

Management of Natural Resources
in the Coastal Zone of Soc Trang Province

Mangrove Nursery Manual

Hoang Van Thoi and Pham Trong Thinh



gtz



Soc Trang Provincial
People's Committee

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Management of Natural Resources in the Coastal Zone of
Soc Trang Province

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About GTZ

As an international cooperation enterprise for sustainable development with worldwide operations, the federally owned Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH supports the German Government in achieving its development-policy objectives. It provides viable, forward looking solutions for political, economic, ecological and social development in a globalised world. Working under difficult conditions, GTZ promotes complex reforms and change processes. Its corporate objective is to improve people's living conditions on a sustainable basis.

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Foreword

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The aim of the project “Management of Natural Resources in the Coastal Zone of Soc Trang Province” is to protect and sustainably use the coastal wetlands for the benefit of the local population. Rehabilitation and afforestation of mangroves will make an important contribution to achieving this aim because mangrove forests protect the coast from erosion, storms and flooding and provide nursery ground, shelter and food for aquatic species on which the livelihood of many people depend.

In order to assist the Forest Protection Sub-department with all aspects of mangrove rehabilitation and management the project has produced a comprehensive tool box for mangrove management covering nursery, planting, tending, protection and monitoring in three separate manuals and a detailed report on the history of mangrove forests in Soc Trang since 1965.

This mangrove nursery manual is an important contribution to successful rehabilitation and afforestation of mangroves because the success of planting is to a large extent dependent on the quality of the seedlings used.

This manual has been prepared by Mr. Hoang Van Thoi (Forest Science Sub-Institute of Vietnam, Ho Chi Minh City) and Dr. Pham Trong Thinh (Southern Sub-Institute of Forest Inventory and Planning, Ho Chi Minh City). Dr. Norman Duke from the University of Queensland, Australia, provided a comprehensive review of the manual.

The cover illustration is from Mr. Le Trong Hai (Architecture University of Ho Chi Minh City) and Mr. Tran Huy Manh (Southern Sub-Institute of Forest Inventory and Planning, Ho Chi Minh City).

This manual is intended for use by staff of the Forest Protection Sub-department and farmers who are involved in managing mangrove nurseries in the Mekong Delta and the coastal zone of Vietnam.

Klaus Schmitt
Chief Technical Advisor



Table of contents

About GTZ	ii
Foreword	iii
Table of contents	iv
List of figures	vi
List of tables and photo credits	vii
Acronyms and explanations	viii
1. Introduction	10
2. Rationale for mangrove nurseries	12
3. Types of nurseries	14
4. Site selection for mangrove nursery establishment	16
5. Designing and building a nursery	18
5.1 Nursery in a low-lying area – a ‘flooded nursery’	19
5.2 An upland nursery on high ground – a ‘floating nursery’	20
6. Selection of suitable mother trees for different types of soil	22
6.1 Collection of fruits and propagules	22
6.2 Identification of maturity of fruits and propagules	23
6.3 Selection of mangrove species for afforestation	23
7. Techniques for planting seeds/seedlings in plastic containers	24
7.1 Soil preparation	24
7.2 Seedbed preparation	24
7.3 Filling plastic containers	25
7.4 Arrangement of soil-mixed containers onto seedbeds	25
7.5 Seed stock for sowing	25
7.6 Management of nursery	26
8. Techniques to produce bare-root seedlings	28
8.1 Soil preparation	28
8.2 Sowing seeds	28
8.3 Seedling management	29

9. Nursery techniques for different species.....	30
9.1 <i>Sonneratia caseolaris</i> (L.) Engl.	32
9.1.1 Harvest, preservation and processing of seeds	32
9.1.2 Seedling production in plastic containers.....	32
9.1.3 Production of bare-root seedlings	33
9.2 <i>Avicennia marina</i> (Forssk.) Vierh.	34
9.2.1 Harvesting, preservation and processing of seeds	34
9.2.2 Planting in plastic containers.....	35
9.2.3 Management of nursery	35
9.2.4 Criteria for the readiness of seedlings for field planting	35
9.3 <i>Rhizophora apiculata</i> Bl.	36
9.3.1 Harvest, preservation and processing of seeds	36
9.3.2 Planting of fruits into soil mixed containers.....	36
9.3.3 Management of nursery	36
9.4 <i>Lumnitzera racemosa</i> Willd.	37
9.4.1 Harvest, preservation and process of seed.....	37
9.4.2 Sowing	38
9.4.3 Management of the nursery	38
9.5 <i>Ceriops tagal</i> (Perr.) C.B. Rob.....	38
9.5.1 Harvest, preservation and process of seed.....	38
9.5.2 Planting of fruit into soil mixed container.....	39
9.5.3 Management of nursery	39
10. Insect pests and diseases in the mangrove plant nursery.....	40
10.1 Sterilisation of seedbed	41
10.2 Sanitation of nursery.....	41
10.3 Maintenance technique	41
10.4 Control methods	42
References	44



List of figures

Figure 1.	<i>Rhizophora</i> , <i>Sonneratia</i> and <i>Avicennia</i> species in mangrove forests of Vinh Chau.	10
Figure 2.	<i>Sonneratia</i> species dominate the mangrove forests of Cu Lao Dung and Long Phu.	10
Figure 3.	A ‘floating mangrove nursery’ in upland locations requires frequent watering.	14
Figure 4.	A ‘flooded mangrove nursery’ on low-lying tidal lands is flooded regularly.	14
Figure 5.	Nursery used to produce seedlings in the soil-mixed containers.	18
Figure 6.	Seedbeds for seeds and saplings are covered by a black mesh fabric.	19
Figure 7.	A ‘flooded nursery’ on low-lying tidal land is suitable for most mangrove species.	19
Figure 8.	Nursery producing bare-root seedlings.	20
Figure 9.	Design of the ‘floating nursery’ on higher elevation land.	20
Figure 10.	Collection of <i>Rhizophora</i> propagules.	22
Figure 11.	Collection of <i>Avicennia</i> propagules.	22
Figure 12.	Soil collection and filling of plastic containers.	24
Figure 13.	Mixing of soil, rice husk ash and fertiliser.	24
Figure 14.	Organic matter is available on the beach.	25
Figure 15.	After filling, containers will be arranged onto seedbeds.	25
Figure 16.	Land prepared for sowing; the net prevents seeds from being washed away and protects the area from fishing activities.	28
Figure 17.	Selection of ‘every other’ tree of <i>Sonneratia</i> for seed collection.	32
Figure 18.	Mature <i>Avicennia marina</i> propagules (cryptoviviparous).	34
Figure 19.	Nursery of <i>Avicennia marina</i> seedlings.	35
Figure 20.	Flooding level of seedlings of <i>Avicennia marina</i>	35
Figure 21.	Propagules with sprouting roots and leaves are not collected.	36
Figure 22.	<i>Rhizophora</i> seedlings ready for planting.	37
Figure 23.	Leaf and flower of <i>Lumnitzera racemosa</i>	38
Figure 24.	Plantation of <i>Lumnitzera racemosa</i>	38
Figure 25.	Leaf and flower of <i>Ceriops</i>	38
Figure 26.	Propagules of <i>Ceriops</i>	39
Figure 27.	Small crabs make their burrows in the soil.	40
Figure 28.	Small crabs eat and damage the seedlings.	40
Figure 29.	Insect caterpillars and fungus damage.	40
Figure 30.	Insect larvae eat young <i>Rhizophora</i> leaves.	40



List of tables

.....

