# Manual on Mangrove Nursery and Mangrove Genetic Resources Conservation Centre

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M. S. Swaminathan Research Foundation
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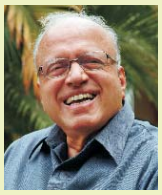

## Foreword

The mangrove ecosystem is one of the important natural resources as it confers multiple benefits to the coastal communities. Mangroves not only protect the coastal areas from the fury of cyclones and coastal storms, but also promote sustainable fisheries and prevent coastal erosion. The ecosystem provides valuable fishery, fodder and medicine to the dependent communities. Mangrove ecosystem is highly productive and sequester large amount of carbon below the ground. In spite of all such gifts they confer, many mangrove wetlands have been cleared for aquaculture ponds and other alternate land uses leading to their degradation. Mahatma Gandhi once said, “Nature provides for everybody's need, but not for everyone's greed”. Mangroves illustrate powerfully the truth behind this visionary statement.

There is now much public awareness on the need to conserve the remaining mangrove forests and also to rehabilitate the degraded mangrove wetlands. This awareness is growing among coastal communities, particularly because of increase in severe storms but also important nursery ground for the commercially important juveniles of fin fishes and shell fishes. The restoration of degraded mangroves has improved the mangrove cover along the Indian coast from 4,046 sq. km. in 1987 to 4,921 sq. km. in 2017. This was achieved through the involvement of multiple stakeholders especially the local community, NGOs and the state Forest Departments in mangrove conservation and management. The traditional knowledge and the participation of the local communities in raising of mangrove nurseries and restoration of degraded mangrove wetlands played a major role in mangrove restoration activities. Still large areas of degraded mangroves have to be regenerated to mitigate the impacts of coastal disasters like cyclones and tsunami. In this context, this manual on Mangrove Nursery and Mangrove Genetic Resources Conservation Centre assumes significance as it helps the local community and the field staff of the forest department for establishing multiple species mangrove nursery. Similarly, the establishment of Genetic Resources Centre in the Coringa Mangroves in Andhra Pradesh, India, with more than 25 species is also significant in the context of academic research and also conservation of species diversity. I am glad that this joint publication with the Andhra Pradesh State Forest Department will be widely used and will promote a community mangrove afforestation movement. I thank Dr. R. Ramasubramanian, Dr. Ravishankar Thupalli, Smt. Shanti Priya Pandey and Sri D. Nalini Mohan for their contributions in preparing this manual.

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## 1. Introduction

Mangrove ecosystems are found along the inter-tidal zones of tropical and subtropical areas. Mangroves are plant species that survive in estuarine conditions and are adapted to the environment through unique characteristics such as stilt roots, viviparous germination, salt glands, salt-excluding mechanism, leathery leaves and pneumatophores (Ravishankar et al., 2003). Mangrove forests act as barriers against cyclones and prevent storm water from entering the mainland and also reduce shoreline erosion. These wetlands serve as spawning, breeding and nursery ground for many economically important fin-fishes and shellfishes (Ramasubramanian et al., 2006).

Globally, mangrove forests occupy an area of about 150,000 sq km along tropical and subtropical coasts. Mangrove wetlands in India are spread over an area of about 4,975 sq km (FSI, 2019), which is 0.15% of the country's geographical area and 3.3% of the world's total mangrove vegetation. Though the mangrove ecosystem is highly productive and has multiple uses, these wetlands have been highly exploited throughout the world. They are undergoing widespread degradation due to a combination of physical, biological and anthropogenic factors.

The mangrove wetlands in Andhra Pradesh are located predominately in the Godavari and Krishna estuaries (Figure 1). They are also found along the coasts of Visakhapatnam, West Godavari, Guntur, Prakasam and Nellore districts. According to the estimation of the Andhra Pradesh Forest Department, the total area covered by the Godavari and Krishna mangrove wetlands is 583 sq km, of which 333 sq km is in the Godavari estuary and 250 sq km in the Krishna estuary. This includes mudflats, degraded mangroves, water bodies and sandy beaches. However, the mangrove cover in Andhra Pradesh is about 404 sq km (FSI, 2019). The degraded areas are formed due to geomorphological and anthropogenic causes. The geomorphological factor, that is, the

elevated topography of the degraded area, prevents free movement of tidal water into the mangrove wetland; this in turn increases soil salinity and leads to the degradation of mangroves. Use of mangrove forests for other non-forest purposes, particularly aquaculture, is also one of the reasons for the loss of this important wetland.

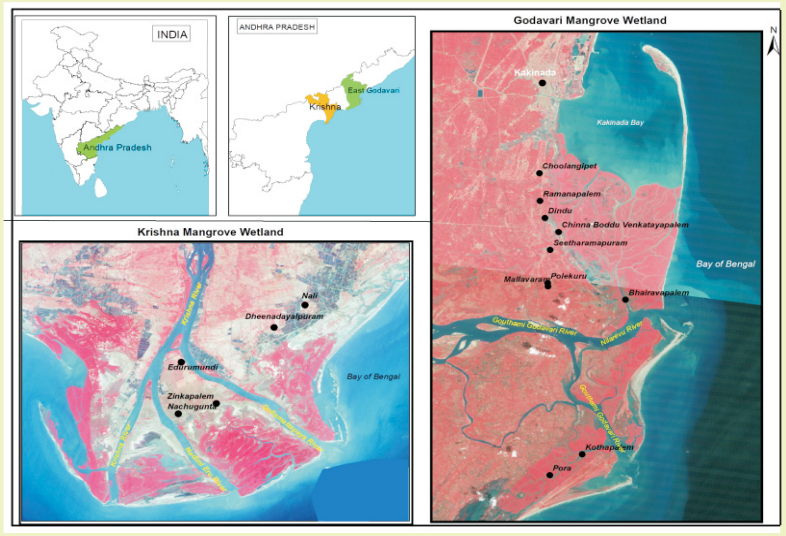


**Figure 1: Krishna and Godavari mangrove wetlands**

The Andhra Pradesh State Forest Department and organizations such as M. S. Swaminathan Research Foundation (MSSRF) have initiated attempts to restore the degraded mangroves in the Godavari, Krishna and Pennar estuaries. MSSRF has restored more than 2,500 ha in Odisha, Andhra Pradesh and Tamil Nadu. In Andhra Pradesh alone, between the years 1996 and 2019, it has restored nearly 900 ha of degraded mangroves in the Godavari and Krishna mangrove wetlands. The restoration of degraded mangroves has improved the mangrove forest cover from 383 sq km in 1995 to 404 sq km in 2017 (FSI, 2019). Natural mangrove regeneration also contributed to the increase in the mangrove extent (Ramasubramanian et al., 2006). Mangrove nurseries played a major role in the success of mangrove plantations (Ramasubramanian and Ravishankar, 2004).

