Enrichment Planting in the Mangrove of Sundarbans - A Review

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Abstract

The mangrove of Sundarbans in Bangladesh is intended to be managed on a sustained yield basis. But a remarkable decline in the growing stock of the merchantable trees is reported in recent decades. This necessitates exploring avenues for improving productivity of the forests. There are sizeable areas in the Sundarbans with scanty or little vegetation due to failure in natural regeneration. Rehabilitation of poorly stocked and vacant areas by enrichment planting could play a vital role in increasing the wood production of the forests.

This paper discusses the scope of artificial regeneration in the Sundarbans to improve the stocking and the yield. Research findings available in this direction have been reviewed. *Excoecaria agallocha* and *Ceriops decandra* appear to be suitable for planting in less productive but normally inundated areas. Plantations of *Nypa fruticans* can be established on vacant canal or river banks over the greater parts of the forests. The raised lands that do not support mangrove vegetation can be planted with non-mangrove species like *Samanea saman*, *Albizia procera*, *Lagerstroemia speciosa* and *Acacia nilotica*. Studies have been initiated for a remedy to the problem of top dying of *Heritiera fomes*, the dominant species of the forest. Research activities from various aspects are underway to evolve methods to increase tree density and forest cover.

সারসংক্ষেপ

বাংলাদেশের সুন্দরবন ম্যানগ্রুভে চলমান উৎপাদন নিশ্চিত করার উদ্দেশ্যে ব্যবস্থাপনা পরিকল্পনা গ্রহণ করা হয়। কিন্তু সাম্প্রতিক দশকগুলোতে গুরুত্বপূর্ণ প্রজাতির গাছের ঘনত্বের এক ব্যাপক অবনতি ঘটেছে। এ কারণে বনের উৎপাদন বৃদ্ধির উপায় খুঁজে বের করার প্রয়োজনীয়তা দেখা দেয়। সুন্দরবনের বিভিন্ন স্থানে পর্যাপ্ত প্রাকৃতিক রিজেনারেশনের অভাবে উল্লেখযোগ্য এলাকায় নগণ্য পরিমাণ গাছপালা রয়েছে। অপর্যাপ্ত গাছপালা এবং খালি এলাকায় সম্পূরক বনায়নের মাধ্যমে কাঠের উৎপাদন বৃদ্ধি করা যেতে পারে।

এ প্রবন্ধে সুন্দরবনে সম্পূরক কৃত্রিম বন পুনঃসৃষ্টি দ্বারা গাছের ঘনত্ব এবং উৎপাদন বৃদ্ধি করা যায় কি না তা আলোচনা করা হয়েছে। এ বিষয়ে বিদ্যমান গবেষণালব্ধ তথ্য পর্যালোচনা করা হয়েছে। গেওয়া *(Excoecaria agallocha)* এবং গরান *(Ceriops decandra)* কম উৎপাদনশীল এবং সাধারণ প্লাবিত এলাকায় বনায়নের জন্য উপযোগী। গোলপাতার *(Nypa fruticans)* বাগান বনাঞ্চলের বিভিন্ন এলাকায় নদী এবং খালের পাড়ের ফাঁকা জায়গায় সৃষ্টি করা সম্ভব। উঁচু এলাকায় যেখানে ম্যানগ্রুভ প্রজাতির উদ্ভিদ নেই সেখানে ম্যানগ্রুভ ব্যতীত অন্য প্রজাতির গাছ যেমন রেইনট্রি *(Samanea saman)*, শিল কড়ই

(Albizia procera), জারুল *(Lagerstromia speciosa)* এবং বাবলা *(Acacia nilotica)* দ্বারা বনায়ন সম্ভব। বনের প্রধান গাছ সুন্দরীর *(Heritiera fomes)* আগামরা রোগ প্রতিকারের উপর কাজ শুরু করা হয়েছে। বিভিন্ন দৃষ্টিকোণ থেকে সুষ্ঠু পদ্ধতি উদ্ভাবন করে গাছের ঘনত্ব এবং বন আচ্ছাদন বৃদ্ধি করার লক্ষ্যে গবেষণা কার্যক্রম চলছে।

Key words: Enrichment planting, mangroves, mesophytes, nipa, Sundarbans, sundri top dying.