Table 1. Planting methods for some mangrove species in Soc Trang. 22

Table 2. Indicators of maturity of propagules of mangrove species. 23

Table 3. Seed characteristics and sowing and maintenance techniques
for some selected mangrove species. 30

Table 4. Action plan for the sowing, tending and selection of seedlings
of some selected mangrove species. 31



Photo credits

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Acronyms and explanations

Atonik 1.8 DD, 5 G	Nitrophenolate 0.9%
Benlat	1-(butylcarbamoyl)-2-benzimidazol-methylcarbamate
BMZ	German Federal Ministry for Economic Cooperation and Development
Captan	Thiophthalimide
DAP	Diammonium phosphate
Formalin	HCHO
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
NPK(16:16:8)	N ₂ O 16% + P ₂ O ₅ 16% + K ₂ O 8%
No.	Number
Vipac 88	α - Naphthyl Acetic Acid (α - N.A.A) + β - Naphthoxy Acetic Acid (β - N.A.A) + ZnSO ₄ + MgSO ₄ + CuSO ₄ + NPK

Introduction

Mangrove forests play several important ecological roles. They protect coastlines from strong winds and devastating sea waves, stabilise the shoreline, prevent soil erosion and facilitate the expansion of coastal areas. Mangroves also enhance the productivity of marine life. The protection and management of mangrove forests is therefore an indispensable component for achieving sustainable economic development in coastal areas.

Mangrove forests in Soc Trang Province are found in the three districts of Vinh Chau, Long Phu and Cu Lao Dung. Each district has its own distinct geography, topography, soil character and socio-economic conditions. The *Sonneratia* species, for example, are dominant in Long Phu and Cu Lao Dung (Figure 1), while *Rhizophora* and several species of *Avicennia* are prevalent in Vinh Chau (Figure 2).

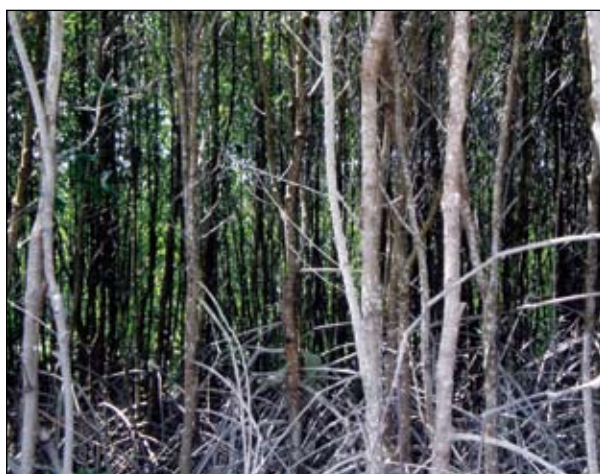


Figure 1. *Rhizophora*, *Sonneratia* and *Avicennia* species in mangrove forests of Vinh Chau.



Figure 2. *Sonneratia* species dominate the mangrove forests of Cu Lao Dung and Long Phu.

About 3,000 ha of mangrove forest have been rehabilitated in Soc Trang Province since 1990 (FIPI 2004). Afforestation activities have been combined with seedling production in nurseries. Seedlings of some mangrove species (*Sonneratia caseolaris*, *Avicennia marina*, *Rhizophora apiculata*) were locally produced (Do Xuan Phuong 2006). Such local production however, has only been able to partially meet the requirements of large-scale reforestation projects in Soc Trang. To augment seedling production, two nurseries were established in the Vinh Chau and Long Phu districts. Several technical problems were, however, noticed in

local nursery management practices. Some of these problems were the inappropriate placement of a seed orchard, poor identification of viable parent trees, and inappropriate criteria for determining the readiness of seedlings for planting. To address these problems, a planting guide describing the technical problems and solutions was urgently needed. This is the primary reason guiding the production of this Manual on Mangrove Nursery Techniques.

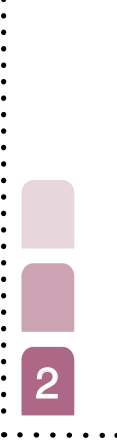


Rationale for mangrove nurseries

The Manual on Mangrove Nursery Techniques describes basic methods and strategies for mangrove growers. Specifically, the manual describes several techniques for the selection of seed orchards, selection of viable parent trees, seed collection, seed processing, seed sowing and general nursery techniques.

Mangrove species naturally regenerate in places where soil conditions are suitable. In areas with unfavourable soil conditions (e.g. eroded ground, alluvial deposits) however, natural regeneration is inconsistent and unreliable. Furthermore, flowering and seed maturation does not coincide with cultivation periods.

In Soc Trang, for example, the ripening of *Sonneratia caseolaris* fruits occurs from September to December. The best time to plant seedlings is from May to July to avoid them being buried under heavy alluvium deposits in August to October, or by soil erosion in November to February. This mismatch between propagule availability and their optimal planting season makes it impossible to produce sufficient numbers of seedlings for planting without establishing a nursery.



Types of nurseries

There are several types of nurseries. A **permanent (fixed) nursery** is constructed to produce seedlings for long-term supply in larger afforestation projects. This type of nursery needs to be large enough to supply the project, and is work intensive. The cost per seedling is also relatively high.

A **temporary nursery** is a nursery constructed to produce seedlings for a one or two-year afforestation project.

Further sub-classification of nurseries can be done based on tidal location.

A **‘floating mangrove nursery’** is one established in upland areas (above the highest tidal range). This nursery is used to provide a longer-term supply of seedlings (Figure 3).

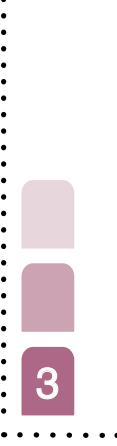
A **‘flooded mangrove nursery’** is established in low intertidal areas, which are regularly flooded by tidal waters (Figure 4). This kind of nursery provides seedlings for one or two-year planting projects, and requires less effort in terms of setup and maintenance.



Figure 3. A ‘floating mangrove nursery’ in upland locations requires frequent watering.



Figure 4. A ‘flooded mangrove nursery’ on low-lying tidal lands is flooded regularly.



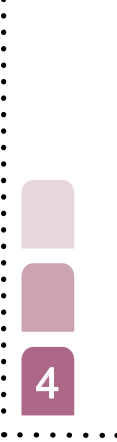
Site selection for mangrove nursery establishment

The selection of a site for establishing a mangrove nursery is the first important step in nursery construction. The location of the nursery influences the survival rate of reared seedlings, and consequently affects the success of plantation projects. Some important criteria to consider are listed below.

- a. Preferred sites are characterised by
 - Relatively flat land;
 - Closeness to fresh water sources;
 - Easy transportation access;
 - Good drainage (not waterlogged) and
 - Close proximity to planting site.
- b. Sites to be avoided when establishing a mangrove nursery include those
 - Far from a water source;
 - Inundated lands;
 - Areas that are difficult to manage, e.g. trampled by cattle and
 - Areas far from material sources (soil and manure fertiliser) for filling into sowing container.