## 2. Importance of the mangrove nursery

In Andhra Pradesh, the matured seeds/propagules of the mangrove species, particularly *Avicennia marina* and *A. officinalis* are available during the north-east monsoon season (October and November). These seeds will not available during the planting season, that is, the south-west monsoon season. In the west coast, most of the seeds are available during the south-west monsoon. Direct dibbling (planting) of mangrove seeds during November leads to low survival rates because of very less rainfall leading to higher soil salinity. During summer, the soil salinity increases further and thus affects the survival of the planted saplings. Generally, the mangrove wetlands in Andhra Pradesh receive fresh water during the south-west monsoon, which significantly reduces soil salinity. In order to take advantage of the monsoon rain, the mangrove saplings are raised in the nursery and planted during the south-west monsoon season the following year. The survival rate of nursery-raised seedlings in restoration areas will be higher when compared to the direct dibbled seeds/propagules due to the fact that nursery-raised saplings have a well-established root system as they are grown in the nursery for 8–9 months (from October to July). The root system of the planted saplings will be further established into the deeper areas before the onset of summer thus reducing the mortality. The local community also finds employment in the nurseries.

## 3. Site for the mangrove nursery

The site for a mangrove nursery should be identified in the inter-tidal area, preferably close to a natural creek to draw water for raising the saplings (Figure 2). The quality of water should be good, and the area should be fenced to prevent grazing. It should be well connected either by road or by creek to ensure and facilitate easy transportation of saplings from the nursery to the restoration site. Water pumping facility should be established for irrigating the saplings as and when required. Generally, during February - April the tidal inundation is less.

As minimum requirements, a mangrove nursery site should have:

- the benefit of periodic inundation;
- access to good quality brackish water with pumping facility from the creeks; and
- access to road or creek to transport the saplings to the restoration/ planting sites.

## 4. Selection of mangrove species for a mangrove nursery

Mangrove species listed in Table 1 are suitable for growing in the nurseries as they are found in the Godavari and Krishna mangroves of Andhra Pradesh. *Avicennia marina* and *A. officinalis* are common and most preferred for planting in the degraded area as they are most suitable.Other mangrove species can also be raised for planting in the degraded areas in order to maintain species diversity. This manual provides detailed guidelines for establishing mangrove nurseries and mangrove genetic resources conservation centre (MGRCC).

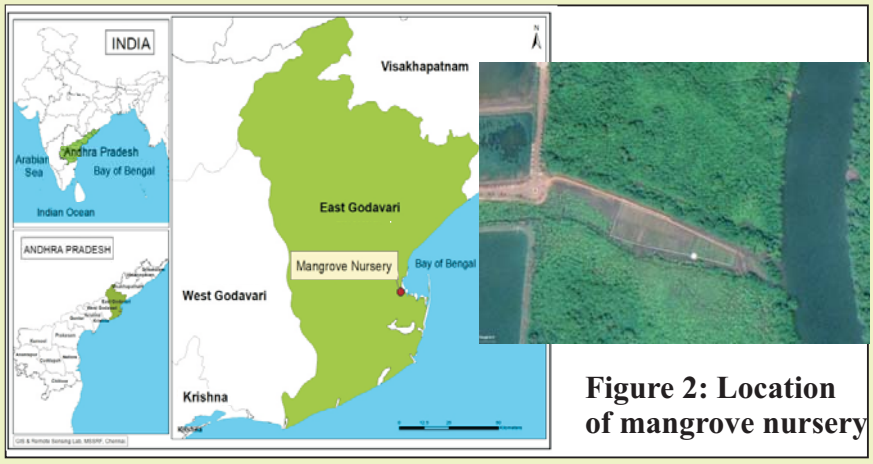


**Figure 2: Location of mangrove nursery**

**Table 1. Mangrove seeds/propagules available in Andhra Pradesh for growing in the nursery**

| S. no. | Species | Available location |
|---|---|---|
| 1 | *Avicennia marina* | Krishna and Godavari wetlands |
| 2 | *Avicennia officinalis* | Krishna and Godavari wetlands |
| 3 | *Excoecaria agallocha* | Krishna and Godavari wetlands |
| 4 | *Aegiceras corniculatum* | Krishna and Godavari wetlands |
| 5 | *Bruguiera cylindrica* | Krishna and Godavari wetlands |
| 6 | *Bruguiera gymnorrhiza* | Krishna and Godavari wetlands |
| 7 | *Ceriops decandra* | Krishna and Godavari wetlands |
| 8 | *Rhizophora mucronata* | Krishna and Godavari wetlands |
| 9 | *Rhizophora apiculata* | Krishna and Godavari wetlands |
| 10 | *Sonneratia apetala* | Krishna and Godavari wetlands |
| 11 | *Xylocarpus granatum* | Krishna wetland |
| 12 | *Xylocarpus moluccensis* | Krishna and Godavari wetlands |

## 5. Collection of seed material

The ideal season for collecting mangrove seeds/propagules in Andhra Pradesh is between September and December. However, *Bruguiera cylindrica*, *B. gymnorrhiza, Ceriops decandra, Rhizophora apiculata*, *R. mucronata* bear fruits most part of the year, though the peak fruiting season is from September to November. The viability of the seeds depends on the age of the tree. The seeds/propagules should be collected from healthy trees that are more than 7 years old.

Matured seeds/propagules of *Avicennia marina, A. officinalis, Aegiceras corniculatum, Excoecaria agallocha, Rhizophora apiculata, R. mucronata, Bruguiera cylindrica, B. gymnorrhiza, Ceriops decandra, Sonneratia apetala, Xylocarpus granatum* and *X. moluccensis* can be collected from the trees or floating in the creeks. The collected seeds and propagules should be kept either in polythene bags or in jute sacks for transportation to the nursery. *Avicennia marina* and *A. officinalis* seeds should be planted within 2 days of collection, as delay in planting reduces the rate of germination. However, the seeds of the Rhizophoraceae members can be stored for a maximum of 15 days by keeping them in water.

