Growth Performance of Underplanted Mangrove Species in *Sonneratia apetala* (Keora) Plantations along the Western Coastal Belt of Bangladesh

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Abstract

Coastal plantations mainly with *Sonneratia apetala* have been established by the Forest Department on the newly accreted lands in the coastline of Bangladesh since 1965-66. An underplanting trial of 11 mangrove species was conducted in the existing *S. apetala* plantations along the western coastline (Patuakhali and Bhola) to assess the site-suitability and growth performance of these species. Survival, height and diameter growth data from 16-21 years old experimental stands of these species were analyzed. The highest survival was found in *Excoecaria agallocha* (62% and 59%) followed by *Heritiera fomes* (51% and 39%) and *Xylocarpus mekongensis* (48% and 26%) among the tree species at Rangabali island of Patuakhali and Char Kukri-Mukri island of Bhola district. Among the shrub and palm species, the highest survival was found in *Aegiceras corniculatum* (63%) followed by *Phoenix paludosa* (58%) and *Nypa fruticans* (40%) at Rangabali and the highest survival in *P. paludosa* (71%) followed by *N. fruticans* (56%) and *A. corniculatum* (46%) at Char Kukri-Mukri. The mean maximum height growth was observed in *E. agallocha* (9.31 m and 9.29 m) followed by *X. mekongensis* (6.84 m and 6.84 m) and *H. fomes* (6.19 m and 5.65 m) in both the areas. The mean maximum diameter growth was also observed in *E. agallocha* (9.83 cm and 9.49 cm) followed by *X. mekongensis* (7.97 cm and 7.34 cm) and *H. fomes* (5.87cm and 5.34 cm) in both the areas. Among the shrub and palm species, *A. corniculatum, P. paludosa* and *N. fruticans* showed good height growth performance in both the study areas. Therefore, these promising mangrove species (*E. agallocha, H. fomes, X. mekongensis, A. corniculatum, P. paludosa* and *N. fruticans*) may be suitable for raising second rotation crops inside *S. apetala* plantations for sustainable management of coastal forests.

সারসংক্ষেপ

বন বিভাগ বাংলাদেশের উপকূলীয় এলাকায় ১৯৬৫-৬৬ সন থেকে নতুন জেগে উঠা চরে প্রধানতঃ কেওড়া প্রজাতির উপকূলীয় বাগান প্রতিষ্ঠা করেছে। পশ্চিমাঞ্চলীয় উপকূলীয় এলাকায় (পটুয়াখালী ও ভোলা) প্রতিষ্ঠিত কেওড়া বাগানের অভ্যন্তরে ১১টি ম্যানগ্রোভ প্রজাতির ভূমির উপযুক্ততা ও বৃদ্ধির হার নির্ণয়ের জন্য একটি আন্ডারপ্লান্টিং পরীক্ষা পরিচালনা করা হয়। উক্ত প্রজাতিগুলির ১৬-২১ বছর বয়সের বাগানসমূহের বেঁচে থাকার হার, উচ্চতা ও ব্যাস বৃদ্ধির উপাত্ত বিশ্লেষণ করা হয়। পটুয়াখালী জেলার রাঙ্গাবালী এবং ভোলা জেলার চর কুকরী-মুকরী দ্বীপাঞ্চলে বৃক্ষ প্রজাতির মধ্যে গেওয়ার বেঁচে থাকার হার সর্বাধিক (৬২% এবং ৫৯%), এরপর সুন্দরী (৫১% এবং ৩৯%) ও পশুর (৪৮% এবং ২৬%) উল্লেখযোগ্য। গুল্ম ও পাম প্রজাতির মধ্যে রাঙ্গাবালী চরাঞ্চলে খলসী প্রজাতির বাঁচার হার সর্বাধিক (৬৩%)। তারপর যথাক্রমে হেঁতাল (৫৮%) এবং গোলপাতার (৪০%) বাঁচার হার ভাল। চর কুকরী-মুকরীতে হেঁতাল প্রজাতির বাঁচার হার সর্বাধিক (৭১%)। এরপর গোলপাতা (৫৬%) ও খলসী (৪৬%) প্রজাতির বাঁচার হার ভাল। বৃক্ষ প্রজাতির মধ্যে উভয় এলাকায় গেওয়া প্রজাতির গড়