Introduction

The mangrove of the Sundarbans has a great importance in Bangladesh for its protective and productive role. The forest is managed for over 120 years, and about half of the forest revenue of the country comes from the Sundarbans ecosystems. It has a diversified resource covering trees, wildlife, fish and valuable minor forest produce. The yield of the forest in terms of wood production is low, being a little above 1 m^3/ha/year. This may be increased through supplementing natural regeneration in the poorly stocked areas by artificial means and planting the vacant lands.

A survey by Forestal (1960) showed that 7% of the area was not covered with forest. However, Chaffey *et al.* (1985) found existence of only 2% non-forest area. They reported great variation of tree density and standing volume among diffenent parts of the forest. In the eastern part, the mean standing volume of commercial species was 48.4 m^3/ha while in the western part, it was as low as 7.5 m^3/ha. Naturally an improvement in crop density is a priority in the Sundarbans management. The paper is designed to discuss the scope of artificial regeneration in the non/less productive areas of the Sundarbans with a view to bring these areas under vegetative cover and increase the wood productivity. It is based on the results of a number of experiments carried out between 1982 and 1995 by the Mangrove Silviculture Division of the Bangladesh Forest Research Institute (BFRI), available literature and observations of the author.

Description of Sundarbans

The Sundarbans covers an area of about 10,000 km^2. Of this, 62% falls within the territory of Bangladesh and the rest in India. The Bangladesh Sundarbans lies between the latitudes 21°31' and 22°30' N and between the longitudes 89° and 90° E. It is located in the southern extremity of the Ganges River (Fig. 1). The entire area is intersected by

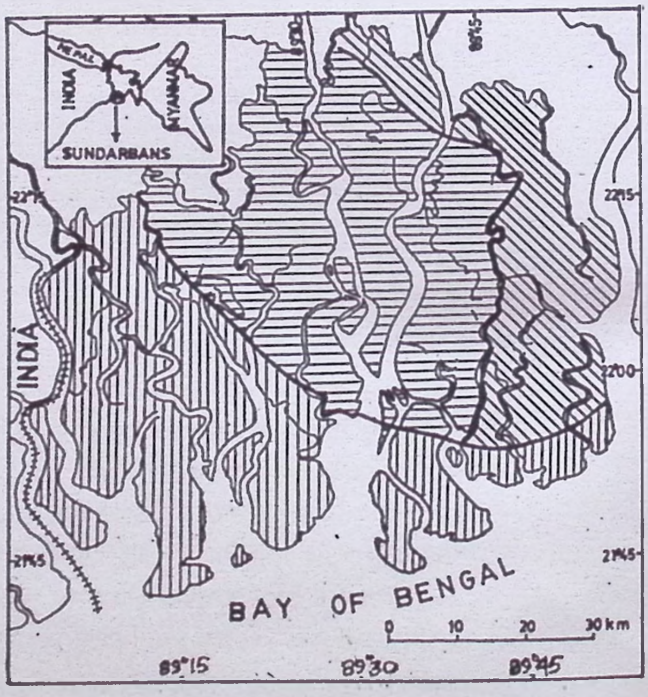

Figure 1. Map of the Sundarbans showing the distribution of less (▨), moderate (▤), and strongly (▥), saline zones.

a complex network of streams and rivers. The land surface is flat, being a deltaic swamp. The soil is finely textured and is neutral to mildly alkaline. The salinity increases from east to west and north to south but remains less than 6 mS/cm. Based on the level of soil salinity, the Bangladesh Sundarbans can be divided into (i) less saline (<2mS/cm), (ii) moderately saline (2-4 mS/cm) and (iii) strongly saline (>4mS/cm) zones (Hassan *et al.* 1990).

