



Growth of Some Mangrove and Mangrove Associate Species inside *Sonneratia apetala* Plantation

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Abstract

The present study aims to investigate the survival and growth performance of eight mangrove and mangrove-associated species at different inundation frequency levels in the western coastal areas of Bangladesh. The study was conducted in the 3-12 months inundated land at Rangabali and Char Kukri-Mukri forest research station. Result showed that the species *Thespesia populnea*, *Calophyllum inophyllum*, *Ficus rumphii*, and *Dolichandrone spathacea* performed better survival and height growth in the 3-5 months of inundated areas at Rangabali in the years 2019 and 2020 significantly different from Char Kukri-Mukri site. But these species did not survive at 12 months and 9 months of inundated areas at Rangabali, except for *D. spathacea* in 2017 and 2018. On the other hand, the species *Cynometra ramiflora*, *Aglaia cuculata*, *T. populnea*, and *D. spathacea* performed better survival 60%, 52%, 50%, 47% and better height performance were observed in *T. populnea* (0.80m) followed by *A. cuculata* (0.70m), *D. spathacea* (0.44m) and *C. ramiflora* (0.30m) at the 9-12-month inundated area at Char Kukri-Mukri sites respectively. The present study found a significant inundation impact on the survival and growth of these eight mangrove and mangrove associates at the initial stage in western coastal areas. The species *T. populnea*, *C. inophyllum*, *F. rumphii*, and *D. spathacea* showed signs of growth that suggested it might be suitable for raising under the older keora forest in 3-5 months inundated areas, and *A. cuculata* and *C. ramiflora* species also showed signs of growth in 9-12 months inundated areas. The findings reveal that it would be appropriate for enhancing coastal vegetation to generate dense forests.

সারসংক্ষেপ

বাংলাদেশের পশ্চিম উপকূলীয় এলাকায় বিভিন্ন প্রাবন স্তরে ম্যানগ্রোভ ও ম্যানগ্রোভ সহযোগি আটটি প্রজাতির বেঁচে থাকা এবং বৃদ্ধি যাচাই করার জন্য গবেষণা পরিচালনা করা হয়। পরীক্ষাটি বাংলাদেশের পশ্চিম উপকূলীয় এলাকার রাসাবালী ও চর কুকরী-মুকরী এলাকার কেওড়া বনের অভ্যন্তরে ৩-১২ মাস জোয়ারের পানিতে প্রাবিত স্থানে পরিচালনা করা হয়। পরীক্ষায় ফলাফলে দেখা যায় যে, রাসাবালী এলাকায় সনবলই, পুনিয়াল, জিরবট এবং পানিকাপিলা প্রজাতির বেঁচে থাকার হার ও বর্ধন ৩-৫ মাস জোয়ারে প্রাবিত স্থানে ভাল হয়েছিল যা তাৎপর্যপূর্ণভাবে চর কুকরী-মুকরী এলাকায় উত্তোলিত পরীক্ষামূলক বাগান হতে পৃথক। কিন্তু পানিকাপিলা প্রজাতিটি ছাড়া ২০১৭ এবং ২০১৮ সালের পরীক্ষামূলক বাগানে অন্য কোনো প্রজাতি ৯ মাস ও ১২ মাস জোয়ারের পানিতে প্রাবিত স্থানে টিকে থাকতে পারেনি। অন্যদিকে চর কুকরী-মুকরী এলাকায় ৯-১২ মাস জোয়ারের পানিতে প্রাবিত স্থানে প্রজাতিগুলোর বেঁচে থাকার হার যথাক্রমে সিংড়া (৬০%), আমুর (৫২%), সনবলই (৫০%) এবং পানিকাপিলা (৪৭%) এবং গড় উচ্চতা যথাক্রমে ০.৮ সে.মি.; ০.৭ সে.মি.; ০.৪৪ সে.মি এবং ০.৩ সে.মি. পাওয়া গিয়েছিল। বর্তমান পরীক্ষায় পশ্চিম উপকূলীয় এলাকায় প্রাথমিক পর্যায়ে এই আটটি ম্যানগ্রোভ এবং ম্যানগ্রোভ সহযোগি প্রজাতির বেঁচে থাকা এবং বর্ধনহারের উপর জোয়ারভাটার প্রভাব পাওয়া গিয়েছে। প্রজাতিগুলোর প্রাথমিক বৃদ্ধির হার ও বেঁচে থাকার হার পরামর্শ দেয় যে, পুরাতন কেওড়া বনের অভ্যন্তরে যেখানে ৩-৫ মাস জোয়ারের পানিতে প্রাবিত হয় এমন স্থানে সনবলই, পুনিয়াল, জিরবট, পানিকাপিলা এবং ৯-১২ মাস জোয়ারের পানিতে প্রাবিত হয় এমন স্থানের জন্য আমুর ও সিংড়া প্রজাতি বাগান সৃজনের জন্য উপযুক্ত হতে পারে। পরীক্ষার এ ফলাফল ঘন বন সৃষ্টির জন্য এবং উপকূলীয় এলাকায় গাছপালা বৃদ্ধির জন্য উপযুক্ত হবে।