The size of a nursery site can vary from 1-10 ha depending on: the species to be planted, the planting area, and seedling requirements. Generally, the nursery should be large enough to include: plots for making seedbeds, a place to store equipment and supplies, an area for preparation of planting materials, and a place for management activities.

- c. Determining the number of seedlings to grow in the nursery can be estimated by following the following guidelines
 - To plant 1 ha of *Rhizophora apiculata* with a density of 10,000 seedlings per ha (an additional 20% of seedling requirement is also included), the seedbed will require 350 m². An area of 150 m² is needed for an office and storage (total area requirement is around 500 m²).
 - To produce 100,000 seedlings of *Avicennia marina*, an area of 2,000 m² is needed, with about 65% designated as seedbeds.
 - To produce 1,000,000 bare-root seedlings of *Sonneratia caseolaris*, an area of 5,000 m² is needed, with seedbeds occupying around 70% of the total area.



Designing and building a nursery

The nursery can be divided into several parts as described below (see front cover and Figure 5):

- (i) A storage area is needed to store all materials required for a nursery such as dry soil, fertilisers, chemicals, rice-husk ash, humus and other materials.
- (ii) A material preparation area is needed for mixing soils and other materials.
- (iii) Seedbeds are needed for seedling production and cover around 60% of the total area.
- (iv) Irrigation areas are constructed using a soil embankment around the nursery site, providing easy access, controlled tidal water flushing, and easier transport of materials. It is recommended that a small ditch be dug to provide good drainage and irrigation.
- (v) Shaded areas are needed to protect young saplings and seedlings from strong sunlight. The sapling area may also be covered by plastic shade cloth sheeting to protect saplings from heavy rain (Figure 6). Materials to make these structures are available locally – e.g. bamboo poles to support the roof. The roof should be at least 1.5 m above the ground to allow easy access while taking care of seedlings. The roof can be covered by a black mesh fabric or dry Nypa leaves.

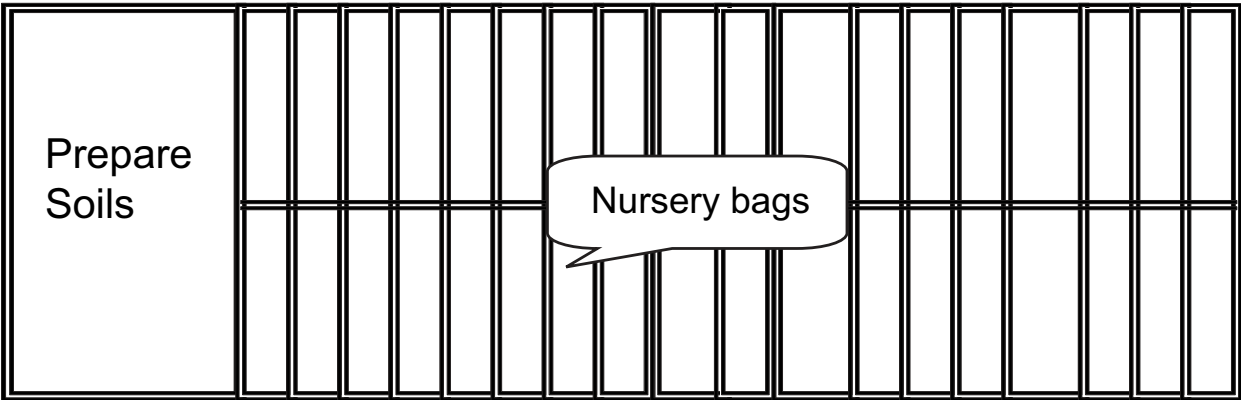


Figure 5. Nursery used to produce seedlings in the soil-mixed containers.



Figure 6. Seedbeds for seeds and saplings are covered by a black mesh fabric.

5.1 Nursery in a low-lying area - a 'flooded nursery'

a. Nursery for planting seeds in a soil-mixed container (Figure 7)

- Seedbed (size: 1.2 m x 20-25 m) should be dug ~15-20 cm deep.
- Seedbeds are separated by a 30 cm footpath.
- Seedbeds are connected with irrigation ditches.

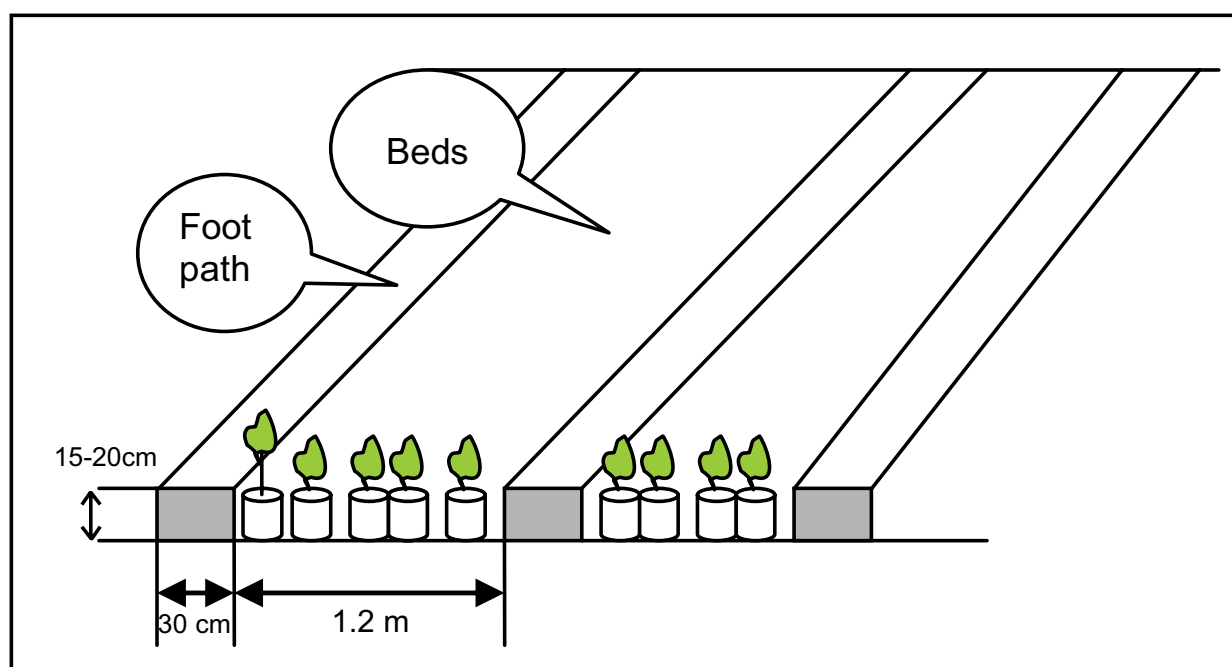


Figure 7. A 'flooded nursery' on low-lying tidal land is suitable for most mangrove species.

b. Nursery for producing bare-root seedlings (Figure 8)

After selecting the location, the site is tilled. All weeds, grass and other vegetation is removed. This nursery can also be divided into small seedbeds (6 x 20-50 m depending on the size of the land). A soil embankment is formed around the nursery site to control tidal water. The trenches are connected to irrigation canals to easily drain excess water.



Figure 8. Nursery producing bare-root seedlings.