The Sundarbans has a diversified floral composition. A good number of plants of high commercial value are available (Table 1). *Heritiera fomes* and *Excoecaria agallocha* are the dominant species of the forest. The height of the forest varies considerably from 5 m to 15 m. Besides, there are areas which are poorly stocked or blank (Choudhury 1968, Chaffey and Sandom 1985, Das and Siddiqi 1985).

Status of less productive areas

The poorly stocked less productive areas, also known as non commerical cover (NCC) areas, are found in the form of raised land, depression and vacant canal or river bank. Relatively raised lands are available in the northern and north eastern part of the forests. These areas only get submerged in the monsoon during the spring tides for a short duration. Due to lack of regular tidal inundation, commercially valuable mangrove species do not

Table 1. List of economically important plants of the Sundarbans and their uses.

Family	Scientific name	Type of plant	Main uses
Avicenniaceae	*Avicennia officinalis*	Tree	Fuelwood, anchor logs
Combretaceae	*Lumnitzera recemosa*	Small tree	Fuelwood, posts
Euphorbiaceae	*Excoecaria agallocha*	Tree	Match sticks and boxes, raw materials for newsprint and other papers
Leguminosae	*Cynometra ramiflora*	Small tree	Fuelwood, charcoal
Malvaceae	*Xylocarpus granatum*	Small tree	Furniture
	Xylocarpus mekongensis	Tree	Furniture, bridge construction
Palmae	*Nypa fruticans*	Palm with underground stem	Thatching house
	Phoenix paludosa	Thorny palm	Posts and rafters for huts
Rhizophoraceae	*Bruguiera spp.*	Tree	Furniture, bridge construction
	Ceriops decandra	Shrub or small tree	Fuelwood, house posts, charcoal
Sonneratiaceae	*Sonneratia apetala*	Tree	Packing boxes, panelling
Sterculiaceae	*Hertiera fomes*	Tree	House construction, boat building, electric poles .

Source : Choudhury 1968 , Das and Siddiqi 1985.

grow in this type of land. The land is usually covered by some non-commercial species like *Derris trifoliata, Dalbergia spinosa, Acanthus ilicifolius, Acrostichum aureum* and *Hibiscus tiliaceous*. Lands in the form of depressions are water-logged areas where mangrove regeneration does not occur naturally. Thus in these areas trees are either dead or there is little tree growth. The depressed areas are available all over particularly in the middle and the western portion of the forest. The Sundarbans is cris-crossed by innumerable canals and rivers. Many areas along the canal or river banks are vacant and do not have mangrove regeneration or plants. In addition to these less productive lands, there are sizeable areas in the moderately or strongly saline zones which do not support adequate regeneration for a rich future stocking.

Need for rehabilitation planting

The yield of the Sundarbans is low being 1.12 m^3/ha/yr (Davidson 1984). Management must be shaped to increase the productivity (Das and Siddiqi 1985). The forest is intended to be managed on a sustained yield basis under a selection -cum-improvement felling system (Chowdhury 1968, Khattak 1979). But the canopy closure of the forest has declined. Moreover, merchantable growing stock of *H. fomes* and *E. agallocha* has depleted by 40% and 45% respectively over a period of 25 years (Chaffey *et al.* 1985). The problem has been aggravated by the incidence of top dying of *H. fomes* which alone contributes over 60% of total merchantable timber. About 17% of the stems are moderately or severely affected by top dying. A planting programme with mangroves may be needed following removal of the affected stems.

Maintenance of a sustainable level of productivity has become a challenge in the management of the forest. Some modification of the long practised selection system might improve in the productivity of the forests. Successful raising of mangroves on little or less stocked areas and raising mainland species on raised lands will contribute considerably is this direction. Thus enrichment planting in the vacant areas was suggested (Sattar 1977, Imam 1982, Habib 1982). Regeneration of valuable species is also inadequate in the Indian Sundarbans and reforestation with mainland and mangrove species is undertaken (Chaudhury and Choudhury 1994).

