**Project ID: 301**

## Competitive Research Grant

# Sub-Project Completion Report

## on

# Development of Climate Resilient Mangrove Ecosystems in the Sundarban

**Project Duration**

**May 2017 to September 2018**

Mangrove Silviculture Division
**Bangladesh Forest Research Institute**

**Submitted to**
**Project Implementation Unit-BARC, NATP 2**
**Bangladesh Agricultural Research Council**
**Farmgate, Dhaka-1215**

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**Citation**

**Project Title**
Development of Climate Resilient Mangrove Ecosystems in the Sundarban

**Project Implementation Unit**

National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
New Airport Road, Farmgate, Dhaka – 1215
Bangladesh

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## Acronyms

| | |
|---|---|
| BARC | Bangladesh Agricultural Research Council |
| BFRI | Bangladesh Forest Research Institute |
| MSD | Mangrove Silviculture Division |
| NATP | National Agricultural Technology Program |
| CRG | Competitive Research Grant |
| PCR | Project Completion Report |
| PIU | Project Implementation Unit |

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# Executive Summary

The average germination percentage of major mangrove species such as sundori (*Heritiera fomes*), passur (*Xylocarpus mekongensis*), vathkathi (*Kandelia candel)*, jhana (*Rhizophora mucronate*), kirpa (*Lumnitzera ramiflora*), kankra (*Bruguiera gymnorrhiza*), amoor ( *Amoora cuculata*), soila (*Sonneratia caseolaris*), baen (*Avicennia officinalis*), golpata (*Nypa fruticans*), keora (*Sonneratia appetala*), amdhekur (*Cerbera manghas)*, bakul kankra (*Bruguiera sexangula*) and dhundul (*Xylocarpus granatum* ) were 70, 80, 95, 90, 60, 90, 90, 80,70, 90, 75, 90, 90 and 90 respectively.

Nursery seedlings of mangrove species were found to have better survival than seeds sown directly in the field or through natural regeneration. So nursery seedlings become the planting material for plantations, whether these plantations are for production, protection or amenity. Eventually those seedlings play positive role for development of mangrove vegetation in the coastal areas and to improve carbon sink as well as enrichment of mangrove ecosystems.

To enrich mangrove ecosystems through establishment and conservation of the mangrove species *Kandelia candel* (L.) Druce in the moderate saline zone of the Sundarban a field experiment was conducted in Sundarban area of Bangladesh from 2012 to 2018 using the research fund of PIU-BARC, NATP 1 and PIU-BARC, NATP 2 under the Competitive Research Grant (CRG). The height (m), DBH (cm), MAI (m) and survival (%) of *K. candel* trees differed significantly due to different spacing. The highest height (m), dbh (cm) and survival (%) have been found 2.99m±0.09, 3.83cm±0.10 and 90% respectively in 2m x 2m spacing as well as the highest mean annual increment (MAI) for height 0.60 m and for dbh 0.77 cm were found at the same spacing. The calculated values were $F_{.05}$ (2) = 64.60$^{**}$ which was highly significant at the 5% level, LSD = 0.23 for height and $F_{.05}$ (2) = 40.71$^{**}$, LSD = 0.25 for DBH. There were significant differences in the mean total height (m) and mean DBH (cm) due to different spacings 2m x 2m, 1.5m x 1.5m and 1m x 1m. On the other hand, coefficient of variation (CV) at different spacing were found 9.36, 11.54 and 13.64 for height and 8.62, 4.17 and 10.79 for DBH. All these findings reflect that growth performance of *K. candel* species was better at 2m x 2m spacing compared to 1.5m x 1.5m and 1m x 1m spacing. Artificial regeneration of *K. candel* species can improve degraded habitats to facilitate recolonization by native mangrove species. To ensure sustainability of mangroves in the Sundarban, it is necessary to protect all the existing mangrove wetlands under *in situ* conservation by setting up natural reserves and excluding further anthropogenic destruction as well as developing a long-term scientific program.

Day long training programs among the local farmers on “Sundarban Conservation and Plantation Techniques” were conducted at 6 Upazillas in four districts adjacent to the Sundarban. The present study can widen mangrove based climate change mitigation and adaptation and enhance the resilience of coastal regions and communities. This research may develop a comprehensive framework for science-based management practices.

# CRG Sub-Project Completion Report (PCR)

## A. Sub-project Description

1. **Title of the CRG sub-project:** Development of Climate Resilient Mangrove Ecosystems in the Sundarban
2. **Implementing organization:** Bangladesh Forest Research Institute
3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s):**
   Principal Investigator:


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4. **Sub-project budget (Tk):**
   4.1 Fund Received: Tk. 42,87,030 (Forty two lac eighty seven thousand thirty)
   4.2 Actual Expenditure: Tk. 42,48,591 (Forty two lac forty eight thousand five hundred ninety one)
5. **Duration of the sub-project:**
   5.1 Start date (based on LoA signed): 09 May 2017
   5.2 End date: 30 September 2018
6. **Justification of undertaking the sub-project:**

Mangroves are one of the most important coastal ecosystems in the coastal region of Bangladesh. Mangrove forests are among the most productive and biologically important ecosystems because they provide important and unique ecosystem goods and services to the coastal communities and marine systems. The mangrove forests help to stabilize shorelines and reduce the impact of natural disasters. They also provide breeding and nursing grounds for marine species, food, medicine and building materials for local communities. Sundarban is the single largest mangrove area coverage in the world. With the recognition of the Sundarban of Bangladesh as a World Heritage Site, conserving and promoting biodiversity of Sundarban is an important through the protection of mangrove ecosystems. However, scientific evidence suggests that timber, aquatic, wildlife and non-timber forest products are

declining in the Sundarban due to historical and current over exploitation. Comparisons with earlier forest inventories also show that the rate of forest degradation is rapidly increasing. Historical selection management system of the Sundarban was focused on harvesting timber and non-timber resources mainly for earning revenue as regards to overall sustainability of the ecosystem. As a result, the major mangrove species in the Sundarban Reserved Forest are overexploited, and the rate of degradation is increasing resulting decline of the natural populations of some mangrove species have declined in a large scale as well as the biodiversity diverse mangrove ecosystem has suffered from unsustainable management and causing the impact on biodiversity and natural forest ecosystem. Lack of knowledge of mangrove ecosystems, their extent, status and linkages to other ecosystems hampers efforts to conserve and manage mangroves, leading to the unsustainable exploitation of these productive coastal resources. Thus, knowledge on nursery and plantation techniques of different threatened mangrove species are most essential for conservation and sustainable management of those species in the Sundarban. Due to anthropogenic and natural causes, mangrove degradation has increased in recent years, turning the implementation of restoration and conservation programs into an urgent issue of attention. Raising awareness of mangrove ecosystems and developing a sense of place for local people is vital to protect and enhance the sustainability of the mangrove conservation. Both economic activities and demographic growth in the adjacent areas of the Sundarban, have caused serious environmental impacts on mangrove ecosystems.

To address the situation, it is needed to implement a comprehensive environmentally sound ecological restoration program. The proposed research agenda includes both bio-ecological and socio-economic investigations in order to improve and maintain sustained productivity, to develop a sustainable management and biodiversity conservation system as well as in reducing of natural disasters and to increase their adaptation to the long term effect of climate change. This research may develop a comprehensive framework for science-based management practices.

7. **Sub-project goal:**
   The overall goal is to respond to climate change and to mitigate its effects through the protection, rehabilitation and wise use of mangrove ecosystems through processes that maintain their protective function, values and biodiversity while meeting the socio-economic development and environmental protection needs in the Sundarban and its adjacent areas.
8. **Sub-project objective (s):**
   - To develop mangrove vegetation in the coastal areas and to improve carbon sink.
   - To promote climate smart and sustainable management of coastal ecosystems through application of innovative approach for ecosystems rehabilitation.
   - Raising awareness among mangrove dwellers through capacity building programs.