উচ্চতা বৃদ্ধির হার সবচেয়ে বেশী (৯.৩১ মি. এবং ৯.২৯ মি.)। তারপর পশুর (৬.৮৪ মি. এবং ৬.৮৪ মি.) ও সুন্দরী (৬.১৯ মি. এবং ৫.৬৫ মি.) প্রজাতির উচ্চতা বৃদ্ধির হার ভাল। উচ্চ এলাকায় গেওয়া প্রজাতির গড় ব্যাস বৃদ্ধির হার সর্বোচ্চ (৯.৮৩ সে.মি. এবং ৯.৪৯ সে.মি.), এরপর পশুর (৭.৯৭ সে.মি. এবং ৭.৩৪ সে.মি.) ও সুন্দরী (৫.৮৭ সে.মি. এবং ৫.৩৪ সে.মি.) প্রজাতির ব্যাস বৃদ্ধির হার ভাল। আবার গুল্ম ও পাম প্রজাতির মধ্যে খলসী, হেঁতাল ও গোলপাতার উচ্চতা বৃদ্ধির হার ভাল দেখা যায়। অতএব, উপকূলীয় বনের টেকসই ব্যবস্থাপনার জন্য কেওড়া বনের অভ্যন্তরে এই সম্ভাবনাময় ম্যানগ্রোভ প্রজাতিগুলি (গেওয়া, সুন্দরী, পশুর, খলসী, হেঁতাল ও গোলপাতা) ২য় পর্যায়ের বন সৃজনের জন্য উপযোগী হতে পারে।

Keywords: Coastal belt, growth performance, mangrove plantation, survival, underplanting.

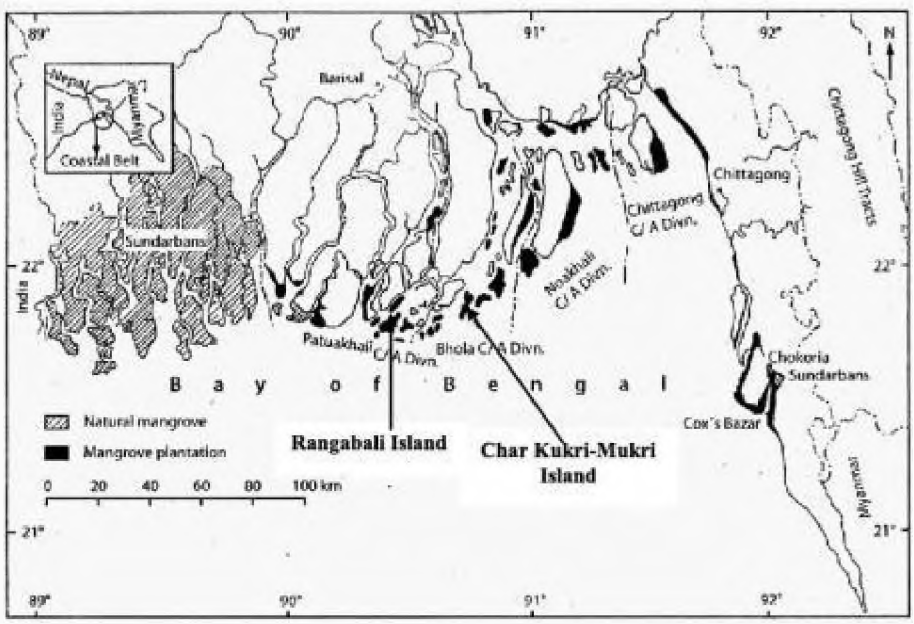
Introduction

The coastal belt of Bangladesh extends over 710 km long along the Bay of Bengal (Siddiqi 2001). There are newly accreted chars and off-shore islands of varying sizes in the coastal belt. Forest Department initiated coastal plantations in 1965-66 with an objective of protecting the lives and properties of the people suffering from the frequent cyclones and tidal bores (Das and Siddiqi 1985). Subsequently coastal afforestation was expanded to reclamation and stabilization of newly accreted lands (Saenger 1987). Initially most of the commercial mangrove species were tried on newly accreted lands, but *Sonneratia apetala* (keora) was the most successful in all along the coastline followed by *Avicenia officinalis* (baen) in the eastern belt. *S. apetala* accounted 94.4% and *A. officinalis* 4.8% of the successful mangrove plantations (Siddiqi and Khan 2004), and to date, approximately 0.19 million hectares of accreted land have been brought under mangrove plantations (Nandy 2010).

