phoenix paludosa at Char Kukri-Mukri and Ceriops decandra, A. corniculatum, Tamarix indica, A. officinalis at Sitakundu site. This natural regeneration could be a second rotation multi-storied sustainable mangrove forest in the coastal belt of Bangladesh.

Keywords: *Sonneratia apetala, growth, mangrove species, regeneration and coastal belt*

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[1] "*Sonneratia apetala* (locally known as Keora) is the largest and tallest tree of the Sundarbans mangrove forests. It can attain a height up to 20 m and a diameter up to 80 cm. The tree occurs on newly accreted soil in moderately to strongly saline areas and is considered as a pioneer species in ecological succession. *S. apetala* is the principal planting species of the massive mangrove plantations in the coastal areas of Bangladesh (Banglapedia, 2015)." Plantation picture of *S. apetala* shown in appendix figure 02.

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I. Introduction

Bangladesh coastline is over 710 km long along the Bay of Bengal and comprises numerous off-shore islands (Siddiqi, 2001). Afforestation along the coastal belt was initiated in 1966 with the objective to protect the lives and properties of coastal communities from regularly occurring cyclone and tidal surges by creating mangrove forest cover in the exposed coastal belt (Das and Siddiqi, 1985). Up to 2013, an area of 0.192 million hectares of accreted lands were afforested with mangrove species in the coastal shoreline (Hasan, 2013). In the beginning, almost all the commercially important mangrove species were tried but mostly failed due to lack of knowledge on appropriate plantation techniques. Among the planted species, only *Sonneratia apetala* is the most successful species in all along the coastal belt and *Avicennia officinalis* is the successful only in the eastern coastal belt. These two species dominate the overall mangrove plantations throughout the coastal belt. At present, *S. apetala* consists of 94.4% and *A. officinalis* 4.8% of the successful mangrove plantations (Siddiqi and Khan, 2004). Some studies also showed that *S. apetala* is the most successful species along the coast of Bangladesh (Uddin and Hossain, 2013; Uddin et al., 2014). However, some other species, i.e., *Excoecaria agallocha*, *Heritiera fomes*, *Nypa fruticans*, *Ceriops decandra*, *Bruguiera sexangula* are found sporadically in different parts of the coastline. In some areas *Sonneratia caseolaris* was found to grow promising in new accretion along the canal and river banks (Siddiqi and Khan, 1990). Some trial plantations with mangrove species have been raised inside *S. apetala* forest as underplanting and some species such as *E. agallocha*, *H. fomes*, *Xylocarpus mekongensis*, *Aegiceras corniculatum* and *Phoenix paludosa* were found suitable for second rotation crops in the coastal belt (Siddiqi et al., 1992; Siddiqi, 2001; Islam et al., 2013).

It is almost 48 years that mangrove afforestation is in progress. The coastal afforestation program in Bangladesh is a very effective one in terms of conservation, growth, stock, soil establishment and shelter belt (Siddiqi and Khan, 1990; Siddiqi, 2001). Plenty seeds of some species are available in the forest floor of the plantations and adjacent areas. But most of them are unable to germinate and survive due to heavy siltation, soil compactness, lack of sufficient inundation, human interference and animal grazing. Artificial regeneration is expensive and can be avoided if natural regeneration is adequate and successful for the development of multi-storied mangrove forests. Very few information regarding density of afforested *S. apetala* plantations and regeneration status in the coastal man-made forest are available that could be helpful for developing appropriate management strategies for coastal ecosystem. It is therefore, necessary to assess the stocking of original plantations and the natural regeneration status of mangroves in the coastal forests. The present study is an exploratory survey of the planted and regenerated vegetation in the afforestation sites of coastal areas of Bangladesh.

