Toolkit for establishing Coastal Bioshield

M. S. Swaminathan Research Foundation

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Preface

Nature has provided biological mechanisms for protecting coastal communities from the fury of cyclones, coastal storms, tidal waves and tsunamis. Mangrove forests constitute one such mechanism for safeguarding concurrently the ecological security of the coastal areas and the livelihood security of fisher and farm families living in the coastal zone. This ecological, economic and social value will further increase, if a rise in sea level taken place as a result of global warming and the melting of glaciers and the artic and antarctic ice caps. The recent tsunami of December 26, 2004 also highlighted the speed-breaking role of mangrove forests.

In addition to mangroves, which can grow only in estuarine environment, there are many other tree species, which can constitute valuable components of coastal shelterbelts. All such species confer in the short-term local economic and ecological benefits and in the long-term global environmental benefits through carbon sequestration. It is only calamities that open our eyes to the "friend in need" role mangrove species play. The December 26th, 2004 tsunami has created a widespread interest in the restoration of degraded mangrove forests, promotion of joint mangrove management systems involving local communities, and in the raising bio-shields and shelterbelts along the coastal zone.

Scientists of MSSRF led by Dr.V.Selvam have been working for over 12 years in the area of conservation, restoration and sustainable management of mangrove forests. Some of the early work has been summarized in a publication titled "The Mangrove Decade and Beyond: Activities, Lessons and Challenges in Mangrove Conservation and Management, 1990-2001". The present toolkit has been prepared to help all

interested, government agencies, non-governmental organizations, academic institutions and local fisher and faming communities to understand restoration of degraded mangrove wetlands and expand mangrove coverage in all areas which are vulnerable to coastal cyclones and to tidal inundation. Information is also given on species useful for raising shelterbelts along the coast.

I hope this publication will be of value to all who are now working with coastal communities in strengthening the coping mechanism for facing the challenge of the fury of the sea and climate. I am grateful to Drs. V.Selvam, T.Ravishankar, V.M.Karunagaran, R.Ramasubramaniam, P.Eganathan and Ajay Parida for their painstaking efforts in compiling this publication designed to stimulate and sustain action at the field level.

M. S. Swaminathan

Content

1.0 Introduction

Tsunami waves, triggered by an earthquake in the sea near Sumatra, struck the southern and eastern coastal areas of India on 26th December 2004. Walls of water as high as 10-metre (33 feet) crashed on the beach and penetrated upto 3 km inland, causing extensive damage in the Andaman and Nicobar Islands and the coastal districts of Tamil Nadu, Kerala, Andhra Pradesh and Pondicherry. According to Government reports about 10,880 people lost their lives and nearly 5800 people are still missing. Almost 1,54,000 houses were either destroyed or damaged entailing losses of about Rs.994 crore or USD 228.5 million. The tsunami destroyed or damaged nearly 75,300 fishing crafts including wooden catamarans, mechanized boats including trawlers worth about Rs.935 crore (USD 215 million); fishing gears worth of Rs.65 crore (USD 15 million) were also lost leading to loss of livelihood for thousands and thousands of fishing families. Apart from these, standing crops of paddy, ground nut, coconut, cashew, mango, banana, minor millets and vegetables were totally destroyed in thousands of hectares and seawater intrusion rendered these productive lands unfit for cultivation.

Even in this situation, it has been reported that damage in terms of loss of lives and properties in the villages, which are behind mangrove wetlands and shelterbelt plantations such as plantations of casuarina and of palm trees and other thick coastal vegetation, was limited as the intensity of the tsunami was reduced by these natural bioshields or biobarriers. It has been reported that in the Pichavaram mangrove region of Tamil Nadu fishing and farming villages namely, T.S.Pettai, Vadakku Pichavaram, Killai Fisher Colony, MGR Nagar and Kalaingar Nagar, which are under direct physical coverage of the mangrove wetlands were protected from the fury of the tsunami. These hamlets are located about 500 m to 2.5 km away from the sea and 50 to 500m away from the mangrove forest. Fishers and farmers in these hamlets narrated that mangrove trees along the first few rows bore the brunt of the tsunami waves and the friction created by these trees and the trees of subsequent rows reduced the speed of the water. According to the villagers, seawater flashed into the mangroves by tsunami was distributed into lagoon, tidal creeks and canals associated with mangrove wetland and therefore, the amount of water reaching a point was very much reduced. This clearly indicates that both the mangrove forests and the associated wetlands together played a crucial role in mitigating the impact of the tsunami.

Similar observations have also been made in Indonesia, Sri Lanka and Thailand. In Hambanthota District of Southern Sri Lanka it was observed that undisturbed mangrove stands in areas such as Rekawa, Kahanda and Kalametiya villages had contributed to reduce the damage caused by the tsunami. Even local communities in Rekawa and Kahanda said that their lives and properties were saved by the intact mangrove stands. In areas where the mangrove stands were totally or partially cleared in this district, the damage was high.

Mission statement

The National Commission on Farmers of Government of India under the chairmanship of Dr.M.S.Swaminathan prepared a detailed action plan in January 2005 for an integrated psychological, ecological, agronomic and livelihood rehabilitation programmes that can be taken up in the tsunami affected areas in three time dimensions as given below:

A. Immediate (January - March, 2005)

- Water, shelter, sanitation, health and revival of livelihoods.
- Psychological rehabilitation
- Repair of catamarans
- Achieving convergence and synergy among all on-going programmes with similar objectives (this is an urgent task)

B. Medium Term (2005-07)

- Ecological rehabilitation
- Agronomic rehabilitation
- Economic rehabilitation
- Disaster preparedness, mitigation and management

C. Long Term (2005-10)

- Strengthening environmental defense systems
- Enlarging opportunities for sustainable livelihoods based on a pro-nature, pro-poor, pro-women orientation to technology development and dissemination.
- Improving the productivity, profitability and sustainability of agriculture and fisheries.

The above plan emphasizes that strengthening the ecological foundations of the coastal area should be taken up as one of the long-term rehabilitation efforts. This

ecological rehabilitation programme includes initiating a coastal bioshield movement along coastal areas, including the raising of mangrove forests, plantations of casuarina, palms, bamboo and other tree species and halophytes, which can grow near the sea. They will serve as speed-breakers under conditions of coastal storms, cyclones and tsunami. They will in addition serve as carbon sinks, since they will help to enhance carbon sequestration and thereby contribute to reduce the growing imbalance between carbon emissions and absorptions. Mangroves are very efficient in carbon sequestration. Mangroves also promote sustainable fisheries by releasing nutrients and acting as nursery ground for juveniles of commercially important species of fish, crab and prawn. The coastal bioshields can also involve agro-forestry programmes like the intercropping of casuarina with groundnut, red gram and other crops. As a part of the bioshield programme community nurseries of mangroves and other trees and vegetation can be raised, which will also provide livelihood to many families that participate in the bioshield movement. Both mangrove and non-mangrove components of bioshield can be integrated with livelihood options and eco-restoration of coastal systems by developing different site-specific models. Thus, the community based bioshield movement will provide multiple benefits to local communities as well as to India as a whole. All these indicate the necessity for developing and demonstrating models of community based bioshields with mangrove and other coastal vegetation, which can be replicated in other suitable areas so as to mitigate the impact of natural calamities such as cyclones, storm surges and tsunami.

M.S.Swaminathan Research Foundation is involved in research and management of the mangrove wetlands for the past 12 years and made significant contribution to restore and sustain mangrove wetlands in the east coast of India. It has developed a comprehensive science-based, people-centred and process-oriented approach to restore and conserve mangrove wetlands that was implemented in selected areas in six major mangrove wetlands located all along the east coast of India including West Bengal, Orissa, Andhra Pradesh and Tamil Nadu in partnership with the concerned State Forest Department and local community with the support of the Canadian International Development Agency and India-Canada Environment Facility. This approach and methodology to restore degraded mangroves was evaluated by an expert committee of the Ministry of Environment and Forest, Government of India and included in its National Mangrove Action Plan. It has also established 45 Village Mangrove Councils in the state of Tamil Nadu, Andhra Pradesh and Orissa through which efforts were taken to restore 1500 ha of mangroves of which nearly 70% of the areas have now been completely restored. About 6.8 million mangrove saplings were planted in these areas. Innovative approaches have also been developed and

demonstrated to increase the economic stake of the user communities in mangrove restoration and conservation. The present toolkit is prepared on the basis of the above experiences. With reference to non-mangrove bioshield institutions such as the State Forest Departments have been involved in raising shelterbelts such as casuarina plantations for long time and has developed and refined the art and science of creating and managing these shelterbelts.

It is to be mentioned that starting of non-mangrove bioshield such as casuarina plantation right from the high tide line may have serious implications on the ecology of the coastal areas, some times even on wildlife because many of the sandy beaches are utilized by sea turtles as nesting grounds and it has been reported in many places that raising of casuarina very close to the sea prevented nesting by sea turtles. Most importantly, sandy beach supplies sand to littoral current, which run parallel to the shoreline. This current system, in combination with wind-induced waves, takes away sand from one place and deposits it in another area. Since this process takes place simultaneously all along the coast, a balance is achieved between removal and supply of sand in a given place and this balance avoids sea erosion. If shelterbelt plantations are raised starting from the high tide line, then the supply of sand to the littoral current would be reduced or stopped (due to sand binding property of the plantation) and to compensate this, current and waves would remove large chunk of sand in other areas, leading to sea erosion in those areas. In order to avoid such a problem shelterbelt plantation should start at least 50 to 75m away from the high tide line.

Part I
Mangrove Bioshield

Part I

2.1 Mangroves - an overview

What are mangroves?

Mangroves are woody trees and shrubs that grow normally in places where river water mixes with seawater. These places are otherwise called estuarine or brackish water environment. Assemblages of mangrove woody trees and shrubs are called mangrove forests. Since mangrove forests are located in the estuarine environment they are intersected by a number of small tidal creeks and channels. In many cases large open brackish water bodies are also found associated with mangrove forests. Mangrove forest and associated tidal creeks and canals and water bodies together constitute mangrove wetland. Mangrove wetlands are a characteristic feature of the tropical coastal areas.

What are the factors that determine area, diversity and growth of mangroves?

The health of the mangrove wetlands with reference to hydrological and soil conditions and the wealth of the mangrove wetlands in terms of area, species diversity, biomass and productivity are determined by

- Degree of protection against high-energy waves
- Quantity and duration of freshwater flow and sediment supply
- Larger tidal amplitude and
- Gently sloping coastal topography

Though mangrove trees are capable of withstanding the forces of cyclones, storms and tsunami they grow only in coastal areas where wave energy is low or in places where mangrove wetlands are protected by sand barriers against high-energy waves. This protection is necessary for the seedlings of the mangrove plants to settle, establish and grow. The coastline of the Muthupet region of the then combined Thanjavur District of Tamil Nadu and that of Sunderbans in West Bengal are the best examples of low-energy wave coasts where mangroves grow luxuriantly along the seashore. In fact, in these areas mangrove forest is slowly growing into the sea! In areas like the Godavari mangroves of Andhra Pradesh, a sand spit known as Hope Island and Kakinada Bay provide protection to mangroves against high waves. In the case of the Pichavaram mangroves of Tamil Nadu, a narrow sandy beach located between the sea and the mangroves prevents exposure of forest directly to the high-energy waves.

Thus, this essential condition of protection against high waves during the early stage of mangrove forest development rules out growing of mangroves all along the entire coast.

Most of the mangrove plants require low salinity condition for their growth and reproduction. Hence, luxuriant mangrove forests can be seen only in the estuarine regions where large amount of freshwater is discharged for longer period of time in a year. For example, the Sunderbans mangrove forest of West Bengal, which receives freshwater from the River Ganges and the Brahmaputra throughout the year, harbours not only high number of mangrove plant species but also dense and tall mangrove forest. Whereas in the Pichavaram and Muthupet mangroves of Tamil Nadu, which receive only a low amount of freshwater and that too only for a few months in a year, both number of plant species present as well as height of the tree is less.

The area of the mangrove wetlands is determined by the tidal amplitude and slope of the coastline (tide is nothing but the temporary raise and fall of seawater due to gravitational pull of the moon and the sun and tidal amplitude is the difference between high tide and low tide). For example, tidal amplitude in the Sunderbans mangroves is about 4.8 m and the slope of the coast is also very gentle. As a result, seawater reaches up to 90 km inland and mangrove wetland is present up to this point. The total area of the Indian part of the Sunderbans mangrove wetland is about 4, 26,000 ha (actual forest cover is about 2,12,500 ha). On the other hand, area of the Pichavaram mangrove wetland of Tamil Nadu, where the tidal amplitude varies from 0.40 to 0.65 m, is only about 1,400 ha (actual forest cover is only 700 ha).

What are the plants and animals in mangrove wetlands?

Plants

The plant community in mangrove environment is classified into two types namely, true mangrove species and associate mangrove species. True mangrove species are found only in the mangrove wetlands whereas associated species are found both in the mangrove environment and in the nearby areas. Globally a total number of 69 plant species have been identified as true mangroves. All these species are able to grow in saline water but only a few of them have the ability to tolerate high salinity. For example, *Avicennia marina* can tolerate soil salinity as high as 90 grams per litre but many of the mangrove plants grow luxuriantly only in places where salinity is between 10 to 20 grams per litre.

What are the unique features of mangrove plants?

Mangrove plants posses a number of unique adaptive features to grow in saline and oxygenless soil.

Breathing roots: The root systems, which are below ground, also require oxygen for respiration. Mangrove soil is characterized by low or nil oxygen and mangrove plants have adapted to survive in such unpromising environment. The most striking adaptations are the aerial roots, which are otherwise called breathing roots. For example, in the species of *Avicennia* small finger like roots branch out from the main underground cable root and protrude out into the atmosphere. These roots have small pores through which gaseous exchange takes place. Similarly, species like *Rhizophora* posses specialized roots called stilt roots, which emerge out as much as 2m from the trunk and penetrate the soil some distance away from the main trunk. These roots also have minute pores through which oxygen is taken into the roots and carbon dioxide is expelled. Stilt roots provide additional support to trees. When mangrove plants grow together these root systems create a complex mesh, which dampen the speed of waves, cyclonic winds, tsunami and also avoid soil erosion.

Mangrove plants tolerate salinity of the soil and water by the following ways:

i) *Salt excretion:* Some mangrove plants take saline water as such through roots. But in the tissues only water molecules and essential salts are retained. Excess salts are excreted through salt glands that are present in the leaves.

ii) *Salt exclusion*: In some of the mangrove plants the roots possess an ultra filtration mechanism called reverse osmosis by which water and salts in the seawater are separated in the root zone itself and only water is taken inside and the salts are rejected (reverse osmosis mechanism is widely used for producing drinking water from seawater!).

iii) *Salt accumulation:* In this type of mangrove, plants posses neither salt glands nor ultra-filtration system but these species have the capacity to accumulate a large amount of salts in their leaves.

Another distinctive feature of most of the mangrove plants is vivipary, i.e. seedlings grow when the seed is attached in the mother tree itself (generally, in terrestrial plants seeds fall from the mother tree and grow into seedlings in the soil). The seedlings of the mangroves that grow in the mother tree itself are called propagules. Since the mangrove environment is harsh (saline condition and low or nil oxygen in soils) most of the seeds falling from the trees might not survive and this would affect propagation of the species. To avoid this, mangrove plants have the habit of producing propagules during the monsoon season, when the salinity of the water and soil is low. Propagules, which fall from the tree sometimes fix directly into the mud and grow as trees or float in the water and fix themselves in suitable areas.

Animals

Almost all groups of animals are present in the mangrove environment but the most striking ones are crabs, snails, bivalves and oysters. Interesting species among

crabs are leaf-eating crabs, tree-climbing crabs, fiddler crabs, hermit crabs, mud crabs, mud lobsters, etc. Among them the most colourful is fiddler crabs. The male fiddler crabs have one greatly enlarged claw, coloured in crimson, orange and intense blue, used in social displays and in jousting with rival males. Crabs of the mangrove environment are called ecosystem engineers since they facilitate air circulation in the soil and thereby influence growth and productivity of the mangrove trees. Fish is the major animal component of the mangrove environment. Many of the estuarine species of fish, crab and prawn are found in mangroves and they constitute the fishery resources of the mangrove wetlands.

Some of the mangrove wetlands harbour larger animals like salt-water crocodiles, sea otters etc. and the Sunderbans mangroves is famous for Bengal Tiger. Many of the mangrove wetlands also act as feeding and breeding grounds for a variety of resident and migrant birds.

What are the uses of mangrove wetlands?

Mangrove wetlands comprise both mangrove forests and associated water bodies and hence, their uses are manifold. The economic value of the mangrove wetlands stems from

1. Availability of wood products like minor timber, poles and posts and firewood
2. Availability of non-wood produce such as fodder, honey, wax, tannin, dye and plant materials for thatching
3. Availability of aquatic food ranging from fish, prawn, crabs, mussel, clam to oysters; mangrove fishery resources ensure livelihood security of thousands and thousands of assetless poor fishing families of the tropical areas

Apart from these, mangrove wetlands provide a variety of amenities to coastal communities.

1. Mangroves mitigate the adverse impact of storms, cyclones and tsunami
2. They reduce coastal erosion
3. They act as nursery grounds for many of the commercially important prawns, fish, crabs and molluscs
4. They enhance the fishery productivity in adjacent coastal waters by providing them with large quantities of organic and inorganic nutrients
5. The root zone of the mangrove trees provide safe havens for young fish and prawns
6. They provide habitats for diverse marine, estuarine and terrestrial wildlife including migratory birds

2.2 Mangrove wetlands of India

Mangrove wetlands are present both along the east and west coast of the mainland of India and in the coastal zone of Andaman and Nicobar Islands. According to Forest Survey of India (1998), total area of the Indian mangrove forest is 487100 ha, out of which nearly 56.7% (275800 ha) is present along the east coast, 23.5% (114700ha) along the west coast and the remaining 19.8% (96600ha) is found in the Andaman and Nicobar islands (Table 1).

Mangrove wetlands of the west coast of India is small in size, less in diversity and less complicated in terms of tidal creek network. This is mainly because costal zone of the west coast is narrow and steep in slope due to the presence of Western Ghats and there is no major west-flowing river. On the other hand, mangrove wetlands of the east coast are larger in area, high in diversity and water bodies associated with mangroves are characterized by the presence of large brackish water bodies and complex network of tidal creeks and canals. This is mainly due to presence of larger delta created by east-flowing rivers and gentle slope of the coast.

Table 1: Mangrove wetlands of India (Forest Survey of India, 1998)

State	Mangrove wetland	Total area of the wetland (ha)*	Actual forest cover (ha)
East Coast			
West Bengal	Sunderbans	426000	212500
Orissa	Mahanadi	67000	21500
Andhra Pradesh	Godavari	33250	24100
	Krishna	25000	15600
Tamil Nadu	Pichavaram	1300	900
	Muthupet	13000	1200
West Coast			
Gujarat	Gulf of Kachchh	58200	85400
	Gulf of Cambay	53123	17700
Other mangroves	-	-	11600
Andaman and	Andaman islands	-	92900
Nicobar islands	Nicobar islands		3700
		Total	**487100**

* Records of the State Forest Departments

Area, species diversity and biomass of the mangrove forest of the east coast of India reduce gradually from the Sunderbans in the north to mangroves of Tamil Nadu in the south. Sunderbans and Orissa mangroves receive freshwater and alluvial sediments in large quantities for longer period of time in a year. Tidal amplitude is also very high in these regions. These factors along with gently sloping coast create favourable environmental settings for mangrove plants to settle and grow luxuriantly. Whereas in Tamil Nadu tidal amplitude is very low and inflow of freshwater is restricted only to a few months. Hence, area of the mangroves and species diversity are least in Tamil Nadu.

Mangrove wetlands of Tamil Nadu

Tamil Nadu has a coastline of about 950 km. Along the coastline major mangrove wetlands are present in two areas: one at Pichavaram in the Cuddalore District and the other in the Muthupet region in the Thiruvarur-Nagapattinam-Thanjavur Districts. Small patches of mangroves are also present along the Palk Bay, particularly in the Devipattinam region and also in some of the islands of the Gulf of Mannar in Ramanathapuram District (Table 2).

Table 2: Major and minor mangrove wetlands of Tamil Nadu

Location	Name of the mangroves	Wetland area (ha)*	Forested area (ha)
Cuddalore District Uppanar Old Coleroon region	Pichavaram	1400	700
Thanjavur-Thiruvarur DistrictsEstuarine region of the distributaries of Vennar	Muthupet	12000	1885
Ramanathapuram District	Devipattinam and in the mouth region of small estuaries	700	Not known
Tuticorin District	Tamirabarani estuary	148	Not known
	Total	**13400**	-

* Approximate estimate

Almost all the above mangrove areas are under the management of the Tamil Nadu Forest Department. In addition, large patches of mangroves, about 2 to 50 ha in area, are present in many places along the coast of Tamil Nadu. These mangroves are mostly present in the Revenue lands (lands owned by Revenue Department).

Mangrove Wetlands of Andhra Pradesh

Andhra Pradesh has a coast line of about 1030 km. Major mangrove wetlands are located in the deltaic regions of Godavari and Krishna rivers and the total area of the mangrove is about 58200 ha. The Godavari mangroves are located in the East Godavari district and the Krishna mangroves are located in the Krishna and Guntur districts. Apart from these, mangroves are also found in small patches in the coastal areas of Vishakapatnam, West Godavari, Guntur, and Prakasam districts (Table 3). The majority of the mangroves are under the management of the Andhra Pradesh Forest Department and there are mangrove areas, which are in the lands owned by other government agencies.

Table 3: Major and Minor mangrove wetlands of Andhra Pradesh

Location	Name of the Mangrove	Wetland Area (ha)	Forested Area (ha)
East Godavari District Godavari Estuary	Godavari	33200	17000 (IRS LIS III- 2001)
Krishna and Guntur Districts Krishna Estuary	Krishna	24999	9500 (IRS LIS III- 2001)
Machilipatnam Krishna Estuary	Machilipatnam	2825	2100
Nizampatnam Guntur District	Nizampatnam	1220	900
Muthukuru Mandal Nellore District	Krishnapatnam	20	Not Known
Chillakuru Mandal Nellore District	-	50	Not Known
Alluru Mandal Nellore District	Pennar	1200	Not Known
Guduru and Tada Mandals Nellore District	Pulicat	2000	Not Known
Chinaganjam Mandal Prakasam District	Chinaganjam	65	Not Known
Visakhapatnam	Visakhapatnam Naval area	100	Not Known
Vamsadhara estuary Srikakulam District	Vamsadhara estuary	35	25
	Total	**65714**	-

Mangrove wetlands of Orissa

Orissa state has mangroves in about 24300 ha. The Bhitarkanika mangroves, which is the major mangrove wetland of Orissa, occupies an area of about 15000 ha and declared as a Wildlife Sanctuary. Among the Indian mangroves the highest diversity of mangrove plants occurs in the Bhitarkanika and hence, it has been identified as one of the important mangrove genetic resource centres of the world. The extent of major and minor mangrove forests of Orissa is given in Table 4.

Table 4: Major and minor mangrove wetlands of Orissa

Location	Name of the Mangrove	Forested Area (ha)
Devi mouth	Devi mouth	346
Mahanadi	Mahanadi	5124
Bhitarkanika	Bhitarkanika	14987
Dhamara mouth	Dhamara	2935
Budha Balanga mouth		135
Subernareka		776
	Total	**24303**

Mangrove wetlands of West Bengal

Mangroves of West Bengal and Bangladesh is together called as Sunderbans and it is the largest mangrove wetland in the world. It covers an area of about 1 million ha, of which 60% is located in Bangladesh and 40% in India. The total part of the Indian Sunderbans is about 4,26,000 ha, of which 2,12,500 ha has thick mangrove forest and 1,78,100 ha is water body. Like Bhitarkanika of Orissa, Sunderban mangrove is also rich in species diversity and biomass.

Mangroves of Gujarat

It has been reported that the total mangrove area of the Gujarat is about 1,05,100 ha, of which nearly 77% is located in the Gulf of Kachchh region and remaining in the Gulf of Khambhat area. Out of about 1 lakh ha of mangroves, mangrove forest is found only in about 21,500 ha. Remaining area comprises of long stretches of mudflat without any vegetation. The factors responsible for poor status of the mangroves of Gujarat are the sub-desertic to arid climate with recurrent drought and very low inflow of freshwater into the mangroves.