In the coastal areas, dynamic geomorphological changes, species succession and insect infestation threaten the sustainability of the pioneer *S. apetala* plantations (Siddiqi *et al.* 1992, Siddiqi 2001). Land accretion, removal of the keora trees and rotation of the species created gaps inside *S. apetala* plantations. In these plantations no regeneration appard due to rising of forest floor, soil compactness and absent of seed sources of other mangrove species. As a result more land become vacant. After harvesting of mature *S. apetala* trees, there will be no second rotation crops for sustainability of this forest. There is little chance for the development of tree cover by a natural process of succession because of rapid physical changes and heavy biotic interferences. Therefore, underplanting trial in the existing *S. apetala* plantations with different mangrove species were laid out since 1990-1995. The objective of this study was to find out suitable species for coastal areas inside *S. apetala* plantations for the establishment of a permanent forest cover with the mangrove species. Initial reports on this trial showed success and suitability of underplanting species (Siddiqi *et al.* 1992, Siddiqi and Khan 1996, Siddiqi 2001, Islam and Nandy 2001). However, the present study describes a comprehensive report on suitability and growth performance of 11 mangrove species planted inside *S. apetala* plantations in the western coastline of Bangladesh.

Materials and Methods

The Plantation Trial Unit Division of Bangladesh Forest Research Institute carried out the experiments along the western coastline in two offshore islands, Rangabali under Patuakhali district and Char Kukri-Mukri under Bhola district. Rangabali is located at latitude 21°92′ N and longitude 90°45′ E. Char Kukri-Mukri is located at



Map 1. Coastline of Bangladesh showing the locations of natural, planted mangroves and the study areas.

latitude 21°85′ N and longitude 90°72′ E (Map 1). Soil of the sites was silt-clay-loam. Soil salinity in the monsoon and dry season was remarkable varying between 1.5-4.0 dS/m. Soil pH was slightly alkaline (7.5-8.0).

Commercially important 11 mangrove species, e.g. *Heritiera fomes* (sundri), *Excoecaria agallocha* (gewa), *Xylocarpus mekongensis* (passur), *Xylocarpus granatum* (dhundul), *Bruguiera sexangula* (kankra), *Aegiceras corniculatum* (khalshi), *Cynometra ramiflora* (shingra), *Ceriops decandra* (goran), *Lumnitzera racemosa* (kirpa), *Phoenix paludosa* (hantal) and *Nypa fruticans* (golpata) were included in the trial. The seeds or propagules of these mangrove species were collected from the Sundarbans. Seedlings of all mangrove species except golpata were raised in polybags of 25 cm x 15 cm or 15 cm x 10 cm in size and kept in the nursery for about ten months. The golpata seedlings were raised in muddy soil near the canal side or in the marshy land.

The plots were established in Nursery Khal (N) and Pashar Khal (P) of Char Kashem, Soner Char, Madarbunia and Baher Char nearby Rangabali island; and Char Zamir, Char Shafi, Zylar Khal and Nursery Khal of Char Kukri-Mukri island. The experiment was laid out in a Randomized Complete Block Design with three replications. Each plot was planted with 100-121 seedlings at a spacing of 1.2 m x 1.2 m and the size of each plot was 144-174 m^2. The plots were fenced to prevent grazing animal up to five years of the plantations. Ten-month-old seedlings of the species were planted in 9-12 years old *S. apetala* plantations, except for *N. fruticans* seedlings, which were planted with 3 months old seedlings. Weeding was made up to five years after out planting. The data in relation to survival, height and diameter growth were collected in June, 2011 when the stand age varied from 16-21 years. Data were analyzed according to the standard statistical packages.

Results and Discussion

The growth performances of the eleven mangrove species were analyzed and the mean values for different parameters are given in Table 1.

The highest survival and height of *H. fomes* were 67% and 8.75 m respectively in 21 years old plantation at Char Keshem (P), and the highest diameter was 7.82 cm in 16 years old stand at Madarbunia. The mean annual height increment (MAI) of this species varied from 0.24-0.42 m and diameter increment from 0.21- 0.49 cm. The maximum survival of *E. agallocha* was 75% in 18 years old stand at Soner Char, the highest height was 13.0 m and the highest diameter was 11.62 cm in 21 years old trees at Char Kashem (P). The MAI in height and diameter of *E. agallocha* was 0.37-0.62 m and 0.40-0.61 cm respectively. The growth performance of this species was found higher than other species in almost all planting sites. The highest survival of *X. mekongensis* was 50% in 17 years old stand at Soner Char, the maximum height was 9.18 m in 21 years trees at Char Kashem (P) and the maximum diameter was 8.91 cm in 21 years trees at Char Kashem (N). The MAI in height and diameter of this species was 0.27-0.47 m and 0.32-0.50 cm respectively. The survival of *X. granatum* ranged from 11-50% in 16-18 years old plantations. The highest height and diameter of this species were 5.37 m and 6.03 cm in 16 years old stand at Madarbunia. The highest survival of *B. sexangula* was 16% in 21 years old stand of Char Kashem (N), the maximum height and diameter were 5.85 m and 6.51 cm respectively in 21 years old stand at Char Kashem (P) shown in Table 1.