II. Materials and Methods

Study sites: The coastal zone of Bangladesh covers an area of 47,201 km^2 includes 19 coastal districts out of 64 districts of Bangladesh. The study was conducted in 4 major locations under 4 coastal districts of the eastern and western coastal belt. The study locations were Char Kukri-Mukri island under Bhola district and Rangabali island under Patuakhali district of the western coastal belt; Hatiya island under Noakhali District and Sitakundu area under Chittagong district of the eastern coastal belt. It lies between latitude 22°20′-22°51′N and longitude 90°39′-91°51′ E. Every year newly accreted lands are added in the coastal belt. The area forms the lowest landmass and is part of the delta of the extended Himalayan drainage ecosystem. The landscapes have been formed by the combined actions of the three mighty rivers the Meghna, the Brahmaputra and the Ganges. These landscapes are low-lying lands, estuaries and inlands along the seacoast. Erosion and accretion are common phenomenon in the coastal areas. Coastal saline soils occur in the river deltas along the sea coast, a few kilometers to 180 kilometers. Salinity of the soil and water at this region decreases toward north and increases towards east and west taking Bhola district in the center. In monsoon, water salinity ranges from 0.3-2.7% while in the dry season from 1.0-3.3% (Siddiqi and Khan, 1990). Soil pH is slightly or moderately alkaline (7.5-8.0). Soil salinity ranges from 0.5-

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9.9 dS/m at Patuakhali, 0.3-31.5 dS/m at Noakhali and 4.7-26.5 dS/m at Chittagong district shown in Table 01 (SRDI, 2010). Soil of the site is non-calcareous, grey floodplain and silt-clay-loam. The climate is humid. Temperatures range between 18 and 32^{0}C. The amount of rainfall is 3000 mm at Bhola, 2500-3000mm at Patuakhali, 2500mm at Noakhali and 2500-3000mm at Chittagong district (FAO, 1988).

Table 01. Soil and climatic characteristics in the study areas

District	Latitude	Longitude	Annual rainfall (mm)	Agro-ecological Zone	Land type	Soil type	Soil salinity dS/m
Bhola	22^{0}39'	90^{0}39'	3000	Saline and non-saline, Meghna eastern char land	Medium high land	Calcareous Alluvium + Grey floodplain soil	-
Patuakhali	22^{0}24'	90^{0}19'	2500-3000	Non saline and non-calcareous saline	Medium high land	Non-calcareous grey floodplain soil	0.5-9.9
Noakhali	22^{0}51'	91^{0}07'	3000	Saline Meghna eastern char land	Medium High land	Calcareous alluvium seasonally saline	0.3-31.5
Chittagong	22^{0}20'	91^{0}51'	2500-3000	Young tidal flood plain, river flood and piedmont plains	Medium high land and + High land	Non-calcareous alluvium	4.7-26.5

Source: FAO, 1988; SRDI, 2010.

Data collection: The survey was carried out in 20 small islands (chars) belongs to 4 major locations (Table 02) through establishing Temporary Sample Plots (TSP). In each location, 27 TSPs were established and thus a total of 108 TSPs were established at 4 study locations. For conducting this survey, the plot size of each TSP was 5m x 5m (25m^2). The TSP plots were randomly selected in various age groups over 20 small chars. Data on the number of naturally occurring seedlings, saplings, poles and trees of different mangrove species were recorded from February-June 2014. Seedlings were noted and counted up to 0.5m in height, saplings were 0.51-1.0m, poles were 1.1-3.0m and trees were above 3.0m in height. Moreover, data on the number of originally planted *S. apetala* trees, tree height and diameter at breast height (dbh) were also recorded.

Analysis of data: The data of different growth parameters and regeneration status of mangrove species were computed and analyzed using Excel and Minitab statistical packages. Data were analyzed statistically through one-way Duncan multiple range tests at 5% significance level to compare the tree density, height and diameter growth.

III. Results and Discussion

Growth performance of *Sonneratia apetala*: The growth and density of 17-42 years old *S. apetala* plantations from 20 small islands (chars) of the coastal belt are shown in Table 02. This study revealed that the significantly highest number of trees per hectare was 2178 at Char Zonaki under Hatiya island and the lowest was 311 trees at Char Mogadia under Sitakundu site. The significantly highest height was found 20.66 m at Char Patila under Char Kukri-Mukri island and the lowest was 6.37 m at Domkhali under Sitakundu site. The significantly highest diameter at breast height (dbh) was found 37.42 cm at Guruvanga under Rangabali island and the lowest was 15.88 cm at Char