Small and discontinuous patches of mangrove forest are also present in Goa, Maharashtra, Karnataka and Kerala.

Mangroves of Andaman and Nicobar Islands

The Andaman and Nicobar islands have mangrove forest of about 1,15,000 ha. The climate of the islands is humid and annual rainfall varies from 2750 to 3080 m. The tidal amplitude is also high, about 1.90 m. Due to all these favourable environmental conditions mangroves of Andaman and Nicobar islands are gregarious, dense and diverse in nature. Some of the mangrove areas in the Nicobar group of islands still remain unexplored.

Map showing distribution of mangroves in India

2.3 Common mangrove plants

A mangrove plant is defined as "a tree, shrub, palm or ground fern, generally exceeding more than half a metre in height, and which normally grows above mean sea level in the intertidal zones of marine coastal environments, or estuarine margins".

True mangrove species

In general, plants of the mangrove wetlands are divided into two groups namely, a) true or exclusive mangrove and b) associate mangrove species. The following are the characteristic features of true mangrove species:

a). True mangrove plants grow only in mangrove environment and do not extend into terrestrial plant communities

b). They play a major role in determining structure of the plant community of the mangrove wetland and ability to form pure stands

c). They are morphologically adapted to live in waterlogged condition – e.g. aerial roots associated with gas exchange

d). They are physiologically adapted to live in saline environment

e). They have viviparous reproduction

f). They are taxonomically isolated from terrestrial relatives

About 69 species in 27 genera, belonging to 20 families are considered as true mangrove species.

Mangrove plants of India

A total number 34 true mangrove plant species are present in the mangroves of India, including mangroves of both the east and west coasts and that of Andaman and Nicobar Islands. The mangrove wetlands of Orissa have the highest number of species (about 30) followed by Sunderbans of West Bengal (about 27) and Andaman and Nicobar Islands (about 24). The least number of species among the east coast mangroves is present in Tamil Nadu (14) and out of this 14 species, two species namely, *Ceriops tagal* and *Pemphis acidula* are present only in the Gulf of Mannar islands. Analysis of the distribution of true mangrove species in different Indian mangrove wetlands indicates that *Acanthus ilicifolius, Aegiceras corniculatum, Avicennia marina, Bruguiera cylindrica, Ceriops decandra, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Rhizophora apiculata* and *R. mucronata* are common to all the

mangroves of India. On the other hand, species such as *Pemphis acidula* is endemic to islands of Gulf of Mannar of Tamil Nadu, *Scyphiphora hydrophyllacea* to Godavari mangroves of Andhra Pradesh. Similarly, *Nypa fruticans* has been reported to be present only in Sunderbans of West Bengal. The Tamil Nadu mangrove is also characterized by the presence of a natural hybrid of *Rhizophora* species.

Common plants used in mangrove plantation

The following mangroves species are commonly used in mangrove restoration and afforestation:

- *Avicennia marina*
- *Bruguiera cylindrica*
- *Ceriops tagal*
- *Rhizophora apiculata*
- *Sonneratia apetala*
- *Avicennia officinalis*
- *Ceriops decandra*
- *Excoecaria agallocha*
- *Rhizophora mucronata*
- *Xylocarpus grantum*

Identification of the common mangrove plants

Rhizophora apiculata and Rhizophora mucronata are glabrous evergreen trees, typically found growing along the banks of tidal creeks and canals and can be easily identified by their stilt roots. These roots arise from the main trunk, grow downwards and penetrate deep into the mud and thereby provide additional support to the tree. The presence of stilt roots helps *Rhizophora* spp. to withstand the fury of cyclones and tsunamis and thereby helps in mitigating the impact of such natural calamities. *R. mucronata* can be easily distinguished from *R. apiculata*, by a) broader leaves, b) long propagules and c) longer peduncle of the flower.

Avicennia marina and *Avicennia officinalis* can be easily identified by their finger like pneumatophores, which emerge as lateral branches from horizontal roots and stand erect, upto 30 cm from the soil. Like stilt roots of *Rhizophora* species, pneumatophores of *Avicennia* species act as breathing roots and provide additional support to trees. The bark of *A. marina* is brilliant white (hence, called as white mangroves) and smooth whereas the bark of *A. officinalis* is grey to black and hence known as black mangroves.

Ceriops decandra and *Ceriops tagal* belong to Rhizhophoraceae family. They are small evergreen trees but do not have elaborate stilt roots like *Rhizophora* species. The propagules of *Ceriops* species are similar to *Rhizophora* species but are smaller. The propagules of *Ceriops decandra* are about 15 cm in length and green to brown in color and clearly ribbed from top to bottom; they are erect. On the other hand, propagules of *Ceriops tagal* are about 20 cm in length and are drooping and smooth.

Avicennia marina

Avicennia officinalis

Bruguiera cylindrica

Ceriops decandra

Ceriops tagal

Excoecaria agallocha

Rhizophora apiculata

Rhizophora mucronata

Xylocarpus mekongensis

Bruguiera spp. grow mostly as a shrub of about 2 m tall; in some places where there is more freshwater inflow, they grow to a height of about 6 m but with slender trunk and branches. They normally grow in the *Rhizophora* zone, just behind *Rhizophora* trees. *Bruguiera* species are distinguishable by their knee roots. The colour of peeling bark is pinkish.

Excoecaria agallocha is a tree species of about 5 to 8 m tall, branched from base. In some areas it grows as a shrub. Bark is grey in colour and smooth with prominent lenticels. This is the only mangrove species that has latex, which is white and causes irritation to skin. Lichens, variously coloured and shaped can be seen on the bark. This plant is unisexual, male and female plants are separate.

Sonneratia apetala is a moderate sized evergreen tree with black smooth bark, wood grey or reddish brown, soft. It has finger like aerial roots but larger than that of *Avicennia* species.

Xylocarpus granatum is a moderate evergreen tree with grey bark and hard dark red wood. It is used as a minor timber. Trunk smooth with flat buttress roots.

2.4 Afforestation of mangroves

Afforestation of mangrove means raising mangrove plantation in the areas where mangrove was not present previously. However, when compared to terrestrial plantation such as casuarina along the coast, mangroves are not normally raised as plantations in new areas because mangrove plants require certain special environmental condition to establish and grow. This chapter provides an outline of the process and procedures to be followed in identifying suitable areas for mangrove afforestation. It also provides details of planting techniques for various mangrove species.

Where mangroves grow luxuriantly?

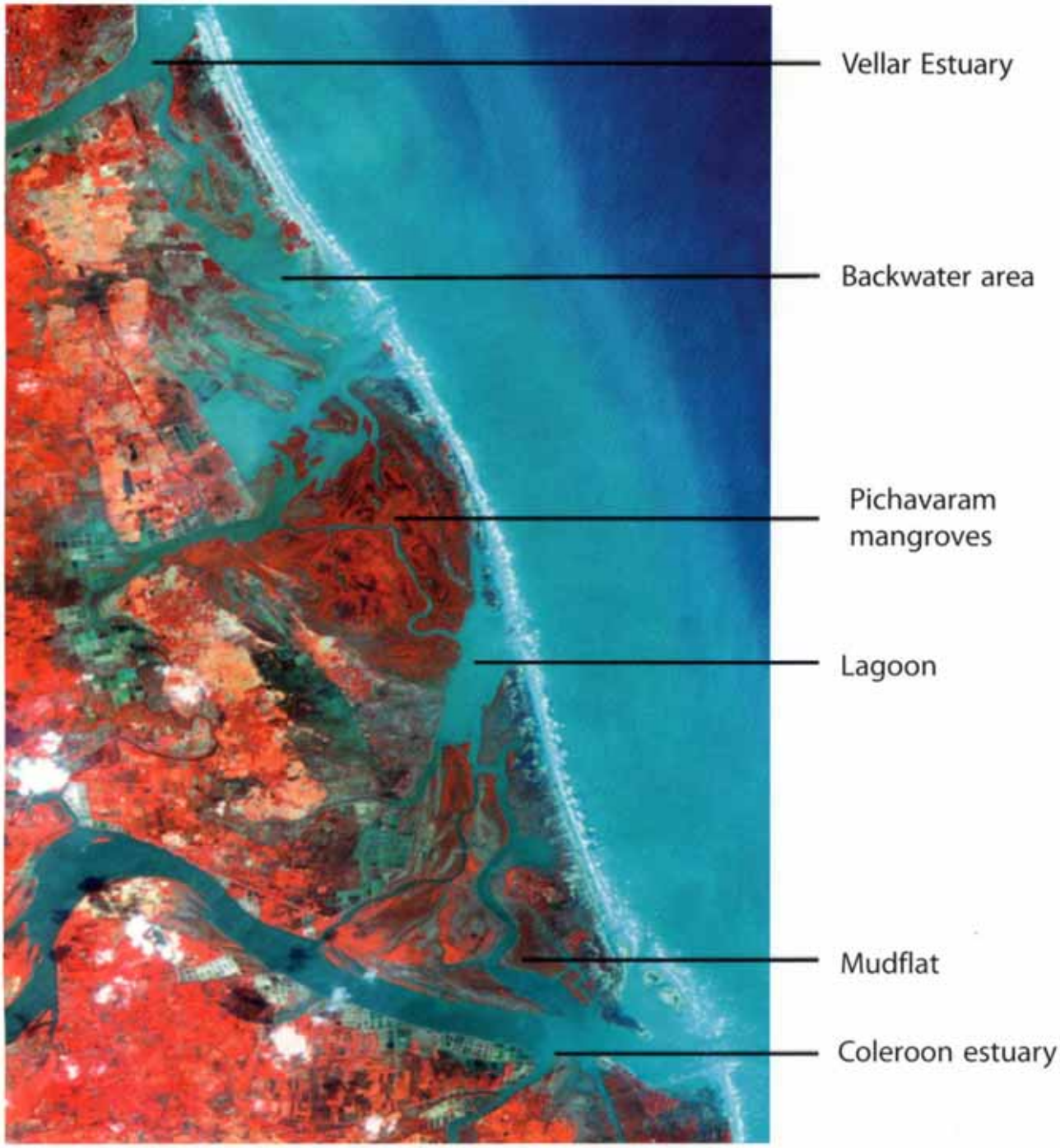
Mangrove species requires the following basic environmental conditions for their luxuriant growth:

- Wave energy along with shoreline should be low (otherwise seedlings would be uprooted)
- Substratum should be muddy or accumulated deposit of sediments
- Salinity of the water should undergo constant variations due to freshwater flow (mangroves require low saline condition for optimum growth and reproduction)
- Area should be regularly flushed by tidal water (for many reasons such as maintenance of salinity, etc.)
- Soil should be saturated with or covered by low saline water at some time during the growing season of every year

Mangroves can be raised successfully only in the places where all the above-mentioned environmental conditions exist.

Identification of mangrove afforestation site at macro level

One of the primary requirements for identifying mangrove afforestation sites at the macro level is a map of the coastal zone that shows details of estuarine areas, lagoon, backwater systems, mudflats etc (see Remote Sensing Imagery of Pitchavaram area). At regional and state level, the above features can be demarcated using maps published by the Survey of India (Toposheets, available both in 1:50000 and 1:25000 scale). Demarcated maps may also be available and these will provide overall



Remote Sensing imagery showing estuaries, mangrove wetland, lagoon and backwater, tidal creek and mudflat areas; Areas such as mud flats may be suitable to raise mangrove plantation and suitability of these sites can be identified by analyzing biophysical conditions

information on location and extent of estuarine, brackish water and mudflats areas available along the coastline. For example, Institute of Water Studies, Government of Tamil Nadu has prepared such a detailed map (1:50000 scale) for the entire coastal stretch of Tamil Nadu. These kinds of maps may also be available with the National Remote Sensing Agencies, Hydrabad and Space Application Centre (SAC), Ahamadabad or in the State Remote Sensing Agency (Kindly refer to the website www.nrsa.gov.in; www.isro.org).

Preparation of field map

Before undertaking micro level analysis, a base map should be prepared using the Survey of India toposheet, which will have only required details such as boundary of the estuary, extent of mudflat, high tide line, low tide line and landmarks such as settlement and roads. This base map can then be used for ground assessment as described later. Details collected in the ground information should be transferred onto these base maps with reference to landmarks for planning and monitoring.

Identification of mangrove afforestation sites at micro level

After identifying and demarcating estuarine, backwater, lagoon and other brackish water areas using regional or state level maps, then it should be known whether an estuary or any other brackish water system and its surrounding area shown in the maps could support growth of mangrove plants. For this purpose environmental factors such as nature of the substratum, tidal flushing pattern, soil properties, etc., should be analyzed thoroughly. Participation of local people is a must in this analysis because they know their environment much better than outsiders. Data on what was the condition of the environment in the past and how these conditions changed with time can be collected from the local people.

Analysis of the substrate

The substrate is an important controlling factor in selecting an area for mangrove afforestation. Type and thickness of substratum will help in deciding which species of mangroves is suitable for a given area. Therefore, a thorough study on type of substratum of the sites, which are selected for mangrove plantation, is essential. Though presence of mangrove trees has been reported in sandy areas, muddy substrate is the most suitable substrate for mangrove growth. The following problem may be encountered in growing mangroves in sandy soils: a) shifting sands may be deposited on aerial roots and kill young seedlings, b) roots of mangroves are of shallow type, which may not find good grip in the sandy soil, c) less nutrient content and d) low moisture keeping capacity. Muddy soil is the best soil for mangrove plantation. Mud is best characterized as soft sediment composed of a combination of organic and

inorganic material; it may be as shallow as a few centimeters or as deep as a few metres. The firmness of mud can vary from loose to hard. Plantation should be avoided in loose soils because propagules or seedlings will be washed away during high tidal currents. Plantation should also be avoided in very firm soils because the root can penetrate deep into the soil, which in turn would affect survival and growth. Mangrove plantation should be avoided in very acidic soil, which can be identified by the foul smell like that of a rotten egg.

Analysis of tidal flushing pattern

What is tidal flushing?

Seawater rises and falls temporarily daily due to gravitation pull of the sun and the moon. This temporary rise and fall of sea level is called tides. The rising tide is called high tide and falling tide is called low tide and the difference between high tide and low tide is called the tidal amplitude. When the seawater rises during high tide, seawater enters into the estuary, backwater, tidal creeks, mudflats and spreads laterally. When the tide falls during low tide, all the seawater that entered during high tide goes back to the sea. Such phenomenon of covering an area with seawater during high tide and moving out of that area during the low tide is called tidal flushing. Only the area that is flushed by tidal water is suitable for mangrove plantation (provided other factors are favorable). The area that is located between the high and low tide is called the intertidal area (Fig.1).

Tidal flushing pattern of a given area is determined by a) tidal amplitude and b) elevation of the ground level (otherwise called topography). Before going into the details of measuring tidal flushing pattern some important aspects of tides are to be understood.

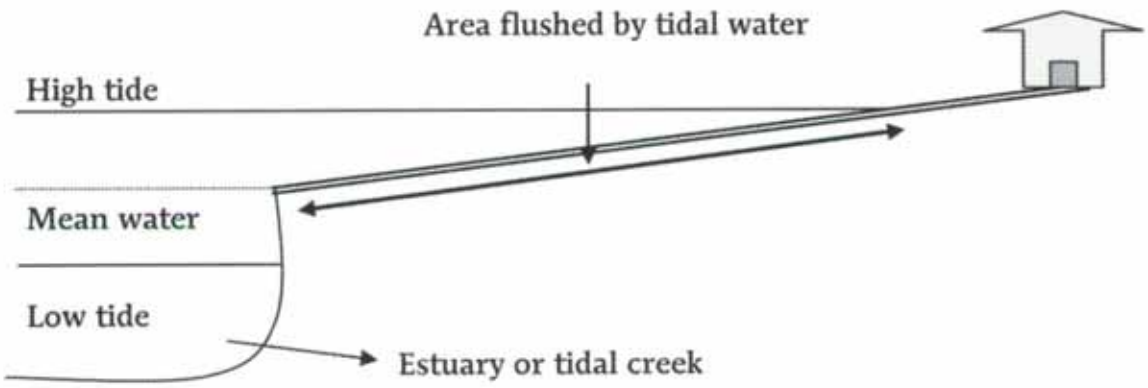


Fig. 1: Intertidal area, which is flushed by tidal water regularly, is the most suitable area to raise mangrove plantation (provided other factors are favourable)

Daily tides

In many places there are two high tides and two low tides each day and each tide continuing for about 6 hours (sometimes this time will vary!). The time of high tide and low tide is determined by the position of the sun and the moon. On an average, the high and low tides occur about 50 minutes later from one day to the next day. For example, if the high tide occurs at about 6.00 am today it will occur at 6.50 am tomorrow in the same spot. However, this is a just a rule of thumb as tides are very complicated. Usually when there are two high and low tides, they will not be of the same height. For example, it is normal for one high tide to be higher than the other. The higher of the two high tides is called the Higher High Water (or HHW); the lower of the two low tides is called Lower Low Water (or LLW).

Spring tides and neap tides

Tidal amplitude reaches peak around full moon and new moon days because during these times the sun and the moon will be in the same line and work together to pull the seawater higher. This is called spring tide. After the spring tide the high tidal level will gradually decrease and reaches the lowest point during the 1st quarter and 2nd quarter (after seven days of new and full moon) when the moon and the sun are at right angles to each other (and thereby they loose their combined gravitational pull on earth's ocean). These lowest tides are called the neap tides.

Tide tables

Tide tables provide daily information on the time when high and low tide occurs in a place and also the height of each high and low tide. Tide table is available for only major coastal cities and ports. In Tamil Nadu, Tide table is available for Chennai, Cuddalore, Nagapattinam and Tuticorin. The time and height of tides given in the tide table is for the specific location (where observation is being made continuously for a number of years) and therefore, time and height of tide at a point inside an estuary or a backwater system will vary slightly. This time lag in tidal conditions needs to be understood.

Measuring tidal flushing pattern

In order to measure the tidal flushing pattern of a selected area the date and time of spring high tide that occur in nearby areas should be noted down from the tide table. On a particular day a group of people should go to the selected site, be positioned in different places like near the mouth of the estuary or mudflat, in the middle portion of the estuary or mudflat etc., and should wait for the arrival of the spring tidal water. The point at which the spring high tide reaches should be marked with a

staff. Similarly, where tidal water falls during the low tide should also be marked. This will give an idea of the breadth of the intertidal area where mangrove plantation can be undertaken. The difference in ground level between the point where spring high tide reached and where spring low tide fell will give an idea of elevation of the ground level with reference to low tide.

After locating the points where spring high tide reaches and spring low tide falls, the intertidal area should be divided approximately into high tidal portion, mid tidal portion and low tidal portion and number of times these areas are inundated by tidal water should be monitored for a period of 15 days. The part of the intertidal area, which is flushed by tidal water only during the spring high tide and one or two days before and after spring tide should be measured, marked and designated as High Tidal Area; similarly, the portion of the intertidal area, which is flushed by tidal water for about 10 days within a period of 15 days should be measured, marked and designated as Mid Tidal Flat. Areas that are flushed by tidal water daily should be marked and designated as Low Tidal Flat (Fig. 2). In the regions where tidal amplitude is very high mangrove plantation is normally undertaken only in the mid tidal flat because saplings planted in the low tidal flat will be immersed in tidal water for many days that would affect their survival. However, in regions with low tidal amplitude like Tamil Nadu coast mangroves can be planted even in the low tidal flat.

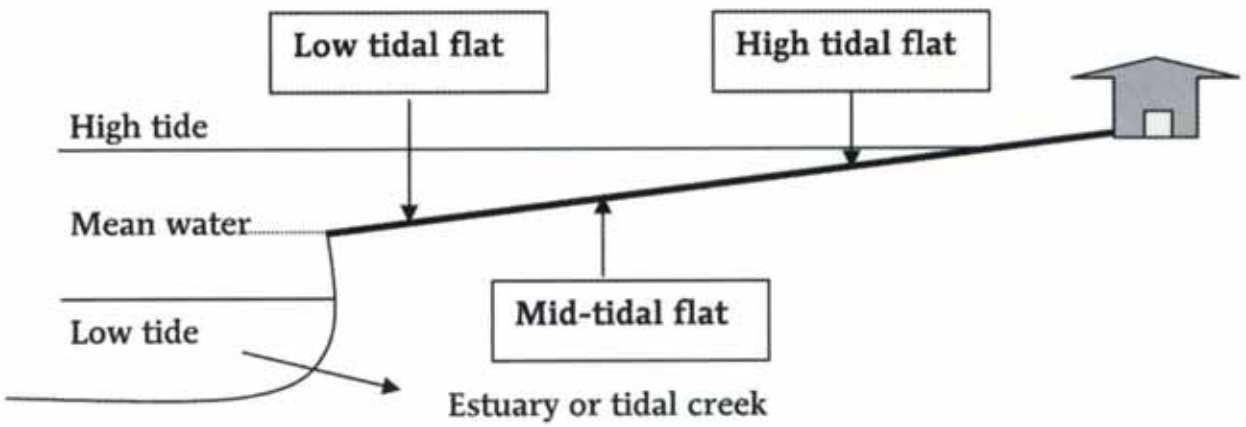


Fig. 2: Three different portions of intertidal area; low tidal flat is flushed by tidal water daily, mid-tidal flat is flushed for about 20 days in a month (most suitable place for mangroves)

Analysis of salinity

Salinity is another important factor that decides the success of mangrove plantation. Salinity of the tidal water, ground water and soil, are all important. Salinity of the running water can be easily measured by "refractormeter or salinometer", which is

commonly available in the market. In case of ground water salinity, pits can be made in many places in the high, mid and low tidal area with auger and water collected from the pits can be used to find out the salinity of the ground water. Soil salinity may be determined with the help of soil testing laboratories.

Mangrove plants are capable of tolerating salinity ranging from 2‰ to 90‰ (salinity is measured as parts per thousand [ppt] means grams per litre, which is indicated as ‰). However, field observations and laboratory experiments show that mangrove plants attain maximum growth only in low saline condition and these experiments showed that for most of the mangrove species the optimal soil salinity ranges between 10 and 20‰. Some group of authors consider optimal salinity for most of the mangroves lies between 4‰ and 15‰. In an experiment conducted it was found out that *Avicennia marina* and *Aegiceras corniculatum* grew at salinities from 0 to 35‰, but maximum growth occurred in salinity between 7 and 14‰. In general, growth rate of mangrove trees falls by at least 50% with an increase in salinity from 20 to 35‰ with a further significant decrease in growth rate at higher salinities. Similarly rate of photosynthesis also reduces drastically in high salinity.

Growth rate of mangrove plants is affected at higher salinity mainly because the rates of ion transport to the shoot of the mangrove plants saturates and as a result *shoot growth* continues only with a reduction in *growth rate*. Similarly at higher salinity regime photosynthetic capacity of the mangrove plants reduces drastically due to high water loss through leaves, which create water imbalances in the leaves. Thirdly, in high saline condition mangrove plants have to spend a lot of energy for maintenance process, which in turn also affect the growth, and to some extent rate of photosynthesis.

All these indicate that growth, productivity of mangrove plants is high in low saline condition, and such low saline condition can be found only when estuarine water, where mangrove plants grow, is diluted with large amount of freshwater for longer period of time.

Analysis of freshwater flow

Mangrove plants require freshwater or low saline condition for reproduction and during the time of the establishment of young plants. Hence, a study should be conducted to find out whether the selected site is receiving freshwater and if yes, duration of the freshwater flow (months) and how long low saline condition exists in the area. This information can be collected with the help of the local community.

Almost all the mangrove species produce propagules and seeds only in low saline

condition. This can be considered as a natural phenomenon of the mangrove species and it is related to their evolution. According to mangrove ecologists all the mangrove plant species originally evolved in terrestrial environment. But they gradually migrated to coastal saline areas to avoid competition from other plant species. During evolution these mangrove species developed morphological characters and physiological mechanism to live in saline condition but still they produce propagules only during the monsoon season when the water and soil salinity is low or freshwater condition may exist which provide suitable condition for the propagules to establish and grow fast.

