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Growth Performance of Mangrove Species in Chakaria Sundarban

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Abstract Mangroves are unique ecosystems of land-sea interface in the tropical and sub-tropical regions of the world. The study was conducted in experimental mangrove nurseries established at two different sites in Chakaria Sundarban of Cox's Bazar, Bangladesh to assess survival percentage and growth performance of four mangrove species (*Sonneratia apetala, Avicennia alba, Avicennia marina* and *Excoecaria agallocha*). Height and collar diameter were measured in one month intervals. The study showed that after three months, the highest (53.33%) and the lowest (6.67%) survival percentage was found in Keora and Gewa seedlings in Chaurfari site. In Chuarfari, the maximum (44.12 cm) height was found in Moricha Baen followed by Sada Baen (36.85 cm) and Keora (29.58 cm). After three month, Keora in both sites showed better collar diameter (1.08 cm in Chaurfari and 1.04 cm in Badarkhali) compared to other species. The study recommends the plantation of Keora, Moricha Baen and Sada Baen mangrove species in both sites.

Keywords Mangrove plantation, Growth, Ecosystem, Forest Degradation, Coastal Afforestation

1. Introduction

Mangroves are salt tolerant forest ecosystem of tropical and subtropical intertidal region of the world [1]. Mangroves are important resources in coastal ecosystems that contribute multiple ecosystem services [2]. Mangroves are highly productive ecosystems occupying brackish water zones along tropical and subtropical coasts [3]. Mangroves offer both tangible and intangible benefit to the people [4]. Mangrove plants are halophytes, well adapted to salt water and fluctuation of tide level. As mangroves thrive in a highly dynamic ecosystem, their growth and declining adaptive function often reflect the changing social and ecological conditions of the coastal environment [5]. With coastal geo-morphological changes, mangroves are facing rapid social changes; population pressure for food production and urban development has changed the habitat into undesirable states along coastlines globally [6]. Coastal ecosystems are facing increasing threats of extreme disaster and climate change related stress in Bangladesh, and mangrove plantations will not substitute for ecological restoration and enhancing the adaptation capacity of local communities [2]. Coastal communities in Bangladesh depend on planted mangroves for limited forest products; most of them depend on livelihoods closely related to climate-sensitive agriculture and open fishing practices [7].

Bangladesh is one of the most densely populated countries in world [8], as per recent population census Bangladesh has about 156 million people with the density of 1056 km^{-2} [9]. Compared with other countries Bangladesh has very low per capita forest area [10]. As per FAO statistics, Bangladesh has low forest coverage about 11.1% (about 1,442,000 ha) and low per capita forest area (0.009 ha) compared to the Asia (0.145 ha) and the world (0.6 ha) [11]. Bangladesh Forest Department reports the area of forest land is 2.52 M ha, 17.08% of the country's total land area [10]. Bangladesh has attained considerable economic growth since independence in 1971. This in turn has resulted in an increased demand for food, fuel and housing amenities much of which is sourced from forests or leads to land being deforested to satisfy this demand [11, 12]. The coastal zone of Bangladesh covers 32% of the country and encompasses the Exclusive Economic Zone in the Bay of Bengal and the landmass of the 19 districts [13]. Natural mangrove forests area cover 0.60 M ha which is about 4.07% of total land mass and 40% of total forest land [10]. But due to population pressure these area become shrinking due to conversion of forest land to human settlement, agricultural land and aquaculture. The Chakaria Sundarban is one of such degraded mangrove forests in Bangladesh [13-15].

Global mangrove coverage is calculated to be just over

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181 thousands km^2, a small area compared to that of other forest types in the world [16]. The Major proportion of mangrove area lies in South and Southeast Asia (41.2%) and USA (27.1%) followed by West Africa (15.5%), Australia (10.4%), and east Africa and the Middle East (5.7%). Major decline of mangrove area are recorded in the Philippines (60%), Thailand (55%), Vietnam (37%) and Malaysia (12%). However, mangrove planting activities are in progress in Bangladesh, Vietnam, Pakistan, Cuba [16]. Since 1965 about 196 thousands ha of coastal areas are planted with mangrove plants and at present net area of mangrove plantation is 132 thousand ha after losing some area due to natural calamities [10].