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Zonaki under Hatiya island. The average density of this species at 20 different chars was 1202 trees/ha and average height was 15.57 m and dbh was 25.34 cm (Table 02). Very few studies pointed out the present stocking of *S. apetala* per unit area in the coastal plantations of Bangladesh. Uddin et al. (2014) reported that the highest density was 1501 stems/ha and the lowest 130 stems/ha after 26 years of plantations at Mirersarai forest range, Chittagong. They found maximum height of 12.8 m and dbh 24.6 cm in a 23 years old plantation. Siddiqi et al. (1995) reported the density of *S. apetala* young plantations at 12 small chars of Noakhali district. They found the highest 3388 stems/ha at Telir char and the lowest 528 stems/ha at char Noman of Noakhali district.

Table 02. Density and growth performance of *S. apetala* in the coastal belt of Bangladesh

Location	Sl. no.	Name of char	Age (year)	No. of trees/ha	Height (m)	DBH (cm)
Rangabali island (Patuakhali)	1.	Madarbunia	17	1158b	16.00bc	33.12c
	2.	Gungipara	21	1800c	18.92c	29.10bc
	3.	Sukanir Khal	24	1867c	20.20c	29.66bc
	4.	Goruvanga	38	1067b	20.00c	37.42c
	5.	Pashar Khal	33	1333b	16.67bc	27.35bc
	6.	Char Kashem	31	1400b	19.33c	34.02c
	7.	Soner Char	26	1800c	16.69bc	24.20b
Char Kukri-Mukri Island (Bhola)	8.	Char Patila	34	1045b	20.66c	26.59bc
	9.	Char Shafi	33	1600c	18.71c	20.59ab
	10.	Char Rawshan	32	1200b	14.11b	21.02ab
	11.	Char Zamir	38	1097b	17.54c	22.29ab
	12.	Nursery Khal	42	933b	18.00c	30.10bc
	13.	Masterer Khal	40	1067b	17.43c	31.44bc
Hatiya island (Noakhali)	14.	Char Zonaki	17	2178d	9.73a	15.88a
	15.	Char Oskhali	38	1200b	16.63	23.46b
	16.	Char Rehana	31	1111b	14.33b	22.51ab
Sitakundu area (Chittagong)	17.	Char Sharan	28	1133b	12.97b	19.93ab
	18.	Char Mogadia	28	311a	7.70a	17.83ab
	19.	Domkhali	30	367a	6.37a	17.32ab
	20.	Bagachattar	22	367a	9.50a	22.93ab
			Average:	1201.70	15.57	25.34

Means followed by the same letter(s) in the same column do not differ significantly at 5% level

Bangladesh Forest Department raised *S. apetala* plantations in the newly accreted lands with 1.2m x 1.2m spacing. Initially, a total of 6944 seedlings per hectare area were planted but huge number of seedlings disappeared at the early stage of plantation establishment. Several factors are responsible for disappearing the planted seedlings, e.g. flooding by high tidal inundation during the monsoon, sedimentation of the planting sites, lacking of seedling maintenance and grazing by buffalos and cattle (Miah et al., 2014). Tropical cyclones from the Bay of Bengal sometimes directly hit the coastal belt resulting many seedlings were damaged or died at the early stage.

Regenerated species diversity: In the western coastal belt, the number of *E. agallocha* regeneration (seedlings, saplings, poles and trees) per hectare area was highest with a value of 50725 stems followed by *H. fomes* (1687), *P. paludosa* (414), *A. officinalis* (162) and *B. sexangula* (161) at Rangabali island. In Char Kukri-Mukri island, the highest number of regeneration per hectare area was recorded for *E. agallocha* (28309), followed by *A. corniculatum* (11821), *A. officinalis* (2577), *H. fomes* (1568), *P. paludosa* (1184) and *Tamarix indica* (1021) (Table 03).

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In the Sitakundu site of the eastern coastal belt, the highest regeneration per hectare area was also recorded for *E. agallocha* (51747), followed by *Ceriops decandra* (6977), *A. corniculatum* (1392), *T. indica* (888) and *A. officinalis* (700). In the Hatiya site, the highest number of regeneration was recorded for *E. agallocha* with a value of 17820 stems/ha (Table 04). Uddin *et al.* (2014) reported that the number of regeneration per hectare was highest for *S. apetala* with a mean value of 3462 stems/ha followed by *B. sexangula* (490), *A. corniculatum* (443), *E. agallocha* (148) and *C. decandra* (107) at Mirersarai Forest Range, Chittagong.