On the basis of the salinity distribution five zones can be identified horizontally in mangrove wetlands. They are euhaline, polyhaline, mesohaline, oligohaline and limnatic zones. The range of salinity in these zones is given below:

Different salinity zones in an estuary

Zone	Range of salinity
Euhaline zone	30 and 40‰ and more
Polyhaline zone	18 to 30‰,
Mesohaline zone	5 to 18‰
Oligohaline zone	0.5 to 5‰
Limnatic condition	0.5‰ (Freshwater)

It is observed that most of the mangrove species are absent in the euhaline condition (due to higher annual average salinity) and limnatic zone because of its pure freshwater nature. The other three salinity zones have their own group of mangrove species and dominance of species in each of these three zones depends on the value of the average salinity, whether it is on the higher side or lower side. The species commonly found in the polyhaline zone belongs to the genus *Rhizophora, Bruguiera, Ceriops, Avicennia* and *Sonneratia*. Species belonging to *Acanthus, Aegiceras* and *Kandelia* are common in the mesohaline zone. Freshwater loving species such as *Hertieria, Nypa fruticans* etc. dominate the oligohaline zone. Some species of the mangroves such as *Avicennia marina,* which tolerate wide range of salinity, may be present in most of these zones.

All the above-described five zones can be found only in mangrove wetland, which receives copious inflow of freshwater for longer period of time in a year. In these mangrove wetlands the number of mangrove plant species present or diversity of mangrove species will be high. Best examples are Sunderbans of West Bengal and Bhitarkanika of the Orissa. On the other hand, such zonation may not be present conspicuously in mangrove wetlands such as the Pichavaram and Muthupet of Tamil Nadu where the amount of

freshwater discharged is very low and only for a limited period of time. In these kinds of mangrove wetlands the diversity of mangrove plants will also be less.

Preparation of treatment maps

After thorough analysis of the environmental condition of the area selected for mangrove afforestation a treatment map of the plantation site should be prepared. A treatment map of the plantation site, which may be of 10 to 15 ha in area, gives details of what is going to be done and where. For example, a plantation site may be divided and quantified into high tidal zone, mid tidal zone and low tidal zone. High tidal zone is the area, which is flushed by tidal water 3 to 4 times once in 15 days; mid tidal zone is the area which is flushed by tidal water 8 to 10 times once in 15 days and low tidal zone is the zone which is flushed by tidal water daily. Such quantification and demarcation would provide details of what kind of species should be planted where and how much planting materials are required for each species. Area of the plantation site may be measured using a chain link and this should be overlaid on the base map described earlier. How to identify and demarcate high, mid and low tidal zones is explained earlier.

Planting methods

This section describes, selection of species for plantation, method of planting of mangrove seed, propagules and seedlings in the selected site.

Choice of species

Success of mangrove plantation largely depends on the choice of species. Normally distribution pattern of the species with reference to tidal inundation and land elevation in a nearby natural mangrove forests is taken as reference for selection of species for planting in different tidal zones. For example, in Tamil Nadu *Rhizophora* spp., *Bruguiera* spp. *Ceriops* spp. are planted in the low tidal zone, though the breadth of this zone is very narrow ranging from 2 m to 10m. *Avicennia officinalis* is planted just a few feet away from the low tidal zone whereas high saline tolerant *Avicennia marina* is planted both in the mid tidal and high tidal regions. In countries like the Philippines species are selected on the basis of the objectives of the planting, either for production purposes such as firewood, charcoal, posts and piles etc or protection purposes such as shoreline or road stabilization, sediment trapping etc.

Plan of planting operation

A plan of planting operation is necessary for efficient planting in terms of cost and time and the following factors should be taken into consideration in the preparation of the plan:

- ***Availability of planting materials*** such as sufficient quantity of seeds, propagules or potted seedlings (nursery grown seedlings).
- ***Planting season:*** Better results can be achieved if planting is undertaken immediately after the monsoon season when the salinity of the water and soil is low but moisture is high. This will allow the seeds/propagules and seedlings to settle and establish as quickly as possible.
- ***Conditions of tide*:** In areas where tidal amplitude is more than a metre the operation of planting is difficult during the high tide because during this time the entire plantation site would be flooded with tidal water. Hence, it is essential to calculate how many hours are available per day to carry out planting for the entire planting season.
- ***Quantity of planting materials*:** There should be exact quantification of how many seeds/propagules or potted seedlings are required for planting during available hours in a day and how much human resources are necessary for transport and planting.
- ***Participation of the local community*:** Community should be involved both in mangrove afforestation and restoration activities from the beginning, i.e. from planning to monitoring and evaluation. Since the local people know the in and out of the environmental and social conditions of the planting site much better than outsiders. Their participation is imperative in preparing and implementing practically feasible planting operation plan.

Planting material

Propagules

Mangrove plants display a unique reproductive mechanism known as vivipary. A distinctive feature of the majority of mangrove species is that they produce unusually large propagating structures called propagules. This term is used because in most mangrove species what leaves the parent tree is a seedling, not a seed or fruit. After pollination the growing embryo remains attached to the parent tree and grows into a propagule. This phenomenon is known as vivipary. *Rhizophora* and other members of Rhizophora family such as *Bruguiera, Ceriops* and *Kandelia* show the most advanced form of vivipary. In these species, after fertilization embryo develops within a small fruit. As the embryonic axis or hypocotyl elongates, it bursts through the seed coat and develops into a spindle-shaped structure. Unlike seeds of terrestrial plants, there is no period of dormancy and growth of the propagules continues. While still attached to the parent tree, the developing seedling (propagule) develops chlorophyll and actively photosynthesizes. The parent tree supplies the water and necessary nutrients. Eventually the hypocotyl detaches from the residual fruit, leaving behind its cotyledons and falls from the parent tree.

Three pairs of leaves and associated stipule pairs are produced while the propagule is still attached to the parent tree. The first pair of leaves aborts and persists only as minute vestiges on the detached propagule so that the plumule is actually protected by well-developed stipules. Lateral roots, visible on older seedlings as apical protuberances, arise early during seedling development and delineate the morphological root at the end of the hypocotyl. Salt concentration declines between the pedicel and the cotyledons, and then again between cotyledons and hypocotyl and decline still further towards the tip of the hypocotyl. Tissues of the propagules are thus preserved from premature exposure to high salt levels. Matured propagules are widely used in direct planting.

Aegiceras, Avicennia, Nypa and a number of other mangrove species show a more or less similar form of reproduction, known as cryptovivipary. In cryptovivipary germination and embryonic development take place on the parent tree itself as in the case of *Rhizophora spp.* but developing hypocotyl fails to penetrate the pericarp and the hypocotyl will not be long.

Seeds

The final group of mangroves reproduces and disperses by more or less conventional seeds, ranging in size from a few millimeters in length to the massive fruits of *Xylocarpus granatum*. Larger seeds such as of *Xylocarpus granatum* are directly used for planting. In case of smaller seeds such as *Sonneratia* spp seedlings are raised in nursery and these seedlings are used for plantation. The following table shows viviparous, cryptoviviparous and non-viviparous mangrove species (Table 5).

Table 5: Viviparous, cryptoviviparous and non-viviparous mangrove species

Viviparous species	Cryptoviviparous species	Non-viviparous species
Rhizophora species	*Avicennia* species	*Sonneratia* species
Kandelia species	*Aegiceras* species	*Excoecaria* species
Bruguiera species	*Aegialitis* species	*Scyphiphora* species
Ceriops species	*Nypa* species	*Lumnitzera* species
	Pelliciera species	*Xylocarpus* species and others

Potted seedlings

Nursery raised or potted seedlings are also used for planting. Details of raising mangrove nursery are discussed in Chapter 6.

Propagules/seed collecting season

For each mangrove wetland, a calendar showing the season and months during which matured propagules/seeds can be collected in large numbers should be prepared for efficient seed collection in terms of cost, time, quality and quantity. For small scale planting it is possible to collect propagules/seeds throughout the year but for large-scale plantation sufficient quantity of planting materials may be available only during the fruiting season.

Propagules/seeds collection and selection methods

Seed collection and selection standards applied in Tamil Nadu and Andhra Pradesh for mangrove restoration are provided below, which may be applied in other areas with suitable modification according to the local condition.

Avicennia marina

Avicennia marina is the species that is commonly planted in large-scale plantation because of its capacity to withstand wide variations in salinity. It is also possible to grow this species in all the tidal zones. Apart from these, propagules (from now onwards called seeds) are also available in large quantities during seed collection season. Mature seeds of *A. marina* can be easily distinguished by the light yellowish colour of the seed coats, which are green in immature seeds. Large mature seeds can be picked directly from mother trees but the following method is commonly practiced in Tamil Nadu. During seed collection season, a rapid survey is conducted to identify the areas where healthy and germinated seeds (also called sprouted seeds) of *A. marina* are floating in large numbers. In these areas, fishing nets are placed at the mouth of the tidal creek during the low tide. All the seeds that move out of the creeks along with tidal water during the low tide are trapped and transported immediately to the planting sites. In the planting sites, matured seeds and small sprouted seedlings, which are damaged during transportation and also by insects, are rejected and disposed off and the remaining seeds are used for planting. This operation is done daily and for this a separate group of people is employed; they collect and transport the seeds to the planting site much before the arrival of the group of people who are engaged in planting.

Avicennia officinalis

Seed collection and selection process for *Avicennia officinalis* is more or less similar to that of *A. marina*. In Tamil Nadu *A. officinalis* is planted only just a few feet away from the tidal creeks and canals because it requires low saline condition and are less tolerant to desiccation (loss of moisture from the soil).

Rhizophora spp.

Rhizophora apiculata and *Rhizophora mucronata* are commonly used for planting along the fringe area of the planting site (low tidal area) because these areas are flushed daily by tidal water and such a condition is favourable for the establishment and growth of *Rhizophora* species. Mature propagules of *Rhizophora* spp. can be easily distinguished by the colour of the cotyledons. In matured propagules, cotyledon will be in yellow to pale green in colour whereas cotyledon of immature propagules is green in color. It is advisable to pick mature propagules from the mother tree but freshly fallen propagules may also be collected and propagules without physical damage and insect attack should be used for planting.

Ceriops spp.

Ceriops tagal and *Ceriops decandra* are also used in planting in Tamil Nadu and Andhra Pradesh but in small numbers. In Tamil Nadu one row of these species are planted immediately next to *Rhizophora* spp. in selected places. Mature propagules of *Ceriops* spp. can be easily distinguished by pale green to yellowish cotyledon. Mature and undamaged propagules can be collected from mother trees and freshly fallen propagules are also useful for planting.

Bruguiera spp.

Mature propagules of *Bruguiera* spp. have reddish brown or greenish red coloured hypocotyls. Healthy and mature propagules can be collected from the mother tree and freshly fallen propagules can also be used for planting. Like *Ceriops* spp. *Bruguiera* is also planted out only in limited numbers in Tamil Nadu and Andhra Pradesh.

Aegiceras corniculatum

Healthy and mature seeds of *A. corniculatum* should be collected only from the mother tree. The mature seeds can be easily identified by the yellow or greenish yellow colour of the seed coat.

Excoecaria agallocha

Mostly young and healthy seedlings collected from the wild can be used for planting. The seedlings should be collected from loose sediments without damaging the root in the early morning hours and planted on the same day, as soon as possible.

Storage

Propagules/seeds must be stored in brackish water in a well-shaded place. They must be regularly sprinkled with low saline water during the entire period of storage. As shown below the effective storage duration varies from species to species (Table 6).

Table 6: Seed storage duration of different species

Species	Place	Period	Remarks
A. marina and *A. officinalis*	Cool and dark place, totally protected from direct sunlight	10 days	-
R. apiculata	Well protected from direct sunlight. Soaked in brackishwater	5 days	No soaking of calyx for long time
R. mucronata	-do-	10 days	No soaking of calyx for long time
Ceriops spp. and *Bruguiera* spp.	-do-	10 days	Calyx should not be removed

Planting technique

The following are the commonly followed methods of planting mangrove species.

Direct planting

Propagules of *Rhizophora, Ceriops and Bruguiera* spp. and seeds of *Avicennia marina* and *A. officinalis* are normally planted directly on the ground. This method is economical with a high percentage of survival. The planting operation for these species is simple and can be done by untrained hands. It involves inserting one-third of the propagules into the soft and moist mud (as shown in Fig 3). One common practice responsible for high mortality rates in mangrove planting is the sowing the propagules to more than half of their length in the soil. This was done because people believed that waves would dislodge the propagules if they were not planted deep enough. Propagules, however, are covered with lenticels and if propagules are planted too deep will render the lenticels useless, causing the slow death of the plants.

Mature seeds or sprouted seedlings of *Avicennia* spp. with a few numbers of roots are widely used for direct planting. In this case, a small depression is made in the soft mud and mature or sprouted seeds are sown into the depression. In order to avoid washing of sown seeds, sides of the depression are filled with mud.

Planting of potted seedlings

Potted seedlings, i.e. seedlings grown in nursery are normally used for trees with tiny seeds such as *Sonneratia* spp., *Excoecaria agallocha, Aegiceras corniculatum* etc. Seedlings of *Rhizophora, Bruguiera, Ceriops* and *Avicennia* can also be raised in the nursery but cost of plantation will become high. Potted seedlings can be planted in

Seeds of *Avicennia officinalis*

Propagules of *Rhizophora apiculata*

Planting method

Fig. 3: Seeds and propagules used for direct planting: Direct Planting - one third of the propagules should be inserted into the mud for high rate of survival and better growth

holes of the same depth of the pot. Shallow planting holes may result in seedlings toppling down or getting washed away by tides. Essentially, planting holes should be of such a depth so as to locate the root collar of the seedling at ground level. Where the soil is soft, holes can be made by scooping out mud by hand. In hard soil, shovel can be used. It is necessary to remove pot (polythene bag) from seedlings before planting. During removal of pot full attention should be paid to avoid causing any physical damage to the roots of the seedlings. Seedlings with damaged roots are unlikely to strike root and grow well.

Wildlings

Where there are not enough seeds or propagules, wildlings may be potted and hardened in the nursery for a month. In uprooting/collecting wildlings, extra care must be taken not to damage the root system. For some species wildlings can be

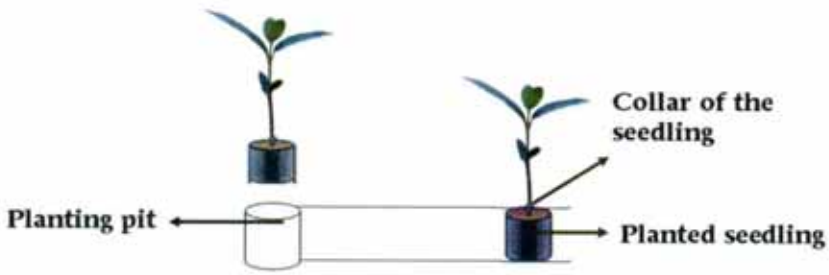


Fig 4: Planting of potted seedlings

directly planted without hardening in the nursery, provided the soil around the root is intact.

Wilding of *Avicennia marina*

Planting organization and spacing

For protective planting, i.e. planting to protect coastlines, an inverted V spacing with the point of the V facing the sea would be useful to deflect the impact of waves. In this case spacing should be less than 0.5 m. In Cuba, planting has been done in triangle formation with one of the corners of the triangle pointing seaward and spacing is less than one metre. Normally in Tamil Nadu, planting is done in strips at an interval of 1 m.

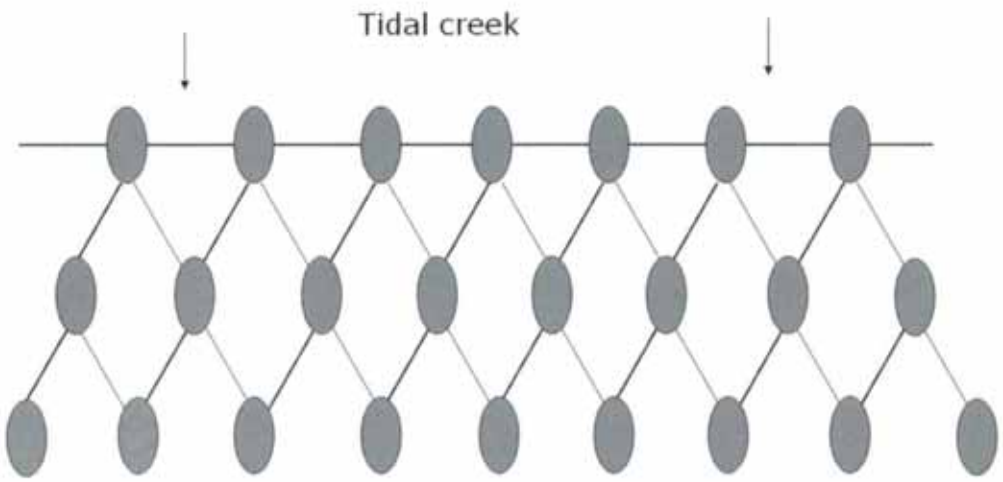


Fig. 5: Schematic diagram of inverted 'V'- shaped plantation

Care and maintenance of plantations

During initial stages, plantation site should be visited daily during the low tide and saplings should be checked for

1. Entanglement by debris and filamentous green algae such as *Enteromorpha* and *Cheatomorpha*
2. Leaf-eating insects and moth larvae
3. Encrustation by sessile organisms like barnacles

Green algae and debris can be manually removed easily and they should be disposed off beyond the high tidal region. If they are thrown out in nearby areas they will be again transported to the plantation site by the tidal current.

Encrusted organisms like barnacles are common in plantation sites where water salinity remains around seawater salinity (35 grams per litre) throughout the year. These organisms do not tolerate low salinity and hence, this problem is normally not encountered in areas where low saline condition exist for a considerable period of time. Wherever this problem is encountered, all the encrusted organisms should be removed by hand. To remove these organisms sharp edged instruments should not be used, which may cause severe damage to the saplings, leading to the death of the saplings.

Grazing organisms like insects and moth larvae should be removed by hand, kept in a bag and disposed in the terrestrial areas.

If the problem of grazing by insects and moth larvae and encrustation by organisms like barnacles is severe and affecting a large area of the plantation *neem* based biopesticide can be used for complete eradication of these pests.

Normally, beyond a period of 2 years mangrove plantations require less care.

2.5 Restoration of mangroves

Restoration of mangrove means bringing back mangrove vegetation in the areas where it existed in the past. As explained in Chapter 1, mangroves are specialized ecosystems and its distribution in the coastal zone is restricted mainly to deltaic regions. Hence, almost all the major mangrove wetlands of India have been declared as Reserve Forests long time back, even before independence, and some of these mangroves have been declared as Wildlife Sanctuaries recently. All the Reserve Forests and Wildlife Sanctuaries are managed by the respective State Forest Departments.

M.S.Swaminathan Research Foundation has been working jointly with the State Forest Departments of Tamil Nadu, Andhra Pradesh and Orissa for the last 8 to 14 years in restoring and conserving the mangrove wetlands. During the course of the work it was found out that mangroves in these areas have been degraded in a large scale due to one or a combination of the following factors:

a) Changes in biophysical condition due to coupe felling in the past (clear felling as a part of the government management practice),

b) Reduction in freshwater flow,

c) Conversion of mangroves forest for other purposes and

d) Over use by local community

MSSRF and State Forest Departments have jointly developed and demonstrated restoration techniques, which primarily address the issues relating to changes in the biophysical condition resulting from the past management practices. This restoration technique is followed mostly in Tamil Nadu and Andhra Pradesh and recently it has been tried in Orissa. Application of these techniques to restore degraded areas located within the reserve forest requires permission from the State Forest Department. A separate section discusses where the canal method will not yield good results.

Restoration technique

Canal method

This method is otherwise called trench method and is largely followed to restore mangrove areas that are degraded due to clear felling in the past under coupe system of management. It is also called fish bone canal method because canals designed like a fish bone produce better results. In the mangrove Reserve Forests of Tamil Nadu

such as Pichavaram and Muthupet and of Andhra Pradesh such as Krishna and Godavari, mangrove forests were clear felled in large areas for revenue generation by various government agencies since the time of the British government. This system of clear felling was called coupe felling and it was followed in 15 to 25 year rotation. Because of large scale felling, soil water in the coupe felled areas evaporated (mangrove soil contains 80% of water), which in turn caused subsidence of sediments in these areas. As a result, smooth topography of the mangrove wetland has become trough shaped and tidal water entering into these trough shaped areas stagnates (see Fig 6). The evaporation of the stagnant water leads to hyper saline condition and that prevents natural regeneration of mangroves in the coupe-felled areas.

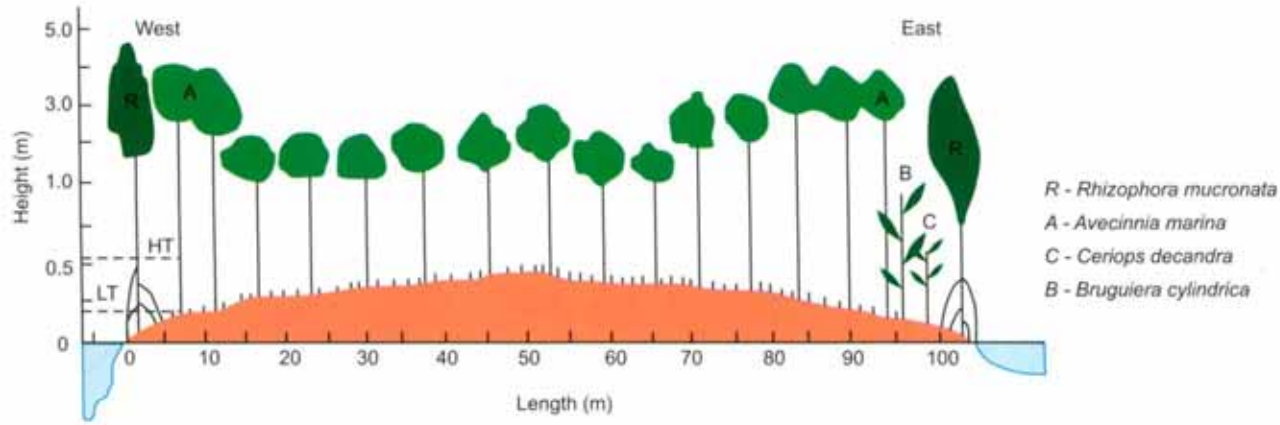
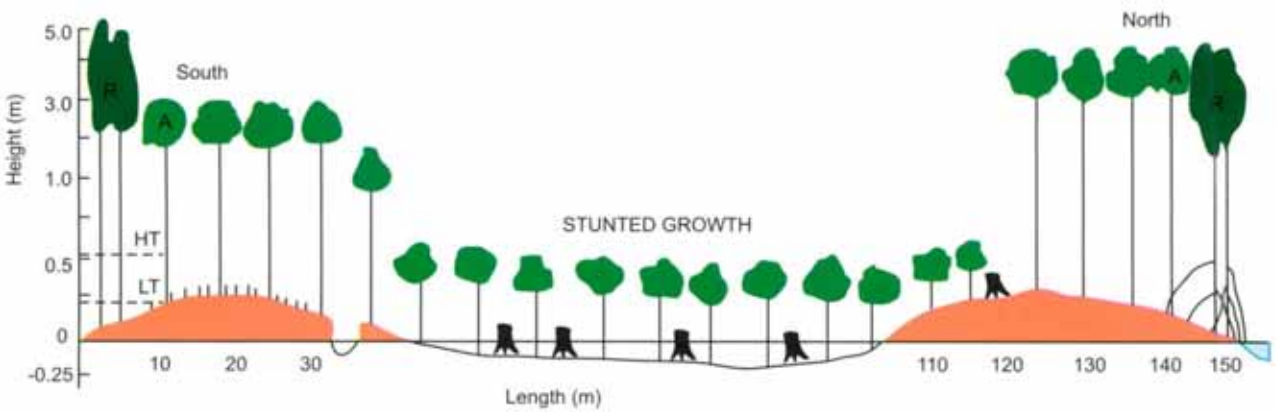


Fig. 6a: Microtopography in healthy mangroves



6b: Trough shaped microtopography in degraded areas: formation of trough shaped topography due to coupe felling where canal method is the most suitable method of restoration

It was found out that these degraded patches could be restored by ensuring free flow of tidal water in and out of the degraded area during the high tide and low tide by digging canals and linking them to the nearby natural creeks. These man-made canals also facilitate flooding of the degraded area with low saline or freshwater

during the monsoon season. These actions create suitable environmental condition for the regeneration of mangrove species. The above technique was demonstrated jointly by local community, Forest Department and MSSRF in about 1500 ha in the states of Tamil Nadu, Andhra Pradesh and Orissa and it is currently being followed by other agencies.