The Chakaria Sundarban (Figure 1) in Cox's Bazar coast of Bangladesh was one of the oldest mangrove forests in the subcontinent [14]. The Chakaria Sundarban mangrove forest was used to be a mosaic of newly formed grassy islands, mangrove forests, river channels, aquaculture ponds, tidal creeks and inter-tidal mudflats located in the estuarine system of the Matamuhuri River and several smaller rivers in the Bay of Bengal [13]. In 1903, the area of Chakaria Sundarban was 8,510 ha (reserve mangrove forest: 7,490 ha and protected forest: 1,020 ha). In 1926, more than 1,600 ha of land were leased to landless families for settlement who have become dependent on the forest for firewood, housing and building materials [14]. Despite the access to mangroves, upto 1977 the mangrove area of the Chakaria Sundarban remained unaltered depicted by a map in 1952 (7,500 ha of mangroves) and an aerial photograph in 1975. About 2,251 ha in 1977 and 694 ha mangrove forest in 1982 were cleared for shrimp farming. Subsequently, during 1985 to 1988 about 3,577 ha forests were converted for shrimp farming. Finally, during 1995 to 1996 rest portion of the forest were altered for shrimp farming [14]. The once flourishing Chakaria Sundarbans has been totally destroyed [17]. Initial vegetation of the Chakaria Sundarban included 53 species belonging to 42 genera and 22 families [18]. The forest was stunted growing to an average height of about 10m and it was only very exceptional that an individual tree would grow to 20m in height. The forest consisted mainly of an association of two species *Ceriops decandra* and *Avicennia officinals*. Other important species were Sundri (*Heritiera fomes*), Gewa (*Excoecaria agallocha*), Kankra (*Bruguiera gymnorrhiza*), Hargoza (*Acanthus ilicifolius*) Nuniagach (*Aegialitis rotundifolia*), and Ananta kata (*Dalbergia spinosa*) [13]. A notable feature of this area was the total absence of *Nypa fruticans*. However, a study [15] showed a very poor condition of the forest flora both in respect to species diversity and abundance (Table 1).

Table 1. Floral Composition of the Chakaria Sundarban in 1991 Adapted from Siddiqi *et al.* [15]

Species name (Family)	Status in 1991	Remark
Acanthus ilicifolius (Acanthaceae)	Abundant	Found along the canal sides and newly accreted areas
Acrostichum aureum (pteridiaceae)	Rare	Found in some raised areas
Aegialitis rotundifolia (Plumbaginaceae)	Rare	--
Aegiceras comiculatum (Myrsinaceae)	Absent	--
Avicennia spp. (Avicenniaceae)	Rare	Few tree present; old and fresh cut stumps occur
Brownlowia lanceolata (Tiliaceae)	Absent	
Bruguiera spp. (Rhizophoraceae)	Rare	Few saplings and coppices on old stumps available
Ceriops decondra (Rhizophoraceae)	Absent	---
Cynometra raniflora (Leguminosae)	Rare	Few plants are available in the northern part
Dalbergia spinosa (Leguminosae)	Common	Found in the North eastern part of the forest outside shrimp ponds
Derriscandens (Leguminoseae)	Absent	--
Excoecaria agallocha (Euphorbiaceae)	Fairly common	Occurs as coppices throughout the forest. Only a few trees available in the north eastern part.
Heritiera fomes (Srerculiaceae)	Rare	Few tall trees available in the north eastern periphery of the forest
Hibiscus tiliaceous (Malvaceae)	Rare	Found along the northeastern periphery of the forest
Imperata cylindrica (Gramineae)	Abundant	Found along the canals and in newly accreted land
Intsia bijuga (Leguminosae)	Rare	Only stumps with bushy coppice available in the northern part
Kandelia candel (Rhizophoraceae)	Absent	---
Nypa fruticans (Palnae)	Absent	Expected to be introduced
Pandarus foetidus (Pandanaceae)	Occasional	Along canal banks
Oabdarys foetidus (Pandanaceae)	Occasional	Scattered all over the forest
Phoenix paludosa (Palmae)	Common	Dense vegetation toward mid northern part of the forest
Pongamia pinnata (Legurninosae)	Rare	Along the periphery of the forest