Plenty of seedlings are available on the forest floor in different parts of the Sundarbans, varying between 10,080 and 53,350 per hactare (Chaffey *et al.* 1995). However, Siddiqi (1994) reported that the failure of the seedlings to survive and establish themselves was a major problem. Seedlings half-life (time for 50% of the seedlings to disappear) was only 8.8, 6.5 and 7.3 months respectively for less, moderate and strongly saline zones (Fig. 2).

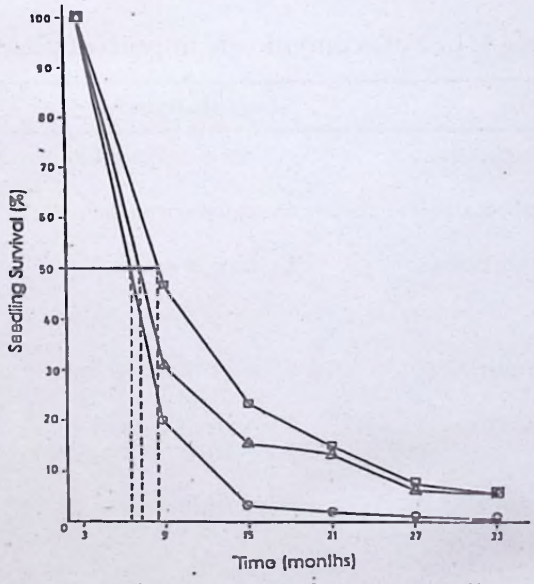

Figure 2. Depletion curve showing seedling half life in less (□), moderate (O) and strongly (△) saline zones.

Only 5.2% of the appearing seedlings existed in the less saline zone, 0.6% in the moderately saline zone and 5.2% in the strongly saline zone after 33 months (Siddiqi 1992). Latif *et al.* (1992) reported that the rate of ingrowth for *H. fomes* was 15 trees/ha/yr. while natural death and removal were 27 trees/ha/yr. The corresponding values for *E. agallocha* were 22 and 8.1 respectively.

Rehabilitation with mangroves

A number of tree species were planted in the vacant areas of the Sundarbans by the Forest Department between 1975 and 1981 (Habib 1982). The performance of the plants and characteristics of the sites were not documented. The Khulna Newsprint Mills also planted *E. agallocha* on some cleared and abandoned areas at the time of shifting the harvesting camp (Ali 1983). A trial with five mangrove species, namely *Excoecaria agallocha, Sonneratia apetala, Avicennia officinalis and Bruguiera sexangula* on a relatively raised land showed that planting mangrove species was not feasible due to ecological changes in site conditions (Siddiqi 1986). Subsequently trials in tidally inundated lands on different parts of the forest were conducted. The sites that do not support natural regeneration were chosen for the trials. These sites were under normal tidal inundation or in water-logged condition. In case of water-logged condition, drainage of tidal water during low tides was ensured by excavating earth. The sites were barren or covered with grasses and located in the moderately or strongly saline zones.

The browsing of the planted seedlings by deer (*Axis axis*) was a problem to ensure successful plantations. So planting was done in the fenced as well as in unfenced areas in each location. An area of 3 ha was brought under trial. Initially naked rooted seedlings from the forest floor were collected during monsoon and planted in the experimental plots. The seedling mortality was high. So, the trial was later on made with one year old seedlings raised in polybags and out planted at a spacing of 0.6 m x 0.6 m (Siddiqi *et al.* 1994a, Siddiqi 1996). Fencing material was illicitly removed by the labourers working inside the forests. Fencing could be maintained only in two locations. Table 2 shows the performance of six mangrove species in those areas. The fencing had

Table 2. Average survival and growth of mangrove seedlings one year after planting in the fenced and unfenced plots.