## 6. Identification of mature propagules

*Rhizophora mucronata* are larger than *R. apiculata* in size. Matured propagules of *R. apiculata* can be identified by the presence of a red collar in the cotyledon while *R. mucronata* have light green or yellow cotyledons. Matured propagules of *Bruguiera* sp. are purplish green in colour and can be collected from the creeks or plucked from trees. The matured fruits of *Aegiceras corniculatum* fruits are yellowish green, and the seed coat of the matured *Avicennia* sp. fruit is pale yellow. The matured fruits of *Sonneratia apetala* can be distinguished easily by the change in colour from pale green to deep green. The taste of the fruit becomes sour as it matures. Mature fruits detach easily from the calyx and float on water. The matured *Excoecaria agallocha* fruits are black/brown while the matured *Xylocarpus* fruits have cracks in the pericarp.

## 7. Techniques for preparing the nursery

In Andhra Pradesh, the mangrove nursery is developed in the inter-tidal areas of both Godavari and Krishna mangroves. The sunken beds are prepared to facilitate tidal flushing.

**Preparation of nursery beds**

The inter-tidal areas close to the high tide line are ideal sites for preparing the nursery as the seedlings will not be submerged over a prolonged period, which cause rotting of the seedlings. Sunken beds could be prepared with the dimensions 10 x 1 x 0.25 m (lbd, respectively) as shown in Figure 3 or as per the layout of the land. The irrigation canals need to be readied for irrigating the saplings. Each bed can hold approximately 2,000 seedlings. Bamboo poles should be placed horizontally at both the ends and also in the middle to keep the bags upright. The nursery bags with the sprouted saplings should be placed inside the beds, which are then irrigated by flooding/pumping. The nursery site and the number of beds may be prepared according to the seedling requirement.

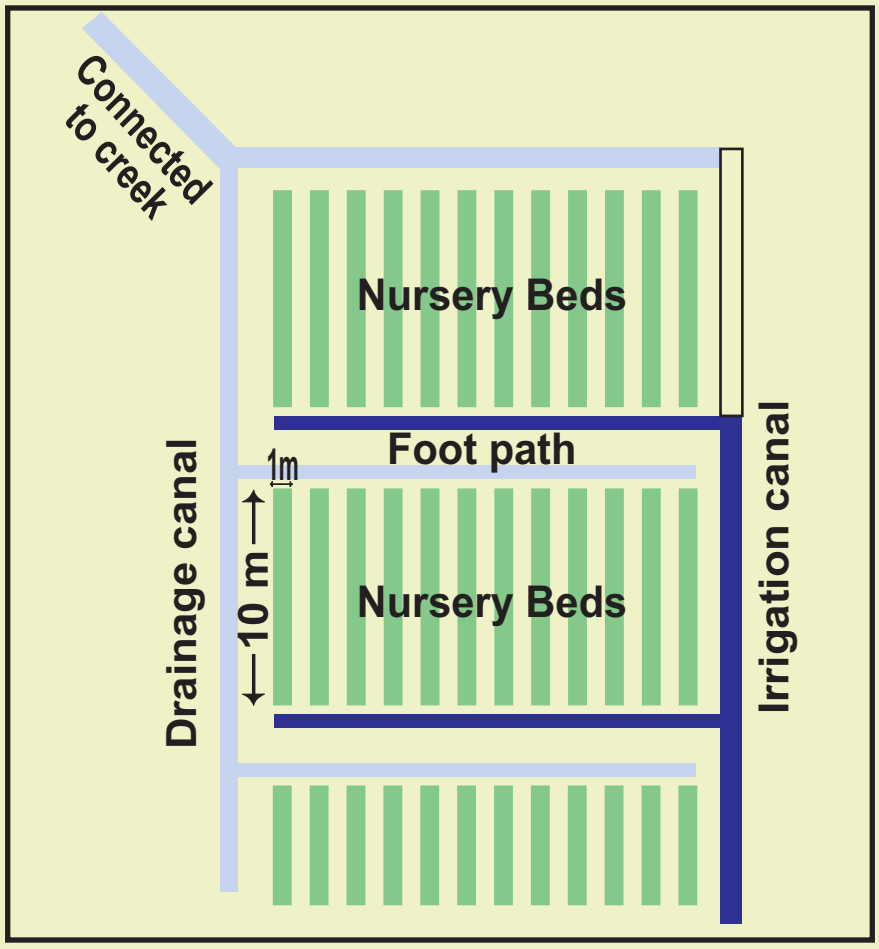


**Figure 3: Layout design for nursery**

**Soil**

Soft clayey mud available in the creeks can be collected during low tide. Debris and hard materials should be removed. The soft mud must be made into paste and used to fill the poly bags. Generally, the alluvial soil deposited in the creek is rich in organic matter.

## Nursery bags

Polythene bags of 5 x 8 in. should be used to raise the mangrove saplings in the nursery. Small perforations should be made at the bottom of the bag to drain excess water. Initially, the soft mud-filled bags should be kept in the shade to harden.

## Sowing

Viviparous seeds of *Rhizophora apiculata, R. mucronata, Ceriops decandra, Bruguiera cylindrica* and *B. gymnorrhiza* could be planted directly in the bags and placed in the beds. Similarly, young seedlings (about 4 in. high) of *Excoecaria agallocha* collected from the forest and *Sonneratia apetala* from the primary bed can be planted directly in the bags. The seeds of *Avicennia marina, A. officinalis, Xylocarpus granatum* and *X. moluccensis* are sown in bags kept outside and should be transferred to the nursery bed after germination. During the initial stages, watering should be done using rose water cans twice a day to obtain maximum germination. Water stagnation for an extended period will lead to rotting of seeds.

## Grading

The sapling bags should be shifted periodically and the empty bags separated. Saplings that do not survive should be replaced with seeds/wildlings before January. Periodic shifting of seedling bags prevents the entry of roots into the soil. Initially, the saplings should be shifted every 3–4 months.

## Pest control

The seedlings should be checked for pest, particularly caterpillars, as the sprouting seeds/propagules are susceptible to pests. Caterpillars are the major pests for *Avicennia,* and when the pest attack is severe, neem-based bio-pesticides can be sprayed to control the pests. Water from the beds should be drained completely before application of the pesticide in order to avoid the spread of pesticide residue to other areas.