5.2 An upland nursery on high ground - a 'flooded nursery'

This design is similar to the flooded nursery in a low land area. No digging is required (Figure 9).

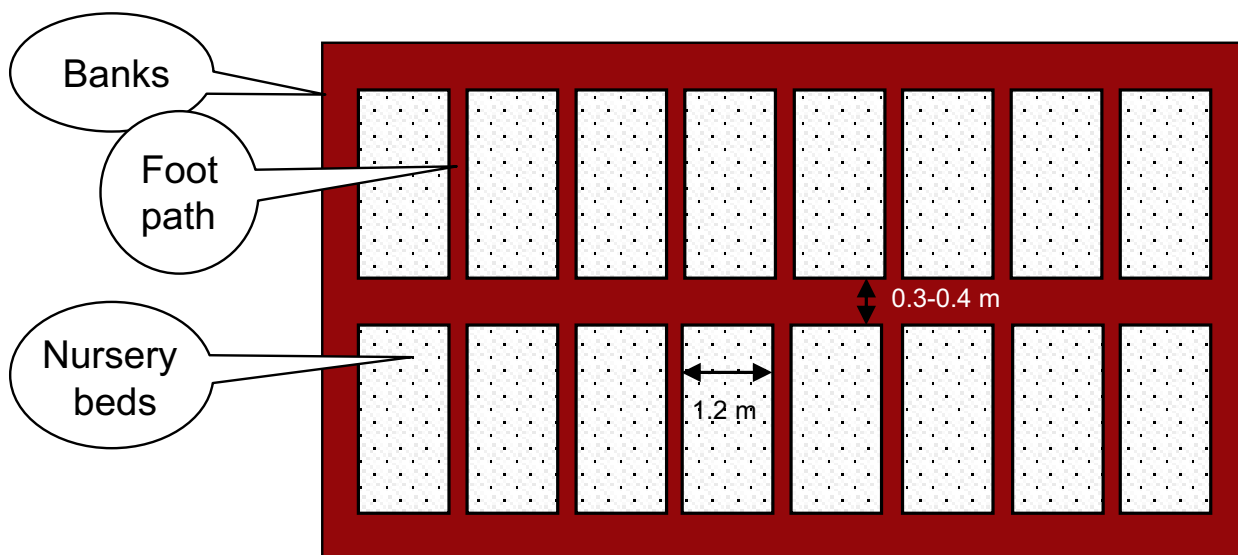
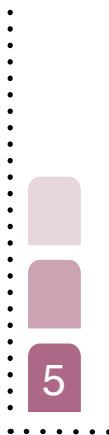


Figure 9. Design of the 'floating nursery' on higher elevation land.



Selection of suitable mother trees for different types of soil

6.1 Collection of fruits and propagules

The availability and type of planting materials vary depending on the species of mangrove. For instance, there are long propagules for *Rhizophora* species, rounded propagules for *Avicennia* and small seeds for *Sonneratia* (Figures 10 and 11 and table 1). The mangrove propagules are usually collected from August to October.



Figure 10. Collection of *Rhizophora* propagules.



Figure 11. Collection of *Avicennia* propagules.

Table 1. Planting methods for some mangrove species in Soc Trang.

Species	Planting materials	Mode of plantation
Mắm biển (<i>Avicennia marina</i>)	Propagules	Monoculture or mixed-culture
Đước (<i>Rhizophora apiculata</i>)	Propagules	Monoculture
Đưng (<i>R. mucronata</i>)	Propagules	Monoculture
Dà vôi (<i>Ceriops tagal</i>)	Propagules	Monoculture
Bần chua (<i>Sonneratia caseolaris</i>)	Seeds	Monoculture
Cóc trắng (<i>Lumnitzera racemosa</i>)	Seeds	Monoculture or mixed-culture

6.2 Identification of maturity of fruits and propagules

The maturity of fruits and propagules can be assessed according to the criteria listed in Table 2.

Table 2. Indicators of maturity of propagules of mangrove species.

Species	Colour	
	Immature	Mature
Mắm biển (<i>Avicennia marina</i>)	Green	yellowish fruit skin
Đước (<i>Rhizophora apiculata</i>)	Dark green	Pale to red brown
Đưng (<i>R. mucronata</i>)	Dark green	Pale
Dà vôi (<i>Ceriops tagal</i>)	Green	Pale to red brown
Bần chua (<i>Sonneratia caseolaris</i>)	Pale green	dark green
Cóc trắng (<i>Lumnitzera racemosa</i>)	Green	red brown

6.3 Selection of mangrove species for afforestation

Pham Trong Thinh (2008) reported about 22 mangrove species in the coastal area of Soc Trang. At this site, there is a zone where fresh water and sea water mix before flowing into the sea and *Sonneratia caseolaris* and *Nypa fruticans* are often seen. Further away from the estuary where salt concentrations are higher, *Avicennia marina* and *A. officinalis* are common. Other species such as *Lumnitzera racemosa* and *Hibiscus tiliaceus* are found in higher lands reached by spring tides.

Since 1993, some species in the mangrove plantations of Soc Trang have had a high survival rate. Newly planted forests have been established. The species that have been planted include *Avicennia marina*, *Sonneratia caseolaris* and *Rhizophora apiculata*. Considering the ecology of mangrove forests as well as the topography and soil conditions in Soc Trang, certain species can be recommended for afforestation in the province.

Sonneratia caseolaris is found on alluvial soils or semi-solid mudflats in estuaries and along the coast of the Cu Lao Dung and Long Phu districts. In these locations, tidal inundation is below 1.5 m and occurs for 6-12 hours per day.

Avicennia marina is found in areas where alluvium deposits are high, as it is far from the estuary in Vinh Chau district. The tidal inundation is below 1.0 m and lasts from 6-12 hours each day.

Rhizophora apiculata and *R. mucronata* should be grown behind *Avicennia* or *Sonneratia* forests. Suitable soils are muddy to soft clay with an inundation frequency of 6-8 hours per day. In places where inundation occurs only during spring tides, the land height can be lowered by digging and removing some hard-clay layers in order to receive regular tides.

Lumnitzera racemosa is grown in coastal areas where soil is mainly solid mud or clay. The wide tolerance of this species helps it grow well in both normal tidal condition and more waterlogged areas. The species can tolerate sustained freshwater inundation and salinity levels of up to 78‰ (Wells 1982).

Ceriops tagal is similar to *Rhizophora apiculata*. *Ceriops tagal* can be grown behind *Avicennia* and *Sonneratia* forests. Favourable soils are semi-solid or solid mud, fertile or sand-mixed soils. Tidal inundation frequency should last no more than 4 hours per day. In places where inundation occurs only at certain times in the day, the land level can be lowered by digging and removing hard-clay layers in order to receive regular tides.



Techniques for planting seeds/seedlings in plastic containers

7.1 Soil preparation

Soil is collected from nearby canals (Figure 12). It is then dried and ground into small particles (<3 mm diameter). Subsequently, the soil is mixed with ashes of rice husks or humus from plants at a 5:1 soil-ash ratio (Figure 13). The soil mixture should be supplemented with a small amount of fertiliser such as 0.5% of NPK (16:16:8) and cow dung at time of mixing and crushing of the soil. Use loam soil and avoid clay soil.



Figure 12. Soil collection and filling of plastic containers.