The following steps describe the technique and process to restore mangrove areas that are degraded due to organized massive clear felling.

Step 1: Getting permission from the State Forest Department

As mentioned earlier all the major mangrove wetlands are under the custody of the respective State Forest Departments. Before undertaking any intervention in these reserved areas necessary permission should be obtained from the Forest Department. In this respect, first the District Forest Officer who is in charge of the area should be consulted for necessary process to be followed to get the permission

Step 2: Identification and demarcation of degraded areas

Degraded area within the reserve forests can be identified with the help of the field staff of the Forest Department and participating community. Once the areas are identified and permission obtained, these areas may be demarcated as management units for the participating village institutions to undertake restoration and conservation activities.

Step 3: Measurement of microtopography

Fish bone canal method produces better results in small pockets of degraded areas of about 10 to 15 ha in size and have trough shaped microtopography as shown in Fig. 7. Microtopography is topographic variations in the wetland occurring at a small spatial scale (say 1m or less) between elevations and depressions. It is assessed by preparing contours at small vertical intervals.

Microtopography of the degraded areas can be easily measured by using a rope, graduated scale and mercury level used by masons. To start with, a benchmark is established at the edge of the low tidal level that is considered as zero. A scale of say one metre height is fixed and reference point is fixed at 85 cm (Point A in Fig. 7). Another scale is fixed at about 10 m distance using a tight rope and the level is adjusted to be straight using a mercury level. The difference in ground level between these two points is measured at 2 m interval. For example, if the height at first reference point is 85 cm and second point (point B in the Fig. 7) is 55 cm, then the difference is +30 cm, which is the height of the land at the second point from zero level. In this

way microtopography can be measured for the entire area, including degraded and nearby healthy mangroves. This will give a clear picture of the microtopography of the degraded areas, which will be used in designing the canals with varying depths according to the contour levels of the degraded areas.

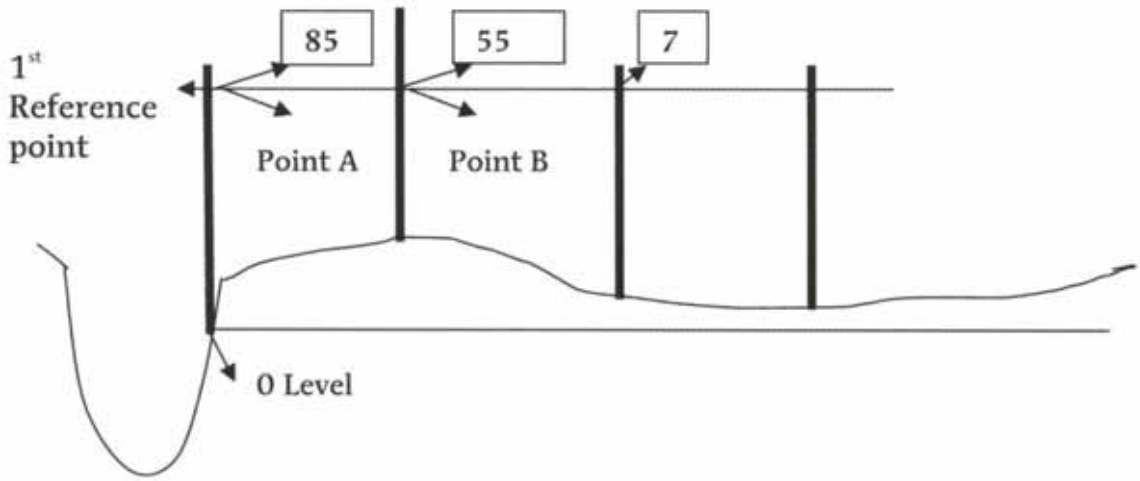


Fig. 7: Method of measuring microtopography in a trough shaped degraded area.

Step 4: Designing of canals

Canal technique produces better results in areas, which are of about 10 to 15 ha in size and where there is stagnation of tidal water. As shown in the figure below (Fig.8) canals for restoration consist of main and feeder canals, which should be dug in the form of a fish bone for better movement of water in and out of the degraded area. Dimension of main and distributory canals are shown in Fig.8, which can be

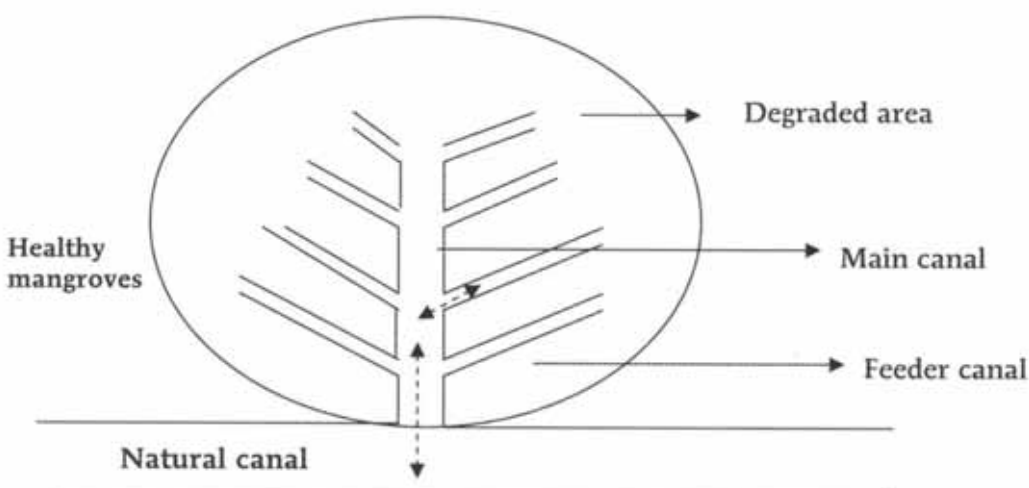


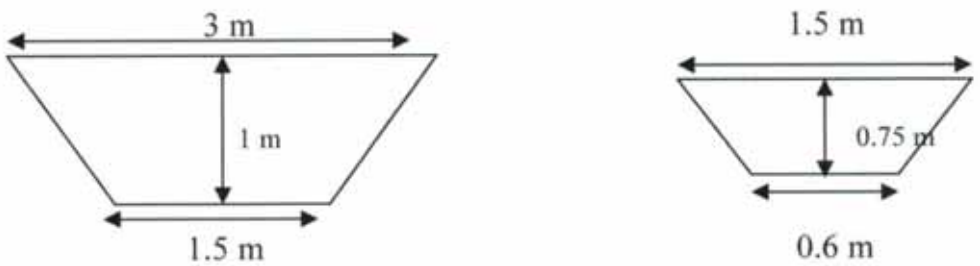
Fig. 8: Aerial view of fish bone type of canal system normally followed in the restoration of degraded areas in Tamil Nadu and Andhra Pradesh

slightly increased or decreased according to condition in the site. One main canal is necessary to restore about 10 to 12 ha of degraded areas. Length of the main canal and number of feeder canal depends on the circumference of the restoration site.

On the basis of the experience gained by restoring about 1000 ha of degraded area in the state of Tamil Nadu and Andhra Pradesh, the following dimension is prescribed for main canal: 3 m upper width x 1.0 m depth x 1.5 m lower width (Fig. 9a). In case the ground level nearby the natural canal is slightly higher than the interior portion, in these areas depth of the canal may be increased by about 30 to 50 cm. The feeder canal can be of 1.5 m upper width x 0.75 m depth x 0.60 m lower width (Fig. 9b). Distance between feeder canals varies from 2 to 4 m in Tamil Nadu (due to low tidal amplitude) to 8 m in Andhra Pradesh (due to slightly high tidal amplitude and low bulk density of the soil)

In microtidal environment (low tidal amplitude) such as Tamil Nadu and Andhra Pradesh it is advisable to have the depth of the main canal always more than that of the mean water level in the natural canal (it means if the mean water level is about 1 metre the depth of the main canal should be more than 1m). The mean water level of the natural canal can be determined by measuring the maximum and minimum water levels over a period of 24 hours using a graduated staff (help of oceanographers or hydrological engineers may be taken, if necessary to determine the mean sea level). The mean of these two levels is the Mean Water Level of the canal. This observation should be made during the summer months, when there is no freshwater flow. Measurement during the month of May should be avoided since there is chance of measuring time coinciding with equinoctial tide.

Experiments need to be conducted to find out whether canal technique is necessary for the restoration of degraded areas of macrotidal mangrove areas such as that of Orissa, West Bengal and Gujarat.



9a. Main Canal **9b. Feeder canal**

Fig. 9: Dimension of main and feeder canals followed normally in Tamil Nadu and Andhra Pradesh

Fish bone type canal as dug in one of the restoration sites in Pichavaram mangrove wetland of Tamil Nadu

Step 5: Organizing canal digging

Canals should be dug two to three months before the onset of the monsoon, so that the salt in the soil and ground water could be leached and flushed out during the monsoon. Secondly, canal digging should be undertaken during the summer months particularly from March to May in Andhra Pradesh and March to August in Tamil Nadu for the following reasons: a) during the summer months wetlands are relatively exposed and slightly dry due to lack of freshwater inflow, which make digging of canals little bit easier and b) during this period most of landless labourers will be in need of employment opportunity and these labour forces can be used for canal digging, which will provide wage employment to them.

Step 6: Canal digging

Responsibility of digging canals should be entrusted to village institutions, which should develop a mechanism of mobilizing and organizing the required labour forces for undertaking the preparatory or advance work. During canal digging the dug out soil should be deposited only adjoining the canals like a bund. It should not be distributed all over the degraded areas. The soil deposited along the bunds will subside in the subsequent summer months when the water in it gets evaporated and bulk density increases.

Canal digging and maintenance creates employment opportunity for the landless poor

Step 7: Planting

Planting is of two types i) direct planting (dibbling) of propagules or seeds of mangrove plants and ii) planting of nursery-raised saplings (pot seedlings). All the details of planting and establihment of nursery are given in Chapter 4. Responsibility of planting should be given to the village institutions and members of these institutions should be sufficiently trained in seed collection, selection, storage and planting methods.

Step 8: Maintenance of canals

In Tamil Nadu desilting of both main and feeder canals are done once in a year for the first three years. Desilting is done only in the canal mouth region during the summer. In Andhra Pradesh entire main and feeder canals are desilted once in a year for the first three years. Village institutions should be organized to shoulder the responsibility of maintaining the canals till the plantation establishes.

Step 9: Care and maintenance of plantation

See Chapter 4 for details

Where canal method should be applied?

Canal method should be applied to restore the following types of areas

Type 1 Area: Type 1 area refers to intertidal areas in the mangrove environment where topography has become trough shaped due to massive clear felling of mangroves (such as coupe felling), which led to stagnation of tidal water and development of hyper saline condition. Development of hypersaline condition prevents natural

regeneration of mangrove plants in the trough shaped areas (Fig. 10). In these areas ground level of the degraded portion will be below the Mean Water Level (MWL). Hence, application of canal method will ensure tidal flushing, which in turn would create biophysical condition for natural regeneration of mangroves.

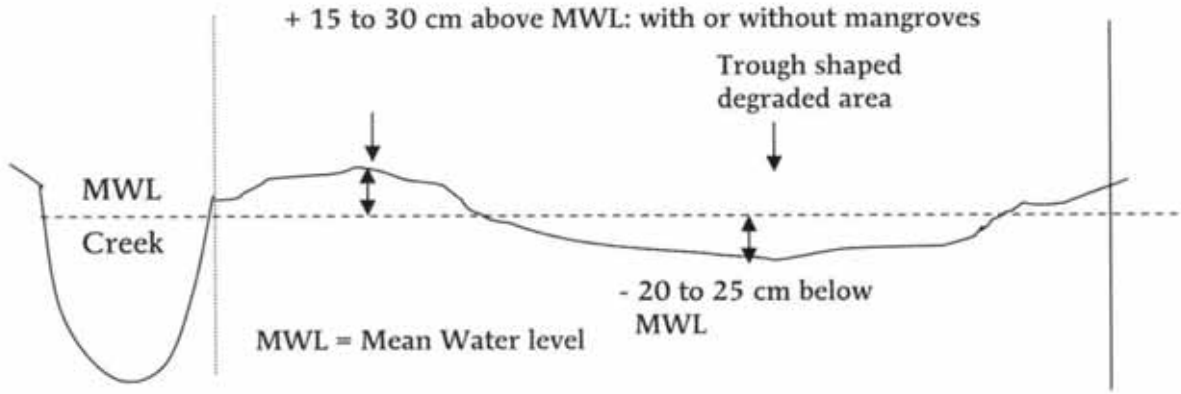


Fig. 10: Type 1 Area: Trough shaped area degraded due to coupe felling

Type 2 Area: Type 2 area refers to areas, which have levee along the creek banks, which prevents free movement of tidal water in and out of the mangrove forest (Fig.11). As a result, environmental condition of the mangrove forest behind the levee gradually deteriorates leading to degradation. In these areas, the ground level might be equal or slightly above the MWL in the creeks. Hence, when canals are dug, there will be free flow of water in the areas where ground level is equal to a slightly higher to MWL. Given the elevation in the levee region, flushing can be ensured only by multiple interconnections between the feeder canals.

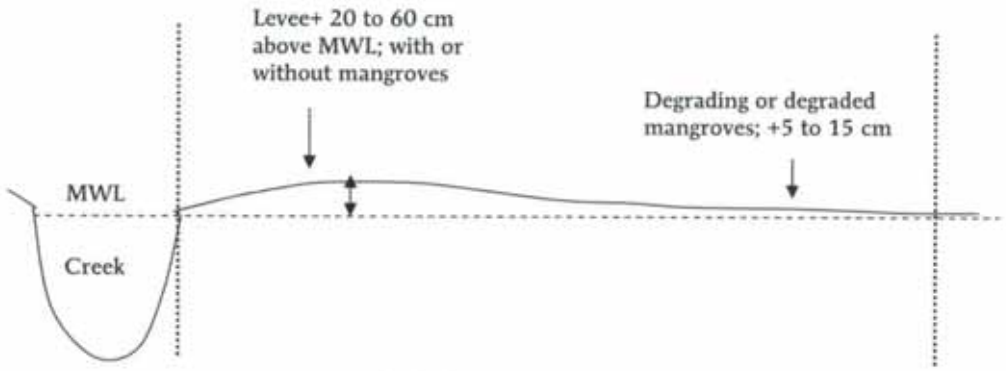


Fig. 11: Type 2 Area: Degraded due to development of levee along the banks of the tidal creeks

Where canal method should not be applied

- This canal method should not be applied in areas beyond the boundary of the high tidal zone, where there is no flow of tidal water. This point is being made here because in some areas this canal method is being applied indiscriminately, resulting in not only non-establishment of mangrove plantation but also leading to disappearance of other existing vegetation. Figure 12 below shows the area where this canal method should not be applied.

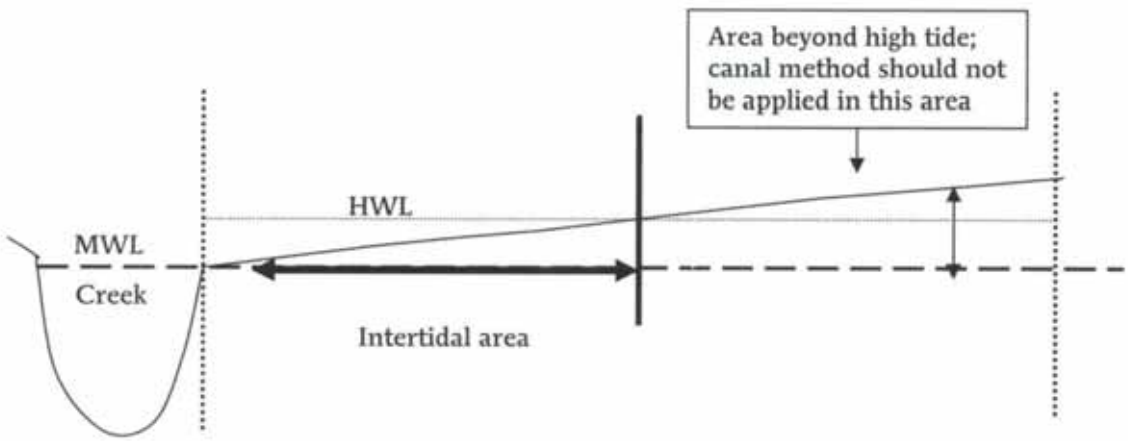


Fig. 12: Area not suitable for mangrove plantation

- Canal method will not yield good results in sandy areas, whether sandy area is below the mean water level or slightly above mean water level, because canals will easily collapse during the monsoon season
- Canal method will not work in accreting type coastal areas, which is prograding due to deposition of sediments, which will cause silting up of the mouth region of the canal and thereby preventing free flow of water.
- Canal method will not work in open coastal sandy areas because sand laden winds deposit sand all over the canals and cause siltation of canals.
- Canal method should not be tried in areas that are close to agriculture lands as this will cause salinization of agriculture lands

2.6 Mangrove nursery establishment and management

To restore the degraded areas, two types of plantings are followed i) direct dibbling or direct planting and ii) planting of nursery-raised saplings or potted seedlings. This chapter provides details of the following:

1. Designing mangrove nursery
2. Establishment and operation
3. Use of nursery stock for mangrove restoration and afforestation
4. Community participation in nursery raising and management

Mangroves regenerate naturally when the conditions are suitable for their establishment and growth. These conditions prevail in places where the natural course of tidal influx and river water flow occurs. Mangroves, like any other forest ecosystem, regenerate as a cyclic phenomenon. Each species has its distinguished character of regeneration: by seeds in the case of species such as *Excoecaria agallocha, Sonneratia apetala* and by viviparous germination (through propagules) in the case of *Rhizophora apiculata, R. mucronata* and *Bruguiera gymnorrhiza*. However, as explained elsewhere in the manual, changes in geomorphological and hydrological conditions hinder the natural regeneration of mangroves.

Need for mangrove nurseries

The season for flowering, fruiting and production of seeds and propagules are not the same as the season of planting in degraded areas, except in some areas like Tamil Nadu. The fruiting season of *Avicennia marina* and *Avicennia officinalis,* which are mainly used in restoration and afforestation, is October to November. However, months suitable for planting will be July to November (in Tamil Nadu suitable season is from December to January) and thus, a period of three months of planting will be lost if we rely only on natural sources for planting materials. Due to the above reason there is a need for raising nurseries so that these seedlings can be utilized for plantation. It is learnt through restoration activities from 1997 to 2003 that in some areas the rate of survival of nursery-raised saplings is more when compared to direct dibbling. This is due to the fact that nursery-raised saplings have a well-established root system as they are maintained for 8 - 9 months in the nursery (from October to July) under simulated conditions before being transplanted in the degraded areas that were under high saline conditions for long periods. Apart from this, the casualty due to crab eating the seeds and young seedlings can be avoided by using nursery-raised seedlings. Above all, raising of mangrove nursery creates employment opportunity for rural women and men. However, cost of raising mangrove plantation would escalate to high level if only nursery raised seedlings are used for planting.

Selection of site for the mangrove nursery

The mangrove nursery site should be selected in the inter-tidal area, in close proximity to creeks as well as near to plantation site. This site should have facility in the form of canals to take in and drain out water periodically. Wherever necessary, the nursery should be fenced to prevent grazing by feral cattle inhabiting the mangrove forests. It should be connected by waterways, to reduce the cost of transportation of seedlings from the nursery to the restoration site. Channels for inflow and outflow of tidal water should be dug to facilitate natural inundation as shown in Fig. 13.

Common species for mangrove nurseries

Avicennia marina, *Avicennia officinalis* and *Excoecaria agallocha* are species used for mangrove restoration and afforestation along with species *Rhizophora, Bruguiera, Xylocarpus, Sonneratia* and *Aegiceras* spp. Seedlings of these species can be raised in the nursery. Common species for mangrove nursery is given in Table 7.

Unlike in terrestrial vegetation, the mangroves are unique in producing different types of planting materials, which range from seeds to propagules. The propagules are produced by means of vivipary, which means that seed germinates while the fruit

Table 7: Details of mangrove species and nursery material

S.No	Mangrove Species	Nursery material
1.	*Aegiceras corniculatum* (L.) Blanto	Propagules
2.	*Avicennia marina* (Forsk.) Vierh.	Fruits
3.	*A. officinalis* L.	Fruits
4.	*Bruguiera gymnorrhiza* (L.) Savigny	Propagules
5.	*Excoecaria agallocha* L.	Young seedlings
6.	*Rhizophora apiculata* Bl.	Propagules
7.	*R. mucronata* Lamk.	Propagules
8.	*Sonneratia apetala* Buch.-Ham.	Seeds
9.	*Xylocarpus* moluccensis (Lamk.) M.Roem.	Seeds

is attached to the mother plant itself. These germinated seeds are normally called propagules. Propagules are slender.

Collection of seed material and planting in the nursery

Mature and healthy fruits / propagules should be collected from the forest in the morning. Local fishermen are knowledgeable about the availability of the seed material. The fruiting season for a majority of the mangrove species is between September and December. The collected seeds should be examined for incidence of diseases or pest attack. Indicators for mature propagules and seeds for different species are given in Table 8.

Ideal season for collecting the propagules is from September to December. However, *Bruguiera gymnorrhiza, Rhizophora apiculata* and *R. mucronata* bear fruits throughout the year, though the peak fruiting season is August – November.

Seed germination and growth of seedling

The germination period, percentage of germination and average height of mangrove saplings raised in the mangrove nursery is given in Table 9.

Viability of seed material

Viable seeds are essential for raising nurseries in order to ensure better germination and survival rate of nursery raised saplings. The viability of the seeds depends on the age of the tree. Age of the tree could also be determined with the help of elderly local villagers. For e.g. Propagules of *Rhizophora* should be collected from the trees older

Table 8: Indicators for mature propagules and seeds for different species

Species	Seed collection (months)	Indicators of maturity	Seed collection (criteria)	Seeds storage (Max. Days)
Aegicerascorniculatum	Aug - Oct	Yellow Epicarp	5 to 6 cm long	15
Avicennia marina	Oct - Nov	Yellowish fruit skin	Weight of seeds > 1.5g.	10
Avicennia officinalis	Oct - Nov	Yellowish fruit skin	Weight of seeds > 5g	7
Bruguiera gymnorrhiza	Jul - Sep	Reddish brown or greenish red hypocotyls	>10 cm. long	10
Excoecaria agallocha	Sep - Oct	Dark brown fruits	< 100 mg.	10
Rhizophora apiculata	Jul - Sep	Reddish cotyledon	>20 cm. long diameter >14 mm	5
Rhizophora mucronata	Jul - Sep	Yellow cotyledon; green hypocotyls	>50 cm. long	10
Sonneratia apetala	Jul - Sep	Floats in water	Fruit >15mm. diameter	5
Xylocarpus moluccensis	Sep - Nov	Yellow to brown fruit Floats in water	Weight of seeds > 30g.	10

than 5 years i.e. trees which are taller than 5-6 m. The viability period of the mangrove seeds is very short once they are taken out of water and hence they are to be planted immediately after collection (within 24 h). The salinity levels of the water that is used for nursery plays an important role in the germination and survival and hence, the saplings should be raised in low salinity initially (10 ppt).

Techniques in preparing the nursery

Soil

Muddy soil, which is clayey, should be used for preparing the nursery bags. The soft clayey mud could be collected from the mud flats during low tide. Mud from

nearby creeks can also be used to fill the polythene bags. Any debris or hard material should be removed before filling the bags with mud.