Table 03. Regeneration of different mangrove species (number per hectare) inside *S. apetala* forest in the western coastal belt of Bangladesh

Species	Rangabali Island					Char Kukri-Mukri Island				
	Seedling	Sapling	Pole	Tree	Total	Seedling	Sapling	Pole	Tree	Total
Excoecaria agallocha	36000	12340	1274	1111	50725	19614	6814	1170	711	28309
Avicennia officinalis	162	0	0	0	162	2059	518	0	0	2577
Heritiera fomes	429	385	414	459	1687	725	577	148	118	1568
Bruguiera sexangula	59	0	14	88	161	296	0	0	14	310
Xylocarpus mekongensis	14	0	0	0	14	103	266	59	0	428
Aegiceras corniculatum	0	0	0	0	00	11333	459	29	0	11821
Phoenix paludosa	414	0	0	0	414	666	474	0	44	1184
Cynometra ramiflora	0	0	0	0	00	88	0	0	0	88
Tamarix indica	0	0	0	0	00	844	133	0	44	1021
Total:	37078	12725	1702	1658	53163	35728	9241	1406	931	47306

Table 04. Regeneration of different mangrove species (number per hectare) inside *S. apetala* forest in the eastern coastal belt of Bangladesh

Species	Sitakundu					Hatiya Island				
	Seedling	Sapling	Pole	Tree	Total	Seedling	Sapling	Pole	Tree	Total
Excoecaria agallocha	37111	13511	844	281	51747	8474	8266	903	177	17820
Avicennia officinalis	700	0	0	0	700	0	0	0	0	0
Xylocarpus mekongensis	0	14	0	0	14	0	0	0	0	0
Aegiceras corniculatum	1363	29	0	0	1392	0	0	0	0	0
Phoenix paludosa	59	163	0	0	222	0	0	0	0	0
Tamarix indica	518	237	89	44	888	0	0	0	0	0
Ceriops decandra	3777	3200	0	0	6977	0	0	0	0	0
Total:	43528	17154	933	325	61940	8474	8266	903	177	17820

In the present study, we recorded natural regeneration of 6 mangrove species at Rangabali, 9 species at Char Kukri-Mukri, 6 species at Sitakundu and 1 species at Hatiya location. Overall regeneration was much higher for *E. agallocha* in all the study sites. The only seedling regeneration per hectare area for *E. agallocha* was 36000 stems at Rangabali, 19614 stems at Char Kukri-Mukri, 37111 stems at Sitakundu and 8474 stems at Hatiya site (Table 03 and 04). The number of seedling regeneration for all species was 37078, sapling was 12725, pole was 1702 and tree was 1658 at Rangabali location. In the Char Kukri-Mukri location, the number of regeneration for all species was 35728, 9241, 1406 and 931 for seedlings, saplings, poles and trees respectively. In Sitakundu site, the number of regeneration for seedlings was 43528, saplings was 17154, poles was 933 and trees was 325. In the Hatiya site, it was 8474 for seedlings, 8266 for saplings, 903 for poles and 177 for trees. The total number of regeneration (seedlings-trees) for all species was 53163 at Rangabali, 47306 at Char Kukri-Mukri, 61940 at Sitakundu and 17820 at Hatiya site. Haque et al. (2000) reported that six naturally regenerated species were found to occur in Sitakundu and Mirersarai Forest Ranges. Siddiqi et al. (1995) made a survey on regeneration status of mangrove species in the *S. apetala* plantation at 12 chars of Noakhali coastal belt. They recorded five species namely *S. apetala, E.*

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agallocha, *A. officinalis*, *B. sexangula* and *C. decandra* and found on an average of 14612 stems/ha. They recorded highest seedling generation for *S. apetala* (9032) followed by *E. agallocha* (3814) and *A. officinalis* (1298).