The Chakaria Sundarban was rich with dense forest cover and diversified flora and faunal distribution. But now it is a barren land, which possesses no forest cover at all. The landmass of Chakaria Sundarban has now been completely engulfed for salt production and shrimp cultivation [13, 17]. Very few studies on the assessment of survival and growth of mangroves species in coastal areas were conducted in Bangladesh. Since 1965-1966 to 2012-2013 Bangladesh Forest Department has planted 1,96 thousands ha of coastal areas [10]. Saenger and Siddiqi [19] studied on survival and growth of 3 mangrove species (*Sonneratia apetala, Excoecaria agallocha and Avicennia officinalis*) in coastal areas of Bangladesh. No study yet undertaken to assess the survival and growth performance of mangrove tree seedlings in the Chakaria Sunderbans area. Hence, it is necessary to assess the site suitability for mangrove species for recovery of Chakaria Sundarban. The study was carried out to assess the survival percentage and growth performance of four mangrove tree seedlings (Gewa, Sada Baen, Moricha Baen, and Keora) at two different locations in Chakaria Sundarbans.

Description of the studied species

***Excoecaria agallocha L.* (Vernacular name: Gewa; Family: Euphorbiaceae)**

Excoecaria agallocha is a common littoral species in Asia and Oceania. In Bangladesh, the species is found in the Sundrabans, once in Chakaria Sundrabans and is grown in the coastal plantations. It is a small medium sized evergreen tree with smooth grey bark covered with prominent lenticels. It comes after some pioneer species in the ecological succession. The species grows well in intermediate levels of salinity and tidal inundation. Natural regeneration of *E. agallocha* occurs along the coastline, but it is insufficient to from a stand [20].

***Sonneratia apetala* (Vernacular Name: Keora; Family: Sonneratiaceae)**

Sonneratia apetala occurs in the Sundarbans proper and once exists in the Chakaria Sundarbans. It is the principal planting species along the shoreline of Bangladesh. It is the largest and tallest tree of the Sundarbans growing up to height of 20m with a diameter of 80 cm. The bark of the tree is black, smooth, with horizontal oval lenticels. It is the pioneer species in the ecological succession. It colonizes first on newly formed soil among other mangrove tree species. Usually it forms pure stands. Trees attain maturity in about 50 years. *S. apetala*, being a pioneer species, colonizes first on newly formed land, grasses and sedges follow it. It can withstand wide range of salinity. It is a strong light demanding species. The reproduction of the species is by seeds. It prefers muddy, soft and well-inundated lands for its establishment.

***Avicennia officinalis L.* (Vernacular Name: Baen; Family: Avicenniaceae)**

A. officinalis is distributed in Asia and the pacific in Bangladesh, once found in the Chakaria Sundarbans. *It* is the second most successful species of the mangrove plantations after *Sonneratia apetala* in the coastal areas of Bangladesh. It alone constitutes about 5% of the total mangrove plantation and 22% in the eastern part of the shoreline.