7.2 Seedbed preparation

High seedbeds are about 1.2 m x 20–25 m (width and length). The edging around seedbeds is made from wooden poles. A pathway of 0.3–0.4 m between seedbeds is designed for watering and supervision of seedlings.

Low seedbeds are similar to high seedbeds and are about 1.2 m x 20–25 m. Mixed plastic containers are placed inside the seedbeds. The seedbeds are 15–20 cm below ground level. The seedbeds are flooded to a depth of about 10 cm. A pathway of 0.3–0.4 m between seedbeds is maintained for watering and caring for the seedlings (Figures 4 and 7).



Figure 13. Mixing of soil, rice husk ash and fertiliser.

7.3 Filling plastic containers

The size of the plastic containers is 10 cm x 18 cm. Small perforations should be made at the bottom of each bag to drain excess water. After mixing the soil and fertilisers, a 5 mm x 5 mm steel mesh is used to remove weeds and other plant residue before filling bags. Organic matter for mixing with the soil is available on the beach (Figure 14). The filled containers should be kept in the shade to harden the substrate.



Figure 14. Organic matter is available on the beach.

7.4 Arrangement of soil-mixed containers onto seedbeds

After filling, containers should be arranged onto seedbeds (Figure 15) 7 to 10 days before planting seedlings. The seedbeds are then submerged in water for some time. The water will be completely drained afterwards. Water submersion should be done once a week to maintain moisture levels.



Figure 15. After filling, containers will be arranged onto seedbeds.

7.5 Seed stock for sowing

Soil-mixed containers should be watered before sowing or planting the seedlings.

- Propagules of *Rhizophora apiculata*, *R. mucronata* and *Ceriops tagal* are planted upright in the centre of a plastic container up to one third of the propagule length. They should be planted in the early morning or late afternoon.
- For *Sonneratia caseolaris* and *Lumnitzera racemosa*, seeds are sown directly into containers with 2-3 seeds per container. An alternate way of planting is to directly sow the seed into seedbeds. Seedlings with a height of 5-7 cm are then uprooted and transplanted into plastic containers.
- For *Avicennia marina*, propagules are placed directly into the plastic container. Once the fruit is germinated, the containers will be arranged onto seedbeds for easy management.

7.6 Management of nursery

7

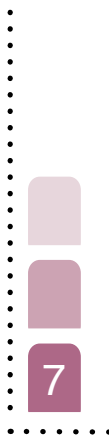
Shade: Shade should be provided for young seedlings for the first two weeks after planting. Shade levels of 60-70% can be provided by a black mesh or *Nypa* leaves. The shaded area can be adjusted to 30-50% after one month depending on the condition of the seedlings and weather. After two months, the shade levels can be further reduced to 20-30%. Shading can be completely removed after three months.

Watering: Watering during the initial stages should be carried out twice a day – once in the morning and again in the late afternoon using a rose-water container. When seedlings are strongly established and developed, a higher volume of water will be required. This water should be provided by tidal waters through canals.

Application of fertilisers: Fertiliser should be applied as 3-4 g of N:P:K (16:16:8) dissolved in 1 litre of water to irrigate seedlings. Some pesticides or fungicides should also be added to control diseases and insect pests. After applying fertiliser, wash the seedlings with water to remove fertiliser residue on leaves which may cause burning. In the final application, potassium is added to strengthen the seedlings. Fertilisation should be stopped 20 days before preparing the seedlings for field planting.

Weeding: Weeding should be carried out regularly to keep the seedlings free from competition. Breaking a film layer on the soil surface is needed to provide oxygen and air incorporation into the soil after each rainy period. A pointed stick can be used to break the film layer by gently digging a 2-3 cm depth of soil far away from root zone.

Re-arrangement of the sapling bags: The sapling bags are rearranged once every three months to prevent roots from penetrating deeply into the soil layer.





Techniques to produce bare-root seedlings

8.1 Soil preparation

Step 1. The nursery site is tilled and harrowed thoroughly, then kept dry for 15-20 days.

Step 2. All weeds, grasses, debris and other vegetation is removed.

Step 3. Using a water pump, the cleaned site is then submerged in 10-15 cm of water for 3-5 days

Step 4. Apply 0.2 m³ ash rice husk in combination with 10 kg of N:P:K (16:16:8) fertiliser for each 100 m² seedbed. The seedbed should be harrowed well and uniformly levelled. Fifteen days before sowing, pesticide (composed of 1 litre of formalin dissolved in 15 litres of water) should be sprayed in each seedbed to control pests and diseases.

8.2 Sowing seeds

Sowing is done by direct seeding on the wet surface (Figure 16). Seeds are divided into three batches to ensure uniform distribution on the seedbed. A day before sowing, excess water from the seedbeds is completely drained. Seeds should be sown in the early morning or late afternoon during calm weather.



Figure 16. Land prepared for sowing; the net prevents seeds from being washed away and protects the area from fishing activities.

8.3 Seedling management

Watering: Seedlings are watered daily by pumping water directly onto seedbeds. Water levels depend on the height of the seedlings. The moisture level in seedbeds should be well maintained.

Fertiliser application: should be made 30 days after sowing seeds. Fertilisation needs to be applied from the second to fifth month after the seedlings emerge and should stop 1.5 months before the actual planting.

Fertiliser application can be divided into different stages as below:

30 days after sowing - dosage of 4 - 6 kg Urea/ha

60 days after sowing - dosage of 6 - 8 kg Urea/ha

85 and 110 days after sowing - dosage of 10 kg Urea/ha

135 days after sowing - dosage of 15 kg Urea/ha and 7 - 9 kg DAP/ha.

Nursery techniques for different species

Table 3. Seed characteristics and sowing and maintenance techniques for some selected mangrove species.

Species	Seed characteristics					Sowing	Nursing
	Collecting time (month)	No. of seeds per fruit	No. of seeds per kg	Sowing materials	Initiation of germination		
Mắm biển (<i>Avicennia marina</i>)	7-9	1	300	fruit	3 days	On top of soil	Daily watering and removal of crabs and caterpillars
Đước (<i>Rhizophora apiculata</i>)	7-10	1	40	propagules	7 days	Sown 1/3 of length	Daily watering and removal of crabs
Đưng (<i>R. mucronata</i>)	7-9	1	10-12	propagules	7 days	Sown 1/3 of length	Daily watering and removal of crabs
Dà vôi (<i>Ceriops tagal</i>)	6-8	1	120	propagules	10 days	Sown 1/3 of length	Daily watering and removal of crabs
Bần chua (<i>Sonneratia caseolaris</i>)	8-11	500-1,500	10-12	seeds	4 days	Push seed into soil	Daily watering and removal of crabs
Cóc trắng (<i>Lumnitzera racemosa</i>)	8-9	1	8,000-10,000	seeds	7 days	On top of soil	Daily watering and removal of caterpillars

Table 4. Action plan for the sowing, tending and selection of seedlings of some selected mangrove species.