Of the total regeneration, *E agallocha* constitutes 95.41% followed by *H. fomes* (3.17%), *P. Paludosa* (0.78%) and so on at Rangabali. In the Char Kukri-Mukri, *E. agallocha* constitutes 59.84% followed by *A. corniculatum* (25.0%), *A. officinalis* (5.45%) and *H. fomes* (3.31%). Similarly, *E agallocha* constitutes 83.81% followed by *C. decandra* (11.32%), *A. corniculatum* (2.25%) and *A. officinalis* (1.13%) at Sitakundu site (Fig. 01). Siddiqi et al. (1995) reported that *S. apetala* constituted 61.78% followed by *A. officinalis* (26.09%), *E. agallocha* (8.8%) and *B. Sexangula* (2.98%).

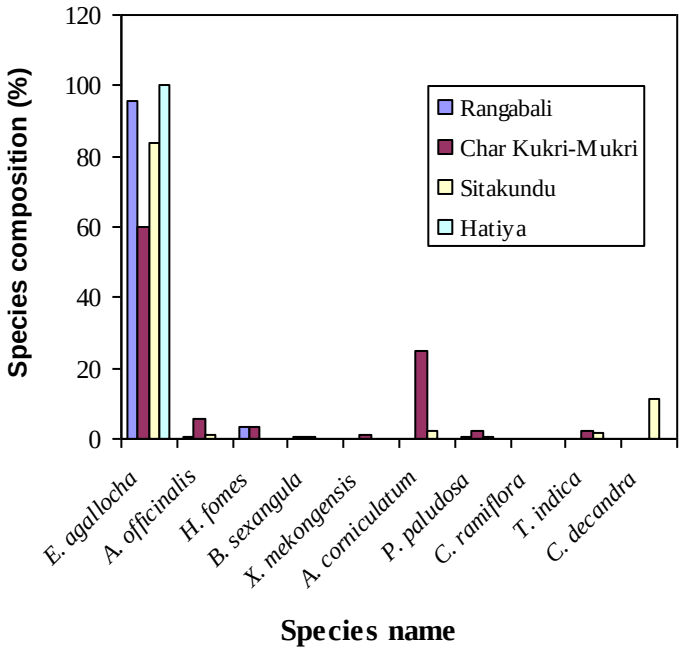

Figure 01. Composition (%) of regenerated mangrove species in the *S. apetala* plantations at 4 study locations

The study revealed that there is an evident change of vegetation takes place in the coastal *S. apetala* plantations. The composition of mangrove species that occurs along the shoreline varies between different islands. The original plantations are gradually matured and successional changes have occurred due to geomorphological changes and lack of inundation in the plantation sites. Other mangrove species regeneration occupied the places of older *S. apetala* plantations although the seed sources are limited in the coastal area. The most dominant regenerated species is *E. agallocha* that appeared all along the coastal belt. Other mangrove species like *A. officinalis*, *A. corniculatum*, *H. fomes* also appeared in most of the islands. The only exception is in Hatiya island, there appeared only *E. agallocha* regeneration, this is probably due to high salinity level and absence of seed sources of other mangrove species. It is now needed to conserve the natural regeneration inside coastal man-made forest for the development of sustainable dense mangrove forest in the coastal belt of Bangladesh.

IV. Conclusion

Bangladesh is a pioneer country for mangrove afforestation mainly with *S. apetala* in the coastal belt. At the initial stage of plantations, many seedlings were disappeared or died due to dynamic coastal environment and animal interferences. As a result gaps are created in the afforested *S. apetala* plantations. On the other hand, the life cycle of *S. apetala* is short (20 years rotation) and can be grown only new accretions, where inundation occurs regularly. In the older plantations, the lands

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are rising up and becoming unfavorable for the growth of this pioneer species. Therefore, it needs to create a second generation forest for further continuation of coastal mangrove forests. It is very interesting that, huge seedlings of some other important mangrove species naturally appeared inside *S. apetala* plantations in almost all along the coastal belt. Furthermore, it is necessary to protect and conserve the mangrove species regeneration for creating second generation sustainable forests in the coastline. It could be a long term mangrove shelterbelt to reduce the impact of climate change as well as the important habitat of wild animals and birds.

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APPENDIX

Figure 02. *Sonneratia apetala* (Keora) plantation in the coastal belt showing huge regeneration inside the forest.

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