9. **Implementing location (s):** The Sundarban Mangrove Forest of Bangladesh

**10. Methodology in brief:**

Seeds/propagules of different mangrove species were collected from the Sundarbans timely. Seeds/propagules were sorted and stored. In mangrove forest nurseries, seedlings were grown bare-rooted or in containers. There are two adopted methods for raising seedlings in the nursery: i) Raising seedlings in nursery beds and ii) Raising seedlings in polybags/containers. For the establishment of nursery and raising the seedlings the following steps are systematically adopted:

- Site selection
- Site preparation
- Seed sowing
- Nursing: The following activities were done.
    - To ensure regular weeding for better growth.
    - Fertilizer and insecticides were applied where necessary.
    - Irrigation was done in dry season when necessary.
- Uprooting of seedlings

**Raising seedlings in polybags/containers**

The polybags of size 10 cm x 15 cm were filled with soil mixed with cow dung at 5:1 ratio. The bags were arranged in a nursery bed of size 1.2 m x 12.0 m, a shed were given on the bed and fenced to protect the seedlings from sun, rain and animals. The seedlings were allowed to grow in the nursery for one year. The shed over the seedlings were removed three months after seed sowing. Various steps were systematically followed for the establishment of nursery and raising polybag seedlings. The steps were as follows:-

- Site selection
- Soil preparation
- Polybag or container filling
- Nursery bed preparation
- Seed sowing
- Mulching or shading
- Nursing: The following activities were done.

- Soil of polybags were maintained moist for several days after seed germination by lightly watering three times in a day.
- Regular weeding were done to keep the seedlings free from weeds. It was carried out once in ten days.
- Fertilization was done to promote rapid growth of seedlings.

- Insecticides were applied if necessary.
- Sorting and grading of polybag seedlings were done at 30 days interval to prevent growth of roots outside the bags and to produce healthy seedlings with uniform height.
- Polybag seedlings were lined-out according to their height, first longer seedlings and then gradually smaller seedlings. This way the seedlings were hardened for making them strong.
- Root pruning was done by using sharp pruning shears to cut off the roots at least one week before the transplanting of the seedlings in the field.

Plantation with mangrove species was carried out at different selected sites. One year old seedlings of height 10-65 cm depending upon species were planted. A closer spacing was followed because of slow growing of mangrove species. Before planting the seedlings were hardened and transferred very carefully to the plantation sites. After planting, staking was given to support the seedlings. Polybags were removed before planting. Plantation should be protected by fencing to protect from the wild animals and fence should be repaired and maintained. Various steps are systematically followed for the establishment of plantation successfully. The steps are as follows:-

- Sit selection
- Site preparation
- Time of planting
- Staking and preparation of planting hole
- Spacing
- Planting
- Plantation maintenance

- Weeding, protection from browsing and grazing, vacancy filling, pruning, thinning etc.

A degree of "self-management" was encouraged among the various users of the mangrove environment so that they could be involved in protecting this ecosystem. Specific training programs targeting the local people living adjacent to the Sundarban were conducted which address issues such as anti-littering of mangrove areas, communal pasture development, landless farmers and monitoring and enforcement, and alternative livelihoods and mangrove legislation.

**Year wise activities of the project were as follows:**

**1st year**:

- Literature review.
- Field visit to the Sundarban before collecting seeds/propagules.
- Seeds/propagules collection.

- Seeds/propagules sorting, treatment and storage.
- Nursery raising (soil collection and preparation, bag filling, bed preparation, shed preparation, fencing, seed sowing, mulching etc.) for next year plantation.
- Selection of promising seedlings at nursery stage for plantation.
- Data collection, statistical analysis and reporting.
- Specific training programs, targeting the local people living adjacent to the Sundarban were conducted.

**2nd year:**

- Site selection and site preparation for experimental plantation (jungle cutting, debris removal, holing-staking, fencing etc.).
- Plantation raising and maintenance.
- Survival and growth data collection twice a year ( pre monsoon and post monsoon).
- Field visit to the Sundarban before collecting seeds/propagules.
- Seeds/propagules collection,
- Seeds/propagules sorting, treatment and storage.
- Nursery raising (soil collection and preparation, bag filling, bed preparation, shed preparation, fencing, seed sowing, mulching etc.) for next year plantation.
- Selection of promising seedlings at nursery stage for plantation.
- Nursery data collection.
- Data analysis and reporting.
- Day long training programs among the local farmers on "Sundarban Conservation and Plantation Techniques" were conducted at 6 Upazillas in four districts adjacent to the Sundarban.

**Statistical design:**

The plantations of Mangrove species were done in Randomized Complete Block Design (RCBD) at 1.5m x 1.5m, 1.75m x 1.75m and 2.0m x 2.0m spacing with seven replications. Microsoft excel programs were used to process all collected data and in preparing tables, charts and graphs.

## 11. Results and discussion:

Scientific evidence suggests that timber, aquatic, wildlife and non-timber forest products are declining in the Sundarban due to historical and current over exploitation (Canonizada and Hossain 1998). Comparisons with earlier forest inventories show that the rate of forest degradation is rapidly increasing. Historical selection management system of the Sundarban was focused on harvesting timber and non-timber resources mainly for earning revenue with little regard to overall sustainability of the ecosystem. As a result, the major mangrove species in the Sundarban Reserved Forest are overexploited, and the rate of degradation is increasing resulting the natural populations of some mangrove species have declined in a large scale as well as the biodiversity diverse mangrove ecosystem has suffered from unsustainable management and causing the impact on biodiversity and natural forest ecosystem.

Knowledge on nursery and plantation techniques of different mangrove species are most essential for conservation and sustainable management of major species in the Sundarban. The problems of the Sundarban are diversified due to its complex ecosystem and hence the proposed research agenda to improve and maintain sustained productivity as well as in reducing of natural disasters and to increase their adaptation to the long term effect of climate change and eventually climate resilient mangrove ecosystems in the Sundarban will be enriched.

**I. Establishment of Nursery of Different Mangrove Species in the Sundarban**

The mangrove forests help stabilize shorelines and reduce the impact of natural disasters. They also provide breeding and nursing grounds for marine species, food, medicine and building materials for local communities. Sundarban is the single largest mangrove area coverage in the world. With the recognition of the Sundarban of Bangladesh as a World Heritage Site, conserving and promoting biodiversity of Sundarban is an important through the protection of mangrove ecosystems.

In Bangladesh part of the Sundarban, mangrove forests have been declining since the start of the century, and therefore there is a need of afforestation. Mangrove nurseries must be established for this since they serve as sources of planting materials for different mangrove species. A brief procedure is mentioned below as to the establishment of a mangrove nursery, describing the construction of a nursery, preparation of potting materials, seed collection, seed sowing, and maintenance and protection.

A total of 56,000 seeds/ propagules of sundri sundri (*Heritiera fomes*), passur (*Xylocarpus mekongensis*), vathkathi (*Kandelia candel)*, jhana (*Rhizophora mucronate*), kirpa (*Lumnitzera ramiflora*), kankra (*Bruguiera gymnorrhiza*), amoor ( *Amoora cuculata*), soila (*Sonneratia caseolaris*), baen (*Avicennia officinalis*), golpata (*Nypa fruticans*), keora (*Sonneratia appetala*),

amdhekur (*Cerbera manghas)*, bakul kankra (*Bruguiera sexangula* ) and dhundul (*Xylocarpus granatum* ) were collected from the Sundarban.