Keywords: Coastal forest, Growth, Inundation, Manmade coastal forest, Mangrove associate, Western coastal region.

Introduction

Bangladesh is a frontrunner in the afforestation of coastal areas (Siddiqi and Khan 1990; Spalding 1997). Bangladesh's 710 km-long coasts are made up of connections between many natural and economic systems (Hossain 2001; Iftekhar 2006). In recently acquired char lands along the coastal belt, an afforestation effort was launched in 1966 (Rahman and Pramanik 2015). In Bangladesh, mangrove plantations have been expanding daily (Hasan 2013). The Bangladesh Forest Department has planted mangrove species over more than 209,140 hectares of the coastal areas, of which 93% have been established (DoE 2015).

The two most successful mangrove species for planting in the coastal areas are *Sonneratia apetala* Buch. Ham. (keora) and *Avicennia officinalis* L. (baen) respectively (Siddiqi 2001). It is also very common for these species, seedlings to die after being planted in coastal locations (Siddiqi and Das 1988; Miah *et al.* 2014). Due to the demise of planted seedlings, large gaps have formed inside *S. apetala* plantations (Serajuddoula *et al.* 1995). The Bangladesh Forest Research Institute (BFRI) later introduced several notable mangrove species through experimental basis, including *Heritiera fomes*, *Excoecaria agallocha*, *Xylocarpus moluccensis*, *X. granatum*, *Bruguiera sexangula*, *Aegiceras corniculatum*, *Ceriops decandra*, *Phoenix paludosa* and *Lumnitzera racemosa* (Islam *et al.* 2013). A few mainland species were also trialed on some elevated ground of Char Island's including *Pithocellobium dulce*, *Samanea saman*, *Casuarina equisetifolia*, *Acacia nilotica*, *Thespesia populnea* and *Albizia lebbeck* on small mounds (Islam *et al.* 2014). Additionally, there is insufficient regeneration throughout the keora plantations. Furthermore, Bangladesh's man-made coastal forest

productivity is lower than that of other Asian countries. (Islam *et al.* 2015; Howlader 1999). Islam *et al.* (2015) observed that in the various coastal regions of Bangladesh, the density of *S. apetala* was 1201/ha. at the age of 17–42 years. The density of *S. apetala* trees planted in Mirersarai, Chattogram, was determined to be 650 trees per hectare at the ages of 20 to 29 years (Uddin *et al.* 2014).