## 8. Nursery techniques for different species

Nursery techniques differ from species to species, depending on the salt tolerance capacity of the species and its ecological zone. The detailed methods for different species are provided in the following chapters.

### *Avicennia marina* (Forsk.) Vierh. (Telugu: *Tella Mada*) and *Avicennia officinalis* L. (Telugu: *Nalla Mada*)

#### Collection and treatment of *Avicennia* seeds

Healthy and matured seeds of *Avicennia marina* and *A. officinalis* should be collected separately. The mature seeds can be distinguished easily by observing the light yellowish colour of the seed coat with cracks on it. The seeds can be collected from October to December. They normally float on the surface of creeks and can be collected using fishing nets.

#### Selection and processing of the seeds

Matured fruits should be soaked overnight in brackish water to remove the seed coat. This treatment reduces the period of establishment. Seeds without seed coat should be used for planting in the polythene bags. If they are to be stored, the seeds should be kept in the shade for a day or two. Young wildlings (maximum height 4 in.) can be used for planting as well as for casualty replacement (after the fruiting season). The survival of saplings will be high when matured seeds are used.

#### Sowing into nursery bags

The soil in the polythene bags must be allowed to harden by placing the bags outside the beds. Once this is done, the polythene bags containing mud should be watered using rose water cans or sprinklers. The radicle part of the seed (one-third of it) must be pushed gently into the soft mud. Deeply buried seeds will tend to rot.

## Watering

During the initial stages, water should be sprinkled twice, using rosewater cans. After 15 days, the polythene bags containing young saplings should be transferred to the sunken beds and watering should be facilitated through tidal inundation/water pumping. Regular watering should be done and care should be taken to prevent water stagnation for long periods.

## Casualty replacement

During the early stages casualty will be slightly high. The seeds that do not survive should be replaced with fresh seeds or seedlings.

## Grading

The seedlings from the beds must be shifted periodically after 5 months of sowing. Empty bags should be kept separately. Grading will help to get saplings of uniform size. After 5 months periodic shifting (every 45 days) and grading of saplings (as per height) has to be done to prevent the entry of roots into the soil.

## *Excoecaria agallocha* L. (Telugu: *Tilla*)

### Seed collection and preparation of primary bed

The fruits of *Excoecaria* are small (less than 1 cm) three-lobed dark brown capsules. Matured fruits should be collected from the trees as these tend to dehisce soon after turning brown. Each capsule has three portions containing tiny black seeds. The seeds should be sown in primary beds, which should be prepared using sandy loamy soil (sand 60% and clay 40%). This will ensure that the roots of the young plant will not get damaged while removing from the primary bed. The young seedlings collected from the mangrove forests can also be used as planting material. They should be collected in the morning and transplanted immediately thereafter. Seedlings having a height of 4 in. are considered to be ideal for planting.

### Sowing into nursery bags

The young seedlings collected from the primary beds or from the wild should be transplanted into the bags. Polythene bags filled with mud should be kept ready. Initial watering for a week may be provided using rose water cans or sprinklers.

### Watering

Watering has to be done daily. However, there should not be any stagnation of water during the initial stages.

### Casualty replacement and grading

The casualties need to be replaced with young seedlings. The seedlings from the beds must be shifted periodically after 5 months of planting.

## *Aegiceras corniculatum* (L.) Blanto (Telugu: *Guggilam*)

### 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.

### Sowing into nursery bags

The calyx region of the fruit should be inserted to a depth of about 2–3 cm. After germination, the young seedlings should be transported to the beds and watered. Polythene bags filled with mud should be kept ready.

### Watering

Watering should be done daily.

### Grading

The casualties should be replaced with seeds/seedlings. The seedlings from the beds must be shifted periodically after 5 months of sowing.

## *Bruguiera cylindrica* (L.) Blume (Telugu: *Urudu*) and *Bruguiera gymnorrhiza* (L.) Savigny (Telugu: *Kandriga*)

### Collection of propagules

Healthy and mature propagules can be collected directly from the trees and also from the creeks using fishing nets. The characteristic and visible indicator of mature propagules of *Bruguiera cylindrica* and *B. gymnorrhiza* are the reddish brown or greenish red colour hypocotyl. *B. cylindrica* propagules are thin when compared to *B. gymnorrhiza*.

### Selection and processing of propagules

The propagules should then be planted in the polythene bags placed in the beds. In case the propagules have to be stored, these should be kept in water.

### Sowing into nursery bags

The hypocotyl of the propagules should be inserted to a depth of about 5 cm. Deeply buried propagules will tend to rot.

### Watering

Watering should be done daily.

### Grading

Germination percentage will be high. The seedlings from the beds must be shifted periodically after 3 months of sowing.

## *Ceriops decandra* (Griff.) Ding Hou (Telugu: *Thogara*)

### Collection of propagules

Healthy and matured propagules can be collected from the trees and also from the creeks with the help of fishing nets. The matured propagules can be identified by the conspicuous ridges; the base of the hypocotyl is slightly thicker than the apex.

### Selection and processing of propagules

The propagules should then be planted in the polythene bags placed in the beds. In case the propagules have to be stored, these should be kept in water.

### Sowing into nursery bags

The hypocotyl of the propagules should be inserted to a depth of about 4 cm. Germination percentage will be high.

### Watering

Watering should be done daily.

### Grading

The seedlings should be shifted periodically after 4 months of sowing

## *Rhizophora apiculata* Bl. (Telugu: *Ponna*) and *Rhizophora mucronata* Lamk. Telugu: (*Uppu Ponna*)

### Collection of propagules

Healthy and matured propagules should be collected from the tidal creeks using fishing nets or directly from the trees. Characteristic indicators of mature propagules of *Rhizophora mucronata* are pale green or yellow cotyledon where as *R. apiculata* have red cotyledons. Propagules of *R. mucronata* are bigger than those of *R. apiculata*.

### Selection and processing of propagules

Healthy propagules should be selected and checked for insect borers. They 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 1 or 2 days, without being exposed to direct sunlight. The propagules may be kept in water.

### Sowing into nursery bags

The hypocotyl of the propagule should be inserted to a depth of about 7–8 cm. The rate of germination is almost 100%.

### Watering

Watering should be done daily.

### Grading

The seedlings from the beds must be shifted periodically after 3 months of sowing.