The polybags of size 10 cm x 15 cm were filled with soil mixed with cow dung at 5:1 ratio. The bags were arranged in a nursery bed of size 1.2 m x 12.0 m. A shed have been given on the bed and fenced to protect the seedlings from the sun, rain and animals. Irrigation was given in the nursery regularly. The seedlings were allowed to grow in the nursery for one year. The shed over the seedlings were removed three months after sowing seeds in bed to allow seedlings in direct sunshine and rain.

**Table-1. List of mangrove species tried in the newly accreted lands and poorly regenerated areas of the Sundarban**

| Sl. No. | Vernacular name | Scientific name | Family |
|---|---|---|---|
| 1 | Sundri | *Heritiera fomes* | Sterculiaceae |
| 2 | Passur | *Xylocarpus mekongensis* | Malvaceae |
| 3 | Vathkathi | *Kandelia candel* | Rhizophoraceae |
| 4 | Jhana | *Rhizophora mucronata* | Rhizophoraceae |
| 5 | Kirpa | *Lumnitzera racemosa* | Combretaceae |
| 6 | Kankra | *Bruguiera gymnorrhiza* | Rhizophoraceae |
| 7 | Amoor | *Amoora cuculata* | Meliaceae |
| 8 | Soila | *Sonneratia caseolaris* | Sonneratiaceae |
| 9 | Baen | *Avicennia officinalis* | Avicenniaceae |
| 10 | Golpata | *Nypa fruticans* | Palmae |
| 11 | Keora | *Sonneratia appetala* | Sonneratiaceae |
| 12 | Amdhekur | *Cerbera manghas* | Apocynaceae |
| 13 | Bakul kankra | ***Bruguiera sexangula*** | Rhizophoraceae |
| 14 | Dhundul | *Xylocarpus granatum* | Malvaceae |

**Table-2. Germination performance of different mangrove species at nursery of the Sundarban in 2017**

| Sl. No. | Name of species | No. of seeds / propagules sown | Initiation of germination (days) | Completion of germination (days) | Germination percentage (%) |
|---|---|---|---|---|---|
| 1. | Sundri | 4,000 | 7 | 40 | 70 |
| 2. | Passur | 4,000 | 16 | 55 | 80 |
| 3. | Vathkathi | 4,000 | 5 | 12 | 95 |
| 4. | Jhana | 4,000 | 6 | 10 | 90 |
| 5. | Kirpa | 4,000 | 35 | 70 | 60 |
| 6. | Kankra | 4,000 | 6 | 12 | 90 |
| 7. | Amoor | 4,000 | 15 | 35 | 90 |
| 8. | Soila | 4,000 | 8 | 15 | 80 |
| 9. | Baen | 4,000 | 6 | 15 | 70 |
| 10. | Golpata | 4,000 | 5 | 20 | 90 |
| 11. | Keora | 4,000 | 20 | 40 | 75 |
| 12. | Amdhekur | 4,000 | 30 | 60 | 90 |
| 13 | Bakul kankra | 4,000 | 6 | 10 | 90 |
| 14 | Dhundul | 4,000 | 6 | 20 | 90 |

The average germination percentage of sundri (*Heritiera fomes*), passur (*Xylocarpus mekongensis*), vathkathi (*Kandelia candel)*, jhana (*Rhizophora mucronate*), kirpa (*Lumnitzera ramiflora*), kankra (*Bruguiera gymnorrhiza*), amoor ( *Amoora cuculata*), soila (*Sonneratia caseolaris*), baen (*Avicennia officinalis*), golpata (*Nypa fruticans*), keora (*Sonneratia appetala*), amdhekur (*Cerbera manghas)*, bakul kankra (*Bruguiera sexangula* ) and dhundul (*Xylocarpus granatum* ) were 70, 80, 95, 90, 60, 90, 90, 80,70, 90, 75, 90, 90 and 90 respectively (Table-2). Nursery with 14 different mangrove species has been maintained in different locations of the Sundarban. The variation of germination percentage of different species might be due to the genetical factor of the species concern.


Figure-1. Mangrove Nursery at Bogi in the less saline zone of Sundarban


Figure-2. Mangrove Nursery at Dhangmary in the moderate saline zone of Sundarban


Figure-3. Mangrove Nursery at Munshigonj in the strong saline zone of Sundarban


Figure-4. Amdhekur (*Cerbera manghas)* seedlings raised at Bogi nursery in the Sundarban


Figure-5. Kirpa (*Lumnitzera ramiflora*) seedlings raised at Munshigonj nursery in the Sundarban


Figure-6. Passur (*Xylocarpus mekongensis*) seedlings raised at Dhangmari nursery in the Sundarban


Figure-7. Golpata (*Nypa fruticans*) seedlings raised at Bogi nursery in the Sundarban


Figure-8. Keora (*Sonneratia appetala*) seedlings raised at Munshigonj nursery in the Sundarban


Figure-9. Golpata (*Nypa fruticans*) seedlings raised at Dhangmari nursery in the Sundarban


Figure-10. Baen (*Avicennia officinalis*) seedlings raised at Dhangmari nursery in the Sundarban


Figure-11. Kankra (*Bruguiera gymnorrhiza*) seedlings raised at Dhangmari nursery in the Sundarban


Figure-12. Vathkathi (*Kandelia candel)* seedlings raised at Dhangmari nursery in the Sundarban


Figure-13. Keora (*Sonneratia apetala)* seedlings raised at Dhangmari nursery in the Sundarban


Figure-14. Sundri (*Heritiera fomes)* seedlings raised at Dhangmari nursery in the Sundarban