The survival of *A. corniculatum* was 46-67% in 16-21 years old stands. The highest height and diameter were 8.14 m and 7.97 cm in 21 years old plantation at Char Kashem (P). The MAI in height and diameter of *A. corniculatum* was 0.26-0.39 m and 0.27-0.44 cm. The species showed promising survival and growth performance in all sites. The maximum survival of *C. ramiflora* was 42%, height was 7.21 m and diameter was 5.75 cm in 21 years old stand at Char Kashem (N). The mean annual height and diameter increment of this species were 0.24-0.34 m and 0.20-0.27 cm respectively. The survival of *C. decandra* was 12-41%, the highest height and diameter were 5.45 m and 5.83 cm. The survival of *L. racemosa* varied from 9-44% in 16-18 years old plantations and the highest height and diameter were 5.42 m and 8.76 cm (Table 1).

Table 1. Growth performance of eleven mangrove species planted at different locations of Rangabali and Char Kukri-Mukri islands.

Species (Local name)	Location	Age of trees (yrs)	Mean survival (%)	Mean height (m) ± SE	Mean annual height increment (m)	Mean DBH (cm) ± SE	Mean annual diameter increment (cm)
Heritiera fomes (Sundri)	Char Kashem(N)	21	30	6.69 ± 0.38	0.32	5.98 ± 0.28	0.28
	Char Kashem (P)	21	67	8.75 ± 0.34	0.42	7.03 ± 0.22	0.33
	Soner Char	18	58	4.98 ± 0.12	0.28	4.91 ± 0.12	0.27
	Soner Char	17	47	5.21 ± 0.17	0.31	3.59 ± 0.09	0.21
	Madarbunia	16	55	5.34 ± 0.09	0.33	7.82 ± 0.11	0.49
	Zylar Khal	21	30	7.28 ± 0.39	0.35	5.01 ± 0. 23	0.24
	Char Zamir	18	34	4.24 ± 0.12	0.24	5.73 ± 0.18	0.32
	Char Shafi	17	53	5.43 ± 0.28	0.32	5.29 ± 0.22	0.31
Excoecaria agallocha (Gewa)	Char Kashem(N)	21	66	10.45 ± 0.53	0.50	9.89 ± 0.48	0.47
	Char Kashem (P)	21	42	13.00± 0.28	0.62	11.62 ± 0.51	0.55