Activities	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Application of requests for budget of planting activities												
Designing for planting												
<i>Sonneratia caseolaris</i>												
Collecting fruit and sowing												
Setting and management of nursery												
Planting												
<i>Avicennia marina</i>												
Collecting fruit and sowing												
Setting and management of nursery												
Planting												
<i>Rhizophora apiculata</i>												
Collecting propagules and sowing												
Setting and management of nursery												
Planting												
<i>Lumnitzea racemosa</i>												
Collecting propagules and sowing												
Setting and management of nursery												
Planting												
<i>Ceriops tagal</i>												
Collecting propagules and sowing												
Setting and management of nursery												
Planting												
Forest management												
Annual assessment of planting programme												

9.1 *Sonneratia caseolaris* (L.) Engl.

9.1.1 Harvest, preservation and processing of seeds

9

Harvesting of seeds

In Soc Trang Province, seeds are harvested from the natural forest and managed forests of An Than Nam (Cu Lao Dung District) and Trung Binh (Long Phu District) villages. The mother trees in these places are healthy, well developed, and well-adapted to climates at the river mouth along Soc Trang's coastal area (Figure 17).

Field inspections should be carried out to determine the best forest sites prior to seed collection. The suggested seed collection period is from October to November.



Figure 17. Selection of 'every other' tree of *Sonneratia* for seed collection.

Some criteria for selecting seed collection sites include:

- General growth of trees is better in comparison with the surrounding areas.
- Uniform tree height and diameter with high survival rate.
- Forest should be at least 5 years old and contain productive trees.
- Harvesting area should be convenient for collection and transportation.

The mother trees must satisfy the following criteria:

- Greater height and diameter than that of surrounding trees.
- Straight trunks with little or no defects.
- Profusely thick root system, which is well distributed.
- Plenty of propagules.

Seed preservation and processing

After collection, seeds should be incubated for 5 to 7 days. Subsequently, a sieve with a suitable mesh size will be used to filter the desired seeds. Finally, seeds should be thoroughly washed with clean water then dried in the shade.

9.1.2 Seedling production in plastic containers

Seed collection should be done from October to November. Dried seeds are sown in seedbeds at 5 to 7 day intervals. This allows growers enough time to take care of the seedlings and prepare for efficient planting during the planting season.

Preparation of seedbed

The seedbed, which used as a platform for plastic containers, is about 10 cm high, 1 m wide and 10 m long. Seed are sown in a seedbed to produce seedlings. Seedbeds should be prepared at a low position on the ground. A thin layer of 5 cm of loose mud is placed on top of the seedbeds. Twenty kilograms of NPK fertiliser should be applied to an area of 1,000 m². Thereafter, a flat stick is used to level the surface of the seedbeds to make the surface take on a semi-solid form. To obtain even sunlight distribution, the seedbeds should be positioned in an East-West direction. One day before sowing seeds, the seedbed should be sprayed with Benlat fungicide (6 g of Benlat is dissolved in 10 litres of water and sprayed over 100 m² of seedbed) or Captan (4 teaspoons of Captan is dissolved in 5 litres of water and sprayed over 100 m²).

Planting of seedlings in plastic containers

Twenty to twenty-five day-old seedlings bearing 8-10 leaves and having a height of 0.5 to 1 m are ideal for planting in plastic containers. To prevent root damage, the seedbed should be saturated prior to the uprooting of seedlings. Next, it is important to hold the seedling by the base of the stem, gently pull it up, and then place it into a tray filled with clean water. A pointed stick is used to make a hole at the centre of a container filled with the soil mixture. The depth of holes should be adjusted to the length of the seedlings' roots. Next, the seedling should be placed upright, then the hole should be filled with the soil mixture, and the soil should be gently pressed down around the base of the seedling. Planting should be done in early morning or late in the afternoon in order to avoid osmotic stresses. Sufficient moisture must be provided when growing the seedlings.

Readiness of seedlings for planting

About 4-5 months after planting, seedlings are ready for transplanting. At this stage, seedlings should be 80-100 cm tall and have a diameter of 1cm. A good seedling should have a profuse root, green leaves, a straight stem, and be healthy and disease-free.

9.1.3 Production of bare-root seedlings

Preparation of soil mixture

Plough the field 15-20 days before the planting of seedlings. Thereafter, the field will be harrowed and mixed with 0.2 m³ rice ash and 10 kg NPK (16:16:8) fertiliser. The field should then be submerged under 10-15 cm of water for 3 days.

Sowing

Seeds are divided into 3 sowing periods This ensures distribution across the seedbed area. A day before sowing, the seedbed should be drained. Sowing should be done in the early morning or late afternoon.

Seed management

Seed germination takes place 7 days after sowing. Two cotyledonary leaves will emerge after between 10 and 12 days. One month after sowing, seedlings are likely to have 8-10 leaves. Irrigation is done by pumping water directly into the seedbed. Growers should inspect the actual status of the seedlings to decide on the level of water and the frequency with which it should be supplied. Fertiliser should be applied to the seedlings after two months and again after the fifth month. This application must be stopped 1,5 months before collecting seedlings for planting.

Guide for fertiliser application:

- 30 - 35 days after sowing – dosage of 4-6 kg Urea/ha
- 45 - 50 days after sowing – dosage of 6-8 kg Urea/ha
- 60 - 65 days after sowing – dosage of 10 kg Urea/ha + 500 ml Atonik
- every 20 days thereafter – dosage of 15 kg Urea/ha +7-9 kg DAP/ha

Criteria to determine the readiness of bare-root seedlings

- Good growth (> 1 cm diameter; 80-100 cm height).
- Age: about 6-9 months old.
- Profuse root system.
- No symptoms of infectious disease or insect pests. Good growth.

Seedling collection

Collect about 40% of good seedlings in the first batch. The remaining seedlings should then be fertilised with 30-50 kg/ha of DAP+NPK+ Vibac 88 after 3 days of thinning depending on the density of the remaining seedlings.

The second selection should take place 1.5 months after the first collection. The number of selections should not exceed three. It should be noted that for every thinning, fertiliser application must be stopped 1.5 months before collection. About 100 seedlings should be bundled together for convenience of delivery.

9.2 *Avicennia marina* (Forssk.) Vierh.

9.2.1 Harvesting, preservation and processing of seeds

The *Avicennia* species flowers around March to May. Propagules (incorrectly called fruit) mature mostly from July to September. At the time of ripening, Propagules turn yellow (Figure 18). The best time to collect propagules is from August to October. Propagules can be collected from the ground or from the tree.

Criteria

- Propagules must be healthy and intact without any infections, disease or insect pests.
- 300 propagules weigh approximately 1 kg.



Figure 18. Mature *Avicennia marina* propagules (cryptoviviparous).

Sowing freshly collected propagules gives the best results. In situations where immediate sowing is not possible, propagules can be preserved in a moist state in a 20 cm layer and kept in the shade. Preservation should not exceed 5-10 days.

9.2.2 Planting in plastic containers

Immediately after collection, propagules should be planted upright in the centre of a plastic bag containing soil. It is best to do the planting during the early morning or late in the evening. Planting bags are placed on seedbeds for management convenience (Figure 19).

9.2.3 Management of nursery

Irrigation: After planting, water is provided by flooding the seedbed once a week. Once the seedlings reach a height of 20-25 cm, a higher volume of water is required. These should be flooded with tidal waters.