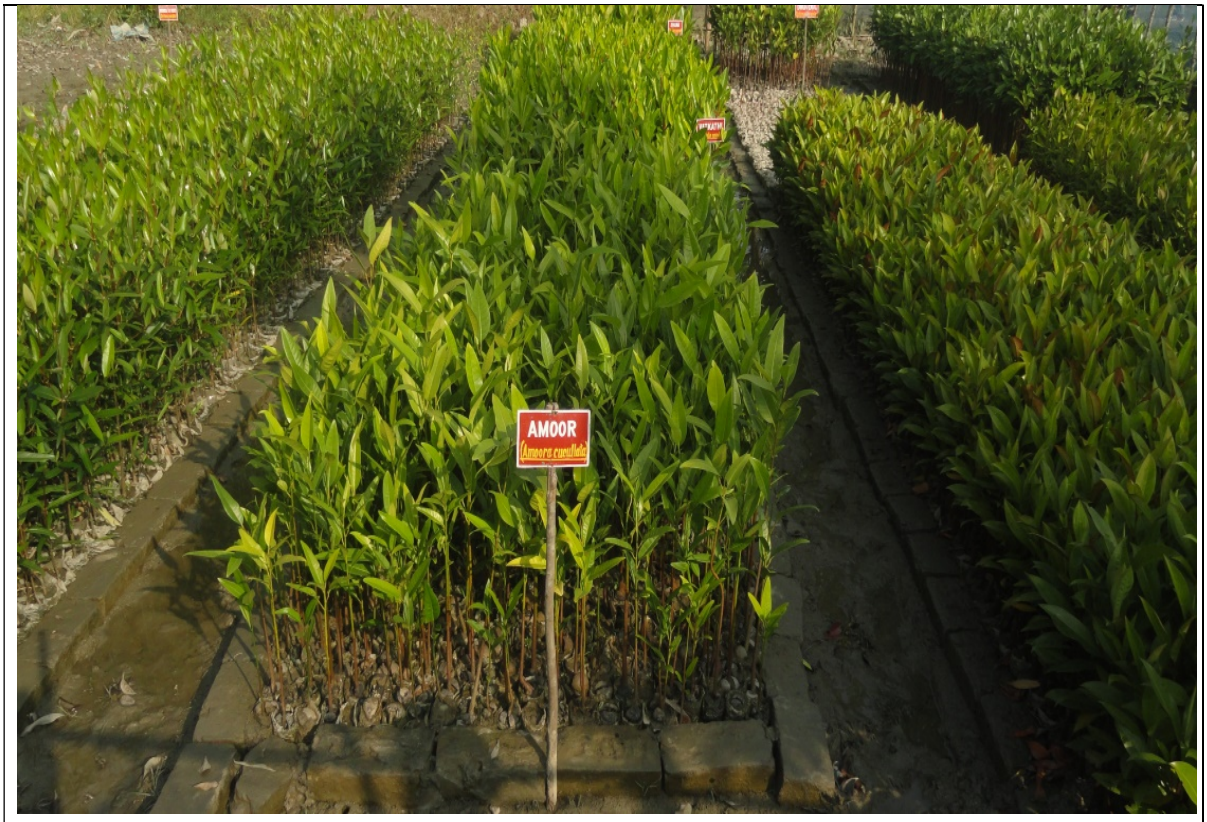


Figure-15. Amoor (*Amoora cuculata)* seedlings raised at Dhangmari nursery in the Sundarban


Figure-16. Dhundhul (*Xylocarpus granatum)* seedlings raised at Dhangmari nursery in the Sundarban


Figure 17: Dr. Rafiqul Hayder, Project Director, RBRTC Project, BFRI visited mangrove nursery at Dhangmari of the Sundarban in March 2018


Figure 18: Dr. Khurshid Akhter, Director, BFRI visited mangrove nursery at Munshigonj of the Sundarban in February 2018

Mangrove nurseries were established at suitable intertidal sites in different salinity zones of the Sundarban. Nursery with fourteen different mangrove species were maintained in three salinity zones of the Sundarban. And then those seedlings were maintained in rectangular nursery beds for about one-year till ready for transplanting in the field. Figure 1-3 show three mangrove nurseries in different locations of the Sundarban and figure 4-12 showed the seedlings of different mangrove species at different mangrove nurseries in the Sundarban.

## II. Plantation of Different Mangrove Species in Three Salinity Zones of the Sundarban

One of the major problems of the mangrove forest of Bangladesh – the Sundarban is the depletion of growing stock though the forest is managed on a sustained yield basis. There are considerable areas in the forest almost without any regeneration or forest cover. To enrich the poorly regenerated areas by artificial regeneration is thus necessary to improve the ecosystems of the forest.

Three experimental sites were selected for mangrove species trials in three salinity zones of the Sundarban shown in figure-19. These were poorly regenerated and covered with grasses or non-commercial species like gila lata, chanda lota, shun grass, hargoja, hanthal, tiger fern, bhola, nal khagra, hogla, kutum kata, dhanshi and kewa katta. The experimental sites were prepared by jungle cutting and clearing. Weeding was done before raising plantation.

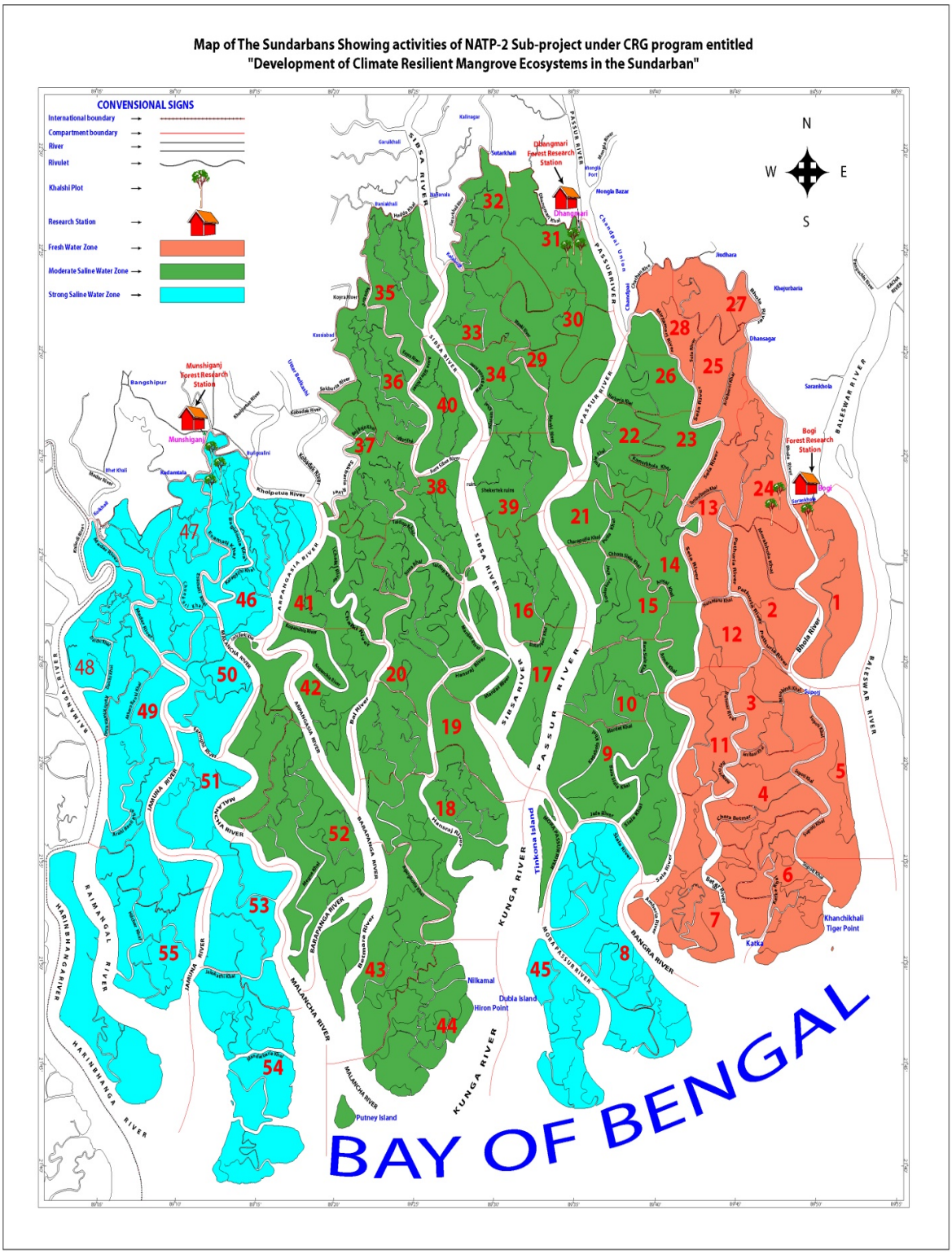


**Figure-19. Map of the Sundarban showing activities of NATP-2 Sub-project under CRG program entitled "Development of Climate Resilient Mangrove Ecosystems in the Sundarban".**

Experimental plantations were raised during May 2018. Planting was carried out over an area of 16.8 ha in three experimental sites of the Sundarban. The seedlings were transferred from the nursery to the planting sites by country boat. The polybags were removed from the ball of soil and the seedlings were planted at 1m x 1m, 1.5m x 1.5m and 2m x 2m spacing. Staking was done to provide support to the newly planted seedlings. Site descriptions of experimental plots in less saline zones of the Sundarban are shown in table-3. Average height (cm) before planting of sundri (*Heritiera fomes*), passur (*Xylocarpus mekongensis*), vathkathi (*Kandelia candel)*, jhana (*Rhizophora mucronate*), kirpa (*Lumnitzera ramiflora*), kankra (*Bruguiera gymnorrhiza*), amoor ( *Amoora cuculata*), soila (*Sonneratia caseolaris*), baen (*Avicennia officinalis*), golpata (*Nypa fruticans*), keora (*Sonneratia appetala*), amdhekur (*Cerbera manghas)*, bakul kankra (*Bruguiera sexangula* ) and dhundul (*Xylocarpus granatum* ) were 60cm, 82cm, 32cm, 78cm, 22cm, 42cm, 54cm, 42cm,24cm, 36cm, 38cm, 50cm, 52cm and 60cm respectively (Table-3). Initially the site were covered with grasses or non-commercial species like shun grass, bhola, nal khagra, hogla, kutum kata, dhanshi and kewa kata.