Table 9: Details of germination period, percentage of germination and average height of mangrove saplings, which can be used for transplantation

Species	Seed material	Germination Period	Germination Percentage	Average height after 8 months (cm)
Aegiceras corniculatum	Fruit	35	80	70
Avicennia marina	Fruit	6	95	75
Avicennia officinalis	Fruit	6	95	75
Bruguiera gymnorrhiza	Propagules	35	100	60
Excoecaria agallocha	Young seedling	-	60	60
Rhizophora apiculata	Propagules	40	100	70
Rhizophora mucronata	Propagules	40	100	80
Sonneratia apetala	Seed	30	20	80
Xylocarpus moluccensis	Seed	20	90	80

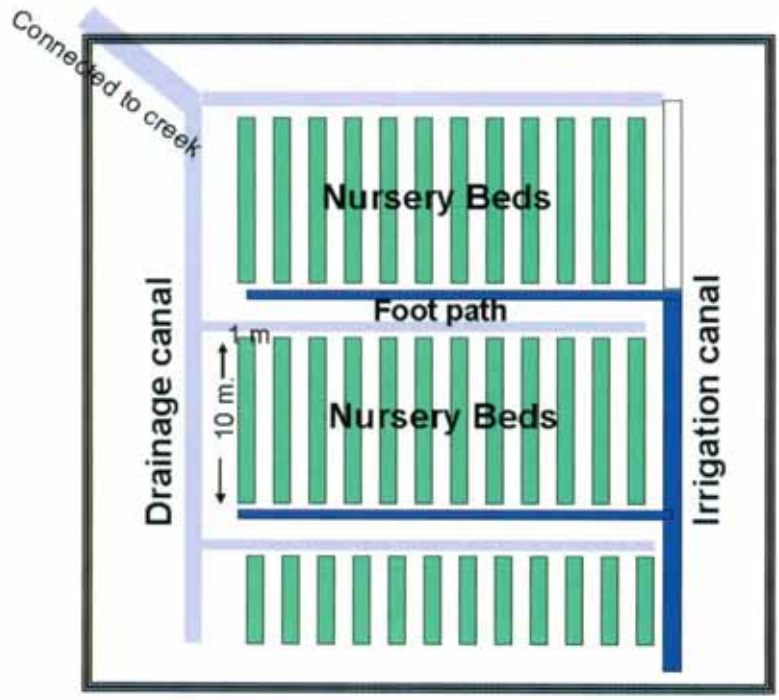


Fig. 13: Mangrove Nursery Layout

Nursery bags

Polythene bags of 5 inches x 8 inches should be used to raise the mangrove saplings in the nursery. Small holes should be made at the bottom of the bag in order to drain excess water. The filled bags should be kept in the shade to harden.

Preparation of nursery beds

In the mangrove nursery, sunken beds (each bed can hold 1500 bags) of 10m (length) x 1m (breadth) x 0.3 m (depth) should be prepared (Fig.13). Bamboo poles could be placed horizontally at both the ends and also in the middle to keep the bags intact. The nursery bags could be placed inside the beds, and should be flooded to a depth of about 10 cm. The nursery sites and beds may be prepared according to the number of seedlings. Care should be taken to provide facilities for inflow and outflow of water, otherwise water stagnation would lead to causalities.

Sowing

Propagules of *Rhizophora apiculata, Rhizophora mucronata* and *Bruguiera gymnorrhiza* could be planted directly in the bags placed in the beds. Similarly, wildlings (about 2" height) of *Excoecaria agallocha* and seedlings of *Sonneratia apetala* from the primary bed could be planted directly in the bags. However, the seeds of *Avicennia marina, Avicennia officinalis* and *Xylocarpus moluccensis* should be sown in bags kept outside and then transported to the nursery bed after germination.

The sapling bags should be shifted periodically to prevent rooting into the soil. The seedlings should be periodically checked for pest or woodborer damage as the sprouting seeds/propagules are susceptible to caterpillar damage. Seedlings with pest attack should be removed. Water from the beds should be drained completely before applying the pesticide in order to avoid the spread of pesticide residue to other areas.

Nursery techniques for different species

Nursery techniques differ from one species to another, depending on the salt tolerance level and the ecological zone. In the following pages, guidelines that should be followed for each species are described. Comprehensive details are given in Table 10.

1.0 Aegiceras corniculatum (L.) Blanto

Local Name: Guggilam (Telugu), Khrasi (Oriya), Narikandal (Tamil), Khalsi (Bengali)

Collection of seeds

Healthy and mature seeds should be collected from the trees. The mature seeds

can be easily identified by the yellow or greenish-yellow colour of the seed coat. As in the case of *Avicennia*, the seeds should be planted in polythene bags directly. While storing the seeds, they should be kept in the shade for two to five days.

Sowing into nursery bags

The calyx region of the fruit should be inserted to a depth of about one third of the length of the fruit. After the germination of the seedlings, they should be transported to the beds and watered. Polythene bags filled with mud should be kept ready.

Specifications for selection of seedlings

The recommended specifications of the seedlings are as follows:

Height	:	50 cm
No. of leaves	:	at least 10
Period	:	8 months

2.0 Avicennia marina (Forsk.) Vierh.

Local Name: *Tella Mada* (Telugu), *Singal Bani* (Oriya), *Venkandal* (Tamil), *Peyara-ban, bain, bani* (Bengali)

3.0 Avicennia officinalis L.

Local Name: *Nalla Mada* (Telugu), *Bani* (Oriya), *Karukandal* (Tamil), *Jat-ban, bain, bani* (Bengali)

Collection and treatment of *Avicennia* seeds

Healthy and mature seeds of *Avicennia marina* and *A. officinalis* should be collected

Table 10: Details of nursery techniques for different species

Species	Nursing	
	Watering	Pests
Aegiceras corniculatum	Fully once a day	Crabs caterpillars
Avicennia marina	Fully once a day	Crabs caterpillars
Avicennia officinalis	Fully once a day	Crabs caterpillars
Bruguiera gymnorrhiza	At neap tide	-
Excoecaria agallocha	Fully once a day	Crabs caterpillars
Rhizophora apiculata	At neap tide	-
Rhizophora mucronata	At neap tide	-
Sonneratia apetala	Twice a day	Rats, Crabs, caterpillars
Xylocarpus moluccensis	Fully once a day	Crabs

separately. The mature seeds can be easily distinguished by observing the light yellowish colour of the seed coat with cracks on it.

Selection and processing of the seeds

Mature fruits should be selected and checked for insect borers. Seeds should be soaked in brackish water overnight to remove the seed coats. This treatment reduces the establishment time by two to three days. Only seeds without seed coats should be used for sowing in the polythene bags. Normally seeds must be planted in the polythene bags immediately after the removal of seed coats. In case of storing, the seeds should be kept in the shade for one or two days with seed coat.

Sowing into nursery bags

The polythene bags with soil must be allowed to harden by placing them outside the beds. After hardening, the polythene bags containing mud should be watered. The radicle part of the seeds must be gently pushed (1/3 of the seed) inside the soft mud. Deeply buried seeds will not germinate and will rot.

Watering

During the initial stages, water should be sprinkled twice, using rose-water cans. After germination, the polythene bags should be transported to the beds and watered through canals.

Pest control

During the sprouting stages, crabs damage young seedlings. These damaged seedlings should be replaced with fresh seed / seedlings. Caterpillars are the major pests for *Avicennia* and when the attack is severe, neem based pesticide can be used.

Grading

To ensure raising of healthy seedlings, casualties should be replaced with seeds/ seedlings. The seedlings from the beds must be shifted periodically for three months after sowing.

Specifications for selection of seedlings

The recommended specifications of the seedlings are as follows:

Height	:	50 cm
No. of leaves	:	at least 12
Period	:	8 months

4.0 Bruguiera gymnorrhiza (L.) Savigny

Local Name: *Kandriga* (Telugu), *Bandari* (Oriya), *Kakra* (Bengali)

Collection of propagules

Healthy and mature propagules should be collected in the creeks with the help of fishing nets. The characteristic and visible indicator of mature propagules of *Bruguiera gymnorrhiza* is the reddish brown or greenish red colour of the hypocotyle.

Selection of propagules

Mature propagules should be selected and checked for insect borers. The propagules should then be planted in the polythene bags placed in the beds. In case the propagules have to be stored, they should be kept in the shade for one or two days, without exposing them to direct sunlight.

Sowing into nursery bags

The hypocotyl of the propagules should be inserted to a depth of about 4 to 5 cm. Polythene bags filled with mud should be kept ready.

Specifications for selection of seedlings

The recommended specifications of the ideal seedlings for planting are as follows:

Height	:	50 cm
No. of leaves	:	at least 6
Period	:	8 months

5.0 Excoecaria agallocha L.

Local Name: *Thilla* (Telugu), *Guan* (Oriya), *Tillai* (Tamil), *Gneoa* (Bengali)

Collection of wildlings

Wildlings could be collected from the mangrove forest and used as planting material. These wildlings should be collected in the morning and planted in the nursery bed on the same day, as early as possible.

Specifications for selection of seedlings

The recommended specifications of the seedlings for plantation are as follows:

Height	:	40 cm
No. of leaves	:	at least 12 to 14
Period	:	8 months

6.0 Rhizophora apiculata Bl. **and** ***7.0 Rhizophora mucronata*** Lamk.

Local Name: *Ponna* (Telugu), Raai (*Oriya*), *Surapunnai* (Tamil), *Garjan* (Bengali)

Collection of propagules

Healthy and mature propagules should be collected from the tidal creeks, using fishing nets. Characteristic indicators of mature propagules of *Rhizophora mucronata*

are pale green or yellow cotyledon and green hypocotyle. Propagules of *Rhizophora apiculata* have red or yellow cotyledons. Propagules of *Rhizophora mucronata* are bigger than *Rhizophora apiculata.*

Selection of propagules

Healthy propagules should be selected and checked for insect borers. The propagules should then be planted immediately in the polythene bags placed in the beds. In case of storing, the seeds should be kept in the shade for one or two days, without being exposed to direct sunlight.

Sowing into nursery bags

The hypocotyl of the propagule should be inserted to a depth of about one third of the length. Small sticks are to be tied to the hypocotyl for providing support. Polythene bags filled with mud should be kept ready.

Watering

Watering is to be done daily through the canals.

Grading

Initially, the casualties should be replaced with propagules. The seedlings from the beds should be shifted periodically for a period of three months after sowing.

Specifications for selection of seedlings

The recommended specifications of the seedlings are as follows:

Height	:	60 cm.
No. of leaves	:	at least 8
Period	:	8 months

8.0 Sonneratia apetala Buch. - Ham

Local Name: *Kalinga* (Telugu), *Keruan* (Oriya), *Marama maram* (Tamil), *Keora* (Bengali)

Collection of fruits

Healthy and mature fruits should be collected from the trees. The characteristic indicators of mature fruits are deep green colour and sour taste of the mesocarp.

Collection of seeds from fruits and sowing

The mature, healthy fruits can be collected during September and October from the trees located near the creeks and river mouth. The fruits should be kept in gunny bags for 15 days, to allow the fleshy mesocarp of the fruits to rot. The fruits should then be gently crushed and the seeds, along with debris, sown in a primary bed. Periodical watering through canals is necessary. After 20 to 30 days, the seeds will start sprouting.

Transplanting of young seedlings

Young seedlings of 30 days old should be transplanted from the primary bed to the polythene bags and kept in beds. Polythene bags filled with mud should be kept ready.

Specifications for selection of seedlings

The recommended specifications of the seedlings are as follows:

Height	:	50 cm
No. of leaves	:	at least 6
Period	:	8 months

9.0 Xylocarpus moluccensis (Lamk.) M. Roem.

Local Name: *Senuga* (Telugu), *Pitamari* (Oriya), *Komandry* (Tamil), *Pasur* (Bengali)

Collection of fruits and seeds

Healthy and mature fruits should be collected from the trees. The characteristic indicators of mature fruits are yellow colour and a cracked pericarp. The seeds should be removed from the fruits. The seeds available in the creeks can be harvested with fishing nets. The seeds should be checked for insect / pest attack before planting.

Sowing into nursery bags

Polythene bags containing hardened mud should be sprinkled with water. The radicle side of the seeds should be placed gently in the polythene bags, ensuring that the mud is soft. Polythene bags filled with mud should be kept ready.

Transporting of young seedlings to beds

Young seedlings of about ten days old should then be transferred to the nursery beds.

Specifications for selection of seedlings

The recommended specifications of the seedlings for planting are as follows:

Height	:	50 cm
No. of leaves	:	at least 12 to 14
Period	:	8 months

Role of nurseries in participatory management

In participatory management the local community should be sufficiently involved and made to own the resources. In this regard, the community mangrove nurseries would help in the long term management of mangrove forest. As a first step, fisherwomen and men and members of self help groups living in and nearby mangrove wetlands should be trained in nursery raising techniques. The saplings thus raised by them could be purchased and planted in the restoration and afforestation areas which provides alternative employment and income generation.

Part II
Non-Mangrove Bioshield

Part II
3.1 Non-mangrove: An overview

Non-mangrove bioshield along the coastal zone is popularly known as shelterbelts. Shelterbelts are strips of vegetation composed of trees and shrubs grown along the coasts to protect coastal areas from high velocity winds and also from devastations like the ones caused by recent Tsunami. They also serve the purpose of sand binders and prevent sand erosion. Shelterbelts are also promoted as a means of reducing wind speed and ameliorating the local microclimate. High wind speeds lead to chilling of livestock and physical damage to crops through abrasion, drying and wind throw. Well-placed and well-managed shelterbelts or bioshields can therefore be used to increase agricultural productivity (Table 11). Bioshields can also serve as a source of livelihood to the local communities if designed with that of view. Choice and mix of species should be decided based on the height and depth of bioshield required to make it effective at the proposed site. If commercial species are an option, with some management (e.g. pruning and thinning), the bioshield can be sold for timber when it has reached the end of its working life. The income will often be more than enough to pay for the replanting of the bioshield.

Table 11: Benefits of bioshields for agriculture

Animals	Crops	Other
Reduced stock losses during breeding	Less soil erosion and nutrient loss	Protection for buildings and work areas
Reduced energy for maintenance	Conservation of soil water	Reduced evaporation from dams
Less winter feed requirements	Reduced need for irrigation	Assist in grass fire control
Faster growth to target weight	Extended growing season	Habitat for wildlife and predatory birds/insects
Reduced physical damage		

In India, since 1970 the state forest departments have been raising shelterbelts in the coastal areas. The forest department has mastered the technique of raising shelterbelts, in which casuarina was extensively used. The massive shelterbelt raised by the Tamil Nadu Forest Department for a distance of about 12 km from Pudhupattinam to Thirumullaivayal in the coastal areas of Nagapattinam District

can be considered as a proven model casuarina shelterbelt. The maximum and minimum width of this shelterbelt is about 1550 and 150m respectively. Raising of this shelterbelt started in 1978, immediately after a severe cyclone hit this coastal stretch in 1977. During the recent tsunami it played a critical role in mitigating the impact along with other factors such as the proximity of villages to the sea and elevation at which villages were located.

Compositions of shelterbelts

The difference in the proposed shelterbelt from the regular shelterbelt is that along with casuarina other ecologically and economically important species can also be grown taking into account the biophysical condition and available breadth and width of the area selected for raising shelterbelts. It is recommended to include coastal plant species of economical value to generate income to the local community who will be involved in the bioshield movement.

Characteristics of plant species for multi-species shelterbelts

Properly established multi-species shelterbelts should be dense in their lower part and more open in the middle and upper parts. While choosing species for raising multi-species shelterbelts, the following criteria should be considered

- The species should have a deep and well-spread root system.
- It must have a small crown and light branching habit
- It must be wind resistant
- It should be easy to propagate and maintain
- It should be able to coppice
- Could provide economic benefit to local communities with food, fodder, etc.

Pointers for establishing bioshields

The bioshield strips should be more or less perpendicular to the main wind direction. The number of rows in the strips largely depends on the velocity of the wind. The higher the velocity of the wind, the broader the strips should be. Usually, a strip for bioshield may contain 1-5 rows of vegetation as given in the figure below. The first and last rows should be planted mainly with shrubs and the central rows should be with a combination of tall and medium-sized trees. Triangular method or V shaped method at 1-meter distance between tree/shrubs can be used. If necessary, space between the plants may be reduced.

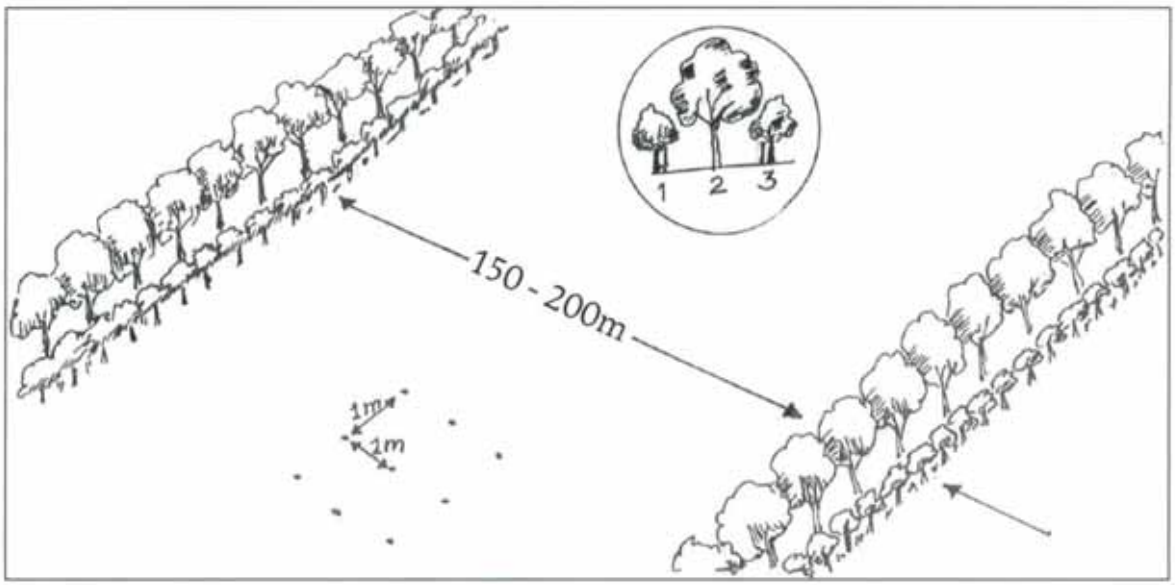


Fig.14: Diagrammatic view of a bioshield

What are the ecological benefits of multi-species shelterbelts?

- Protection from soil erosion by reducing the wind velocity
- The water loss due to evaporation of the soil moisture is greatly reduced.
- Bioshields arrest the force of the blowing wind during cyclones and protects against the entry of seawater into the main land during cyclones and tsunami.

What are the livelihood benefits of multi-species shelterbelts?

The biomass benefits in the form of firewood, fencing material, construction material, fruits, fodder, etc. could accrue to the community if the multi-species shelterbelts are developed jointly with the local community and are taken proper care by the community. Before starting the multi-species shelterbelts activity, local community should be involved and made partners, which will ensure proper care of the multi-species shelterbelts and livelihood benefit to the community.

Bioshields as sources for carbon sequestration

Properly raised bioshields will also serve the purpose of sequestering carbon. The bioshields can be used to derive benefits of carbon sequestration using the Kyoto protocol for sustainable management of bioshields.

3.2 Common plants in bioshields

The plant species are chosen with the twin goal of raising the bioshields and deriving livelihood benefits to the local communities. Following plant species could be commonly raised in Bioshields.

Brief description for identification and uses of plants recommended for bioshields

***Anacardium occidentale* L.** **ANACARDIACEAE**

***Local Names*:** Kaju (Hindi); Jeedi Mamidi (Telugu); Mundhiri (Tamil); Cashew nut tree (English)

Trees, evergreen up to 6 m tall. The canopy has a spread area of about 5 - 10 metres. Leaves simple, alternate, obovate-elliptic, glabrous, base attenuate, apex obtuse. Flowers yellow with pink streaks, fragrant in terminal panicles. Nuts reniform, seated on fleshy pedicel.

Uses: Fleshy pedicel and roasted kernel edible.

***Flowering and fruiting*:** February - May.

***Azadirachta indica* A. Juss.** **MELIACEAE**

***Local names*:** Nim, Nimb (Hindi); Vepa (Telugu); Vembu (Tamil); Neem tree (English)

Trees, up to 12 m tall. Leaves simple pinnate; leaflets lanceolate, serrate, base oblique, apex acuminate. Flowers white, fragrant in axillary panicles. Drupes 1-seeded, yellow.

***Uses*:** Tender leaves and inflorescence along with jaggery (*Saccharum officinarum*) consumed as a vegetable. Tender twigs used as toothbrush. Leaves fumigated as a mosquito repellant. Leaf bits put into granaries as an insect repellent. Wood used for house building. Leaf twigs kept in house premises to keep off evil spirits. Leaf twigs and branches used in religious rituals and ceremonies. Local communities worship the tree.

***Flowering and Fruiting*:** February - July

***Bambusa arundinacea* (Retz.) Roxb.** **POACEAE**

***Local names*:** Kanta bans (Hindi); Mulla Veduru or Mulla bongu (Telugu);

Mullu Mungil, Periya Mungil (Tamil); Spiny or Thorny bamboo (English)

A long thorny bamboo, up to 40 m tall green or purplish green when young, turning to golden yellow when it matures.

Uses: Poles used in house construction, basket and mat weaving, highly useful in cottage industries and handicrafts. Poles used by fishermen in fishing.

Flowering and Fruiting: Once in 30 or 45 or 60 years

Bixa orellina L. — BIXACEAE

Local names: Lotpan, Senduria (Hindi); Jafra (Telugu), Varagu manjal (Tamil); Lipstick tree, Saffron (English)

Shrubs or small trees. Leaves simple. Flowers white or purplish in color. Fruits in capsules, reddish brown in color.

Uses: Seeds as a source of natural dye. Used in dye industries

Flowering and Fruiting: September – November; December - February.

Borassus flabellifer L. — ARECACEAE

Local names: Tad, Tal, Tar-ka-jhar (Hindi); Thati (Telugu); Panai (Tamil); Palm tree (English)

Trees, dioecious, up to 20 m tall; trunk greyish-black. Leaves palmatifid, base sheathing. Peduncles sheathed with spathes. Drupes subglobose, black when ripe.

Uses: Toddy tapped from the inflorescence. Boiled primary root, tender kernel and fruit pulp edible. Trunks from 50 to 60 year old trees used for house building. Leaves used for thatching, making baskets, mats and umbrellas. Fiber from petiole used for making ropes.

Flowering and Fruiting: February; May.

Cassia fistula L. — CAESALPINIACEAE

Local names: Amaltas, Bandarlauri (Hindi); Rela (Telugu); Aavaram, Arakkuvadam (Tamil); Indian Laburnum (English)

Trees, up to 5 m tall; bark rough, dark brown. Leaves pinnate; leaflets opposite, ovate or ovate-oblong, base cuneate, apex acute. Flowers yellow, in axillary lax racemes. Fruits indehiscent, terete, brownish-black.

Uses: Inflorescence used as vegetable. And also kept along with unripened mangoes for quick ripening. Bark used for extraction of dye. Wood used for making agricultural implements.

Flowering and Fruiting: April - September.

Casuarina equisetifolia Forst. — CASUARINACEAE

Local names: Jangli saru (Hindi); Sarugudu (Telugu); Savukku (Tamil); Horse tail tree (English)

Tall trees up to 40 to 60 ft. Leaves in whorls of 6 to 8.

Uses: Poles used in scaffolding, fuel and construction material. Fishermen use them as fishing poles. A good bioshield plant.

***Flowering* (twice a year):** February-April and September - October
***Fruiting*:** June and July - December.

Clerodendrum serratum (L.) Moon — VERBENACEAE

Local names: Ciruteku (Telugu), Vadamadakki (Tamil)

Shrubs, up to 2 m tall; stems 4-angled. Leaves oblong-elliptic, coarsely serrate, apex acute. Flowers bluish-purple, in long pyramidal panicles. Drupes broadly obovoid, black.

Uses: Roots as well as the leaf twigs boiled in water and the water used for bathing for rheumatic pains.

Flowering and Fruiting: May - September.

Cocos nucifera L. — PALMAE

Local names: Nariyal (Hindi); Kobbera or Tenkaya (Telugu); Thennai maram (Tamil); Coconut (English)

Tall trees, up to 40 to 80 ft. Leaves up to 15 ft. long. Fruit green or yellowish.

Uses: Trunks used in house construction. Leaves used for thatching. Toddy obtained. Fruit edible and is a source of cooking oil. Coir used in micro-enterprises.

Flowering and Fruiting: Throughout the year

Hibiscus tiliaceus L. — MALVACEAE

Local names: Bola, Chelwa (Hindi); Attakanara (Telugu); Neer-Parutthi, Atthu Puvarasu (Tamil); Coast cotton tree (English)

Trees up to 4 meters tall; stems much branched, glabrous, close to ground level. Leaves, orbicular crenulate, stellate beneath, acute or acuminate at apex, cordate at base; stipules 2-3 cm long, subulate. Flowers 7-10 cm across, campanulate, bright yellow with crimson eye in the centre, turning bright purple when old, solitary or

rarely two, on terminal peduncles; bracteoles 5-6, lanceolate. Capsules 3-5 cm across, ovoid, closely tomentose, splitting into 5 mericarps. Seeds black with pale dots.