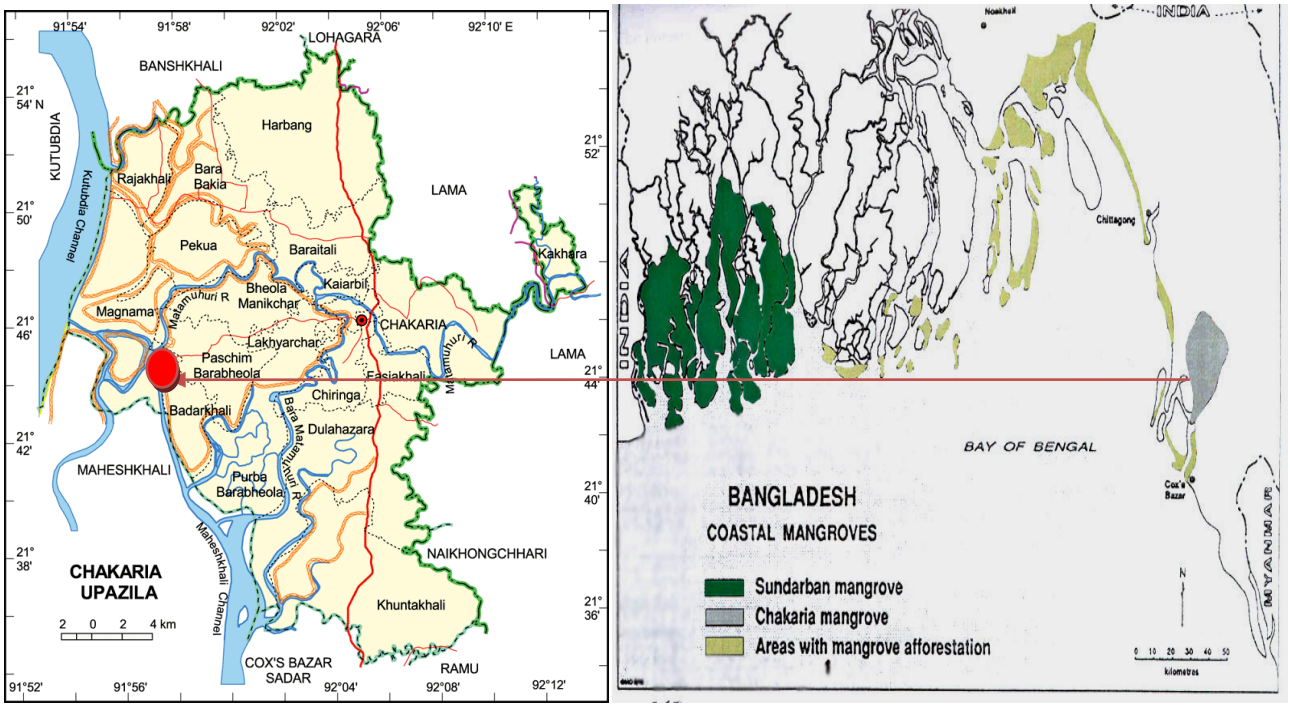

Figure 1. Study area map (Source: Banglapedia)

2. Materials and Methods

The Chakaria Sundarban is situated between latitude 21°36′ N to 21°45′ N and longitude 91°58′ E to 92°05′ E, lies in the delta of Matamuhuri River of Cox's bazaar district, the south eastern part of Bangladesh. Mean annual maximum and minimum temperature of the area varies between 20℃ and 32 ℃ and annual rainfull is about 3500 mm. The Chakaria sundarban is bounded by Maheskhali channel and Matamuhuri khal to the west and Medi khal to the east. To the north it is extended up to Malumghat. In Chuarfari site the soil varies from clay to clayey loam. Most of the area of this site is occupied for shrimp culture. Badarkhali site is in the Maheskhali channel where soil is clayey and sandy loams. The salinity is remarkably easily lower during the monsoon as a result of increased downward flow of the Matamuhri River and it is not above 10 ppt in any point of the forest [15]. Four tree species namely; Keora (*Sonneratia apetala*), Sada Baen (*Avicennia officinalis*), Moricha Baen (*Aviccnnia alba*) and Gewa (*Excoecaria agallocha*) were selected purposively for the study. A reconnaissance survey was conducted at Chuarfari and Badarkhali sites in Chakaria Sundarban. In each site 15 plots were prepared for planting the seedlings. In total, two hundred and forty seedlings (60 seedlings of each species in both sites) were planted. Seedlings were planted in Chaurfari on 29 June 2009 and in Badar Khali on 30 June 2009. In Chuarfari, Sada Baen on plot 1-4, Moricha Baen on 5-7, Gewa on 8-10, Keora on 11-15 and in Badar khali, Sada Baen on plot 1-4, Maricha Baen on 5-7, Gewa on 8-11, Keora on 12-15 were planted. Then growth data were measured at one month intervals for 3 successive months. Collar diameter measured using slide callipers at 2 cm above the soil and height was taken from the ground to the tip of the plants. Data were analyzed using MS Excel 2007.