In contrast, the natural Sundarban has a richer floristic composition than any other mangrove in the world. The Bangladesh Sundarban contains 66 species, according to a list provided by Chaffey and Sandom in 1985. Karim (1994) reported 123 plant species from 22 families and 30 genera in the Bangladesh Sundarban. The Sundarban mangrove forest's 44 undergrowth species were counted by Hossain (2003). It is necessary to introduce several mangrove and mangrove associated species inside the *S. apetala* plantation through underplanting in order to fill up the gaps of the coastal plantation and produce a dense mixed forest. The dense forest can shield against climate change-related extreme weather events that could harm human habitation, lives, property, and agricultural crops. Therefore, a study was carried out to ascertain the viability and growth of eight mangrove and mangrove-associated species in the western coastal region of Bangladesh at different inundation frequency level.

Materials and Methods

In this experiment, the following species namely *Aglaiia cucullata* Roxb., *Ficus rumphii* Blume, *Tamarix indica* Wild, *Thespesia populnea* L., *Calophyllum inophyllum* L., *Cynometra ramiflora* L., *Rhizophora mucronata* Lamk and *Dolichandrone spathacea* (L.f.) K. Schum were tried.

Study area

This experiment was conducted by the Plantation Trial Unit Division (PTUD) of BFRI between 2017 and 2020 at two offshore islands, namely Rangabali in Patuakhali district and Char Kukri–Mukri in Bhola district. Rangabali is located at latitude 21°92' north and longitude 90°92' east. Char Kukri–Mukri is situated at latitude 21°85' north and longitude 90°72' east (Islam *et al.* 2015). There are many similarities between the two sites. The average lowest and highest temperatures are 18°C and 32°C respectively (Siddiqi 2002). The soil is silty clay loam and non-calcareous. In the monsoon and dry seasons, soil salinity ranges from 0.3 to 4.2 DS/m. The pH of the soil is fairly alkaline, ranging from 7.5 to 8.0. (Siddiqi and Khan 2000).

Nursery raising

The seeds gathered from trees with superior phenology were utilized to grow seedlings of species such as; *A. cucullata*, *T. populnea*, *C. inophyllum*, *C. ramiflora*, and *D. spathacea*. The seedlings of *T. indica* and *F. rumphii* were generated by cutting, and *R. mucronata* from propagules. The polybag, measuring 18cm × 12cm and filled with a 3:1 ratio mixture of loamy soil and cow manure was used to raise seedlings. The seedlings were maintained in the nursery for 8 to 10 months by weeding and watering.

Site selection, site preparation, data collection

The experimental sites were chosen within the 15–30 years-old *S. apetala* plantation at several char land at Rangabali and Char Kukri-Mukri island where flooding occurs three to twelve months in the year. In Rangabali Island experimental plantations were set up in 2017, 2018, 2019 and 2020 with an inundation frequency of 12, 9 and 3 to 5 months, respectively. At Char Kukri-Mukri site,

plantations were made in regions with a inundation frequency of 9–12 months. The experimental were prepared through clearing and cutting of bush. Seedlings were planted with three replications at 1.5m × 1.5m spacing in a Randomized Complete Block Design (RCBD). Barbed wire and wooden posts were used to fence the experimental plots to prevent biotic interference. Experimental plantations were maintained through weeding and climber cutting to keep the test plots in good condition twice in year. The data was collected from the experimental plantations twice, in June and December. Data on growth characteristics were collected at these plantations for comparison with experimental plantations.

Statistical analysis

The Minitab statistical software and an excel spreadsheet were used to evaluate all of this data. Growth of experimental species survival, height, and collar diameter were measured using analysis of variance (ANOVA) to determine the effect of inundation frequency of these species.

Results

The results of the experiments are shown in tables 1 and 2. In the experimental year 2020, the highest survival was recorded for *T. populnea* (86%), followed by *F. rumphii* (81%), *D. spathacea* (71%) and *C. inophyllum* (61%) at the age of one year at the Rangabali site. The mean highest height was recorded for *F. rumphii* (1.26m, Fig. 1), followed by *T. populnea* (1.08m), *D. spathacea* (0.99m), and *C. inophyllum* (0.76m, Fig. 1). The highest mean collar girth was found at *F. rumphii* (3.98cm), followed by *D. spathacea* (3.88cm), *C. inophyllum* (3.31cm), and *T. populnea* (3.27cm) at 3-5 months inundation areas of Rangabali site in the plantation year 2020 (Table 1). In the experimental year 2019, the

Table 1. Survival and Growth performance of species planted in 2017, 2018, 2019, and 2020 at Rangabali Forest Research Station.