Flowering and Fruiting: June - July

Pongamia pinnata L. — FABACEAE

Local names: Karanj, Karanja (Hindi); Kaanuga (Telugu); Pungam (Tamil); Indian Beach tree (English)

Trees, up to 5m tall; bark soft, greyish-green. Leaves imparipinnate; leaflets opposite, ovate-oblong, entire, base rounded or acute, apex acuminate. Flowers white or pale rose, in axillary racemes. Pods obliquely oblong, compressed, 1-seeded.

Uses: Seed oil warmed and applied for skin diseases. Seed oil widely tried for bio-fuel

Flowering and Fruiting: March-August.

Salvadora persica L. — SALVADORACEAE

Local Names: Jhak, Kharjal (Hindi); Varagogu (Telugu); Kalawa (Tamil); Tooth Brush Tree (English)

Much branched, evergreen shrub or small tree. Leaf: elliptic ovate and slightly succulent. Flower: greenish white or greenish yellow. Fruits: red when ripe.

Uses: Grows in wide range of soils; stem used as tooth brush, leaves used for asthma and cough. Fruit: sweet and edible.

Sapindus emarginatus Vahl — SAPINDACEAE

Local names: Retha (Hindi); Kunkudu (Telugu); Bunthikottai, Puvamkottai (Tamil); Soap nut (English)

Trees, up to 10 m tall. Leaves paripinnate; leaflets coriaceous, elliptic obovate or oblong, entire, apex emarginate. Flowers brownish-yellow, in terminal panicles. Drupes ovoid, 3-lobed.

Uses: Fruit juice mixed with water, used as hair wash; fruits sold in market.

Flowering and Fruiting: September - March.

Thespesia populneoides (Roxb.) Kostel. — MALVACEAE

Local names: Parsipu, Gajadanda (Hindi); Gangaraavi (Telugu); Poovarasam (Tamil); Indian Tulip tree (English)

Trees, 3 - 6 m tall, young twigs covered with bronze-coloured lepidotes. Leaves deltoid to cordate or subcordate; stipules early caducous. Flowers yellow, red in centre,

axially, solitary, recurved in fruits. Capsules 3 - 4 cm across, globes, exude deep yellow latex when young, mature fruits dehiscing apically into two distinct layers.

Uses: Fruits and flowers yield yellow dye, which are useful for coloring the cloths.

Flowering and Fruiting: June - July

Vitex negundo L. VERBENACEAE

Local names: Sambhalu (Hindi); Vaayila (Telugu); Nochi (Tamil)

Shrubs, up to 3 m tall; bark thin, grey. Leaves 3-5 foliolate; leaflets elliptic-lanceolate or lanceolate, entire, glabrous above, white tomentose beneath, base acute, apex acuminate. Flowers blush-purple, in terminal panicles. Drupes subglobose, black when ripe.

Uses: Leaf twigs put in hot water and taken bath for rheumatic pains.

Flowering and Fruiting: Throughout the year. Common; along hedges and waste places.

3.3 Nursery practices

Nursery practices for commonly used shelterbelt species such as casuarina is well established by the respective State Forest Departments. The Forest Department can be approached both for getting the saplings as well as training in raising and establishing nurseries for shelterbelts. The multi-species shelterbelts being proposed after the tsunami are included with the component of livelihood enhancement of the local communities. In this respect nursery practices for some of the commercially important species such as coconut have been standardized by the Agriculture Department and they can be approached for saplings and getting training in establishing nurseries.

The multi-species shelterbelts nursery practices vary from species to species depending on their characteristics. The main aim of the nursery is to get healthy seedlings, which are capable of establishing well in the plantation. Generally, the nursery practices have two phases.

- Germination of seed
- Tending the seedlings in the containers/ secondary bed

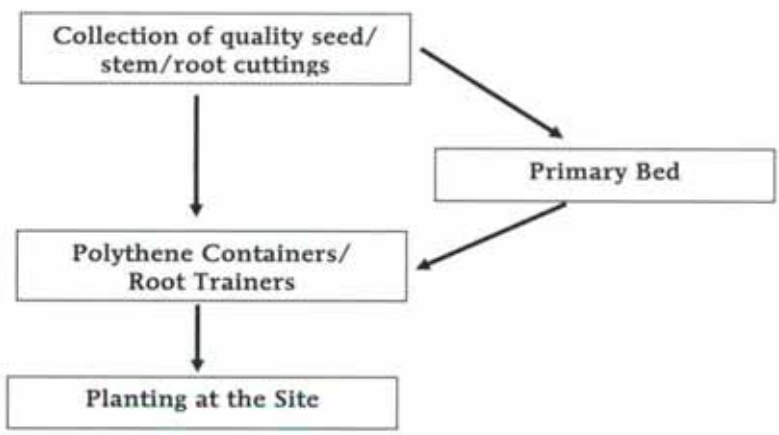


Fig. 15: Different stages of establishing mangrove nurseries

Nursery Site

Nursery site plays an important role in afforestation. The topography of the selected nursery sites should be flat or gently sloping. The soil also should be loamy. The following should be the important criteria while selecting nursery site.

- The site should have easy access and must be convenient for transporting the seedlings to the planting site.
- Good water source such as well, stream, river or pond with pumping facility should be available or made available in the site for watering the saplings.

Size of the nursery and Site preparation

The size of the nursery should be decided dependent on the saplings requirement and the area to be planted. The site should be cleared and the site could preferably be ploughed. Stones and stumps should be removed and the area should be levelled.

Soil preparation

The soil used is a mixture of loamy soil (earth), river sand and farmyard manure (FYM) in the ratio of 6:3:1. Vermi-compost could be used but the undecomposed manure should not be used as it attracts termites and grubs. Inorganic fertilizers can also be used but the quantity has to be determined carefully and it will vary with the age and the species grown in the nursery. However, dilute spray of these fertilizers and the vermi-wash help in getting healthy saplings.

Preparation of Primary Bed

Normally primary bed is prepared for small seeds like *Casuarina*. These primary beds are usually 1.25 metres in width but the length may be decided given the area of the nursery. The working space of about 0.5 metres should be created to carry out the nursery operations like watering, weeding etc. The soil is mixed with the farmyard manure before sowing the seeds. The seeds should be covered with soil to a proper depth, normally equal to the diameter of the seed. Large seeds like the cashew could be directly sown in poly bags. Pretreatment of seeds may be required for a few species before sowing.

Time of Sowing

Seeds for raising the potted plants are normally grown between January and March. While sowing in summer, the top layer of the seedbed should be soaked well before the sowing operation starts.

Container Plants/ Poly bags

Saplings are grown in container (poly tubes) and poly bags in order to produce hardened saplings and ensure sufficient supply during the plating season. Poly bags/ poly tubes are to be filled with mixture of good quality soil, sand and the farmyard manure in the ratio of 2:1:1 or 1:1:1. The mixture should be sieved with a sieve of 2 mm size to remove stones and clods. If needed, inorganic fertilizers like

NPK (2 kg / cubic metre of the soil) can be added before filling the soil mixture in the bags. The seedlings from the primary bed are transplanted to the polythene bags/ poly tubes.

Transplanting

The young seedlings from the primary bed are to be transplanted into the poly bags / poly tubes containing the soil mixture, which is wet (saturated with water). Small hole in the middle portion of the bag has to be made and the root up to the collar should be inserted. Soil can be heaped around the seedling to cover the vacant space. The plants should be watered and kept in shade for a day to recover. Then the saplings can be arranged in open / shaded places according to the requirement.

Shading

Shading can be provided to some species like *Eucalyptus*. The shading should be provided more for the young seedlings and gradually the shading should be reduced in order to harden the plant.

Grading

The seedling can be graded according to its height. More attention should be paid to smaller saplings that can be done by keeping them separately. This helps to get good quality saplings for planting. The weak saplings can be planted later in the cycle or in the next planting season after giving sufficient hardening treatment.

Hardening of seedlings

The nursery saplings must be hardened before planting. This will help the saplings to survive better after planting. Normally in this process the watering should be gradually reduced from daily to once in a week. This helps to develop better roots and the base of the seedlings become stronger. It has been noticed that the hardened saplings have better survival rate.

Pest Control

Termites, grasshoppers, nematodes and caterpillars are some of the pests that damage the seedlings in the nursery. Care should be taken to control these pests in the early stages using neem extract or other biopesticides available in the market.

Calendar of operations

Calendar with definite time sequence should be prepared so that all the activities are handled within the stipulated timeframe. This will ensure better survival rate and hence saves time, money and energy.

Nursery Practices for individual species

In this chapter an outline of the nursery practices for some suggested species for multipurpose shelterbelts is given. For further information State Forest Department, Horticulture Department and Agriculture Department can be approached. In addition, enterprising farmers who have developed private nurseries can be approached.

Anacardium occidentale

The seeds could be collected from selected high yielding trees. The seeds should be sown in polythene bags with the stalk end upwards. Germination will take 15 – 25 days and the saplings could be planted after 4 to 6 weeks after having been raised in the nursery. Sapling should be raised in the nursery before 2 months of planting.

Azadirachta indica

The seeds could be collected from ripe fruits either from the tree or from the ground under the tree. The seeds should be sown within 10 days in poly bags of 10 cm X 15 cm. The seeds lose their viability if sown very late after collecting from the fruits. Nursery can be raised during the onset of the rainy season and the plantation could be done later. Though it can be easily raised through nurseries, plantations with direct sowing of seeds proved to yield better results. The seedlings should be changed to bigger bags (20 cm X 30 cm) after three months of sowing. The saplings should be grown for another eight months; during that period the saplings will attain a height of 1 m.

Bambusa arundinacea

Seeds could be collected from the panicles and sown in nursery and should be grown for nine months. Germination period is normally 12 to 15 days. About 30 – 60 % of seeds will germinate. The seeds should be soaked in water for at least 12 hours before sowing. Vegetative propagation through stem/rhizome cutting is also possible.

Bixa orellina

The seeds should be soaked in cold water for 24 hrs. Then they should be either sown directly into the polythene bags or in primary beds during June - July. The seedlings should be kept in the nursery for 4-5 months before planting.

Cassia fistula

The seeds could be obtained by breaking the pods, which can be collected form the ground. The germination period is between 6 and 52 days and about 20 – 50 % of the seeds will germinate. The seeds need pre-treatments such as soaking in sulphuric acid or boiling water for 5 minutes or stratified or must be scarified to remove the seed coat. The seeds should be sown 25 cm apart in the prepared seedbeds and regularly

watered. The seedlings are indifferent to shade or open conditions in the nursery. Saplings should be in the nursery for at least 1 - 2 years and the sapling height should be 20 - 30 cm while planting.

Casuarina equisetifolia

Seeds could be collected from trees, which are 10-15 year old. The old trees provide good viable seeds. The ripe cones could be collected from the trees. They should be spread in the shade and covered with gunny bags. After 3 - 4 days the cones will open and brown seeds with light yellow wings could be collected and used immediately. If the seeds should be stored, they should be mixed with ash and stored in earthen pots for about 2 months. Seeds will germinate in 10 -20 days. The germinated seedlings could be transplanted into polythene bags and should be grown in the nursery for 5 - 6 months.

Cocos nucifera

Fully matured nuts should be selected and sown 30 cm apart (center to center) in raised nursery beds. Germination period is between 3 - 6 months and the saplings should be grown for 12 - 18 months.

Pongamia pinnata

The pods are generally collected between March and May and the seeds should be sown within a month to have better survival. The root/stem cuttings could also be used for raising plantations.

Salvadora persica

Seeds collected from trees could be used for raising the nursery. Since it is slow growing plant, the saplings have to be raised for at least 3 years in the nursery before planting.

Sapindus emarginatus

The seeds should be collected from better yielding trees.The seeds collected from the fruits should be immersed in hot water for 5 minutes and then soaked in cold water for 48 hrs to hasten the process of germination. The saplings should be grown in the nursery for 8 - 9 months (about 30 to 40 cm).

Thespesia populneoides

Seeds should be collected from healthy trees for growing in the nurseries. The germination of the seeds ranges from 30 - 60%. They also could be regenerated through stem cuttings but propagation through seed has advantage of getting knot-free straight poles, which will be useful as timber.

3.4 Planting methods

General Rules for Planting

- Before rains set in, the seedlings should be lifted carefully from the nursery to the plantation site.
- The polythene bag should be cut open and the seedling along with the sod of earth should be planted.
- The empty poly tubes or poly bags should be removed from the site.
- The tall seedlings should be planted in the dry areas.
- The soil round the plant should be carefully pressed down to bring it in close contact with the roots.
- The collar of the seedling should be in the same position while planting as in the nursery.
- Centre of the pit should be slightly elevated.
- Planting should be done preferably in the morning.

Preparation of the Planting site

The usual spacing for all plants in the bioshields is 2.5 m x 2.5 m. However, in the *Casuarina* plantation grown for the bioshields, the espacement should be 1.5 x 1.5 m for the first 20 rows from the sea and 2 x 2 m for the next 60 rows.

Number of saplings planted with different spacing in 1 ha. is given below.

Spacing	Plants per hectare
1.5 m x 1.5 m	4360
2.0 m x 2.0 m	2500
2.5 m x 2.5 m	1600
3.0 m x 3.0 m	1111
5.0 m x 5.0 m	400
6.0 m x 6.0 m	278
8.0 m x 8.0 m	156

Pitting

Pits should be wide and deep enough to hold the ball of the earth in the polythene bag holding the seedling. Pitting should be dug at the time of planting and not before since sand will collapse.

Transporting of nursery stock to the planting site and planting of saplings

Light wooden or wire trays are available for transporting the saplings to the planting sites. The ball of the earth should not be broken while transporting. While planting *Casuarina* and other species water should be provided immediately if there is no rain. Watering should be continued once in 4 days if there is no rain.

Replacing the causalities

The entire plantation area should be examined for causality. They should be replaced and normally it will be combined with first weeding. Healthy and good quality seedlings should be used for causality replacement.

Manuring

Organic manures can be applied while filling the pit along with the soil. However, while applying inorganic fertilizers, care should be taken to avoid direct contact of the salts with the plant especially the root portion. Always watering should be followed immediately after adding the inorganic fertilizer. Only super phosphate, muriate of potash, and magnesium sulphate should be added for *Casuarina* plantation.

Watering and Fencing

Plantations raised on the sand should be watered weekly during summer up to 2 years. Live hedges could be used for fencing. Species like *Acacia nilotica, Jatropha, Agave* are some of the live fencing which will be effective and long lasting.

Planting methods for individual species

Anacardium occidentale

Pits of 0.3 cubic meters should be dug and the nursery-raised saplings should be planted during the commencement of monsoon. Either 8 m x 8 m or 10 m x 10 m espacement should be followed for this species. Casuality replacement and proper care should be taken of the plantation. The trees will start bearing fruits from fifth year onwards.

Azadirachta indica

The nursery raised saplings as well as seeds could be used for raising plantation. The pits measuring 0.3 cubic metre should be dug at an interval of 5m X 5m. The saplings along with the soil should be planted. Watering during the initial stages of planting and in summer for the first 2 years is a must and helps in successful establishment of the plantation.

Bambusa arundinacea

Pits of 60 cm x 30 cm x 30 cm dimension should be dug at an interval of 8 m x 8 m or 10 m x 7 m. These saplings should be transplanted in the pits during the monsoon season. Adding ammonium sulphate or calcium ammonium nitrate (200 gms.) and super phosphate (200 gms.) would enhance the growth of the saplings. Intercropping could be done with a row of subabul or Eucalyptus in the middle.

Bixa orellina

The nursery-raised saplings should be planted at an espacement of 4 m x 4 m. Pits of 0.30 cubic meters should be dug and the sapling along with the mud should be planted. Watering should be provided during summer months during the first year.

Borassus flabellifer

Direct sowing of seeds in the early monsoon season could help in establishment of plantation. It requires very little attention. It can be cultivated on every type of wasteland.

Cassia fistula

Planting is done by either direct sowing or through nursery-raised saplings or stump planting. Root suckers could also be used for regeneration. Saplings should be in the nursery for at least 1 - 2 years and the sapling height should be 20 - 30 cm while planting. Pits of 0.30 cubic meters should be dug and the sapling along with the mud should be planted with an espacement of 6 m x 6 m. The seedlings are sensitive to weeds and hence weeding is very important. Roots suckers could also be used for regeneration.

Casuarina equisetifolia

Small pits of 0.3 cubic meters should be dug and the sapling should be planted at 1x 1 or 2 x 2 m interval. Intercropping with groundnut or pulses is normally practiced. Irrigation is required in the first year.

Cocos nucifera

One cubic meter pits with an interval of 7 - 9 m should be dug and the dugout soil should be mixed with organic manure. The sapling is planted and mulched. Manuring and watering are important for sustainable yield.

Hibiscus tiliaceus

Seeds and cuttings could be used for raising planting material

Pongamia pinnata

The trees are grown in variety of soils ranging from sandy to black cotton soil. But they establish very well in properly-drained alluvium soils. The seeds could be directly sown or nursery raised saplings could be used to raise the plantation. One-year-old saplings should be planted in 0.3 cubic meter pits with an interval of 5 m X 5 m.

Salvadora persica

The saplings should be planted at an interval of 5 m x 5 m. The pits should be dug for 0.3 cubic meters.

Sapindus emarginatus

Pits measuring about 0.30 cubic meters should be dug at an interval of 6 m x 6 m. The saplings should be planted during the onset of the monsoon and if required watering should be done in summer for the first year.

Thespesia populneoides

Nursery raised saplings grown for 6 - 8 months and stem cuttings could be planted. The pits should be dug with the dimension of about 0.30 cubic meters. Saplings should be planted at an interval of 5 m x 5 m.

Vitex negundo

The stem cuttings and the root suckers could be used as planting material for raising the plantations.

Annexure I

Vegetative and micropropagation of mangroves and mangrove associate plants

1.0 Vegetative propagation

Introduction

Definition

Vegetative propagation is a method of producing plants identical in genotype with the mother plant. It is a method of producing large number of plants from the vegetative part of mother plant. Any part of the plant such as stem, leaf, propagule and root can be used to produce plants through vegetative propagation. It is an asexual method of propagation. The vegetative propagation forms an integral part of tree improvement programme. In this approach, the best planting stock with highest genetic equality can be obtained, which is not always possible with the sexually propagated progenies. Another advantage is that, by this technique, plants can be raised almost throughout the year and the palatable stock for some species can be obtained in shorter time that those raised through seeds.

Need for vegetative propagation

- Vast areas of coastal wetlands potential for mangrove growth could be covered with mangrove vegetation for domestic and commercial utility. To achieve this, large scale production of planting materials could be produced through vegetative propagation.
- In many mangrove ecosystems planting season does not coincide with the reproductive season of the mangrove plants and in such situations, vegetative propagation would be ideal to supply planting material round the year.
- Endangered species can be easily multiplied though vegetative propagation
- Propagation of sterile hybrids is possible mainly through vegetative propagation

Advantages and limitations of vegetative propagation

Advantages

- Single stock can provide large number of plants
- The clones offer the advantages of genetic uniformity
- Seedlings produced through vegetative propagation take lesser time to develop, therefore, it is normally quicker and cheaper
- Multiplication of desired hybrids is easier without loss of desirable genes
- Helps to utilize maximum genetic gain of potential species in a shortest time
- Commercialization of planting materials is made attractive

Disadvantages

- Only a few species are amenable for vegetative propagation
- Standardization of methodology is time consuming and sometimes expensive
- Vegetative propagation is easier with young rather than old trees

Types of Vegetative Propagation

Vegetative propagation consists of three major types namely, 1.Stem cutting. 2.Propagule cutting and 3. Air layering.

Stem cutting:

Production of saplings from stems and/or branches of plants is called vegetative propagation by stem cuttings. Stem and/or branches of plants cut into small pieces ranging from 12 to 20 cm in length with 3 to 5 or several nodes are known as "stem cuttings". Stem cuttings are divided into three categories namley, i) soft wood (tender branches), ii) semi-soft wood (intermediate of softwood and hardwood) and iii) hard wood (tertiary or secondary branches).

Propagule cutting

A propagule (hypocotyl) is a seed germinated in the mother tree itself. It is an unique feature of mangrove plants. A propagule contains different parts such as pedicel, fruit, collar and radicle. In a ripened propagule, plumules can be seen when the fruit is removed. Viviparous propagules are produced in all the Rhizophoraceae species of mangroves. The mature viviparous propagule (black or brown or mixture of both) can be collected from the mother tree and cut into small pieces of 2 to 7 cm. This is called "propagule cutting", which could be used for vegetative propagation.

Air layering

Air layering is another method of vegetative propagation popularly called as "Chinese Layering" . In this method, roots are produced in small branches by applying rood producing hormones and rooting media. This method can be followed for tertiary branches without much damage to the mother plant.

A. Vegetative propagation of species of Rhizophoraceae

The species under the family to Rihizophoraceae are one of the important compoenents in mangrove ecosystem. The genus *Rhizophora* encompasses evergreen trees having strong stilt roots and long propagules. The stilt roots of *Rhizophora* spread laterally and are buried deep in the mud, providing additional support to the tree. In view of this character, these trees are able to withstand high cyclones. Secondly, the root zones provide microhabitat for the juveniles of fish and prawn to grow. In the Pichavaram mangrove wetlands three species of *Rhizophora* namely, *Rhizophora*

apiculata, *Rhizophora apiculata* and a *Rhizophora* hybrid are present. Generally, the maternal and paternal parents of the sterile hybrids are *R. mucronata* and *R. apiculata* respectively.

Propagule cutting

Materials

Mature propagules, distilled water, solution to remove phenolics, growth hormones, refrigerator, knife, mist chamber, humidiffer and mud filled polythene bags.

Method

Step1. Collection of propagules

Collect mature propagules from the plus trees. Good propagules are fleshy, shining with red colored collar.

Step 2. Cutting of propagules

Cut the collected propagules into 2 to 5 cm pieces using a clean and sharp knife. The entire propagule can be used for cutting (Plate 1 A)

Step 3. Removal of phenolic compounds

Phenolics are a group of compounds present mostly in the bark and wood of almost all the mangrove species. Phenolics are essential compounds for the survival of mangrove plants in extreme environmental conditions, since they regulate growth and other physiological functions. However, in vegetative propagation they act as inhibitors in the formation of roots and shoots and hence, phenolics from propagule cuttings are to be removed before further processing.

The following method describes the preparation of solutions and treatment methods to remove the phenolic compounds. Removal of phenolic compounds involves short-term and long-term treatments

- **Preparation of stock solution:** Take 20 g of Sodium carbonate (Na_2CO_3) and 20g of Sodium tungstate ($Na_2WO_4.2H_2O$), dissolve successively in 80 ml distilled water and make up the final volume to 100 ml. It is a 20% stock solution
- **Preparation of working solution (10% and 5%):** Take 50 ml from the 20% stock solution and add 50ml of distilled water. This gives a 10% working solution. Take another 25ml of stock solution and add 75ml of distilled water. This gives a 25% working solution.
- **Sort-term treatment to remove phenolic compounds:** Take 10% solution in small cups. Keep the basal portion of the cuttings immersed in the solutions for 5 to 10 minutes. Wash the treated cuttings in distilled water two to three times. Now the propagule cutting is ready for hormone treatment.

Step 4. Hormone treatment

Hormone treatment is necessary to induce root formation. Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) are commonly used as root promoters. These promoters are a available in many of the agro shops in powder form.

- **Preparation of hormone stock solution:** Take 1g of IBA (Himedia, Mumbai) and add little drops of IN NaOH until it dissolves, and make it up with distilled water to 100ml. The strength of this stock solution is 10,000ppm
- **Preparation of hormone treatment solution:** The following table (Table A-1) shows the method of preparing treatment solutions of different concentrations from the stock solution.

Table A-1: Preparation of hormone treatment solutions of different concentrations

Quantity of stock solution (ml)	Quantity of Distilled water (ml)	Concentrations (ppm)
10	90	1000
15	85	1500
20	80	2000
25	75	2500

- **Hormone treatment of the cuttings:** Propagule cutting treated to remove phenolics are again dipped in root promoting IBA hormone for 10 to 30 minutes. Since the concentration of IBA required for root promotion differs from species to species, propagule cuttings should be dipped in solutions of different concentrations as shown in Table A-2.