**Table-3. Site descriptions and seedling transplantation with different mangrove species in less saline zone of the Sundarban in May, 2018**

| Species | Average height at the time of plantation (cm) | Compt. No. | Area of plantation (ha) | Spacing | Soil pH | Soil texture | Water salinity (ppt) | Flooding Frequency (times/month) | Inundation condition | Initial vegetation |
|---|---|---|---|---|---|---|---|---|---|---|
| Sundri | 60 | 01 | 0.3 | 1mx1m, 1.5m x1.5m & 2mx2m | 6.3 | Silty-clay-loam | 1.0 | 36-46 | Inundation by all tides in monsoon | shun grass, bhola, nal khagra, hogla, kutum kata, dhanshi and kewa katta |
| Passur | 82 | | | | | | | | | |
| Vathkathi | 32 | | | | | | | | | |
| Jhana | 78 | | | | | | | | | |
| Kirpa | 22 | | | | | | | | | |
| Kankra | 42 | | | | | | | | | |
| Amoor | 54 | | | | | | | | | |
| Soila | 42 | | | | | | | | | |
| Baen | 24 | | | | | | | | | |
| Golpata | 36 | | | | | | | | | |
| Keora | 38 | | | | | | | | | |
| Amdhekur | 50 | | | | | | | | | |
| Bakul Kankra | 52 | | | | | | | | | |
| Dhundul | 60 | | | | | | | | | |

Site descriptions of experimental plots in moderate saline zones of the Sundarban are shown in table-4. Average height (cm) before planting of sundri (*Heritiera fomes*), passur (*Xylocarpus mekongensis*), vathkathi (*Kandelia candel)*, jhana (*Rhizophora mucronate*), kirpa (*Lumnitzera ramiflora*), kankra (*Bruguiera gymnorrhiza*), amoor ( *Amoora cuculata*), soila (*Sonneratia caseolaris*), baen ( *Avicennia officinalis*), golpata (*Nypa fruticans*), keora (*Sonneratia appetala*), amdhekur (*Cerbera manghas)*, bakul kankra (*Bruguiera sexangula* ) and dhundul (*Xylocarpus granatum* ) were 57cm, 80cm, 32cm, 76cm, 20cm, 40cm, 52cm, 40cm, 22cm, 35cm, 39cm, 52cm, 50cm and 62cm respectively (Table-4). Initially the site were covered with grasses or non-commercial species like gila lata, chanda lota, shun grass, hargoja, tiger fern, dhanshi and kewa kata.

**Table-4. Site descriptions and seedling transplantation with different mangrove species in moderate saline zone of the Sundarban in May, 2018**

| Species | Average height at the time of plantation (cm) | Compt. No. | Area of plantation (ha) | Spacing | Soil pH | Soil texture | Water salinity (ppt) | Flooding Frequency (times/month) | Inundation condition | Initial vegetation |
|---|---|---|---|---|---|---|---|---|---|---|
| Sundri | 57 | 31 | 0.3 | 1mx1m, 1.5mx1.5m & 2mx2m | 5.6 | Silty-clay-loam | 4.0 | 32-40 | Inundation by all tides in monsoon | gila lata, chanda lota, shun grass, hargoja, tiger fern, dhanshi and kewa katta |
| Passur | 80 | | | | | | | | | |
| Vathkathi | 32 | | | | | | | | | |
| Jhana | 76 | | | | | | | | | |
| Kirpa | 20 | | | | | | | | | |
| Kankra | 40 | | | | | | | | | |
| Amoor | 52 | | | | | | | | | |
| Soila | 40 | | | | | | | | | |
| Baen | 22 | | | | | | | | | |
| Golpata | 35 | | | | | | | | | |
| Keora | 39 | | | | | | | | | |
| Amdhekur | 52 | | | | | | | | | |
| Bakul Kankra | 50 | | | | | | | | | |
| Dhundul | 62 | | | | | | | | | |

Site descriptions of experimental plots in strong saline zones of the Sundarban are shown in table-5. Average height (cm) before planting of sundri (*Heritiera fomes*), passur (*Xylocarpus mekongensis*), vathkathi (*Kandelia candel)*, jhana (*Rhizophora mucronate*), kirpa (*Lumnitzera ramiflora*), kankra (*Bruguiera gymnorrhiza*), amoor ( *Amoora cuculata*), soila (*Sonneratia caseolaris*), baen ( *Avicennia officinalis*), golpata (*Nypa fruticans*), keora (*Sonneratia appetala*),

amdhekur (*Cerbera manghas)*, bakul kankra (*Bruguiera sexangula* ) and dhundul (*Xylocarpus granatum* )were 56cm, 75cm, 28cm, 74cm, 18cm, 38cm, 48cm, 37cm, 19cm, 32cm, 35cm, 46cm, 47cm and 56cm respectively (Table-5). Initially the site were covered with grasses or non-commercial species like hargoja, tiger fern, hanthal, dhanshi and kewa katta.

**Table-5. Site descriptions and seedling transplantation with different mangrove species in strong saline zone of the Sundarban in May, 2018**

| Species | Average height at the time of plantation (cm) | Compt. No. | Area of plantation (ha) | Spacing | Soil pH | Soil texture | Water salinity (ppt) | Flooding Frequency (times/month) | Inundation condition | Initial vegetation |
|---|---|---|---|---|---|---|---|---|---|---|
| Sundri | 56 | 46 | 0.3 | 1mx1m, 1.5mx1.5m & 2mx2m | 6.8 | Silty-clay | 18.0 | 16-24 | Inundation by all tides in monsoon; seldom in non-monsoon | hargoja, tiger fern, hanthal, dhanshi and kewa katta |
| Passur | 75 | | | | | | | | | |
| Vathkathi | 28 | | | | | | | | | |
| Jhana | 74 | | | | | | | | | |
| Kirpa | 18 | | | | | | | | | |
| Kankra | 38 | | | | | | | | | |
| Amoor | 48 | | | | | | | | | |
| Soila | 37 | | | | | | | | | |
| Baen | 19 | | | | | | | | | |
| Golpata | 32 | | | | | | | | | |
| Keora | 35 | | | | | | | | | |
| Amdhekur | 46 | | | | | | | | | |
| Bakul Kankra | 47 | | | | | | | | | |
| Dhundul | 56 | | | | | | | | | |

Nursery seedlings of mangrove species were found to have better survival than seeds sown directly in the field or through natural regeneration. So nursery seedlings become the planting material for plantations, whether these plantations are for production, protection or amenity. Eventually those seedlings play positive role for development of mangrove vegetation in the coastal areas and to improve carbon sink as well as enrichment of mangrove ecosystems.