3. Results and Discussion

Survival percentage of mangrove seedlings in Chuarfari and Badarkhali study areas

The highest (86.67%) survival percentage was found in first month of Keora in Chaurfari site, whereas, in Badarkhali it was 80%. Survival percentage was found the lowest (6.67%) in third month of Gewa in Chaurfari plantation site. Keora in both the sites showed better survival compared to other species. Gewa plantation were not suitable in both the sites as in first month survival percentage was below 50% and declined in consecutive months. Sada Baen and Moricha Baen showed significant survival percentage in first two months in Chaurfari sites, while in Badarkhali it was much lower. Seedlings survival percentage in all species in both sites showed the declining rate with time (Figure 2). Saenger and Siddiqi [19] found that survival of mangroves is generally poor and replacement planting often needs to be undertaken for up to 3 years. In experimental plots at Barisal coast survival in 5-year old *S. apetala* ranged 29-52% [21]. Saenger and Siddiqi [19] also observed that the survival rates of *A. officinalis* after 5-years in the Chittagong coastal district ranged 30-60%. However, survival rate depends on season. Planting during June to August appears to result in maximum survival of newly planted seedlings of *S. apetala* [19] which is coincided with the present findings.

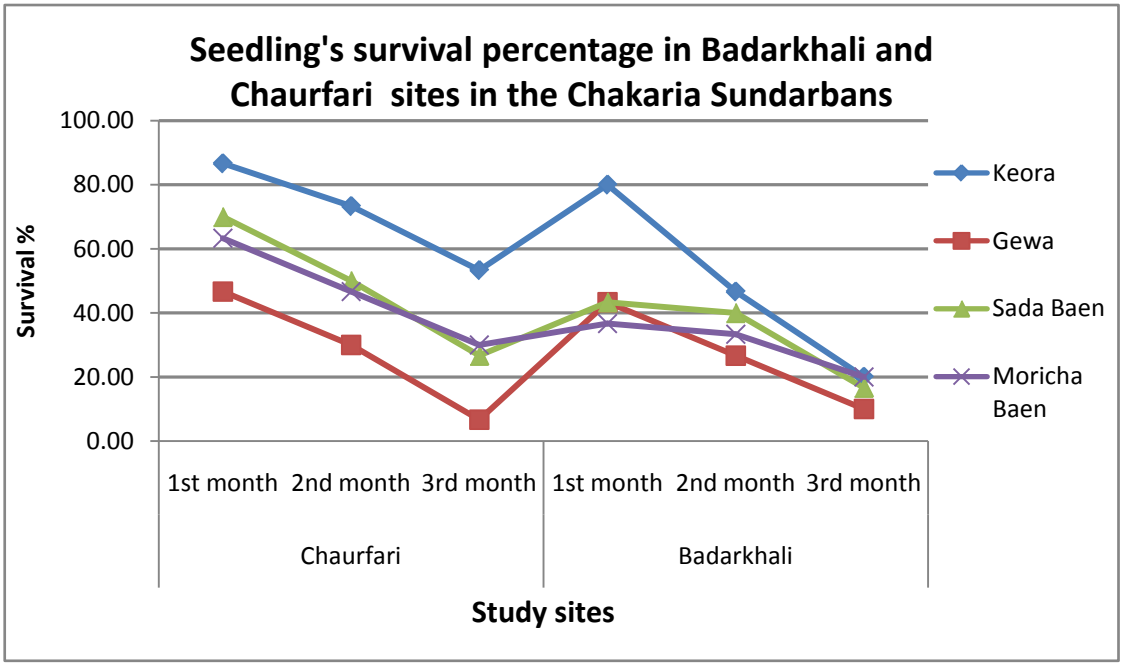

Figure 2. Seedlings survival percentage in 3 months in Chaurfari and Badarkhali sites

Table 2. Measurement of seedling's height in 3 consecutive months in Chaurfari and Badarkhali study sites (Source: Field study, 2009)

Species	Seedling's height at Chaurfari			Seedling's height at Badarkhali		
	First month	Second month	Third month	First month	Second month	Third month
Keora	25.61	26.72	29.58	18.32	20.91	23.12
Gewa	31.82	35.69	0.00	27.33	29.60	32.11
Sada Baen	29.26	32.88	36.85	29.83	35.15	37.72
Moricha Baen	32.22	38.23	44.12	29.84	34.78	36.55