Name of Species	Plantation year and age									
	2017 (4 years)		2018 (3 years)		2019 (2 years)			2020 (1 year)		
	Inundation Frequency 12 Months		Inundation Frequency 9 Months		Inundation Frequency 3-5 Months			Inundation Frequency 3-5 Months		
	Mean survival %	Mean Height (m)	Mean survival %	Mean Height (m)	Mean survival %	Mean Height (m)	Mean collar girth (cm)	Mean survival %	Mean Height (m)	Mean collar girth (cm)
<i>C. inophyllum</i>	0	0	0	0	4.0± 0.16b	0.61± 0.02c	4.4± 0.12a	61.4± 1.23d	0.76± 0.17c	3.31± 0.15b
<i>A. cucullata</i>	0	0	0	0	35.0± 0.15d	1.05± 0.12b	4.39± 0.11a	-	-	-
<i>T. populnea</i>	0	0	0	0	97.0± 0.16 a	1.71± 0.47 a	4.32± 0.12a	86.0± 0.96a	1.08± 0.03b	3.27± 0.15b
<i>F. rumphii</i>	0	0	0	0	80.0± 0.19c	1.84± 0.09a	4.82± 0.18a	81.0± 1.47b	1.26± 0.03a	3.98± 0.31a
<i>D. spathacea</i>	19.00 ±3.21	1.2 ±0.42	19.85 ±0.58	1.15 ±0.19	32.0± 0.19d	1.10± 0.04b	4.28± 0.23a	71.48± 0.95c	0.99± 0.03b	3.88± 0.32 a
<i>R. mucronata</i>	0	0	0	0	22.0	0	0	0	0	0
<i>C. ramiflora</i>	0	0	0	0	0	0	0	0	0	0
P value					0.000	0.000	0.000	0.000	0.000	0.000

Notes: Means with different letters in a column are significantly different at 5% level (\pm SE. Mean).

highest survival rate (97%) was recorded for *T. populnea*, followed by *C. inophyllum* (94%), *F. rumphii* (80%), *A. cucullata* (35%), *D. spathacea* (32%) and *R. mucronata* (22%) at the age of two years at the Rangabali site where inundation frequency was 3-5 months. The significantly highest mean height was recorded for *F. rumphii* (1.84m, Fig. 2), followed by *T. populnea* (1.71m, Fig. 2), *D. spathacea* (1.10m), *A. cucullata* (1.05m) and *C. inophyllum* (0.61m). The highest collar girth was recorded 4.82cm for *F. rumphii*, 4.40cm for *C. inophyllum*, 4.39cm for *A. cucullata*, 4.32cm for *T. populnea* and 4.28cm for *D. spathacea*.

At the Char Kukri-Mukri sites, in the experimental plantation of 2020, the highest survival was recorded for *C. ramiflora* (60%)

followed by *A. cucullata* (52%), *T. populnea* (50%) and *D. spathacea* (47%), *C. inophyllum* (30%) and *T. indica* (22%) at the age of one year. The highest mean height was recorded for *T. populnea* (0.80m), followed by *A. cucullata* (0.70m), *C. inophyllum* (0.70m), *D. spathacea* (0.44m), *C. ramiflora* (0.30m) and *T. indica* (0.20m). The highest mean collar girth was found in *T. indica* (4.73cm), followed by *A. cucullata* (3.47cm), *T. populnea* (2.29cm), *C. inophyllum* (2.12cm), *D. spathacea* (1.78cm), and *C. ramiflora* (1.36cm) (Table 2). In the experimental plantation of 2019, the highest survival was found for *D. spathacea* (32%) followed by *T. indica* (22%), *T. populnea* (21%) and *A. cucullata* (11%). The highest mean height was recorded for *T. populnea*