## *Sonneratia apetala* Buch. – Ham (Telugu: *Kalinga*)

### Collection of fruits

Matured fruits should be collected from the trees. Generally, the matured fruits get detached from the calyx and float on the water. These fruits can be collected from the water. The characteristic indicators of matured fruits are deep green colour and a sour taste of the mesocarp.

### Collection of seeds from fruits and sowing

The matured fruits should be kept in polythene bags for 15 days to allow the fleshy mesocarp to rot. The fruits should then be gently crushed and the seeds, along with debris sown in a primary bed. Periodic watering has to be done. After 20–30 days, the seeds will start to sprout. The 30-day-old seedlings should be then transplanted into the polythene bags and kept in the shade.

### Watering

Watering should be done regularly.

### Grading

The casualties need to be replaced with young seedlings that are collected from the primary bed /wildlings. The seedlings from the beds must be shifted periodically after 5 months of planting.

## *Xylocarpus moluccensis* (Lamk.) M. Roem. (Telugu: *Senuga*) and *Xylocarpus granatum* J. Koenig (Telugu: *Puchakaya*)

### Collection of fruits

Matured fruits can be collected from the trees and the fallen seeds can be collected using fishing nets. The characteristic indicators of matured fruits are yellow colour in the case of *Xylocarpus moluccensis* and brown colour in the case of *X. granatum*. Cracks in the pericarp can be noticed in the matured fruits.

### Collection of seeds

The seeds should be removed from the fruits. Generally, the pericarp tends to peel off within 2 -3 days after harvest.

### Sowing into nursery bags

The mud in the bags should be soft, and the radicle side of the seeds should be placed gently in the polythene bags.

### Transporting the young seedlings to beds

Young seedlings of about 10 days should be transferred to the nursery beds. Initially, long shoots with thin scaly leaves will emerge. These scaly juvenile leaves then turn into normal leaves.

### Watering

Watering should be done daily.

### Grading

The rate of germination will be high (more than 95%). The seedlings from the beds must be shifted periodically after 4 months of sowing.

## 9. Seed germination and growth of seedlings

The germination period, rate of germination and average height of mangrove saplings raised in the mangrove nursery are shown in Table 2. *Excoecaria agallocha, Avicennia marina* and *A. officinalis* germinate within 6–10 days of sowing. Other mangrove species take nearly 20–40 days. The rate of germination of these two *Avicennia* species is also high. As these species have high tolerance to salinity, they should be raised in larger numbers. Some mangrove species such as *Rhizophora apiculata, R. mucronata, Bruguiera cylindrica,B. gymnorrhiza, Ceriops decandra, Xylocarpus moluccensis* and *Sonneratia apetala* take more than 20 days to germinate. The nursery saplings should be irrigated with saline water (5–30 ppt). The salinity levels should be around 5 ppt during October (germination period) and 30 ppt after March. The initial growth of *Xylocarpus moluccensis* is rapid, and the colour of the shoot is brown. The germination rate of the propagules of *R. apiculata, R. mucronata, C. decandra, X. granatum, X. moluccensis, B. cylindrica* and *B. gymnorrhiza* is high, that is, above 90%. Nevertheless, their establishment time is longer. The germination rate in higher salinities is comparatively lower.

## 10. Viability of seed material

The viability period of some of the mangrove seeds is very short, and hence these should be planted soon after collection (within 24 h). The seeds of *Avicennia* can be stored for only 2 days. However, the Rhizophoraceae members and *Xylocarpus* can be stored for up to 2 weeks in water. Salinity also plays an important role in the germination and survival of mangrove saplings. Young seedlings require low salinity levels (less than 10 ppt during October) for better survival rates. *Sonneratia apetala* seeds tend to germinate better in lower salinity (less than 10 ppt) as against higher salinity. Casualty of the propagules can be minimized by selecting healthy propagules and planting them during the monsoon season.

**Table 2. Germination and growth of mangrove species**

| Species | Seed material | Germination period (days) | Rate of germination (%) | Average height after 8 months (cm) |
|---|---|---|---|---|
| *Avicennia officinalis* | Fruits | 6 | 75 | 75 |
| *Avicennia marina* | Fruits | 6 | 75 | 75 |
| *Excoecaria agallocha* | Seeds/young seedlings | 10 | – | 65 |
| *Aegiceras corniculatum* | Fruits | 35 | 80 | 70 |
| *Sonneratia apetala* | Seeds | 30 | 20 | 80 |
| *Xylocarpus molluccensis* | Seeds | 20 | 90 | 80 |
| *Xylocarpus granatum* | Seeds | 30 | 90 | 80 |
| *Bruguiera gymnorrhiza* | Propagules | 35 | 100 | 60 |
| *Bruguiera cylindrica* | Propagules | 40 | 95 | 60 |
| *Ceriops decandra* | Propagules | 40 | 95 | 60 |
| *Rhizophora apiculata* | Propagules | 40 | 100 | 70 |
| *Rhizophora mucronata* | Propagules | 40 | 100 | 80 |

## 11. Vegetative propagation

***Excoecaria agallocha***

**Stem cuttings**

Branches having a diameter of 2 cm should be cut into lengths of 20 cm each and planted in the polythene bags filled with mangrove soil, which should be readied beforehand. Watering should be done regularly. Young leaves appear at the nodes after 10–15 days. The saplings can be shifted to the nursery beds for regular watering. Roots start emerging after about 40 days. The saplings need to be shifted after 3 months, at an interval of 30 days, until planting in the degraded areas.

**Air layering**

Air layering is one of the methods used for vegetative propagation. It is popularly known as 'Chinese layering'. Using this method, root formation is encouraged on tiny branches by the application of root-producing hormones and rooting media. This method can be followed for tertiary branches without much damage to the mother plant. Some tropical trees that are difficult to propagate through stem cuttings are propagated successfully using this method.

Healthy plants should be chosen as mother plants for air layering. Branches having a diameter of 3 cm should be used for air layering. The bark of the selected branch should be removed to a width of 2 cm. Rooting medium (mangrove wet soil) should be used as the primary layer, and coir fibre can be used as the secondary layer to retain moisture. Thick polythene paper measuring 12 x 30 cm can be used to wrap firmly the primary and secondary layers. Care should be taken to ensure a tight wrap to prevent moisture loss. Roots start emerging after 30 days. Once the roots are well established, the rooted stem can be removed from the parent plant and planted in polythene bags containing mangrove soil. Initially, these saplings should be kept in

shade for 15 days to protect them from direct sunlight. Then, the saplings should be kept in the mangrove nursery for further growth.