	Soner Char	18	75	8.05 ± 0.80	0.45	8.41 ± 0.23	0.47
	Soner Char	17	34	9.10 ± 0.33	0.53	10.22 ± 0.28	0.60
	Madarbunia	16	72	5.97 ± 0.09	0.37	9.01 ± 0.21	0.56
	Zylar Khal	21	70	10.04 ± 0.33	0.48	8.51 ± 0.33	0.40
	Char Zamir	18	54	8.49 ± 0.25	0.47	9.55 ± 0.28	0.53
	Char Shafi	17	52	9.33 ± 0.31	0.55	10.42 ± 0.31	0.61
Xylocarpus mekongensis (Passur)	Char Kashem(N)	21	52	7.14 ± 0.28	0.34	8.91 ± 0.21	0.42
	Char Kashem (P)	21	44	9.18 ± 0.31	0.44	8.66 ± 0.17	0.41
	Soner Char	18	42	4.95 ± 0.19	0.27	5.83 ± 0.15	0.32
	Soner Char	17	30	7.99 ± 0.15	0.47	8.50 ± 0.16	0.50
	Madarbunia	16	50	4.94 ± 0.08	0.31	7.93 ± 0.14	0.49
	Char Shafi	17	26	6.84 ± 0.27	0.40	7.34 ± 0.25	0.43
Xylocarpus granatum (Dhundul)	Soner Char	18	30	4.40 ± 0.26	0.24	4.91 ± 0.33	0.27
	Soner Char	17	11	4.34 ± 0.27	0.25	4.78 ± 0.18	0.28
	Madarbunia	16	30	5.37 ± 0.12	0.33	6.03 ± 0.12	0.38
Bruguiera sexangula (Kankra)	Char Kashem(N)	21	16	5.16 ± 0. 44	0.25	5.36 ± 0.26	0.26
	Char Kashem (P)	21	16	5.85 ± 0.15	0.28	6.51 ± 0.14	0.31
	Soner Char	18	10	4.10 ± 0.14	0.23	4.52 ± 0.26	0.25
Aegiceras corniculatum (Khalshi)	Char Kashem(N)	21	61	6.06 ± 0.15	0.29	6.09 ± 0.09	0.29
	Char Kashem (P)	21	64	8.14 ± 0.24	0.39	7.97 ± 0.16	0.38
	Soner Char	18	64	4.72 ± 0.16	0.26	4.91 ± 0.13	0.27
	Soner Char	17	58	5.43 ± 0.11	0.32	5.01 ± 0.12	0.29
	Madarbunia	16	67	5.13 ± 0.09	0.32	6.66 ± 0.13	0.42
	Char Zamir	18	46	6.61 ± 0.12	0.37	7.96 ± 0.18	0.44
Cynometra ramiflora (Shingra)	Char Kashem(N)	21	42	7.21 ± 0.37	0.34	5.75 ± 0.14	0.27
	Char Kashem (P)	21	30	5.86 ± 0.27	0.28	4.73 ± 0.39	0.22
	Zylar Khal	21	18	4.96 ± 0.15	0.24	4.27 ± 0.16	0.20
Ceriops decandra (Goran)	Char Kashem(N)	21	41	4.78 ± 0.11	0.23	5.18 ± 0.10	0.25
	Char Kashem (P)	21	16	5.45 ± 0.21	0.26	5.83 ± 0.21	0.28
	Soner Char	18	12	4.71 ± 0.21	0.26	4.12 ± 0.21	0.23
Lumnitzera racemosa (Kirpa)	Madarbunia	16	44	5.24 ± 0.10	0.33	6.31 ± 0.11	0.39
	Char Zamir	18	9	5.42 ± 0.50	0.30	8.76 ± 0.43	0.49
	Char Shafi	17	15	5.17 ± 0.26	0.30	6.26 ± 0.36	0.37
Phoenix paludosa (Hantal)	Char Kashem(N)	21	52	7.02 ± 0.28	0.33	5.80 ± 0.09	0.28
	Char Kashem (P)	21	58	6.40 ± 0.17	0.30	6.81 ± 0.18	0.32
	Soner Char	18	65	5.76 ± 0.09	0.32	5.48 ± 0.09	0.30
	Zylar Khal	21	59	4.92 ± 0.11	0.23	4.85 ± 0.09	0.23
	Char Zamir	18	89	5.14 ± 0.08	0.29	7.01 ± 0.09	0.39
	Char Shafi	17	66	5.68± 0.15	0.33	6.48 ± 0.10	0.38
Nypa fruticans (Golpata)	Madarbunia	16	37	3.55 ± 0.09	-	-	
	Baher Char	16	43	5.63 ± 0.07	-	-	-
	Nursery Khal	18	56	3.43 ± 0.04	-	-	-

N= Nursery Khal, P= Pashar Khal

The highest survival of *P. paludosa* was 89% in 18 years old stand at Char Zamir and the highest height was 7.02 m in 21 years old plantation at Char Kashem (N). The survival of *N. fruticans* ranged from 37-53% in 16-18 years old plantations.

Latif *et al.* (1992) found the mean diameter increment ranged from 0.062- 0.151 cm for *H. fomes*, 0.049-0.189 cm for *E. agallocha* in the Sundarbans. Siddiqi and Khan (1990) mentioned that the height and diameter increment varied between 0.27-0.70 m and 0.50-0.90 cm for 11-14 years old *E. agallocha* plantations in the coastal belt. The height and diameter increment of *X. mekongensis* in 14 years old trees were 0.34 m and 0.30 cm respectively in the coastal belt. The annual height increment in this genus varied from 0.23-0.38 m for the plantation of age 10-13 years (Siddiqi and Khan 1996).

The average survival percentage, height and diameter at breast height (DBH) from 16-21 years old stands of eleven mangrove species were analyzed separately for Rangabali and Char Kukri-Mukri locations. The result showed that the highest survival was recorded for *A. corniculatum* (63%) followed by *E. agallocha* (62%), *P. paludosa* (58%), *H. fomes* (51%) and *X. mekongensis* (48%) at Rangabali. The maximum survival was found for *P. paludosa* (71%), followed by *E. agallocha* (59%), *N. fruticans* (56%) *A. corniculatum* (46%) *H. fomes* (39%) and *X. mekongensis* (26%) at Char Kukri-Mukri island (Fig. 1). Siddiqi *et al.* (1992) reported very initial information on survival and height growth performance of mangrove species based on only 1990 plantations (4 places) at Rangabali and Char Kukri-Mukri. They found more than 90% survival for *E. agallocha, P. paludosa* and *H. fomes* at Rangabali and Char Kukri-Mukri. Siddiqi and Khan (1996) reported growth performance of 4 years old stands from the same experiment and they found higher survival for *E. agallocha* (97%) followed by *H. fomes* (93%), *P. paludosa* (92%) and *A. corniculatum* (68%). Siddiqi (2001 and 2002) prepared a partial and interim report on survival, height and diameter growth of 11 mangrove species at the age of 8 years at Char Kukri-Mukri. He found higher survival for *N. fruticans* (97.3%), followed by *E. agallocha* (90.3%), *H. fomes* (84.7%), *P. paludosa* (84.7%), *B. sexangula* (61.3%) and *X. mekongensis* (58.3%).