Table A-2: Optimum concentration of root promoting hormones for maximum root initiation

Species	Growth Hormone	Concentration (ppm)	Rooting
Bruguiera cylindrical	IBA	500	83
Bruguiera gymonorrhiza	IBA	700	75
Bruguiera parviflora	IBA	500	90
Bruguiera sexangula	IBA	500	93
Ceriops decandra	IBA + NAA	500 + 200	79
Kandelia candel	IBA + NAA	1000 + 500	95
Rhizophora apicuata	IBA	1500	93
Rhizophora mucronata	IBA	2000	89
Rhizophora x hybrid	IBA	1500	75

Step 5. Planting propagules in poly-bags / plastic pots

After hormone treatment, cuttings are planted in ploy-bags containing sand and clay at the ratio of 2:8. Keep planted cuttings in the mist chamber at 28 ± 2°C and 70-80% relative humidity.

Step 6. Hardening the cutting in mist chamber

Cuttings are continuously monitored and maintained in controlled environment in the mist chamber. Roots will from after 20 to 25 days and shoots will form after 30 to 35 days (Plate 2). Water is sprayed 3 to 5 times / day inside the chambers to maintain the humidity and temperature.

Step 7. Hardening the saplings in nursery

After 2 months, successfully established saplings should be kept under shady areas in nursery for 3-4months. Before 25 days of field transfer treat the saplings with saline water with maximum salinity level of 20 ppt of diluted sea water, or mangrove water itself or water in which common salt is dissolved for desired concentration (Plate 3)

Step 8. Planting in the field

After successful hardening, saplings are ready for planning. At the end of the monsoon, transfer and plant the saplings in the prepared field.

Air-Layering

Materials

Growth hormones, distilled water, knife, syringe with needle, brush, sphagnum moss, rooting medium (clay : sand : soil), threads, and polythene,

Methods

Step 1. Selection of braches

Select semi-hard wood and hard wood branches of plus trees. Avoid selecting branches that are drooping too much and twigs that are very young or tender.

Step 2. Removal of bark of selected branches

Remove the outer bark of the selected branch at 2 to 5 cm below the node. The portion of the branch where the bard is removed is called, wounded portion. Make a bridge of bark or 2 to 4mm thickness to connect the upper end of the mother plant and the lower end of the daughter plant (offspring) to be produced. This bridge is necessary for the maintenance of some of the important physiological functions, since in mangrove species formation of roots is very slow.

Step 3. Preparation of root promoting hormone

Method is explained in Step 4 Hormone Treatment in Section Propagule Cutting of vegetative propagation of species of Rhizophoraceae.

Step 4. Applying root – promoting hormone

Apply the hormone all around the wounded portion using a fine brush. Hormone should be applied twice. Different concentrations of hormone are used for different species as shown in Table A-3.

Step 5. Applying rooting medium

Prepare a mixture of sand and clay at 3:7 ratio and wet it with nearby mangrove water. This forms the first layer of the rooting medium. This first layer of rooting medium is followed by a layer of wet sphagnum mass (to retain moisture). Apply this medium of two layers around the wounded portion and finally cover it with a polythene cover and tie both the ends as shown in Plate 4. If shoot portion droops, the branch should be tied with nearby one to avoid drooping. Step 2 to step 5 are shown in plate 4 A to E.

Step 6. Monitoring the air layering

Periodically check the layered portion and whenever necessary, inject tap water through a syringe. Roots will be visible after 40-60 days.

Step 7. Hardening in growth chamber

After the root system is well established, separate the rooted sapling from the mother plant using a sharp knife. Keep rooted saplings under mist chamber in the field nursery at 28°C and 70% relative humidity for 2 to 3 months. The procedure followed in hardening the saplings produced through propagule cuttings can be followed for hardening the saplings produced through air layering also.

Step 8. Planting in the field

After 2 to 3 months, successfully established saplings should be treated with saline water of maximum salinity upto 20ppt. Diluted seawater, or mangrove water itself or water in which common salt is dissolved for desired concentration could be used.

Table A-3: Optimum concentration of root-promoting hormone used in air-layering in different mangrove species for maximum rooting.

Species	Hormone	Concentration (ppm)	Rooting%
Amoora cucullata	IBA + NAA	500 + 200	59
Avicennia marina	IBA	2500	42
Avicennia officinalis	IBA	2000	54
Cerbera manghas	IBA + NAA	1000 + 2000	61
Cerbera odollam	IBA	1000	55
Excoecaria agallocha	IBA	2000	48
Heritiera fomes	IBA	2500	55
Heritiera littoralis	IBA	2000	51
Intsia bijiuga	IBA	2000	46
Rhizophora apiculata	IBA	2000	48
Rhizophora mucronata	IBA	2500	52
Rhizophora x hybrid	IBA + NAA	1000 + 500	46
Sonneratia apetala	IBA	1500	45
Xylocarpus granatum	IBA	2000	46
Xylocarpus mekongensis	IBA	1500	64
Xylocarpus moluccenensis	IBA	1000	60

B. Vegetative propagation of other species of mangroves

This method described hereunder is applicable to the following species: *Acanthus ilicifolius, Amoora cucullata, Avicennia marina, Cerbera manghas, Excoecaria agallocha, Heritiera fomes, Heritiera littoralis, Intsia bijuga, Lumnitzera racemosa, Sonneratia apetala* and *Xylocarpus granatum.*

Stem cutting

Materials

Tree twigs, solution to remove phenolics, growth hormones, refrigerator, knife, mist chamber, humidifier and mud filled polythene bags.

Methods

Step 1. Collection of branches / stems

Collect narrow / straight twigs from plus trees.

Step 2. Cutting of stems

Select and cut stems of different types such as soft wood, semi- hard wood and hard wood. Length of the cut stems may vary from 15 to 20 cm (plate7A).

Step 3. Removal of phenolic compounds

The following method describes the preparation of solutions and treatment methods to remove the phenolic compounds. Removal of phenolic compounds involves short-term and long - term treatments.

- **Preparation of stock solution:** Take 20g of Sodium carbonate and 20g of Sodium tungstate, dissole successively in 80 ml distilled water, and make up the final volume to 100 ml. It is a 20% stock solution.
- **Preparation of working solution (10% and 5%):** Take 50 ml from the 20% stock solution, and 50 ml of distilled water. This gives a 10 % working solution. Take another 25 ml of stock solution and add 75 ml of distilled water. It is a 5% working solution.
- **Short-term treatment to remove phenolic compounds:** Take 10 % solution in small cups. Keep the basal portion of the cuttings immersed in the solution for 5-10 minutes. Wash the treated cuttings two to three times in distilled water.
- **Long –term treatment to remove phenolic compounds:** Keep the cuttings treated in 10% solution for about 20-30 minutes in 5% working solution for final treatment. Wash the treated cuttings two to three times in distilled water. Now the stem cutting is ready for hormone treatment.

Step 4. Hormone treatment

Hormone treatment is necessary to induce root formation. Indole Acidic Acid (IAA), Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) are commonly used as root promoters. These promoters are available in most of the agro shops in the form of powder.

- **Preparation of hormone stock solution:** Take 1g of IBA (Himedia, Mumbai) and add little drops of 1N NaOH until it dissolves, and make it up with distilled water to 100ml. The strength of thes stock solution is 10,000 ppm.
- **Preparation of hormone treatment solution:** The following table (Table A-4.) shows the method of preparing treatment solutions of different concentrations from the stock solution.

Table A-4: Preparation of hormone treatment solutions of different concentrations

Quantity of stock solution (ml)	Quantity of distilled water (ml)	Concentration (ppm)
10	90	1000
15	85	1500
20	80	2000
25	75	2500

Hormone treatment of the cuttings: Stem cuttings treated to remove phenolics are again dipped in root promoting IBA hormone for 10-30 minutes. Since the concentration of IBA required for root promotion differs from species to species, stem cuttings should be dipped in solutions of different concentrations as shown in Plate 7 B. Table A-5 shows the optimum concentration of the hormones for maximum rooting in the stem cuttings of different mangrove plants.

Table A-5: Optimum concentration of hormones for maximum rooting in the stem cutting of different mangrove species

Species	Hormone	Concentration (ppm)	Rooting (%)
Acanthus illicifolius	IBA + INNA	500+1000	83
Amoora cullata	IBA	1500	75
Avicennea marina	IBA	2000	56
Cerbera manghas	IAB	1500	63
Cerbera odollam	IBA	1000	69
Excoecaria agallocha	IBA	2000	68
Heritiera fomes	IBA	2500	72
Heritiera fomes	IBA + NAA	1500+500	64
Intsia bijuga	IBA	2000	68
Xylocarpus granatum	IBA	2500	85

Step 5. Planting stem cuttings in poly-bags/plastic pots

After the treatment, plant the cuttings in poly bags containing sand and clay. Keep planted cuttings under the mist chamber at 28±2°C and 70-80% relative humidity.

Step 6. Hardening the cuttings in mist chamber

Monitor the cuttings continuously and maintain controlled environment. Roots can be seen after 20 to 25 days and shoots can be seen after 30 to 35 days. Spray water inside the mist chamber 3 to 5 times/day, using hand sprayer, to maintain the humidity and temperature (Plate 7 C). Plate 8 and 9 show the rooting from stem cuttings in different mangrove species.

Step 7. Harding the saplings in nursery

After 2 months, keep the successfully established saplings under shady areas in the nursery for 3-4 months. Treat the established sapling with salt water up to 20 ppt for 25 days.

Step 8. Planting in the field

After successful hardening, saplings are ready for planting. Immediately after the monsoon season, transfer and plant the saplings in the selected field.

2.0 Micropropagation

Development of micro propagation protocols for mangrove plants

Micropropagation or plant tissue culture is a technology of growing isolated plant cells, tissues, organs or whole plants on semisolid or liquid synthetic nutrient media under aseptic and controlled environment. It is the most useful and widely used technology in tree improvement programmes. Mangroves are classical examples of plants, which have adapted to the shifting, saline and muddy environment. To fully adapt to this environment, mangroves have acquired a number of unique morphological, ecological and physiological characteristics. However, these special adaptive features make the mangrove plants recalcitrant to *in vitro* culture. There have been several inherent problems in the tissue culture of these species and hence, there has been only a few attempts as of now to propagate them through micro propagation. They are highly recalcitrant to the time tested media like Murashige and Skoog (1962) and Lloyd and McKown (1981). The tissue browning occurs within few hours of inoculation, which limits the chance of survival of the explant tissue. There has been a high degree of contamination due to several microbial and fungal endophytes and the growth is very slow in the culture. The M.S.Swaminathan Research Foundation over came these problems and has established protocols for the first time for three species of mangroves viz., *Excoecaria agallacha, Aicennia officinalis* and *Acanthus ilicifolius.*

The micro propagation protocol developed for mangrove plants by the M.S.Swaminathan Research Foundation consists of a unique combination of macro nutrients while micro nutrient and vitamin composition are similar to regular MS media (Rao. et al., 1998). The protocol is useful in propagating the plus tree of mangrove plants for ongoing mangrove afforestation programmes, keeping in view the alarming rate of mangrove forest degradation throughout the world.

Types of Micropropagation

There are two types of Micropropagation techniques namely, a) Direct organogenesis and b) Indirect organogenesis. In direct organogenesis, stems with internodes are grown in culture media to produce multiple shoots and these shoots are removed and grown in rooting media. Once the rooting is established, the explants, which are now called as saplings, will be hardened in growth chamber, field nursery and then transferred to the field.

Production of saplings through indirect organogenesis involves the following steps. In the first step, a mass of undifferentiated cells is obtained from living tissues of plants in a culture medium. This mass of cells is called "callus". The callus is removed from the medium and grown in another medium to individual shoots, and shoots. The next step involves the removal and isolation of individual shoots, and growing them in a rooting medium. Finally the rooted saplings are hardened in growth chamber, nursery and then transferred to the field.

Advantages and limitations in Micropropagation

Advantages

- It is useful in raped multiplication of plant material and can be used to produce both asexually (through plant parts) and sexually propagated (through seeds) plants.
- Small pieces of plants (explants) can be used to produce a large number of plantlets in a small space.
- Tissue culture provides a high degree of phenotypic uniformity.
- Plantlets can be stored *in vitro* in a small space and less labour is required for maintenance of stock plants.
- Plantlets produced through Micropropagation are usually free from infection by bacteria, fungi and viruses.
- Nutrient levels, light, temperature and other factors can be precisely controlled to accelerate vegetative multiplication and regeneration.
- Tissue culture is independent of seasons. Tissue culture could be carried out round the year.
- Plants *in vitro* require minimal attention between subcultures. Therefore, only limited labour and materials are required.

Disadvantages

- Chemicals used in medium preparation are expensive and less available.
- High phenolics in mangrove plants delay the growth and thus the process becomes time consuming.
- Growth in the culture medium is slow.
- Entophytic fungal contamination is high in mangrove species.

Media used in micropropagation

The following are the culture media used in tissue culture: i) Murashige and Skoog (1968) medium or MS medium, ii) Woody Plan Medium or WPM medium (Lloyd and McKown, 1981), and iii) Schank and Hilderbrandt medium (1972) or SH medium. Apart from these, M.S.Swaminathan Research Foundation has developed a medium, for the tissue culture of mangrove plants, which is designated in the manual as X medium.

Composition of different culture media

The following table (Table A-6) shows the nutrient composition of the different culture media used in the Micropropagation of mangrove plants. In all the three species of mangroves for which protocols have been developed, cultures are initiated in the X medium developed by the M.S.Swaminathan Research Foundation. MS medium can be used for the subculture of *Avicennia officinalis* and *Excoecaria agallocha* from second subculture onwards. SH medium can be used for shoot elongation in *Acanthus ilicifolius* and *Excoecaria agallocha.*

Table A-6: Nutrient composition of different culture media

Nutrient composition	MS (1962)	WPM (1981) mg/l	SH (1972)	X (1998)
Major Nutrients				
NH_4NO_3	1650	400	0	0
$(NH_4)_2SO_4$	0	0	320	500
KNO_3	1900	0	2500	525
$Ca(NO_3)_2.4H_2O$	0	556	0	0
$MgSO_4.7H_2O$	370	370	400	0
$CaCl_2.2H_2O$	440	96	200	200
KH_2PO_4	170	170	0	250
K_2SO_4	0	900	0	0
Iron stock				
$FeSO_4.7H_2O$	27.8	27.8	15	27.8
$Na_2EDTA.2H_2O$	37.3	37.3	20	37.3
Minor Nutrients				
$MnSO_4.4H_2O$	22.3	22.3	13.2	22.3
$ZnSO_4.7H_2O$	8.6	8.6	1	8.6
H_3BO_3	6.3	6.2	5.0	6.3
KI	0.83	0	1.0	0.83
$Na_2MoO_4.2H_2O$	0.25	0.25	0.1	0.1
$CuSO_4.5H_2O$	0.025	0.025	0.2	0.2
$CoCl_2.6H_2O$	0.025	0	0.1	0.1
Vitamins				
Inositol	100	100	100	100
Glycine	10	2	0	10
Thiamine.HCL	1	1	5	1
Nicotinic acid	1	0.5	5	1
Pyridoxine.HCL	1	0.5	5	1
Sucrose (g/l)	30	30	30	30
Agar (g/l)	8	8	8	8

Preparation of stock solution

In order to avoid delay in the preparation of the culture media, stock solution of major and minor nutrients, iron and vitamins are prepared separately. These stock solutions can be stored at 4° C for about 6 months. Needed quantity of culture media is prepared whenever necessary by mixing these stock solutions and diluting them with double distilled water to get original concentration.

Preparation of 20X major nutrient solution

To prepare 20X stock solution of major nutrients, dissolve all the chemicals exept $CaCl_2.2H_2O$ one by one in about 500 ml of double distilled water as shown in Table A-7. Stir the solution using a magnetic stirrer and ensure that all the chemicals are dissolved completely. Finally, add $CaCl_2.2H_2O$ and stir the solution till it is completely dissolved and make up the volume to 1000ml.

Table A-7: Composition of Stock solution of 20X major nutrients

Nutrient composition	MS (1962)	WPM (1981) (g/l)	SH (1972)	X (1998)
NH_4NO_3	33	8	0	0
$NH_4)\ _2SO_4$	0	0	6	10
KNO_3	30	0	50	10.5
$Ca\ (NO_3)\ _2.4H_2O$	0	11.12	0	0
$MgSO_4.7H_2O$	7.4	7.4	8	0
$KCaCl_2.2H_2O$	8.8	1.92	4	4
KH_2PO_4	3.4	3.4	0	5
K_2SO_4	0	19.8	0	0

2.4 Preparation of 200X minor nutrient solution

To prepare 200X stock solution of minor nutrients, dissolve all the chemicals one by one in about 500 ml of double distilled water as shown in Table A-8. Stir the solution using a magnetic stirrer and ensure that all the chemicals are dissolved completely and make up the final volume to 1000ml

Preparation of 200X iron stock solution

Table A-9 gives the composition of the 200X iron stock solution. To prepare 500ml of iron stock solution, first dissolve $FeSO_4.7H_2O$ in about 400ml double distilled hot water. After ensuring that $FeSO_4\ 7H_2O$ is completely dissolved, add Na_2 EDTA.$2H_2O$, Stir the solution and make up the volume to 500ml. It is advisable to prepare only

low quantity of iron stock solution since it will easily get contaminated. Discard the prepared solution if turbidity or precipitate is seen in the solution.

Table A-8: Composition of stock solution of 200X minor nutrients

Nutrient composition	MS (1962)	WPM (1981) (g/l)	SH (1972)	X (1998)
$MnSO_4.4H_2O$	4.46	4.46	2.64	4.46
$ZnSO_4.7H_2O$	1.72	1.72	0.200	1.72
H_3BO_3	1.26	1.24	1.0	1.26
KI	0.166	0	0.200	0.166
$Na_2MoO_4.2H_2O$	0.050	0.050	0.020	0.020
$CuSO_4.5H_2O$	0.005	0.005	0.040	0.040
$CoCl_2.6H_2O$	0.005	0	0.020	0.020

Table A-9: Composition of 200X iron stock solution

Iron Stock	MS (1962)	WPM (1981) (g/500ml)	SH (1972)	X (1998)
Fe SO4 . 7H2 O in grams	2.78	2.78	1.5	2.78
Na2 EDTA.2H2 O in grams	3.73	3.73	2.0	3.73

Preparation of 1000X vitamin stock solution

Table A-10 gives the composition of 1000X vitamin stock solution. Weight the vitamins accurately and dissolve them one by one in 80 ml of double distilled water. Once the vitamins are completely dissolved, make the final volume to 100 ml. Like iron stock solution should also be prepared in less quantity, since it will also be easily contaminated. The stock solution should be used as early as possible.

Table A-10: Composition of vitamin stock solution

Vitamins	MS (1962)	WPM (1981) (g/100ml)	SH (1972)	X (1998)
Glycine	1000	200	0	1000
Thiamine. HCl	100	100	500	100
Nicotinic acid	100	50	500	100
Pyridoxine. HCl	100	50	500	100

Other Chemicals

The following chemicals can be directly added to the culture medium:

i.) Inositol 100mg / 1

ii.) Sucrose 30g/l

iii.) Agar 8g/ l or Phytagl 2g/l

Preparation of X culture medium

To prepare 1 liter of X culture medium, take 600ml of double distilled water and add 50 ml of the 20X stock solution of major nutrients, 5 ml of 200X stock solution of micro nutrients, 5 ml of 200X iron stock solution, 1 ml of 1000X vitamin stock solution in succession and ensure that they are completely mixed. Add 100mg of Myo-inositol and 30 g of sucrose. Mix well using a magnetic stirrer until a clear solution is obtained. Ass appropriate quantity of growth hormones such as IAA, IBA, NAA, Kn, BA and 2,4-D as shown in Table 14. Adjust pH to 5.75 to 5.85. by adding 1N NaOH or 1 N HCL. Make the final volume to 1000ml. Add 8 g of agar or 2g of Phytagel. Cook the media on a hot plate until the agar or Phytagel is completely dissolved. Pour 3 to 5 ml of the cooked media into sterilized test tubes. Close the mouth of the test tube with sterilized cotton plug. Autoclave the test tubes for about 15 minutes at 121°C under 15 lb pressure. After autoclaving, keep the test tubes in a slanting position inside a sterile chamber.

Addition of growth hormones in culture media

The experiments conducted in the M.S. Swaminathan Research Foundation showed that for successful shoot and root formation, different mangrove species require different growth hormones as shown in Table A-11. These combinations and concentrations of growth hormones should be added to the culture and sub-culture media.

Methods of micropropagation

Materials

Stock solution of MS, WPM, SH and X media, explants, glassware, inoculation chamber, sterilized culture racks, growth chamber.

Methods

Step 1. Collect explants, preferably shoot portion, from the field or mist chamber or nursery. The explant material may be leaf segments, uninodal and bimodal segments from mature trees as well as seedlings.

Table A-11: Combination and concentration of growth hormones to be used in culture and sub-culture media:

Species	Growth hormone (ppm)				
	BA	Zealtin	IBA	2ip	IAA
E. agallocha					
Shoot induction (1st culture)	3	1	-	-	-
Shoot elongation (1st sub culture)	3	-	0.5	-	-
Rooting (2nd subculture)	-	-	0.5	-	-
Avicennia officinalis					
Shoot induction (1st culture)	1	-	0.5	-	-
Shoot elongation (1st sub culture)	-	-	-	-	-
Rooting (2nd subculture)	-	-	0.5	-	-
Acanthus ilicifolius					
Shoot induction (1st culture)	0.5	-	-	0.2	1.0
Shoot elongation (1st sub culture)	-	-	0.5	-	-

Step 2. Wash the explants in running tap water for 1 hour. This is necessary to remove the exudates (Phenolics, tannins, and mucilage) present within the tissue.

Step 3. Again wash the explants with Tween 20 (2% , V/V) and rinse until traces of soap are removed. Take the explants to a sterile laminar flow and surface sterilize the explants with $HgCl_2$ (0.1%, W/V) followed by three washes with sterile distilled water.

Step 4. Trim the explants with sterilized knife and cut them into small pieces of leaf, uninodal and bimodal segments. Cut the lower portion of the nodal explants at an angle of 20 to 30 degrees to get a slanting basal portion, which facilitates in effective absorption of nutrition from the medium.

Step 5. Transfer the trimmed explants to the culture media.

Step 6. Incubate the culture at 24±2°C and 60 % relative humidity under a 16-hour/day photoperiod. Provide light intensity of 50 μ Mol m^{-2} s^{-1} using a cool white fluorescent light.

Step 7. After shoot initiation, sub-culture the explants for shoot elongation and multiplication. For this purpose use different combinations and concentrations of growth hormones.

Step 8. After shoot elongation, remove the explants, cut the shoots in a sterile inoculation chamber, and transfer the shoots to rooting media for root initiation. Transfer the well established rooted plants into a growth chamber.

Step 9. Harden the rooted plants in growth chamber (e.g. N.K. System LP-1PH) at 80 % relative humidity and 26 °C for a period of three weeks.

Step 10. Transfer the hardened plants to the mangrove nursery and after hardening for about 2 to 5 months, treat them with different salinities ranging from 5 to 20 ppt.

Step 11. Transfer the hardened plants to the selected for plantation.

Micropropagation of *Excoecaria agallocha*

- Binodal segments respond well in X medium with a combination of BA, Zeatin and IBA.
- The X medium has an overall low mineral content with relatively high concentrations of SO42-, NH4+, PO4 and K + ions. Auxiliary shoot induction is high in this medium compared to MS and WPM media.
- Per cent shoot induction and mean shoot length is maximum (52%) when the X medium has BA, Zentin and IBA. Addition of Zeatin in the culture medium (up to 1ppm) futher increases shoot induction of response (72%) with no significant effect on shoot length.
- Binodal segments give a better shoot induction over uninodal segments. The shoot elongation rate enhances from the second subculture onwards (Plate 10A).

Micropropagation of *Avicennia officinalis*

- Uninodal explants of A. officinalis responded well in the X medium with a combination of BA and IBA.
- There is an increase in the shoot induction response with the increase BA and IBA concentrations to 1.0ppm and 0.5ppm repetitively.
- Rooting response is good when the regenerated shoots of 5 cm length are transferred to the X medium supplemented with 0.5 ppm IBA.
- After 2 weeks of rooting in the growth chamber, the plantlets can be transferred to the potting medium consisting of 1:1 garden soil and sand mixture. A high humidity condition is to be maintained for another 4 weeks (Plate 10B).