Figure-20. Experimental plantations of *Nypa fruiticans* species at Munshigonj (Comt. No.46) in strong saline zone of the Sundarban raised in May, 2018


Figure-21. Experimental plantations of *Nypa fruiticans* species at Dhangmari (Comt. No.32) in moderate saline zone of the Sundarban raised in May, 2018

Figure-22. Experimental plantations of *Nypa fruiticans* species at Bogi (Comt. No.24) in less saline zone of the Sundarban raised in May, 2018


Figure-23. Experimental plantations of *Bruguiera gymnorrhiza* species at Bogi (Comt. No.24) in less saline zone of the Sundarban raised in May, 2018


Figure-24. Experimental plantations of *Avicennia officinalis* species at Dhangmari (Comt. No.32)in less saline zone of the Sundarban raised in May, 2018


Figure-25. Experimental plantations of *Sonneratia caseolaris* species at Dhangmari (Comt. No.32) in less saline zone of the Sundarban raised in May, 2018


Figure-26. Experimental plantations of *Bruguiera sexangula* species at Bogi (Comt. No.24) in less saline zone of the Sundarban raised in May, 2018


Figure-27. Experimental plantations of *Amoora cuculata* species at Dhangmari (Comt. No.32) in less saline zone of the Sundarban raised in May, 2018


Figure-28. Experimental plantations of *Sonneratia appetala* species at Munshigonj (Comt. No.46) in less saline zone of the Sundarban raised in May, 2018


Figure-29. Experimental plantations of *Xylocarpus granatum)* species at Munshigonj (Comt. No.46) in less saline zone of the Sundarban raised in May, 2018

## III. Enrichment of mangrove ecosystems through *Kandelia candel* (L.) Druce species in the Sundarban Mangrove Forest of Bangladesh

To enrich mangrove ecosystems through establishment and conservation of the mangrove species *Kandelia candel* (L.) Druce in the moderate saline zone of the Sundarban, a field experiment was conducted in Bangladesh Sundarban from 2012 to 2018 using the research fund of PIU-BARC, NATP 1 and PIU-BARC, NATP 2 under the Competitive Research Grant (CRG).

*Kandelia candel* (L.) Druce is a mangrove species under the family Rhizophoraceae. Locally it is known as *vathkathi*. It grows as a shrub or a small tree up to 5 meters tall with DBH (Diameter at Breast Height) less than 16cm, found around the Sundarban of Bangladesh. It thrives on soft mud along in inland river banks associated with *Aegiceras corniculatum*, and as gregarious undergrowth on the same habitat (Peng and Xin-men 1983). According to Tomlinson (1986) it was found from the Ganges Delta, Myanmar through Southeast Asia to China, the Ryu Kyu Islands and southern Japan. Throughout its range, the species was considered to be nowhere abundant (Tomlinson 1986). At first the species was discovered in Malabar, India. It was named "Tsjerou-kandel" by van Rheede in 1686. Carl Linnaeus, the father of taxonomy, named it *Rhizophora candel* as its hypocotyl resembles a candle (as the Latin word "candel" suggests). Until recently, it had the name *Kandelia candel* and was recognized as the monotypic species of the genus. Chromosome numbers of *K. candel* is 2n=38 (Das *et al* 1995).

Mangroves occupy less than 1 % of the world's surface and are mainly found between the Tropic of Cancer and the Tropic of Capricorn on all continents covering an estimated 75 percent of the tropical coastline worldwide (Saenger 2002). Mangroves are one of the most valuable coastal habitats providing enormous benefits both tangible and non-tangible to the local communities as well as the ecology and environment surrounding them. Mangrove forests are the economic foundations of many coastal regions and provide a range of US$2000 to US$9000 per hectare per year in 'ecosystem services' (Wells *et al* 2006). In the last few decades, due to their service value in providing resources and services, mangroves and their ecosystems have been enormously overwhelmed. The deterioration of mangroves and the changes in coastal environments have been noted as one of the most important environmental issues in the coastal region of Bangladesh and globally also. Population dynamics and the market economy have boosted the development of coastal industries and expansion of intensive shrimp farming systems which together have caused widespread damage of mangrove ecosystems.

At least 40% of the animal species that are restricted to mangrove habitat and have previously been assessed under IUCN Categories and Criteria are at elevated risk of extinction due to extensive

habitat loss (Luther and Greenburg 2009). It is assessed that 26% of mangrove forests worldwide are degraded due to over-exploitation for fuelwood and timber production (Valiela *et al* 2001). Given their accelerating rate of loss, mangrove forests may at least functionally disappear in as little as 100 years (Duke *et al* 2007). The loss of individual mangrove species is also of great concern, especially as even pristine mangrove areas are species-poor compared to other tropical plant ecosystems (Alongi 2002). In Sundarbans, the population of the globally endangered species, *H. fomes*, is estimated to have declined by 76% since 1959 and about 70% of the remaining *H. fomes* trees are affected by the 'top dying' diseases (Chowdhury *et al* 2007). Dramatic declines in other dominant mangrove species (e.g. *E. agallocha* and *X. mekongensis*) have also been reported (Iftekar and Saenger 2008). In our observation, *Kandelia candel* species in the Bangladesh Sundarbans are declining rapidly.

*K. candel* play an important role in creating habitats for a diverse community of organisms ranging from bacteria and fungi to fishes and mammals. They grow in intertidal flats, estuaries and offshore islands. A brief procedure is given here as to the establishment of *K. candel* nursery, describing the construction of a nursery, preparation of potting materials, seed collection, seed sowing, maintenance and protection. This nursery is a place for raising and tending seedlings until they are ready for permanent planting. Assessing the performance of *K. candel* plantations were done annually by monitoring the survival rate and one or more structural characteristics of the stand, including height (H), diameter at breast height (DBH) and mean annual increment (MAI).

A very few reports are available about growth performance and site suitability of *Kandelia candel* (L.) Druce grown in the Sundarban. This study presents data concerning growth performance of the species at moderate saline zone of the Bangladesh Sundarban. The purpose of raising plantations of *K. candel* are to check soil erosion; enhancement of natural regeneration in future; to produce improved sources of planting materials, plus trees are selected from seed sources, seed production areas are established as well as seed orchards; production of fuel wood; beautification of coastal area; improvement of habitat; to support fisheries, apiculture etc. as well as eventually enrich the mangrove ecosystems.

**Materials and Methods**

For the purpose of raising seedlings, intertidal mangrove nurseries were established in 2012 in the Sundarban. Nursery sites were cleaned and leveled. All the weeds, grasses and other undesirable materials were removed from the area. The area was fenced by using wooden poles and barbed wire for protection purposes. To raise seedlings of *K. candel* species in the nursery, perforated polybags of 12cm x18cm size were filled with sandy/silt clay collected from the area adjacent to nursery site and

arranged in beds of convenient size. To provide support to these filled polybags, a framework made up of bamboo splinters was used along the boundary of the individual bed. Perforated polybags were used in the nursery so as to promote interaction of water inside and outside polybags. All the nursery works were done during low tide. Propagules of *K. candel* were collected from healthy, mature, and vigorously growing trees in the morning time from the Sundarban mangrove forest. The propagules are recommended to collect directly from the donor trees at the time that coincides with the natural drop. Ti is discouraged to use of propagules that have been collected from the ground or washed-up on a shoreline. The collected propagules were kept in either polythene bags or in jute sacks and transported to the nursery. While storing, the propagules should be kept in shade for two to five days. The fruiting season of the species in Sundarban is between May and June. The collected propagules were examined for incidence of diseases or pests. Propagules were carefully inserted in the soil filled polythene bags. About one-fifth to one-sixth portion of the propagule was inserted in the soil. Deep insertion was not done. Growth of the propagules of *K. candel* was monitored regularly, as well as irrigation was provided regularly in the mangrove nursery. The seedlings were ready for transplantation once prop roots were started to grow, which need 12 months.