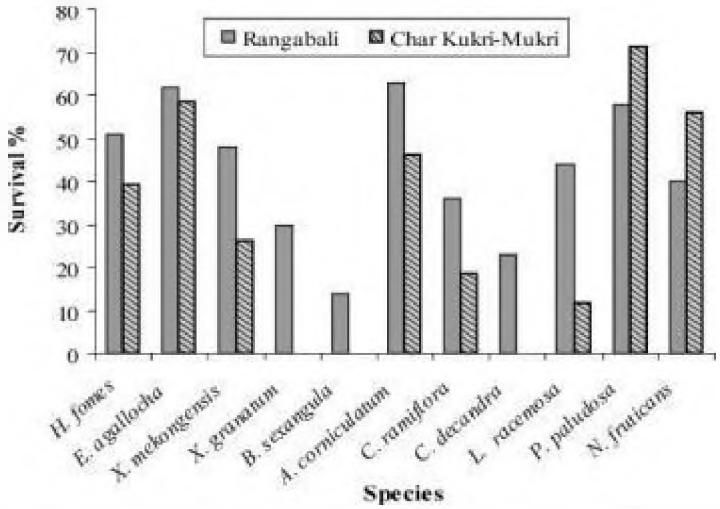


Figure 1. Mean survival percentage of 16-21 years old mangrove species at Rangabali and Char Kukri-Mukri islands.

In the present study, the highest mean height was recorded for *E. agallocha* (9.31 m) followed by *X. mekongensis* (6.84 m), *C. ramiflora* (6.54 m), *P. paludosa* (6.39 m), *H. fomes* (6.19 m) and *A. corniculatum* (5.90 m) at Rangabali. The highest mean height was also recorded for *E. agallocha* (9.29 m) followed by *X. mekongensis* (6.84 m), *A. corniculatum* (6.61 m) and *H. fomes* (5.65 m) at Char Kukri-Mukri island (Fig. 2). The highest mean DBH was recorded for *E. agallocha* (9.83 cm) followed by *X. mekongensis* (7.97 cm), *L. racemosa* (6.31 cm), *A. corniculatum* (6.13 cm), *P. paludosa* (6.03 cm) and *H. fomes* (5.87 cm) at Rangabali. The highest mean DBH was also recorded for *E. agallocha* (9.49 cm) followed by *A. corniculatum* (7.96 cm), *L. racemosa* (7.51 cm), *X. mekongensis* (7.34 cm), *P. paludosa* (6.11 cm) and *H. fomes* (5.34 cm) at Char Kukri-Mukri (Fig. 3). Siddiqi and Khan (1996) found higher height growth for *E. agallocha* (6.20 m) followed by *H. fomes* (2.60 m) and *X. mekongensis* (2.40 m) in four years old stands. Siddiqi (2001, 2002) recorded highest height for *E. agallocha* (9.23 m), followed by *H. fomes* (5.33 m) and *P. paludosa* (2.93 m) in 8 years old stands. He also found maximum DBH for *E. agallocha* (7.33 cm), followed by *P. paludosa* (5.06 cm) and *H. fomes* (3.13 cm) in the same experiment. Siddiqi and Khan (1990) found a height and diameter growth was 7.4 m and 11.14 cm for *E. agallocha* in 12 years old trees at Char Kukri; 3.75 m and 3.32 cm for *E. agallocha* in 11 years old trees at Char Kashem, and 3.5 m and 5.05 cm for *H. fomes* in 14 years old trees at Char Kukri-Mukri in other plantations.