Location	Species	Mean survival (%) ± S. E.		Mean height (cm) ± S.E.	
		Fenced	Unfenced	Fenced	Unfenced
Modorately saline area	*H. fomes*	73.5±3.51	55.3±8.53	70.2+1.30	50.6+3.47
	E. agallocha	85.4±1.35	48.9±8.63	50.5±1.91	40.6±3.13
	X. mekongenisis	85.2±1.72	0.0	98.9±4.72	0.0
	B. sexangula	79.4±0.00	0.0	63.7±2.21	0.0
	C. decandra	86.5±2.40	51.4±23.73	23.3±1.36	13.3±1.26
	A. officinalis	74.1±5.59	0.0	95.1±8.82	0.0
Strongly saline area	*H. fomes*	80.2±4.38	64.0±7.18	61.6±2.54	51.5±1.78
	E. agallocha	93.2±2.17	75.5±9.86	54.6±2.46	51.5±1.53
	X.mekongensis	79.0±3.89	0.0	88.6±1.70	0.0
	B. sexangula	69.6±2.57	0.0	44.4±0.60	0.0
	C. decandra	70.6±4.48	27.6±3.71	23.0±1.10	14.3±0.96
	A. officinalis	31.4±4.74	0.0	64.0±2.87	0.0

Source : Siddiqi 1996

a significant impact on the survival and height increment of the seedlings. The deer ate up the shoots of the seedlings or partially browsed the leaves resulting in their death. *Excoecaria agallocha* and *Ceriops decandra* were not preferred by the deer, and the effect of deer browsing on these species was non-significant. Fencing appears to be uneconomic. Aided natural regeneration with *Xylocarpus mekongensis, B. sexangula* and *A. officinalis* was not possible in unfenced areas. *H. fomes* was also not preferred by the deer. However, the species showed a poor performance due to higher level of salinity and tidal inundation. In two years, the seedlings of *A. officinalis* attained an average height of 1.29 m, *X. mekongensis* 0.97 m, *B. sexangula* 0.8 m, *H. fomes* 0.6 m, *E. agallocha* 0.66m, and *C. decandra* 0.32 m in fenced areas.

The deer has roughly a population size of 80,000 individuals (Hendrichs 1975). In natural state, the animal did not adversely affect regeneration of *H. fomes, E. agallocha* and *C. decandra*. But browsing by the deer was harmful to many other species (Siddiqi and Husain 1994). Both abiotic and biotic factors affect success in enrichment planting or aided natural regeneration. However, a negative impact of crabs, which are menacing to the mangrove regeneration in different countries, was not noticed in the Sundarbans (Siddiqi 1995a). The other natural mangrove, the Chokoria Sundarbans located in the eastern part of Bangladesh, has completely been destroyed by human interference in recent decades (Siddiqi *et al.* 1994b). Although the land is still suitable for mangroves, unplanned conversion of the forest to shrimp ponds, has narrowed down that option for reforestation of the Chokoria Sundarbans (Shahidullah and Siddiqi 1994). Contrary to this, the Sundarbans being a reserve forest and free from human habitation is not much subject to human stresses. So, there is the scope to improve the forest cover and productivity of the Sundarbans by evolving a suitable method.

Rehabilitation of canal bank with Nipa

Nipa plam *(Nypa fruticans)* is one of the most valuable non-timber forest produces in Bangladesh. It grows luxuriantly along the river and canal banks over the greater parts of the Sundarbans. Now, sizeable vacant areas on the canal bank are available which have the potentiality to support nipa. Studies were made on possibility of raising nipa and on its site suitablity (Siddiqi *et al.* 1991, Siddiqi 1995b). Pre-germinated seeds (untreated), short-treated seeds (soaking allowed for 30 days when seedlings become 8 cm long) and long-treated seeds (soaking allowed for 60 days when seedlings become 24 cm long) were sown/planted. Maximum survival was obtained from long-treated seeds (68%) followed by short-treated (49%) and untreated (25%) ones.