Micropropagation of *Acanthus ilicifolius*

- Uninidal explants of Acanthus ilicifolius culture on SH Medium supplemented with BA (0.5ppm), 2ip (0.2 ppm) and IAA (1ppm) show maximum shoot induction.

- Shoot elongation can be achieved when the shoots are divided and sub cultured on the SH basal medium supplemented with half of the above concentrations of hormones.
- The individual elongated shoots subcultured on the ½ SH medium supplemented with 0.5 ppm IBA produce healthy roots.
- The rooted plants can be grown in pots with vermiculite in the growth chamber with 75% relative humidity and 26°C, to get maximum survival (Plate 11).
- In the experiments conducted in the M.S. Swaminathan Research Foundation, 95 % of the plantlets survived in the hardening chamber when the above procedures were followed.

3.0 Propagation of mangrove associates

Atriplex lentiformis (Saltbush)

The plant prefers light (sandy) and medium (loamy) soils, requires well-drained soil and can grow in nutritionally poor soil. The plant prefers acid, neutral and basic (alkaline) soils and can grow in very alkaline and saline soils. It cannot grow in the shade. It requires dry or moist soil and can tolerate drought.

Importance: Seed cooked (Kunkel, 1984 and Moerman 1998) reported it could be used as a pinole or be ground into a meal and used as porridge, a thickener in soups or added to flour for making bread and the seed is rather small and fiddly to use. He reported the fresh leaves can be chewed, or the dried leaves smoked, in the treatment of head colds and the crushed flowers, stems and leaves can be steamed and inhaled to treat nasal congestion and a poultice of the powdered roots has been applied to sores.

Propagation

Seed and nursery: Seed - sow April/May in a cold frame in a compost of peat and sand.

Vegetative propagation: Cuttings of mature wood of the current season's growth, November/December in a frame. Pot up in early spring and plant out in their permanent position in early summer.

Tissue culture: Mei *et al.* (19970 reported shoot organogenesis (265 shoots) from leaf disc explants was accomplished at rates of 12.3 shoots/disc or 1.7 shoots/ mm^2 of leaf disc explants. Root organogenesis was induced in 63% (168) of the shoots, using indolebutyric acid (IBA, 0.5 mg $liter^{-1}$) and gibberellic acid (GA3, 0.1 mg^{-1} liter) in a Murashige and Skoog (MS) medium.

Cultivation: Huxley (1992) reported plants require a position in full sun in any well-drained but not too fertile soil. Tolerates saline and very alkaline soils. Succeeds in a hot dry position.

Salicornia brachiata (Glasswort)

Importance: *Salicornia* spp. (Chenopodiaceae) grows in most coastal marine environments throughout the world, from warm tropical to cold temperate zones. It is perhaps the most promising of all halophytes currently under commercial

cultivation; common names for this annual salt marsh succulent include sea asparagus, pickleweed, glasswort, and samphire. The high protein edible oil has a fatty acid composition similar to safflower, with a nutty taste and the texture of olive oil. When mixed with traditional fodder, the residual meal makes for an excellent feed supplement. Select varieties of *S. brachiata* are now being cultivated in the deserts of India where value-added by-products like vegetable salt are being test marketed. S. brachiata crop can be used as vegetable, salad, oil extraction, salt extraction, animal fodder.

Propagation

Seed and nursery: Eganathan (2002) reported the best seed germination (84%) was observed when seeds treated with a combination of GA_3 + KN (25 + 40 ppm). These seedlings were established well in the natural environment.

Explants	Purpose	Growth regulators (mg/l)					
		BA	IAA	NAA	GA3	KN	IBA
Nodal	Shoot induction	0.5-5.0	1.0-1.5	-	-	0.1-0.5	-
Shoot	Multiple shoot	0.2-0.8	0.2-1.0	-	-	0.1-0.3	-
Multiple Shoot	Elongation	0.2-0.7	-	-	0.2-1.5	-	-
Elongated Shoot	Rooting	-	-	0.1-0.5	0.1-1.0	-	0.5-2.0

Vegetative propagation: Not recommended

Tissue culture: MS medium

Plantation

The seed sowing is done in April to June. The following lands can be utilized for Salicornia cultivation - degraded coastal zones, hyper saline areas. Pretreated seeds could be cultivating on broad casting methods and tissue culture plants spacing of 1 foot is found most suitable. Traditionally burned for soda ash used in glass and soap making, it is now being seriously considered for its oil (30%) production with yields that exceed many freshwater oilseed crops. Commercial cultivars of *Salicornia bigelovii* have demonstrated seed yields of 2-3 tons/ha with an overall biomass production of 20 tons/ha.

Salvadora persica

Importance: Salvadora persica, a facultative halophyte and a good source of seed oil have been found to be highly salt tolerant (Rao et al. 2004). Leaves make good fodder as they have a high water content (15 to 36%) and are rich in minerals (FAO 1986). The leaves are readily consumed by goats and cattle and the fodder is available during the dry season. Adapted to alkaline or very saline soils, usually clay-rich, and soils without salt. It prefers clays, but is found on loams, black soils, and sand (FAO 1988).

Propagation

Seed and nursery: Fruits are small, round, and pea-sized, bearing 1 seed per fruit. Seeds turn from white to pink or purple-red and are semitransparent when mature. Pretreatment is not necessary (RSCU 1992). Seeds exhibit no dormancy but the fruit pulp contains germination inhibitors which should be removed before sowing. Seed can be stored for about 1 month.

Vegetative propagation

Tissue culture: Mathur et al (2002) reported maximum shoot proliferation from single explants was obtained on MS medium incorporated with BAP (4.0 mg/l), IAA (0.5 mg/l), adenine sulphate (40 mg/l), glutamine (100 mg/l) and thiamine HCl (10 mg/l). *In vitro* produced shoots were induced to root on a range of IBA concentrations (0.5-5.0 mg/l) supplemented to half strength MS medium. The highest frequency of root proliferation was on half strength MS medium supplemented with 3.0 mg/l IBA.

Plantation: Alluvial plains but soils are moderately saline.

Porteresia coarctata

Importance: *Porteresia* is a halophytic species, which can withstand total submergence in seawater and taxonomically related to rice. Land soil builder, control soil erosion rive banks of mangrove areas.

Propagation

Seed and Nursery: seed can be collected from October to December from mother plants. It is germinate other non-vegetated riverbank areas.

Vegetative propagation: clum cuttings and nodal cuttings can be achieved in monsoon seasons.

Micropropagation

Woody Plant (WP) medium supplemented with benzyladenine (5.5 microm) and kinetin (2.3 microm) gave the greatest response to initiation and multiplication. The multiplication rate of 11 shoots/explant with an average shoot length of 3.5 cm was observed after 8 weeks of culture period. The rooting response was observed simultaneously in the multiplication media, but subsequent establishment was poor. When the in vitro raised shoots were transferred to optimal 1/2 WP and 1/2 MS media with 10.7 microm alpha-naphthaleneacetic acid, the rooting response was enhanced.

Plantation: Exposed mangrove saline soil containing riverbank is ideal for cultivation of Porteresia. A spacing 0.5 x 0.5 m and depth 2 to 3 cm.

Sesuvium portulacastrum

Importance: It is a very good nutritious green vegetable, fodder, and good soil creeper.

Propagation

Seed and Nursery: Nursery can be established for rapid multiplication from elite clones for supply saplings to farmers.

Vegetative propagation: Sea purlane can be propagated from rooted stem cuttings taken from established plants. IBA and NAA treated plants give better rooting and shoot development, shoot tip is compare to other portion of plants give better response and growth.

Tissue culture: Multiple shoot was achieved from uninodal explants in X medium combination of BA, NAA, Kn (Eganathan, 2002) and callus induction found in X medium with 2,4-D, NAA, Kn and differentiation was achieved in X medium with 0.5 IBA.

Cultivation: Saline lands can be utilized for cultivation of Sesuvium. Moonsoon season is ideal for trans planting saplings. Spacing is 0.5 to 1 m enough it will grow rapidly. All new shoots and young shoots can be harvest periodically for domestic use.

Abbreviations

$(NH_4)_2SO_4$	-	Ammonium Sulphate
10%	-	10 g of Sodium carbonate (Na_2 dissolved in 80 ml distilled water and up to 100ml
1N HCL	-	8.77ml of 35% HCL (Generally Available) made up to 100 ml using double distilled water.
1N NaOH	-	4g of Sodium hydroxide in 80 ml of double distilled water and made up to 100 ml
2ip	-	6-(g, g - Dimethyl allyl-Amino) purine Riboside
Agar and Phytagel	-	Used for solidification of tissu culture media
BA	-	Benzyl Adenine
$Ca(NO_3)_2.4H_2O$	-	Calcium Nitrate Tetrahydrate
$CaCl_2.2H_2O$	-	Calcium Chloride Dihydrate
$CoCl_2.6H_2O$	-	Cobalt Chloride Hexahydrate
$CuSO_4.5H_2O$	-	Copper Sulphate Pentahydrate
Explant	-	Any plant part used in tissue culture
$FeSO_4.7H_2O$	-	Ferrous Sulphate Heptahydrate
H_3BO_3	-	Boric Acid
$HgCl_2$	-	Mercuric Chloride
Hormone	-	Growth regulating substance in plants
Humidifier	-	Mist forming instrument in mist chambers
IAA	-	Indole Acidic Acid
IBA	-	Indole Butyric Acid
K_2SO_4	-	Potassium Sulphate
KH_2PO_4	-	Potassium Dihydrogen Phosphate
KI	-	Potassium Iodide
KNO_3	-	Potassium Nitrate
$MgSO_4.7H_2O$	-	Megnesium Sulphate Heptahydrate
$MnSO_4.4H_2O$	-	Manganous Sulphate Tetrahydrate
Na_2CO_3	-	Sodium Carbonate
$Na_2EDTA.2H_2O$	-	Ethylene Diamine Tetra Aceticacid Disodium Salt
$Na_2MoO_4.2H_2O$	-	Sodium Molybdate dihydrate
$Na_2WO_4.2H_2O$	-	Sodium Tungstate
NAA	-	Naphthalene Acetic Acid
NH_4NO_3	-	Ammonium Nitrate
pH (-log {H+})	-	Denotes the concentration of hydrogen ions in a solution
ppm	-	parts per million
Sphagnum moss	-	A plant body creeping of the surface of a rock/soil in hilly areas
Tween-20	-	Surfactant used for surface sterilization of explants
v/v	-	Volume by volume
w/v	-	Weight by volume
$ZnSO_4.7H_2O$	-	Zinc Sulphate Heptahydrate

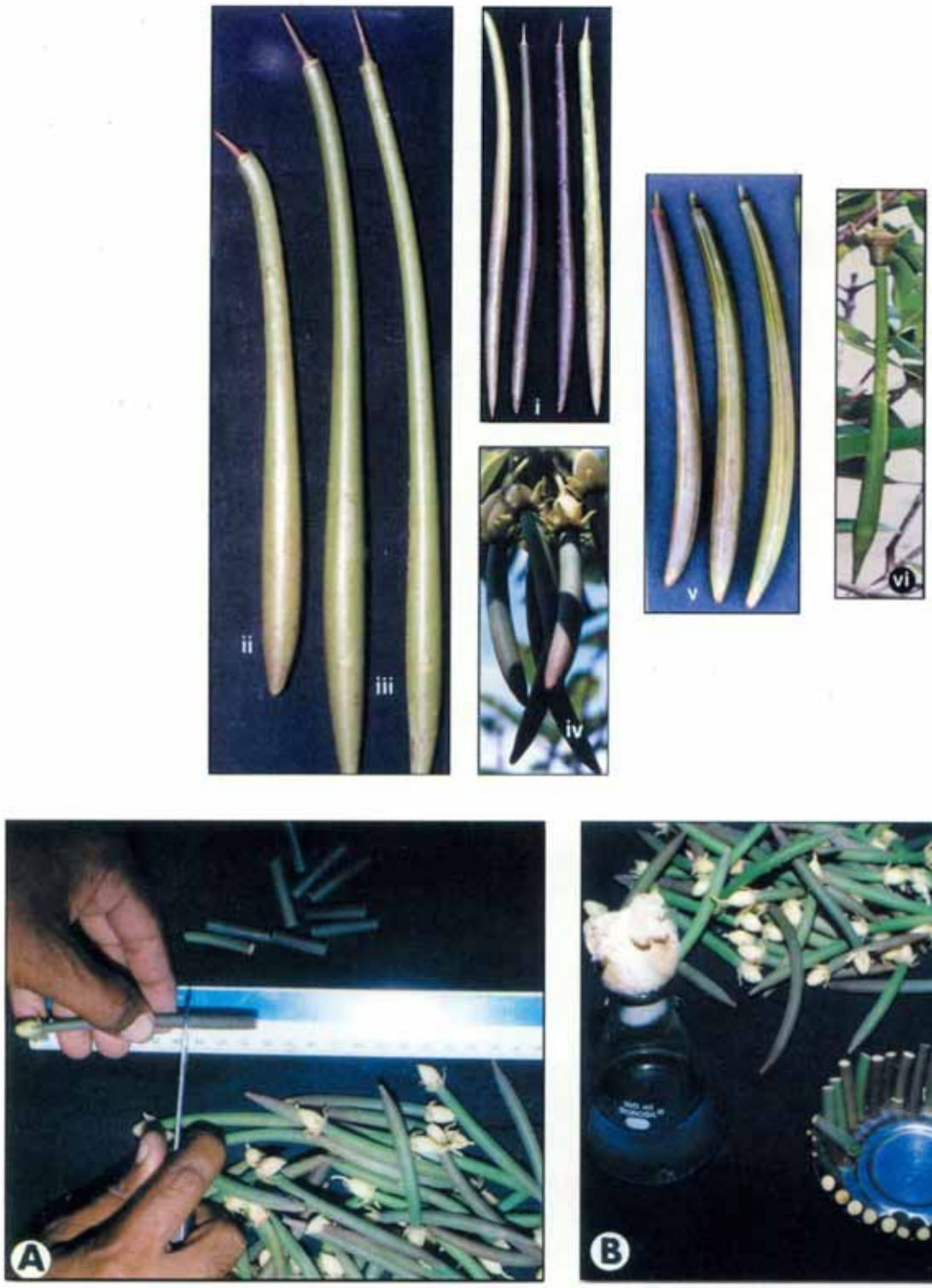


Plate 1 : Propagules of different species of Rhizophoraceae

i. *Rhizophora mucronata*
ii. *Rhizophora apiculata*
iii. *Rhizophora* hybrid
iv. *Bruguiera cylindrica*
v. *Ceriops decandra*
vi. *Kandelia candel*

A. Propagule cutting - Bruguiera cylindrica *B. Hormone treatment*

Plate 2: Root and shoot development in propagule cuttings

A. Bruguiera cylindrica
B. Ceriops decandra
C. Kandelia candel
D. Rhizophora mucronata
E. Rhizophora apiculata
F. Rhizophora hybrid

Plate 3: Development and hardening of propagated plants in the nursery and mist chamber

A. General view of the field nursery with mist chamber

B. Stem cuttings of the Acanthus ilicifolius

C. Inside view of the mist chamber

D. Flow of mist inside the mist chamber

Plate 4: Air-layering in *Excoecaria agallocha* in the field

A. Removal of bark
B. Application of root promoting hormone
C. Application of rooting media
D. Wrapping with polythene sheet
E. Closing the end of the wrapping
F. Air-layering

Plate 5: Rooting through air-layering in different mangrove species

A. *Heritiera fomes* B. *Excoecaria agallocha* C. *Xylocarpus moluccensis*
D. *Rhizophora* hybrid E. *Sonneratia apetala*

Plate 6: Rooting through air-layering in different mangrove species

A. *Avicennia officinalis* B. *Avicennia marina* C. *Intsia bijuga*
D. *Heritiera littoralis* E. *Xylocarpus granatum*

Plate 7 : Stem cuttings in Excoecaria agallocha

A. Cutting of stem
B. Treating the stem cuttings with hormone
C. Development of stem cuttings into sapling

Plate 8 : Rooting in stem cuttings in different mangrove species

A. Acanthus ilicifolius
B. Avicennia marina
C. Excoecaria agallocha
D. Heritiera littoralis

Plate 9 : Rooting in stem cuttings in different mangrove species

A. Heritiera fomes
B. Amoora cucullata
C. Cerbera manghas
D. Intsia bijuga
E. Lumnitzera racemosa
F. Xylocarpus granatum

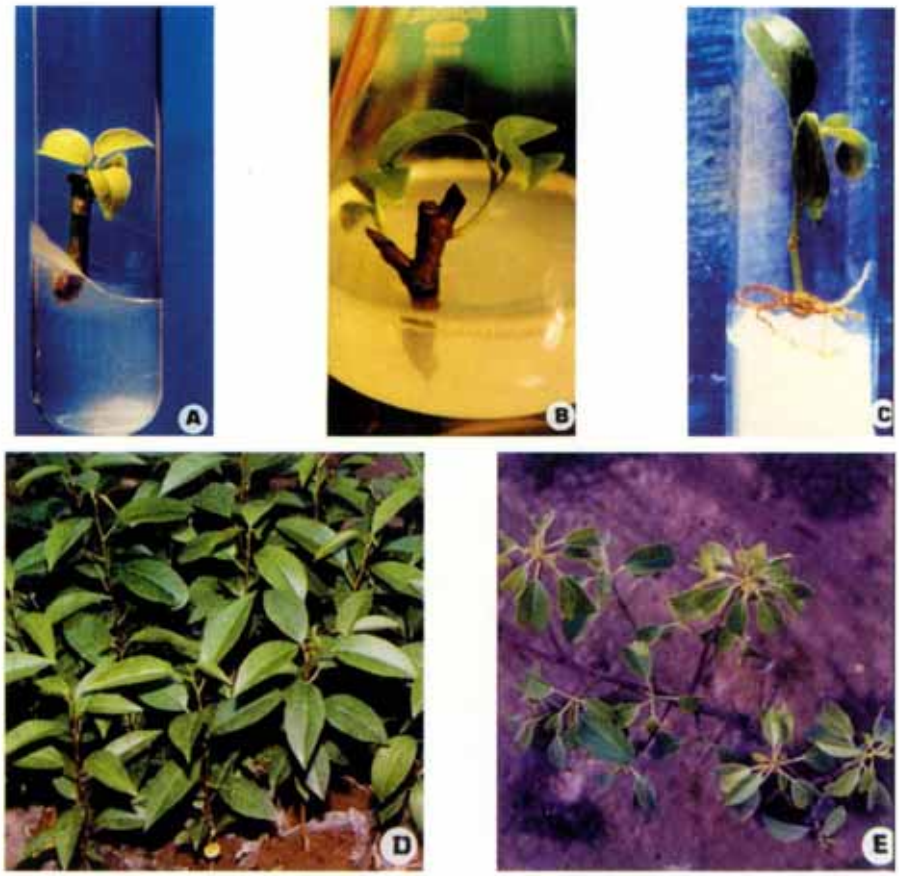
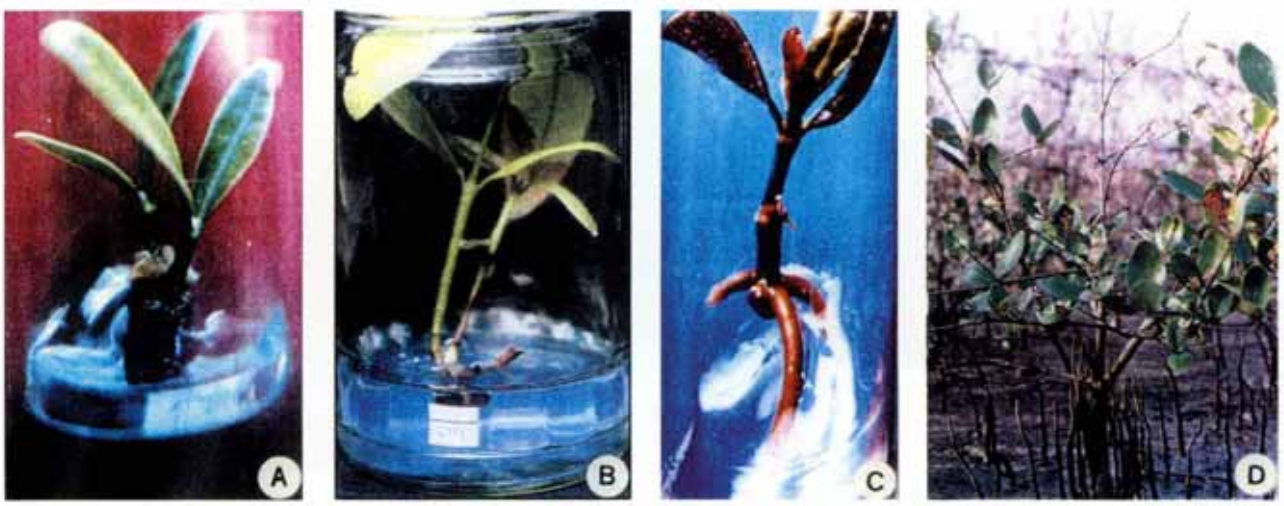


Plate 10A: Micropropagation of *Excoecaria agallocha*

A. Uninodal explant *B. Binodal explant*

C. Rooting of shootings *D. Hardening plants*

E. Field transfer plant



B. Micropropagation of *Avicennia officinalis*

A. Uninodal explant shoot initiation *B. Shoot elongation*

C. Rooting of shoots *D. Field transferred plant*

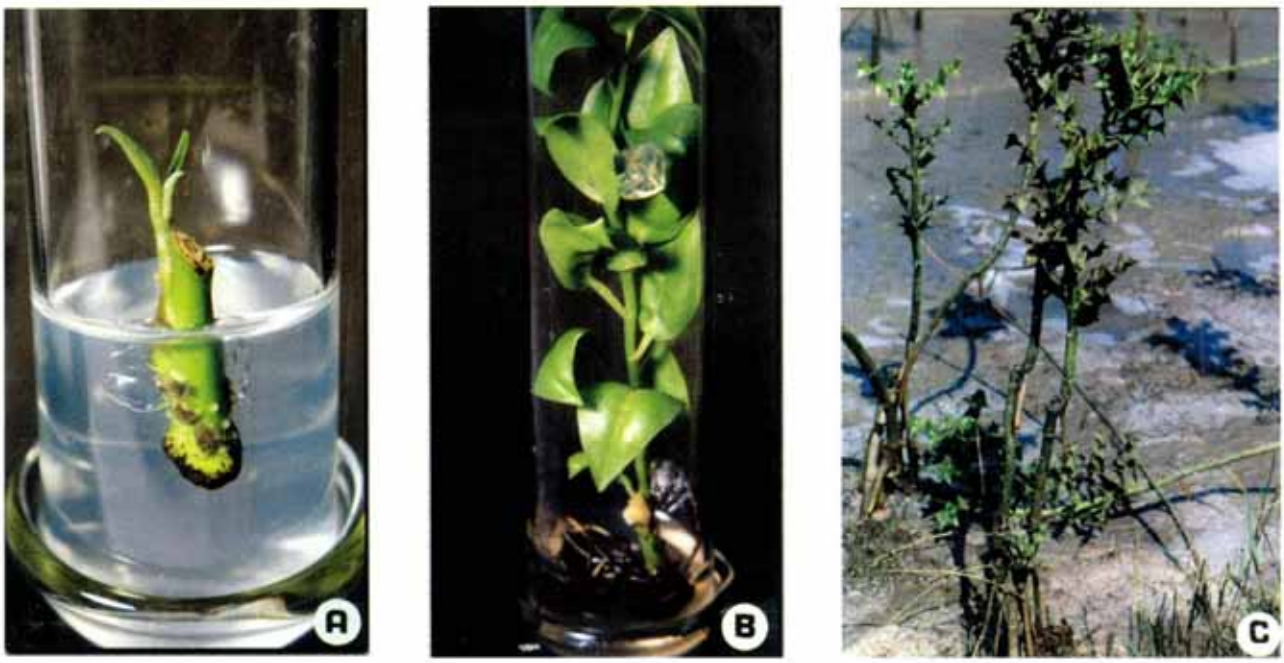


Plate 11 : Micropropagation of *Acanthus ilicifolius*

A. Uninodal with shoot initiation *B. Rooting of shoots*

C. Field transferred plant

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