***Excoecaria agallocha***

***Scyphiphora hydrophyllacea***

In the Godavari mangrove wetland *Scyphiphora hydrophyllacea*, a rare and endemic plant, occurring near the Sacramento lighthouse in Kothapalem Reserved Forest. The viability of the seeds of *S. hydrophyllacea* is very poor as seen in germination trials where not even one seed germinated. Hence, other propagation techniques such as stem cutting and air layering are used. Literature survey has indicated that stem cuttings and air layering are successful propagation methods.

**Stem cuttings**

Root-promoting hormone was used for air layering and stem cuttings (Keradix). Healthy stems of 1.5–2.0 cm diameter and 20 cm length were cut and transported in polythene bags to the laboratory. The cut edges were dipped in Keradix rooting powder and planted. However, the trials were not successful.

## Air layering

### Selection of branches

Semi-hard wood and hard wood branches should be selected. Branches that droop too much and twigs that are very young should be avoided. Straight branches of at least 20 cm length should be used for air layering.

### Removal of bark

The bark of the selected branch should be removed partially (about 70%) to a length of about 2 cm below the node. The remaining area of the bark will maintain some of the important physiological functions, since formation of roots will take at least 2 months.

### Application of root-producing hormone

The Keradix root-producing hormone available in the market could be used to promote root formation. The hormone powder should be applied all around the wounded portion using a fine brush.


### Application of rooting medium

Wet mangrove soil should be used as the first layer of the rooting medium. Coir fibre/sphagnum moss could be used as the secondary layer to retain moisture. Thick polythene paper should then be wrapped tightly around the medium. Intermittent moistening should

be done to keep the rooting medium wet to enable rooting. Roots will appear after 3 months of layering. Once sufficient roots are formed, the layer should be removed from the mother plant (after 4 months). The layers should be planted in the polythene bags containing mangrove soil and kept in the shade for another 20 days. After sufficient root formation, the saplings should be maintained in the nursery for further establishment.

## 12. Mangrove Genetic Resources Conservation Centre (MGRCC)

Mangrove forests in tropical and subtropical regions are important natural reservoirs of biological diversity similar to that of tropical rain forests. It is important to conserve the gene pool of existing mangrove species and retain the genetic diversity for sustainable utilization of these resources. The species diversity of mangroves is influenced by various physicochemical parameters. In Sunderbans, *Heritiera fomes* zones (a freshwater-loving species) are gradually occupied by *Ceriops decandra* (saline tolerant) due to reduction in freshwater levels (Ahmed et al., 2011). The loss of species diversity was recorded in Pichavaram, Tamil Nadu, due to reduction in freshwater flow (Kathiresan, 2002; Selvam, 2003; Sathyanathan et al., 2014). Saline-sensitive species such as *Cynometra ramiflora, Xylocarpus granatum, Kandelia candel, Bruguiera gymnorrhiza* and *Sonneratia apetala* were collected from these mangrove wetlands by the Botanical Survey of India and French Institute of Pondicherry and maintained in their herbarium. The genetic resources centres would eventually serve as repositories of mangroves species present in Indian wetlands and also as 'field gene banks'.

MSSRF, with the support of EGREE Foundation and the Andhra Pradesh Forest Department (APFD), established a mangrove genetic resources conservation centre in Coringa Wildlife Sanctuary in East Godavari district, Andhra Pradesh. This project was supported by GoI-GoAP-UNDP-GEF. The mangrove species established and conserved in the mangrove genetic resources centre is given below.

**Seeds/seedlings collected from Mahanadi delta, Odisha**

The following matured seeds were collected from the Mahanadi delta, Odisha. The seeds were planted in polythene bags and watered regularly.

***Bruguiera sexangula*** **(Lour.) Poir. RHIZOPHORACEAE (Oriya: *Bandari*)**

Evergreen trees, up to 6 m in height; bole, occasionally buttressed, sometimes with stilt roots, and underground roots produce numerous knee roots; bark, grey to pale brown, with few large corky lenticels; fruit, a drupe, reddish green, 2.0–2.5 cm long; hypocotyl, 10–15 x 1.2 cm, cylindrical, with blunt tip, surface slightly ridged.

***Kandelia candel*** **(L.) Druce RHIZOPHORACEAE (Oriya: *Sinduka*)**

Evergreen trees, up to 6 m in height; bole, buttressed; bark, dark brown, smooth; hypocotyl, 40 x 1.5 cm, spindle shaped, slightly curved with pointed radicle, surface smooth, green; cotyledonary collar, protruded and exposed on maturity.

***Aglaia cucullata*** **(Roxb.) Pellegrin MELIACEAE (Oriya: *Ooanra*)**

Trees, 20–25 m in height; bark, grey with numerous blind root suckers; leaves, compound; inflorescence, densely lepidote; male panicles, drooping, almost as long as leaves, with many diverging branches; female racemes, much shorter, few-flowered; flowers, bracteate, female and bisexual flowers larger than male flowers; capsules, ca. 6 cm across, pyriform-globose, obtusely three lobed, three valved; seeds, three, orange, rounded with fleshy aril.

***Cerbera odollam*** **Gaertn APOCYNACEA**E **(Oriya: *Paniamba*)**

Small evergreen trees, up to 6 m in height; bark, greenish brown; blaze, creamy yellow; branchlets, stout with prominent leaf scars,

milky latex; leaves, simple, alternate, crowned at the end of branches; flowers, bisexual, calyx lobes five, linear; corolla lobes five, tube funnel shaped above the throat with five villous scales; fruit, a drupe, globose or ellipsoid, pericarp green turning rose; seeds, one or two, compressed.

***Bruguiera sexangula***

***Cerbera odollam***

***Nypa fruticans***

***Aglaia cucullata***

***Cynometra ramiflora***

***Xylocarpus mekongensis***

***Cerbera odollam***

***Cynometra ramiflora***

***Kandelia candel***

***Heritiera fomes***

***Cynometra ramiflora* L. FABACEAE (Oriya: *Singada*)**

Trees of medium size, about 10 m tall; leaves, compound with two leaflets; inflorescence axis, about 13–25 mm long; fruits, about 2.5 x 4 cm, crescent shaped, outer surface having wart-like protuberances.