Two months old seedlings (long-treated) were planted along the canal banks in less saline zone for determining site suitablity. The banks were characterized with different levels of tidal inundation (Siddiqi 1995b). Apparently, stable site with lower level of tidal inundation appeared most suitable for planing *N. fruticans* (Table 3). Successful

Table 3. Performance of *Nypa fruticans* two years after planting seedlings in different site conditions.

Site	Mean survival (%) ± S.E.	Mean height (cm) ± S.E.
Most inundated	0	0
Moderately inundated	3.29±0.95	119.28±8.37
Less inundated	19.07±5.13	108.93±1.04

Source : Siddiqi 1995b

pilot plantation programme with nipa is in progress by the Mangrove Silviculture Division of BFRI. The species has showed good performance all over the forests including moderately and strongly saline zones. A flat site or with gentle slope, only inundated by the highest spring tides, is most suitable for nipa. The growth of weeds in those sites is, however, vigorous. Thus, a higher intensity of weeding is desirable which would improve survival and growth rate of the planted seedlings.

Rehabilitation of raised lands with mesophytes

A total of 19 non-mangrove tree species were planted to observe their performance in the raised areas of the Sundarbans (Siddiqi *et al.* 1994a). These species grow well in the vicinity of the forests. The seedlings for the trials were raised in polybags. The experiment was set in less, moderately and strongly saline zones in the fenced plots as well as in the open. Six months old seedlings were planted at 1.2 m x 1.2 m spacing during the late monsoon to ensure less influence of tide water. Before planting, the site was prepared by jungle cutting, clearing and weeding. The growth of weeds and climbers was vigorous in the raised areas compared to tidally inundated areas. So, regular weeding was made following planting for three consecutive years.

A significant difference was found in respect of survival and height increment between the fenced and unfenced plots. All the species except *Acacia nilotica, Azadirachta indica, Melia azedrach* and *Acacia catechu* were susceptible to browsing by the deer. The performance of the planted species in the moderately and strongly saline zones was poor. Later on, the experiment was confined to less saline zone only. The findings are based on data collected from an area of 3.25 ha under five sites in the less saline zone.

Four species, namely *Samanea saman, Albizia procera, Lagerstroemia speciosa* and *Acacia nilotica* appeared promising for plantation in the raised areas(Table 4, 5). However, these species except *A.*

Table 4. Average performance of 10 mesophytic species in fenced and unfenced areas at the age of three years.

Species	Mean survival (%)		Mean height (m)	
	Fenced	Unfenced	Fenced	Unfenced
Samanea saman	62.91	34.27	6.94	2.20
Acacia nilotica	57.06	43.37	5.14	4.47
Albizia procera	55.67	6.95	6.50	0.90
Albizia lebbeck	49.04	10.96	4.34	0.82
Calophyllum inophyllum	52.13	15.33	1.96	0.44
Delbergia sissoo	31.06	2.54	4.01	0.57
Lagerstroemia speciosa	87.50	6.02	5.36	0.59
Azadirachta indica	55.42	39.49	2.66	1.76
Melia azedarach	35.83	14.35	3.68	3.62
Acacia catechu	27.49	9.66	4.03	1.13

Source : Siddiqi *et al.* 1994a

Table 5. Average survival and growth performance of 10 mesophytic species tried in fenced areas at different locations.

Species	Survival (%) ± S. E.	Annual height increment (m) ± S. E	Annual diameter increment (cm) ± S. E
Samanea saman	62.91 ±8.54	2.22 ±0.28	3.23 ±0.32
Albizia procera	55.67 ±8.33	2.43 ±0.33	2.90 ±0.24
Acacia nilotica	57.06 ±5.26	1.52 ±0.15	1.47 ±0.10
Legerstroemia speciosa	87.50 ±2.50	1.60 ±0.15	1.77 ±0.10
Albizia lebbeck	49.04 ±7.95	1.49 ±0.17	1.79 ±0.22
Calophyllum inophyllum	52.13 ±4.90	0.75 ±0.12	0.87 ±0.18
Dalbergia sissoo	31.06 ±5.67	1.50 ±0.14	1.54 ±0.18
Acacia catechu	27.49 ±10.86	1.29 ±0.10	1.56 ±0.12
Azadirachta indica	55.42 ±7.60	0.89 ±0.14	1.17 ±0.18
Melia azedarach	35.83 ±9.32	1.35 ±0.42	1.92 ±0.23