The results of survival, height and diameter growth data revealed that *E. agallocha* are the most promising species both in Rangabali and Char Kukri-Mukri areas followed by *A. corniculatum*, *H. fomes* and *X. mekongensis* among the tree species. Among the shrubs and palms species, the most promising species was *P. paludosa* followed by *N. fruticans* both in Rangabali and Char Kukri-Mukri. In Rangabali area, *C. ramiflora* and *L. racemosa* showed better performance but very poor survival at Char Kukri-Mukri areas. Out of 11 species tried, all species were successful at Rangabali area but 8 species were successful and remaining 3 species fail

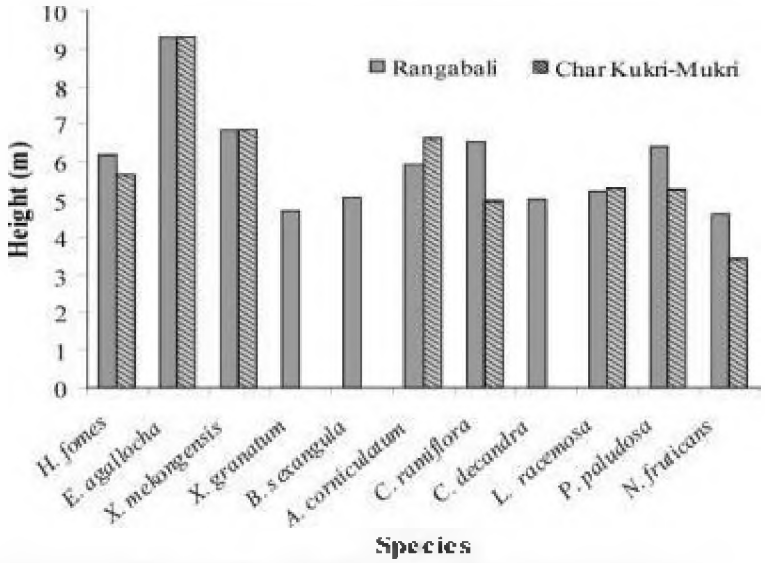


Figure 2. Mean height growth of 16-21 years old mangrove species at Rangabali and Char Kukri-Mukri islands.

to survive at Char Kukri-Mukri areas (Fig. 1). Grazing of domestic animal like cattles and buffalos has a highly detrimental impact on the successful establishment of mangrove plantations. Moreover, the introduced deer (*Axis axis*) in the Char Kukri-Mukri island browsed seedlings of some palatable species like *X. granatum* and *B. sexangula* which ultimately affect the growth and survival of the species. Therefore, survival of most of the species was found lower in Char Kukri-Mukri than in Rangabali. On the other hand, human interference and illicit felling of superior trees in the established experimental plots were very common in the coastal belts. Therefore, the survival was decreased for *H. fomes* and *X. mekongensis* in some places.

Natural regeneration mainly of *E. agallocha, H. fomes* and *P. paludosa* were observed in and around trial plots both at Rangabali and Char Kukri-Mukri areas. Flowering and fruiting of these species were started in 8-10 years old stands. Huge seedlings of the species were appeared in the areas. As these trial plantations have also been serving as the mangrove seed sources in the western coastal belt and thus it may become an opportunity to develop naturally second rotation vegetation inside *S. apetala* forests. Pictorial status of *E. agallocha, H. fomes, X. mekongensis, A. corniculatum, N. fruticans* and *P. paludosa* as underplanting is shown in Figure 4–9.

Bangladesh is a pioneer country in raising successful plantations with *S. apetala* in the newly accreted char lands along the coastline. But the existence of these plantations is under tremendous pressure due to geomorphic changes in the plantation sites and human interferences. Moreover, the life cycle of *S. apetala* is short (20 years rotation) and after harvesting this pioneer species, there will be no forests in absence of natural regeneration. Therefore, in order to maintain continuous forest vegetations, raising of second rotation forests under the canopy of existing plantations are immense important before harvesting. In the western coastline, the mangrove species like *E. agallocha, H. fomes, X. mekongensis, A. corniculatum* and *P. paludosa* were found promising as underplanting at the age of 4 and 8 years (Siddiqi and Khan 1996, Siddiqi 2001). On the basis of survival and growth performance of mature experimental stands of this study, *E. agallocha, H. fomes, X. mekongensis,*

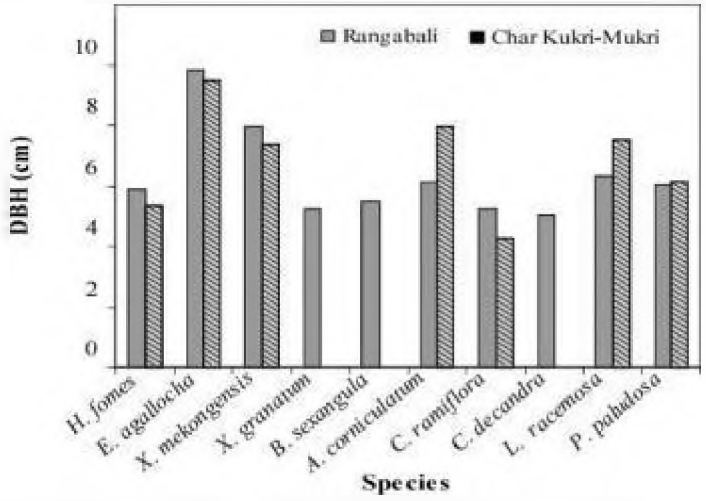


Figure 3. Mean diameter at breast height (DBH) of 16-21 years old mangrove species at Rangabali and Char Kukri-Mukri islands.