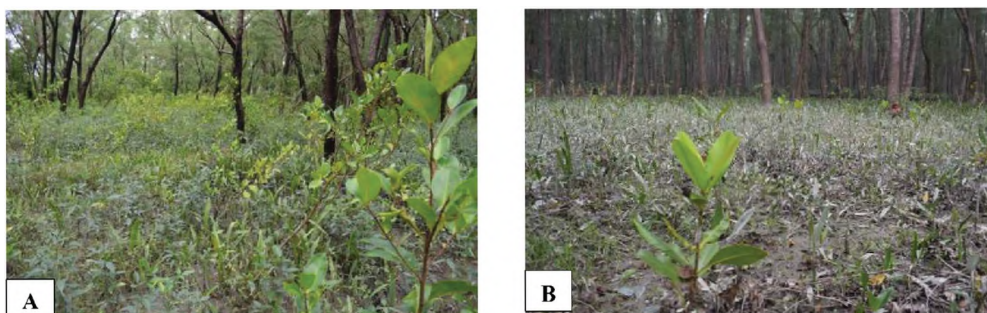


Figure 1. Understoried experimental plantation of *F. rumphii* and *C. inophyllum* at Char Nazir, Rangabali, Patuakhali (1 Year) (A&B).



Figure 2. Experimental plantation of *T. populnea* and *F. rumphii* under the *S. apetala* forest at Char Nazir (3-5 months inundation area), Rangabali, Patuakhali (2 years) (A&B).

Table 2. Survival and growth performance of mangrove and mangrove associated species planted in 2018, 2019 and 2020 at Char Kukri-Mukri Forest Research Station under the *S. apetala* forest.

Name of species	2018 (age 2.5 years)			2019 (age 2 years)			2020 (age 1 year)		
	Mean survival %	Mean height (m)	Mean collar girth (cm)	Mean survival %	Mean height (m)	Mean collar girth (cm)	Mean survival %	Mean height (m)	Mean collar girth (cm)
<i>C. inophyllum</i>	12.0±0.01b	0.78±0.26a	3.44±0.17c	10.00±0.16c	0.65±0.12b	2.58±0.14c	30.0±0.90d	0.47±0.19b	2.12±0.10c
<i>A. cucullata</i>	8.50±0.02c	0.98±0.56a	4.33±0.11b	11.00±0.03c	0.73±0.46b	3.72±0.12b	52.0±1.28b	0.70±0.18a	3.47±0.15b
<i>T. populnea</i>	-	-	-	21.00±0.09b	0.95±0.53a	2.6±0.02c	50.0±2.14b	0.80±0.03a	2.29±0.13c
<i>F. rumphii</i>	-	-	-	-	-	-	-	-	-
<i>D. spathacea</i>	30.0±0.02a	0.65±0.02b	3.80±0.20c	32.00±0.65a	0.54±0.02c	2.58±0.14c	47.5±1.32b	0.44±0.02b	1.78±0.08c
<i>C. decandra</i>	0	0	0	0	0	0	0	0	0
<i>R. mucronata</i>	-	-	-	-	-	-	-	-	-
<i>C. ramiflora</i>	0	0	-	-	-	-	60.0±1.90a	0.30±0.00c	1.36±0.05c
<i>T. indica</i>	15.0±0.16b	0.56±0.09bc	5.75±0.16a	22.00±0.10b	0.35±0.12d	4.92±0.11a	22.0±0.27d	0.20±0.00d	4.73±0.15a
<i>P value</i>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Means with different letters in a column are significantly different at a 5% level

(0.95m), followed by *A. cucullata* (0.73m), *D. spathacea* (0.54m), and *T. indica* (0.35m). The highest mean collar girth was recorded for *T. indica* (4.92cm), followed by *A. cucullata* (3.72cm), *D. spathacea* (2.58cm) and *T. populnea* (2.6cm) at the age of two years (Table 2). The growth performance of the species was found to be better at the Rangabali site than at the Char Kukri-Mukri site in respect of survival, height, and collar girth.