Application of fertiliser: Dissolve 3-4 g of NPK (16:16:8) + DAP in 1 litre of water and spray this on the seedbed. Thereafter, clean water should be sprayed to wash off residues on the leaves and prevent them from getting burnt. The application of fertiliser should be combined with the application of pesticides. In the final fertiliser application, only potassium should be used in order to enhance the seedlings' vigour. Fertiliser application must be stopped at least 20 days before planting.

Regular inspection of the nursery should be conducted to detect incidence of insect pests and diseases.



Figure 19. Nursery of *Avicennia marina* seedlings.

9.2.4 Criteria for the readiness of seedlings for field planting

- Age: 6-8 months old;
- Height: 35-40 cm and bearing 8-10 leaves (Figure 20);
- Stem: upright with profuse root system and
- Healthy with no symptoms of disease or insect pests.

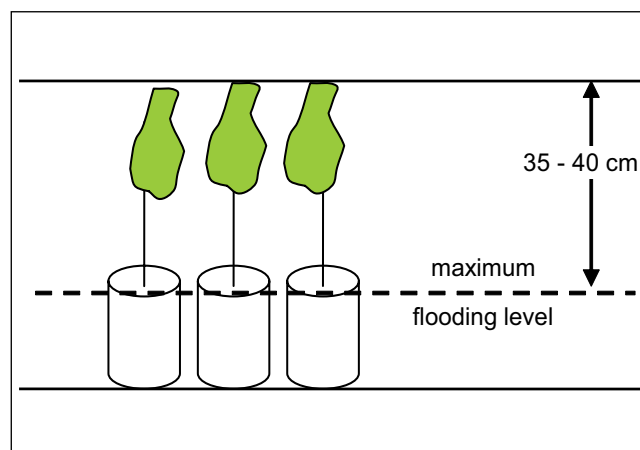


Figure 20. Flooding level of seedlings of *Avicennia marina*.

9.3 *Rhizophora apiculata* Bl.

9.3.1 Harvest, preservation and processing of seeds

Propagules of *Rhizophora apiculata* should be collected in the Vinh Hai village area in Vinh Chau District. The flowering of *Rhizophora* occurs from March to May and ripening occurs from July to December. To obtain propagules of the best quality with the highest survival rates, these should be collected in August and September.

Criteria for propagule selection

- Intact propagules without symptoms of infectious disease or insect pests.
- Length of propagules is at least 23 cm with >1 cm diameter and more than 20 g fresh weight. It should have no roots or leaves (Figure 21).

Fruit preservation: Immediately planting freshly collected propagules will yield the best results. If preservation is needed, the following procedure should be followed:

- Place propagules in a shady place, arranged in 20 cm layers.
- Make sure sufficient water is provided.
- Preservation should not exceed 10 days.



Figure 21. Propagules with sprouting roots and leaves are not collected.

There is a routine method used by farmers to preserve propagules. After collection, propagules are kept in a jute-bag and placed in a shadow canal where tidal waters keep them wet. This method of preservation can prolong their survival for 15 days. When *Rhizophora* propagules are transported over long distances, it is important to ensure that moist conditions are maintained in order to reduce losses during seedling establishment.

9.3.2 Planting of fruits into soil mixed containers

Plant one third of the fruits into the centre of a soil mixed container in an upright position. The planting is best done in the early morning or late afternoon.

9.3.3 Management of nursery

Prepare shade mesh

Overt the first 1-2 weeks of planting, seedlings should be shaded with a black mesh. The percentage of shade varies from 30-50% depending on actual weather conditions. A lesser degree of shade is applied when seedlings produce new roots and are stronger.

Irrigation

In the first two weeks, water is provided by flooding the seedbeds once a week. As seedlings develop, watering can be done using water from the regular flood tide.

Fertilisation

Dissolve 3-4 g NPK (16:16:8)+DAP into 1 litre of water and then spray it onto the seedbed. It is important to subsequently spray clean water to wash fertiliser residues off of leaves in order to avoid leaf burn. Fertiliser application should be combined with pesticides and fungicides to control leaf eaters and pathogens. The final application of fertiliser should use Phosphorus and Potassium in order to promote robust saplings, but should be discontinued at least 20 days before delivering seedlings for field planting.

Weeding and turning over the top layer of soil is important to provide oxygen for root development, particularly after rain or irrigation. This should be done at a depth of about 2-3 cm and 10-15 cm away from the root zone.

Criteria for the readiness of seedlings for field transplanting

- Age: 4-5 months old.
- Seedling height: 40-50 cm, with 8-10 leaves (Figure 22).
- Upright stem and profuse root with no symptoms of disease or insect attack.



Figure 22. *Rhizophora* seedlings ready for planting.

9.4 *Lumnitzera racemosa* Willd.

9.4.1 Harvest, preservation and process of seed

Criteria for the selection of mother trees:

- Age: 10-15 years old.
- Good growth without any defects or disease.
- Good distribution of canopy.
- Ideally, the seeds are collected from the best parts of the natural forest without mixing with other species, or from the best quality cultivated forests.

Seed collection and preservation:

The seed ripening period is from August to October. The best time for seed collection is in September when propagules are still attached to the tree. After collection, propagules are sun dried to harvest the grain, and then preserved in shady places.

9.4.2 Sowing

Technique 1. Soak seed in clean water for 24 hours. The seed is then incubated for three days after being sown onto a tray. Sprouted seeds are inoculated into a soil-mixed container.

Technique 2. Direct seeding on seedbeds.



Figure 23. Leaf and flower of *Lumnitzera racemosa*.

9.4.3 Management of the nursery

Regular irrigation is important. Irrigation can be done by taking water from regular tidal flooding. The seedlings are ready for planting after 8-10 months if they reach a height of 30-40 cm.

Figures 23 and 24 show the flowers and growth form of *Lumnitzera racemosa*.



Figure 23. Leaf and flower of *Lumnitzera racemosa*.

9.5 *Ceriops tagal* (Perr.) C.B. Rob.

9.5.1 Harvest, preservation and process of seed

Areas like river mouths and coastal areas where the soil is covered with a thick layer of solid mud and with regular tides are suitable for growing *Ceriops*. The tree is adapted to a wide range of different soil elevations. However, 100 to 200 days in a tidal regime is the most suitable environment for optimally growing *Ceriops*. If the environment extends beyond this range, growth will not be favourable. Salinity is the other factor affecting *Ceriops* growth and can have different effects depending on the genotype.



Figure 25. Leaf and flower of *Ceriops*.

A *Ceriops* variety in Ca Mau Province can survive in saline water of 0.02 to 0.03‰, while those observed in Can Gio, Ho Chi Minh City and Bac Lieu Province can tolerate salinity levels of up to 0.06-0.08‰.

Figure 25 shows a typical flower.

The propagules of *Ceriops* (Figure 26) mature from August to October. Upon ripening, the propagules turn from brown to grey. The best time to collect propagules is in September. After collection, it is advised that the propagules be immediately sown. If immediate planting is impossible, propagules need to be kept in a place where water is moving and it is shady. If they are not shaded and moist, then they should be watered regularly and irrigated twice each day. Preservation should not exceed 15 days.

Criteria of propagules

- Propagules must be intact without sprouting roots;
- Length: 15-25 cm;
- Diameter: 0.5-1.0 cm;
- Average weight: 80-120 propagule/kg.

9.5.2 Planting of fruit into soil mixed container

Insert one third of the fruit into the centre of the container maintaining an upright position.