Figure 4. *E. agallocha* underplanting plot at Zylar Khal of Char Kukri-Mukri.

Figure 5 *H. fomes* underplanting plot at Sonar Char of Rangabali.

Figure 6. *X. mekongensis* underplanting plot at Char Kashem of Rangabali.

Figure 7. *A. conicalatum* underplanting plot at Char Kashem of Rangabali.

Figure 8. *N. fruticans* underplanting plot at Zylar Khal of Char Kukri-Mukri.

Figure 9. *P. paludosa* underplanting plot at Char Kashem of Rangabali.

A. corniculatum, *P. paludosa* and *N. fruticans* are also appeared promising at the age of 16-21 years. Thus these species can be recommended for afforstation inside *S. apetala* plantation for sustainable management of coastal forests. In many places, the coastal forests have been destroyed due to illegal occupation by erosion victim people. The influential persons behind the homeless people using them to grab government land. In the last few years, about 6,045 ha coastal forest land has been encroached and destroyed forest resources in only Noakhali coastal area (Sajjaduzzaman *et al.* 2005). So, participatory approach of forest management may also be considered for the development and conservation of mangrove forests. In addition, Forest Department must take intiative to declare the areas as reserve forests for protection of the existing coastal plantations.

References

Das, S. and Siddiqi, N. A. 1985. *The Mangroves and Mangrove Forests of Bangladesh*. Mangrove Silviculculture Division. Bulletin No. 2. Bangladesh Forest Research Institute. 142 pp.

Islam, M. R. and Nandy, P. 2001. Site suitability of different mangrove species and planting techniques for baen (*Avicennia officinalis*) in the coastal areas of Bangladesh. In: Siddiqi, N. A. and Baksha, M. W. (eds.) *Mangrove Research and Development*. Bangladesh Forest Research Institute, Chittagong, pp. 39-48.

Latif, M. A.; Rahman M. F.; Das, S. and Siddiqi, N. A. 1992. Diameter increment of six mangrove tree species in the Sundarbans Forest of Bangladesh. *Bangladesh Journal of Forest Science* 21 (1 & 2): 7-12.

Nandy, P. 2010. *Coastal Afforestation at a Glance with Particular Emphasis to Char Kukri-Mukri*. Community Based Adaptation to Climate Change through Coastal Afforestation in Bangladesh Project in association with Bangladesh Forest Department. 10 pp.

Saenger, P. 1987. *Bangladesh Mangrove Afforestation Project*. Shedden Pacific Pty, Limited, Melborns, Australia. 62 pp.

Sajjaduzzaman, M. D.; Muhammed, N. and Koike, M. 2005. Mangrove plantation destruction in Noakhali coastal forests of Bangladesh: a case study on causes, consequences and model prescription to halt deforestation. *International Journal of Agriculture and Biology* 7(5): 732-734.

Siddiqi, N. A. 2001. *Mangrove Forestry in Bangladesh*. Institute of Forestry and Environmental Science, University of Chittagong, Chittagong. 201pp.

Siddiqi, N. A. 2002. Development and sustainable management of coastal plantations in Bangladesh. *Journal of Asiatic Society of Bangladesh, Science* 28(2): 144-166.

Siddiqi, N. A. and Khan, M. A. S. 1990. Growth performance of mangrove trees along the coastal belt of Bangladesh. *Mangrove Ecosystems Occasional Papers*. No. 8. UNDP/UNESCO REGIONAL MANGROVES PROJECT RAS/86/120. Thomson Press, Delhi. 5-14 pp.

Siddiqi, N. A. and Khan, M. A. S. 1996. Planting techniques f or mangroves on new accretions in the coastal areas of Bangladesh. In: Field, C. (ed.). *Restoration of Mangrove Ecosystems*. International Society for Mangrove Ecosystems. Okinawa, Japan. pp. 143-159.

Siddiqi, N. A. and Khan, M. A. S. 2004. Human-induced succession of vegetation on new accretions in the coastal areas of Bangladesh. *Journal of Tropical Forest Science* 16(2): 187-198.

Siddiqi, N. A.; Khan, M. A. S.; Islam, M. R. and Hoque, A. K. F. 1992. Underplanting - a means to ensure sustainable mangrove plantations in Bangladesh. *Bangladesh Journal of Forest Science* 21:1-6.