**Seeds/seedlings collected from the Sunderbans**

*Xylocarpus mekongensis, Aegialitis rotundifolia* and *Heritiera fomes* saplings were raised in the mangrove nursery established in the Sunderbans by Nature Environment and Wildlife Society (NEWS), Kolkata. *Nypa fruticans* fruits were collected with the help of the state Forest Department.The seeds were planted in polythene bags and watered regularly.

***Xylocarpus mekongensis* Pierre MELIACEAE (Bengali: *Passur*)**

Medium-sized, evergreen or briefly deciduous, glabrous tree with very short or even no buttresses; root system, with peg-like pneumatophores; bark, dark red, longitudinally fissured; leaf, compound, usually with four leaflets; inflorescence, 10–35 flowered; fruit, smaller than X. granatum, up to 10 cm in diameter, green, leathery, contains 4–10 seeds.

***Aegialitis rotundifolia* Roxb. PLUMBAGINACEAE (Bengali: *Tora*)**

*Aegialitis rotundifolia* is an evergreen shrub growing 30–300 cm tall. The plant is classified as 'near threatened' in the IUCN Red List of Threatened Species (2013).

***Aegialitis rotundifolia***

***Heritiera fomes* Buch.-Ham. MALVACEAE (Bengali: *Sundari*)**

*Heritiera fomes* is an evergreen tree that can grow up to 25 m tall. The bole can be 60 cm or more in diameter, grey in colour with vertically fissured bark. Buttresses and pneumatophores are present. The leathery leaves are elliptical and tend to be clustered at the ends of the twigs. The panicles with pink or orange bell-shaped flowers are each about 5 mm (0.2 in.) across, each flower being either male or female. The fruit carpels are up to 5 cm (2.0 in.) long and 3.8 cm (1.5 in.) wide. The plant is classified as 'endangered' in the IUCN Red List of Threatened Species (2013).

***Nypa fruticans* Wurmb. ARECACEAE (Bengali: *Golpata*)**

Nipa palm is a large, evergreen palm forming a loose clump of growth from a prostrate or subterranean stem up to 45 cm in diameter. This stem branches at intervals to form individual clumps of large, erect leaves that can each be up to 6 m long. Flowers appear on a long stalk (1 m) as an inflorescence. Female flowers are encased in bracts and resemble a cone while male flowers appear as a long spike. Fruits are chestnut brown and appear in cluster forming a globular shape (20–25 cm). Each fruit bears one seed which starts to germinate while still on the parent palm, and just when the fruit drops off, the seedling is already starting to pierce through the husk of the fruit. Seeds are edible and leaves are used in thatching. The palms are also planted along swampy coastlines, often with mangroves, in order to protect the shore from erosion.

**Seeds/seedlings collected from Ratnagiri coast, Maharashtra**

*Ceriops tagal* popagules were collected from the Ratnagiri coast of Maharashtra.

***Ceriops tagal* (Perr.) C.B. Robinson RHIZOPHORACEAE (Marathi: *Chauri*)**

A small tree or a glabrous shrub with a compact crown with many buttresses at the base; bark, dark red; leaves, obovate to elliptical, 5–10 cm long, 2–6 cm wide; flowers, about 6 mm in length; fruit, small; hypocotyl, 15–25cm long with ridges along the length with a white collar when ready to drop.

**Seeds/seedlings collected from Tamil Nadu**

Matured propagules of *Rhizophora mucronata* were collected from the Pichavaram mangrove wetlands in Tamil Nadu.

***Rhizophora mucronata*** **Poir. RHIZOPHORACEAE (Tamil: Sura Punnai)**


Trees, up to 5 m tall, with many upwardly growing branches; leaf scars, prominent; stem, base supported by numerous branched stilt roots; leaves, 10–18 x 4–10 cm, broadly elliptic or ovate oblong, with a rolled-up tip at apex, cuneate at base; flowers, in axillary cymes, four–eight in number, pedicellate, cream coloured, fragrant; hypocotyl, 30–65 cm long, cylindrical.

**Seeds/seedlings collected from Andhra Pradesh**

The following seeds/seedlings were collected from the Andhra Pradesh coast. *Scyphiphora hydrophyllacea*, a rare species has been propagated through air layering and successfully transplanted in the MGRCC.

***Aegiceras corniculatum*** **(L.) Blanco MYRSINACEAE (Telugu: *Guggilam*)**

Evergreen trees, 2–4 m; stem, much branched, with grey bark and broom-shaped stilt roots arising from base; leaves, 4–8.5 x 2–4.5 cm, alternate, obovate or ovate oblong; flowers, 1.5–2 cm long, white,

fragrant, subsessile, mostly in leaf-opposed umbels; fruits, 6–8 cm long, sharply pointed, coriaceous, yellowish brown with persistent imbricate calyx.

***Rhizophora apiculata*** **Blume RHIZOPHORACEAE (Telugu: *Ponna*)**

Trees, 5–6 m tall, 30–100 cm in diameter; stem, with aerial stilt roots; leaves, 10–20 x 5–9 cm, elliptic oblong, apiculate at apex, cuneate at base; flowers, 10–12 mm long, yellow, sessile, paired; fruits, 2.5–3 cm across; hypocotyl, 20–30 cm long, smooth, cylindrical, pointed towards the radical end.

***Ceriops decandra*** **(Griff.) Ding Hou RHIZOPHORACEAE (Telugu: *Thogara*)**

Trees, about 3–4 m tall; stem, reddish brown, much branched; bark, light grey, lenticular fissures, peeling in thin flakes; stem base, pyramidal in outline, with many stilt roots; leaves, 5–14 x 4–10 cm, obovate or elliptic oblong; flowers, white, 3–4 mm across, resinous, 8–14 flowered, condensed; fruits, ovoid, conical; hypocotyl, 12–14 cm long.

***Bruguiera cylindrica*** **(L.) Blume RHIZOPHORACEAE (Telugu: *Urudu*)**

Trees, 3–4 m tall; stem, smooth, lenticellate; stem base, buttressed, with many knee roots; leaves, 8–16.5 x 5.5–6.5 cm, oblanceolate, or rarely elliptic, acute at apex, cuneate at base; petioles, 3–3.5 cm long; flowers, white, 1–11.3 cm across, three, in axially pedunculate cymes; peduncles, 7–8 mm long; petals, white, as many as the calyx lobes; hypocotyl, 10–14 cm long, 5 mm in diameter, more or less cylindrical, straight or slightly curved towards apex.