9.5.3 Management of nursery

Similar to management techniques for *Rhizophora*.

Criteria for the readiness of seedlings for transplanting into the field:

- Age: 4-5 months after planting in soil mixed container.
- Height: 30-35 cm with 6-8 leaves.
- Profuse root and upright stem.
- Healthy and without any symptoms of infectious disease or insect pests.



Figure 26. Propagules of *Ceriops*.



10

Insect pests and diseases in the mangrove plant nursery

Young mangrove plants are at great risk in plant nurseries because they are close together and removed from their usual environments, which would help control harmful pests and diseases.

Some of the key risks to young seedlings growing in nursery conditions include:



Figure 27. Small crabs make their burrows in the soil.



Figure 28. Small crabs eat and damage the seedlings.



Figure 29. Insect caterpillars and fungus damage.



Figure 30. Insect larvae eat young *Rhizophora* leaves.

10.1 Sterilisation of seedbed

- Eliminate insect pests and diseases in seedbeds by sun-drying for about 10 days before sowing. This should be done during good weather with ample sun light, followed by ploughing, drying and soil treatment (see Chapter 8.1).
- If seedbeds have to be sown more urgently in unfavourable weather conditions, only a chemical treatment is applied by spraying the seedbeds with formalin 15 days before sowing to eliminate fungi in the soil (Solution includes 4 litres of Formalin 38%, diluted in 60 litres of water. This volume is used to spray about 150 m² seedbed surface).
- Before sowing, seeds may be stimulated for better germination and growth by using a treatment that eliminates seed-borne diseases and insect pests via the following physical and chemical methods:
 - + Removal of contaminated substances from the seed lot.
 - + Soaking or mixing seeds with a sterilising solution, such as Formalin 0.15% solution for 15-30 minutes.
 - + Soaking or mixing seeds with a Cupric Sulfate 0.3-0.5% solution for about 2 hours, or Permanganrat Kali 0.5% solution for about 2 hours.

10.2 Sanitation of nursery

- Polluted water sources should not be used for watering the nursery.
- Collect, remove and burn all infected and dead seedlings to outside the nursery.
- Regularly clear weeds and bushes from around the nursery. Scatter powder lime around the lanes and dykes.
- The nursery needs to be ventilated as much as possible. Contaminated water must be quickly drained from the nursery site.
- Gardening tools, equipment and materials must be thoroughly cleaned and well-maintained.

10.3 Maintenance technique

Collected seeds must be examined for the presence of diseases or pests before being brought to the nursery site. Planted seedlings should be checked regularly for pests and damage - especially when they are sprouting, as seeds/propagules are more susceptible to caterpillar damage at this stage.

During the sprouting stages, crabs can damage young seedlings (Figures 27 and 28). Damaged seedlings should be replaced with fresh seeds/seedlings. Caterpillars are major pests for *Avicennia* (Figure 29). When an attack is severe, pesticides like Monochrotophos and Ekalux may be used. Standing water should be drained from the beds before pesticide application.

Seedlings should be sprayed with pesticides when pest damage looks like it could be severe. The water in the beds should be drained completely before applying the pesticide in order to avoid the spread of pesticide residue to other areas.

Be careful with the following:

- Foliar spray of chemicals, because an overdose will cause burning of leaves.
- Fertilisation, because an overdose, like of nitrogen based fertiliser, will cause the overgrowth of seedlings.

- Excessive watering will lead to waterlogging (if potted seeds are placed directly on the hard seedbeds).

In general, regular inspection and early detection of insect pests and diseases are essential for the effective maintenance of mangrove nurseries.

10.4 Control methods

- Cultural method: To control an infected field, it is submerged in water up to the tree base to kill insect pupae and larvae. In addition, the area surrounding the nursery must be clean. This is an effective and environmentally-friendly method for controlling insect pests. It should be used before other treatments are considered.
- Chemical methods: Several kinds of contact pesticides can be effectively used to control the 1st and 2nd instar insect pests, such as: 0.5 litres of Viher 25ND diluted in a 400 litres of water for spraying over 1 ha. 10 cc of Decis 25EC diluted in an 8 litre container and used with 50 containers to spray for 1 ha.
- Digestive pesticide can be used to control 3rd and 4th instar insect, such as Diazinon 50%. Dilute 1 litre of Diazinon 50% with 400 litres of water, then spray for 1 ha. Other pesticides are also used for pest control such as Bundock, Padan, Regent, etc.

Control shoot borer

- On detection of egg masses deposited on leaf blades, these affected leaf parts must be removed from the nursery site and burned.
- On detection of larvae levels with the potential to become an epidemic, pesticides can be used such as Padan 10G at 0.6 to 0.8 kg/ha. Padan is also mixed with other pesticides such as Padan 10G 380 ingredient + Azodrin 375 ingredient; Padan 380 ingredient + Parathion + 280 ingredient. The total volume is about 400 litres and can be applied over 1ha.

Control fungi infesting root bases

Fungi can cause severe symptoms that often lead to the death of infested seedlings. The cause of the disease has been identified as Rhizoctonia fungus. This disease may occur on a large scale and can spread rapidly throughout the nursery.

The incidence of this disease is usually observed in potted seedlings around 1.5 months old. In nurseries with bare-root seedlings, symptoms may be detected in 2 to 4 month old plants.

Symptomatic of this fungus are black marks near the base of root extending to traces around the stem base. In more advanced stages, the infested areas become a spider web hanging in the centre part of the stem. In the final stage, infested seedlings turn pale and die. Serious infections usually occur in areas characterised by excessive humidity and in poorly ventilated nurseries.

The land must be well prepared before being sown. Old plants, especially those with signs of disease infestation, must be collected and burned. Soil for the nursery site must be clean and well drained.

Soil used in the nursery should be free of pests and diseases. It should be sterilised using a treatment of drying at 60°C for 30 minutes in an oven, or spread in the sun to dry for about 10 days at around 30°C.

It is very important that nursery plants be inspected regularly for early detection of disease symptoms. When disease symptoms are detected, they should be dealt with immediately. A film condition must not be allowed to occur with waterlogging in the nursery.

Severe disease may be controlled by chemical methods if all other methods have been exhausted and unsuccessful. Various chemical substances could be used, including:

- Kitazin and Rovral fungicides for soil treatment.
- Vicben - C50 BHN at 20g/8 litre container. Vicben - C50 BHN at 15g + Fuji one 40ND at 20ml/8 litre container.
- Tobsim and Tilt 250 ND can also be mixed to spray at 24ml/8 litre container.

It is very important that these chemicals only be used in accordance with the manufacturers' recommended dosages for the particular target pest species.


Bare-root seedlings are particularly susceptible to pests due to their long nursery growing stage and the low intensity cultivation condition. Some pesticides must be used during the transition between dry and rainy weather to prevent leaf eater insects, especially 2-3 days after applying fertiliser. Some pesticides are commonly recommended such as Decis, Regent, Cyper Alpha, Padan, Bulldock at periodical 10-15 day intervals.

It should be emphasised that the cultural method is an important option for obtaining effective and environmentally-friendly results. This is assisted by good management, with regular inspection and early detection of infestation symptoms, coupled with proper preparation of land before sowing/cultivating the nursery beds.



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