Discussion

Results of experimental plantations raised in 2020 indicated a significant differences in survival, height growth and collar girth of the species at the Rangabali locations and shows disparities in height growth and survival in 2019 plantation. Survival, height growth, and collar girth of various species raised in 2020 at Char Kukri-Mukri site also revealed a significant differences. The growth performance of the species *T. populnea*, *C. innophyllum*, *D. spathacea* and *F. rumphii* was shown to be superior in terms of survival, height, and collar girth at the Rangabali site, where inundation occurs for 3-5 months than at the Char Kukri-Mukri site, where inundation occurs for 9-12 months of the year. Difference in the performance of the species seems to be due to the frequency and duration of *C. ramiflora*, *A. cuculata*, *T. populnea* and *D. spathacea* species performed better in the 9–12 month inundated area at Char Kukri-Mukri areas than in Rangabali sites. It was noted that the plantation years 2017 and 2018 were more negatively impacted by grazing and caused damage. For that reason the results may be different from Char Kukri-Mukri site. The species *C. ramiflora* totally failed at Rangabali areas having 9 and 12 months inundation. The growth performance of these species was found to be better at the Rangabali site than at the Char Kukri-Mukri site in respect of survival, height, and collar girth could be due to the

inundation frequency. Severe disturbance was noticed at the Char Kukri-Mukri site also. The species *T. populnea*, *C. innophyllum*, and *F. rumphii* are usually grown in coastal raised land areas. Meepol *et al.* (2020) found *A. cucullata* measuring 30 cm in dbh and 15-20 m in height on the banks of the Kraburi River in Ranong Province, Thailand. According to Ahmed *et al.* (2009) and Hossain (2015), the species *F. rumphii* can grow as tall as 20 meters. Serajuddoula *et al.* (1995) was found *T. populnea* had a mean survival rate of 98.67%, a mean height of 3.67 m, and a mean diameter at breast height of (DBH) 3.8cm at Rangabali research station. Islam *et al.* (2014) found that at the Rangabali location in 17-year-old plantations had a mean survival rate of 52%, a mean height of 7.19m, and a mean DBH of 13.77cm. On homogeneous peat near Buntai in Indonesia, Leksono *et al.* (2021) identified 81.4% mean survival, 1.74m mean height, and 3.97 cm DBH at the age of two years in *C. innophyllum*. At the age of two years, *C. ramiflora* showed 67% mean survival and 1.02 m height at the Rangabali site and 71% mean survival and 0.96 m height at the Char Kukri-Mukri site, according to Siddiqi *et al.* (1992). Rahman (2016) observed that *R. mucronata* at the age of eight years in Sundarbans had a 74% mean survival rate, 5.23 m mean height, and 4.83 cm DBH. The height of *D. spathacea* is 4–10m (Weereesa and Chatchai 2021).

Conclusion

Making a choice about which species to use in an evaluation program based on tree growth performance may be helpful. To improve the density and biodiversity of manmade coastal forests, trials were initiated in the coastal areas to select suitable mangrove and mangrove associate species. Some of the species, like *T. populnea*, *C. innophyllum*, *D. spathacea* and *F. rumphii*, were found promising at the ages of

2 and 1 years old in the 3-5 month inundation frequency level at Rangabali research station. The species *C. ramiflora* and *A. cuculata* performed better in 9–12 months-old inundated areas of Char Kukri-Mukri research station. According to the initial results of the study, *T. populnea*, *C. innophyllum*, *D. spathacea*, and *F. rumphii* should be planted under the Keora forest, where the inundation frequency is 3-5 months. In 3–12 months inundated areas, the species *C. ramiflora* and *A. cuculata* can be performed. These species can be used to create a dense coastal forest to protect against natural calamities. This is, however, an interim report. The experimental trials will be maintained and the comprehensive ones will be available after a few year.

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