Site selection for plantation was concerned, only those sites were selected for planting where soil substratum was stable and presence of some grasses and other vegetation were noticed or poorly regenerated areas of the Sundarban. Weeds and debris were removed from the planting site. Protection of planting site was ensured. The seedlings were transported from nursery site to the planting site by boat. Transportation care was taken to avoid damage/ disturbance to the root system. Before planting the seedlings in the pit of appropriate size, the polythene bags were removed carefully by using sharp blade/ knife so as to cause minimum disturbance to the root system. The experimental sites were prepared by jungle cutting and clearing. Weeding was done before transplantation. The transplantation of *K. candel* was done by planting nursery raised seedlings in polybags in Randomized Complete Block Design (RCBD) at 1.0m x 1.0m, 1.5m x 1.5m and 2.0m x 2.0m spacing with ten replications in three locations of moderate saline zone. The number of seedlings were planted in each plot is 81(9 x 9). Thus a total of 2430 (81 x 10 x 3) seedlings were planted in intertidal region where they were inundated by water regularly. The plantations were initially protected by fencing against browsing up to the period it reached beyond the browsing height. Growth and survivability data of planted *K. candel* species were recorded twice in a year. Meteorological data were recorded. Data on water salinity, soil salinity, soil pH, sedimentation, soil erosion and inundation were recorded. Microsoft excel programs are to be used to process all collected information and in preparing tables, charts and graphs. The analysis of variance (ANOVA)

was done to note whether there are any difference existed in the species and between different spacing.

**Results and Discussion**

Three mangrove nurseries were established in the Sundarban mangrove forest of Bangladesh. Sufficient number of *Kandelia candel* seedlings were grown for experimental plantations. The mangrove nursery in the Sundarban is used as a mangrove demonstration and education site. More than 3,000 seedlings were grown at the three mangrove nurseries established at the given time (Figure 30).


Figure 30: One year old seedlings of *Kandelia candel* at mangrove nursery in moderate saline zone of the Sundarban

The young seedlings require regular watering (daily in the summer months and 3-4 times a week in the dry season). Weeding as well as protecting the seedlings from pests and stray animals may ensure the good health of the propagules for planting. Depending on the age of the young seedlings and the time of the year, proper shading is necessary. In their first 2-3 months, partial shade was provided, before gradually moving them to areas with full sun. Seedlings are the most economical sources of planting materials and the easiest to transport. Raising seedlings of *K. candel* in nursery before planting can increase the survival up to 100% and render good growth. This allowed the seedlings to develop an healthy root system before planting. The average germination percentage of *K. candel* was 100 and average height after one year was 40cm (Table-6).

Table 6. Propagule morphology, phenological observations and germination performance of planted *Kandelia candel* species in the Sundarban of Bangladesh

| Sl. No. | Parameter | Moderate Saline Zone of the Sundarban |
|---|---|---|
| 1. | Propagule collecting time | May - June |
| 2. | Number of seed/fruit | 1 |
| 3. | Number of propagule/kg | 55 - 60 |
| 4. | Length of propagule (cm) | 25 - 35 |
| 5. | Propagule storage time (days) | 7 |
| 6. | Number of propagules sown | 3000 |
| 7. | Initiation of germination (days) | 5 |
| 8. | Completion of germination (days) | 12 |
| 9. | Germination percentage (%) | 100 |
| 10. | Average height after one year (cm.) | 40 |

The experimental sites were selected for *K. candel* species trials in the moderate saline zone of the Sundarban. These were poorly regenerated and covered with grasses or non-commercial species like gila lata (*Derris trifoliate*), chanda lota (*Dalbergia candenatensis*), tiger fern (*Acrostichum aureum*), dhanshi (*Myriostachya wightiana*), nal khagra (*Phragmites karka*) and kewa katta (*Pandanus foetidus*). Detailed site descriptions of the experimental plots for *K. candel* species in the moderate saline zone of the Sundarban is given in table 7.

Table7. Site descriptions of the experimental plots for *Kandelia candel* species in the Sundarban.

| Sl. No. | Parameter | Moderate Saline Zone of the Sundarban |
|---|---|---|
| 1. | GPS of the experimental site | Latitude: $22^0$ 26' 51"<br>Longitude: $89^0$ 35' 53" |
| 2. | Year of plantation | 2012 |
| 3. | Area of plantation (ha) | 1.5 |
| 4. | Spacing | 2.0m x 2.0m, 1.5m x 1.5m, & 1.0m x 1.0m |
| 5. | Soil texture | Silty-clay |
| 6. | Soil pH | 7.5 |
| 7. | Soil salinity (m mhos) | 2.7 |
| 8. | Water salinity (ppt) | 12.0 |
| 9. | Inundation condition | Inundation by all tides in monsoon |
| 10. | Initial vegetation | Dense cover of gila lata (*Derris trifoliate*), chanda lota (*Dalbergia candenatensis*), tiger fern(*Acrostichum aureum*), dhanshi (*Myriostachya wightiana*), nal khagra(*Phragmites karka*) and kewa kata (*Pandanus foetidus*) |

Transplantation of *K. candel* was done with the raised polybag seedlings and monitored regularly to assess their success and growth rate. After three months of planting, growth and survival data were recorded twice a year. In case of mortality, it is important to investigate the underlying causes and initiate appropriate remedial measures. *Kandelia candel* species have adaptations that allow them to tolerate medium levels of salinity. Salinity is an important factor in reducing competition between mangrove species and other vascular plants. *K. candel* species need freshwater for their germination, initial growth and survival. Due to the fact that mangroves are halophytes, it might seem strange that these species required freshwater, but some mangrove species even grow well in only slightly brackish conditions. Restoration planners need to take into consideration of the dominant mangrove species in the restoration site and determine the optimum salinity levels or thresholds for those plants (Field 1998; Waycott *et al*. 2011).

Table 8. Phenology of raised *Kandelia candel* species in the Sundarban

| Sl. No. | Parameter | Moderate Saline Zone of the Sundarban |
|---|---|---|
| 1. | Flowering age of the plant (year) | 3 (including one year in the nursery) |
| 2. | Flowering period | November - December |
| 3. | Fruiting period | January - April |
| 4. | Propagule dropping time | May - June |

Phenological studies are involved with the observation and documentation of the timings of life history events of plants. There was no information on the phenology of *K. candel* species in the Sundarban of Bangladesh in the past. In the last few years, emphasis was given regarding *K. candel* plantation in the Sundarban. Initial studies have shown that flowering is precocious among the Rhizophoraceae, commencing from about 3 to 4 years of age. *K. candel* started flowering under moderate saline zone of the Sundarban 2 years after planting. The first flowering appeared in November. Fruiting and propagule production of *K. candel* is annual and prolific. The propagule production occurs mainly from January to June (Table 8). During the rainy season, the salinity of tidal water decreases facilitating the sprouting of propagules and growth of seedlings, so that they can gradually tolerate the higher salinity of soil and water in the dry season.

Figure 31: Monitoring the growth performance of five years old experimental plantations of *Kandelia candel* at 1.0m x 1.0m spacing in moderate saline zone of the Sundarban

*K. candel* was planted on July 2012 in the moderate saline zone of the Sundarban. The first flowering appeared in November 2014. However, the number of flowers on different saplings was varied. The better growing saplings had an average of 12-16 flowers/plant. Its propagules were mature in April then ripened and fell in May - June. Flowers were whitish with numerous stamens. Propagules are viviparous and smooth. It becomes reddish at the tips when it matures. After five years of plantation of *K. candel* species at 1.0m x 1.0m spacing in moderate saline zone of the Sundarban are shown in figure 31 (Photo: November 2016).