Source : Siddiqi *at al.* 1994a

nilotica are browsed by deer. Fencing is a prerequisite for raising moderately fast growing commercially important species like *A. procera*, *S. saman* and *L. speciosa*. Moreover, fencing by wooden stakes needs their replacement after two years. So, one or two years old saplings instead of six months old seedlings may be used. This would ensure higher survival and avoid repairing cost of fencing. The height growth of the suggested species is quite fast, varying from 1.5 to 2.4 m/year. So, in two years, the saplings would attain a height beyond the browsing limit of deer. Besides the deer, damaged caused by other animals like wild boars *(Sus scrofa)*, rhesus macaque *(Macaca mulatta)* and procupines *(Hystrix hodgsoni)* was also noticed to a limited extent in a few places.

The elevation of the forest is a highly important factor for deciding whether the land is suitable for mesophytes. A slightly higher elevation improves the survival and growth of the plantations substantially. The tidal inundation is a serious problem for all the mesophytes. In fact, the inundation combined with deer browsing seems to be the main factor for determining the success of the plantations. To overcome the effect of inundation, the seedlings can be planted on heaps as done in the coastal plantatons (Siddiqi *et al.* 1993). But in the Sundarbans, such an attempt is undesirable as raising mesophytes instead of mangroves should not be the goal.

Rehabilitation in the Sundri top dying areas

Sundri *(Heritiera fomes)* is one of the most important tree species of Bangladesh. The incidence of the top dying, a disorder causing death from top downwards, of *H. fomes* is spreading throughout the forest. It has become a serious concern at the national level. Approximately 17% of the stems is affected by top dying (Chaffey *et al.* 1985). They need replacement following harvest by artificial regeneration. Exact cause for top dying is unknown. Studies so far made at BFRI do not indicate that insect infestation (Chowdhury and

Baksha 1983) or pathogenic attack (Rahman *et al.* 1983) could be the direct cause of top dying in *H. fomes*. Top dying seems to be the result of a complex phenomena (Rahman 1990). Trees could be exposed to stress conditions due to a single or combination of factors including salinity, reduction of critical level of inundation, loss of canopy due to cyclonic storms, water-logged condition in the soil, and excessive sediment deposition on pneumatophores (Karim 1994).

A little research attention has been given on the prospect of rehabilitating the areas now covered by dead or dying *H. fomes* stems. Adequate natural regeneration has been observed in top dying areas. But no report is there on the magnitude of establishment of these regeneration to ensure a rich future stocking. After harvest of the affected stems, the cleared areas will require planting. Research is underway by the Mangrove Silviculture Division of BFRI to identify top dying resistant *H. fomes* trees and develop propagules of resistant ones through seeds and vegetative propagation.

Conclusions

The Sundarbans is a natural forest and is dependent on natural regeneration for sustainable yield and existence. The declining trend in the growing stock is a major problem of the forest. The existing forest management system needs to be examined as to whether it can ensure adequate regeneration and satisfactory stocking all over the forests. There are areas in the Sundarbans under different site conditions with scanty or no vegetation. Research is underway to select suitable species for planting in different sites. Some mangrove tree species have been recommended for less stocked vacant areas. Raising plantations of *Nypa fruticans* has been found successful on canal or river banks. Besides, raising mesophytes has been suggested for relatively raised lands of the Sundarbans. Top dying problem of *Heritiera fomes*, the dominant species is being dealt with. Research on various disciplines has been intensified to develop methods to improve productivity of the forests by artificial regeneration or aided natural regeneration in different areas of the forests.

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