***Bruguiera gymnorrhiza* (L.) Savigny RHIZOPHORACEAE (Telugu: *Kandringa*)**

Trees, 3–4 m tall, 30–60 cm in diameter; bark, rough, fissured, corky lenticellate; stem base, short, buttressed with knee roots; leaves, 12.5–20.5 x 5.5–7.5 cm, elliptic oblong acute at apex, obtuse at base; petioles, reddish green in colour; flowers, scarlet, up to 3.5–4 cm, solitary; calyx, tubes ribbed, 10–14, lobed; petals, as many as calyx lobes; hypocotyl, cigar shaped, 15–17 x 1.5–2.5 cm, narrowed at apex.

***Sonneratia apetala* Buch.-Ham. LYTHRACEAE (Telugu: *Kaalinga*)**

Trees, 5–7 m tall, 30–80 cm in diameter, with dense crowns; stem, with many pale-green, soft drooping branches; bark, thin, light brown, irregularly fissured; stem base, not buttressed, provided with 15–30 cm long, peg-like, corky pneumatophores sometimes forked twice or thrice; leaves, 5–14 x 2–3.5 cm, narrowly elliptic oblong; flowers, 1.5–2 cm across, apetalous, green or yellowish white in axially solitary or cymes from the branch-axils; fruits, 2–2.5 cm across, smooth globes, many seeded berries, shortly pointed at apex.

***Avicennia officinalis* L. AVICENNIACEAE (Telugu: *Nalla Mada*)**

Trees, 4–10 m tall; stem, 70–150 cm in diameter, glabrous, much branched; bark, thin, ash coloured, tap root absent; pneumatophores, 10–20 cm long, straight, pointed, lenticellate, often forked with hook-like bending at apex; leaves, 6 x 3 cm, obovate or broadly ovate oblong; flowers, up to 1 cm long, yellow, fragrant, in axillary or terminal head-like congested cymes; capsules, broadly ovoid, almond-shaped, densely silvery papillose, beaked at apex.

***Avicennia marina* (Forssk.) Vierh. AVICENNIACEAE (Telugu: *Tella Mada*)**

Shrubs or small bushy trees, 3–6 m tall, 15–25 cm in diameter; pneumatophores, 3–10 cm long, narrowly pointed; leaves, 5–6 x 2.5–3 cm, elliptic oblong, coriaceous, dark green above, yellowish papillose beneath, acute or obtuse at apex, cuneate at base; flowers, 2–4 mm across, yellow, fragrant, 6–10, crowded in terminal condensed cymes; capsules, ovoid, half the size of A. officinalis, apiculate at apex.

***Xylocarpus granatum* Koen. MELIACEAE (Telugu: *Puchakai*)**

Trees, 10–15 m tall, 60–80 cm in girth; stem, buttressed; bark, smooth, yellowish white with papery flakes; leaves, unijugate or bijugate, lower pairs subopposite; leaflets, 6–10 x 3–5 cm, obovate, entire, coriaceous, rounded at apex, tapering at base; flowers, 5–7 mm across, white, red glandular within; calyx, four-lobed; petals, four, free; fruits, 20–25 cm across, spherical, pendulous; seeds, more than 15, each 4–7 x 3–4 cm pyramidal or triangular.

***Xylocarpus moluccensis* (Lam.) M. Roem. MELIACEAE (Telugu: *Senuga*)**

Large trees, up to 10 m tall, trunk up to 60 cm in diameter at base, buttressed; bark, red with thick flakes; wood, red in colour; pneumatophores, woody; leaflets, 7–12 x 3-6 cm, ovate, acute at apex, oblique at base; flowers, 2–3 cm across, white with red glands inside; staminal teeth, obscure, anthers exceeding in the teeth; stigma, cup shaped; fruits, 10–15 cm across, globose.

Small trees, 2–4 m tall, without pneumatophores; bark, reddish brown, lenticellate; leaves, 4–8.5 x 1.5–3.5 cm, obovate, thick, coriaceous, entire, emarginate at apex, cuneate at base; petioles, very short; flowers, 9–11 mm long, white, sessile in axillary spikes; fruits,

***Lumnitzera racemosa* Willd. COMBRETACEAE (Telugu: *Thanduga*)**

8–10 x 4–6 mm, compressed, woody, ellipsoid, single-seeded drupes; seeds, elongated, pointed towards apex.

***Excoecaria agallocha* L. EUPHORBIACEAE (Telugu: *Tilla*)**

Evergreen trees with milky, acrid juice, 3–8 m tall, 10–40 cm in diameter; bark, greyish white, smooth, lenticellate; wood, soft, light; leaves, 2–8 x 1.5–3 cm, ovate, ovate elliptic or ovate oblong, coriaceous, shining dark green, turning red before shedding; flowers, unisexual, fragrant; male flowers, 2–3 mm across, sessile, yellow, in axially many flowered catkin like spikes 3–7 cm long; female flowers, 2.5–3.5 mm across; fruits, 1–1.5 cm across, depressed globes, three lobed.

**Female inflorescence**

**Male inflorescence**

***Scyphiphora hydrophyllacea* Gaertn. f. RUBIACEAE (Telugu: *Naara thanduga*)**

Small trees resembling Lumnitzera racemosa; branchlets, stout, swollen at the nodes; leaves, coriaceous, obovate; stipules,

interpetiolar, short; flowers, small, in dense axillary shortly pedunculate cymes; fruit, a subcylindric 8- to 10- grooved drupe.

***Acanthus ilicifolius* L. ACANTHACEAE (Telugu: *Alchi*)**

Erect, ascending or scandent under shrubs, 0.5–1.5 m tall; stem, terete, often provided with aerial roots, glabrous, with two sharp spines in leaf axils; leaves, 5–11 x 3–10 cm, decussate, ovate oblong or lanceolate, margins spiny, narrowed at base, spiny at apex; flowers, violet, 3.5–4 cm long; capsules, 2–3 cm in diameter; ovoid oblong, compressed, apiculate, shining green or brown.


**Planting of saplings**

In the MGRCC, the saplings should be planted in the inter-tidal areas where constant tidal flushing occurs. Shallow canals could be dug to facilitate tidal flushing.

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