Table 3. Measurement of seedling's collar diameter in 3 consecutive months in Chaurfari and Badarkhali study sites (Source: Field study, 2009)

Species	Seedling's collar diameter at Chaurfari			Seedling's collar diameter at Badarkhali		
	First month	Second month	Third month	First month	Second month	Third month
Keora	0.71	0.95	1.08	0.47	0.55	1.04
Gewa	0.61	0.93	0.00	0.56	0.91	0.97
Sada Baen	0.64	0.84	1.02	0.51	0.66	0.83
Moricha Baen	0.59	0.76	0.87	0.57	0.63	0.88

Height of mangrove seedlings in Chuarfari and Badarkhali sites

In first month, seedling height was the highest (32.22 cm) in Moricha Baen of Chaurfari site whereas, lowest (18.32 cm) in Keora of Badarkhali. Moreover, in second month, maximum (38.23 cm) height was found in Moricha Baen at Chaurfari and minimum (20.91 cm) in Keora at Badarkhali site. However, in third month all the Gewa seedlings of Chaurfari were died. In third month, again Moricha Baen showed highest (44.12 cm) height at Chaurfari site. Compared with other species Moricha Baen showed better performance in case of height growth in both the sites. Moreover, Sada Baen also showed better height growth in both the sites compared to Keora and Gewa (Table 2).

Collar diameter of mangrove seedlings in Chaurfari and Badarkhali sites

In first month, the highest (0.71 cm) collar diameter was found in Keora at Chaurfari, whereas, the lowest (0.47 cm) was in Keora at Badarkhali. In second month, the highest (0.95 cm) and the lowest (0.55 cm) collar diameter were recorded in Keora of Chaurfari and Badarkhali sites respectively. However, in third month Keora in both sites showed better collar diameter (1.08 cm in Chaurfari and 1.04 cm in Badarkhali). Compared to other species Moricha Baen showed lower collar diameter in both the sites (Table 3).

Present problems of Chakaria Sundarban

Mangrove ecosystem is important because of its ability to provide a variety of goods and services. The Chakaria mangroves have been destroyed due to over exploitation, conversion to shrimp farms, agricultural lands, and other human interventions which would influence environmental degradation. The following problems were identified during the study:

- Reckless shrimp farming by destroying forest lands is main problem for the Chakaria Sundarban.
- Sedimentation by newly accreted sand and silt cover the pneumataphore especially in the new plantation that restricts the growth performance.
- Mangroves species requires two times tides for their survival. But in the study area, during winter season in many places tides cannot reach due to char formation.
- Local people collect fuel wood from the plantation area before maturity of the trees that causes failure to the plantation.
- Wave action is responsible to wash out the newly planted seedlings.
- Grazing is another problem in the plantation areas. Due to grazing soil become compact that hampers pneumataphore, ultimately the plant growth stunts [22, 23].
- Lack of awareness of the local people is also responsible for destroying the mangrove plantations.

4. Conclusions and Recommendations

The Chakaria Sundarban is now producing large amount of shrimp and salt which are contributing greatly to our national economy. Considering the loss due to shrimp culture and salt production, particularly mangrove forest in terms of the value of mangrove products, economic implications of increased coastal erosion, loss of livelihood for coastal communities, fish production and environmental degradation, shrimp culture and salt production is definitely less economic. Although mangrove plantations occur in several locations of the Chakaria Sundarbans, the sites have not perhaps recovered from the damages caused from the retrogression resulting from widespread destruction of mangrove forests in the recent decades. Therefore, the sites are not ready for any mid- or later succession of tree species such as Gewa. Therefore, in order to protect the Chakaria Sundarban from ecological disaster and also to sustain the shrimp culture and salt production government should take necessary steps ensuring the win-win approach among local communities. The study recommends the following strategic measures:

- ❖ In Badarkhali coastal area, there is no plantation so soil may be not that much fertile to sustain the seedlings growth and survival. Therefore, the area should be brought under plantations for further amelioration of the site.
- ❖ In Chuarfari there are few mangrove plantations, therefore soil may contain comparatively more nutrients than Badarkhali, however more plantations need to be established for amelioration, protection and restoration of the mangrove ecosystem.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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