Figure 32: Monitoring the growth performance of five years old experimental plantation of *Kandelia candel* at 1.5m x 1.5m spacing in moderate saline zone of the Sundarban

Assessment of the plantations were done annually by monitoring the survival rate and one or more structural characteristics of the stand, including height (H), diameter at breast height (DBH) and mean annual increment (MAI). A five years old plantation of *K. candel* species at 1.5m x 1.5m spacing in moderate saline zone of the Sundarban, bearing propagules are shown in figure 32 (Photo: April 2017).

Figure 33: Five years old plantation of *Kandelia candel* at 2.0m x 2.0m spacing in moderate saline zone of the Sundarban

The total height, diameter at breast height (DBH), mean annual increment (MAI), coefficient of variation (CV), survival %, F-value and LSD-value of *K. candel* trees as a view of growth performances of five years old monoculture plantations under moderate saline zone in the Sunderban were shown in the table 9. The height (m), DBH (cm), MAI (m) and survival (%) of *K. candel* trees differ significantly at different spacing. The highest height (m), DBH (cm) and survival (%) were found 2.99m±0.09, 3.83cm±0.10 and 90% respectively at the spacing 2m x 2m as well as the highest mean annual increment (MAI) for height 0.60 m and for DBH 0.77 cm were found in the same spacing. A gregarious growth of five years old plantation of *K. candel* at 2.0m x 2.0m spacing in moderate saline zone of the Sundarban are shown in figure 33 (Photo: April 2017). The most suitable spacing for *K. candel* species was 2.0m x 2.0m in moderate saline zone of the Sundarban.

Table 9. Growth performance of five years old *Kandelia candel* species planted in moderate saline zone at different spacing in the Sundarbans.

| Indicators | Moderate saline zone, Dhangmari | | | | | |
|---|---|---|---|---|---|---|
| | Spacing | | | | | |
| | 2m x 2m | | 1.5m x 1.5m | | 1m x 1m | |
| | Height m ±se | DBH cm ±se | Height m ±se | DBH cm ±se | Height m ±se | DBH cm ±se |
| Mean data | 2.99 ±0.09 | 3.83 ±0.10 | 2.08 ±0.08 | 3.12 ±0.04 | 1.76 ±0.08 | 2.78 ±0.09 |
| Mean annual increment (MAI) | 0.60 | 0.77 | 0.42 | 0.62 | 0.35 | 0.56 |
| Coefficient of variation (CV) | 9.36 | 8.62 | 11.54 | 4.17 | 13.64 | 10.79 |
| Survival (%) | 90 | | 65 | | 40 | |
| Analysis of variance (ANOVA) | $F_{.05}$ (2) = 64.60$^{**}$ for height and 40.71$^{**}$ for dbh | | | | | |
| Least significant difference (LSD) | LSD = 0.23 for height and 0.25 for dbh | | | | | |

Considering height and DBH data, analysis of variance (ANOVA), least significant difference (LSD) and coefficient of variation (CV) have been done. The calculated values were $F_{.05}$ (2) = 64.60$^{**}$ which was highly significant at the 5% level, LSD = 0.23 for height and $F_{.05}$ (2) = 40.71$^{**}$, LSD = 0.25 for DBH. There were significant differences in the mean total height (m) and mean DBH (cm) among the spacing 2m x 2m, 1.5m x 1.5m and 1m x 1m (Table 9). All these findings reflect that growth performance of *K. candel* species was better on 2m x 2m compared to 1.5m x 1.5m and 1m x 1m spacing.

The mangrove plantation approaches use hand planting of desired propagules/seedlings and saplings at selected areas to restore mangrove forests. There are different techniques used in the plantation approach with *Kandelia candel* species. First technique is to transplant seedlings from a mangrove forest to the plantation site. Second technique is to collect ripe propagules and directly plant them at the plantation site. Third technique is desired seedlings or propagules may be raised under nursery conditions and then transplanted at the plantation site. In this research study we followed the third technique for raising experimental plantations with *K. candel* species.

*Kandelia candel* in Longhai, Fujian, China, started flowering and producing propagules at about 8 years old, and the number and density of flowers varied among plants of different ages (Chen 2000). In our plantation, it was recorded that *K. candel* species begins to flower and produce propagules after 3 years. In South East Asia, *K. candel* grows best on the banks of tidal rivers, or the landward side of the mangrove community, in brackish water (Watson 1928). In Hong Kong, *K. candel* mangroves were replanted in an intertidal mudflat area of 1,000 $m^2$ as a mitigation project to

compensate from the damage from coastal construction activities from 1990-1991. In Ha Tinh Province of Vietnam, a mudflat area of 580 ha was planted with mangrove species *K. candel* from 1989-1993. Mangroves around the world are affected by human activities, and all may be influenced by global changes in climate or sea level. Because mangrove coverage is being reduced, we hope that future exploitation of mangroves will be preceded by environmental impact assessments that will include estimates of biomass. Apart from the geographical location and forest structural attributes, the net primary productivity depends on abiotic factors such as hypoxic conditions, tidal height, frequency of tidal inundation, availability of nutrients, salinity, and climatic factors (Aksornkoae 1993; Hutchings and Saenger 1987). *K. candel* grows on soft mud along in inland river banks associated with *Avicennia officinalis, Sonneratia apetala, Xylocarpus granatum, Nypa fruticans, Aegiceras corniculatum*, and as gregarious undergrowth on the same habitat in the Sundarban. The best growths of *Aegiceras corniculatum* were recorded in moderate saline zone and significantly lower growths were recorded in strong saline zone of the Sundarban (Rahman 2016a). The growth performance of *Rhizophora mucronate* was better on 2.5m x 2.5m compared to 2.0m x 2.0m and 1.5m x1.5m spacing in the moderate saline zone of the Sundarban (Rahman 2016b).

It is obvious that the successful transfer of a species in order to protect it as *ex-situ* conservation requires a comprehensive environmental assessment. A wide range of plant spacings have been used in mangrove planting program. Proper spacing for *K. candel* species was determined. Nursery and planting techniques differ significantly among different mangrove species. Nursery and planting techniques for *K. candel* species were determined. Incorporating *K. candel* species for coastal green engineering is to use multi-species planting on certain prearranged environmental engineering structures and other biodegradable structures. These innovative structures may help to boost mangrove formations, accrete sediments and perhaps even enriching recruitment of seedling.

## IV. Training -Workshop on Sundarban Conservation and Plantation Techniques

Training is a learning process. People can learn new information, re-learn and reinforce existing knowledge and skills, and most importantly have time to think and consider what new options can help them improve their effectiveness at work. Effective trainings convey relevant and useful information that inform participants and develop skills and behaviors that can be transferred back to the workplace. Generating and disseminating knowledge on the causes, patterns and consequences of changes in mangrove ecosystems at the local to globe scales, reporting on the status of mangrove management worldwide, and raising awareness of the vital importance of mangrove ecosystems to planetary well-being are the outcome of proposed training workshop on“Sundarban Conservation and Plantation Techniques”.

# Schedule of the Training Workshop on "Sundarban Conservation and Plantation Techniques"

**Objectives:**

The objective of the training program for the development of mangrove ecosystems by increasing homestead forest of the people living adjacent to the Sundarban which will ultimately decrease pressure on the Sundarban and developing the public awareness for forest conservation.

**Participants:** Local people/ farmers living adjacent to the Sundarban

**Training Workshop Coordinator:** Dr. M. Masudur Rahman, Divisional Officer, Mangrove Silviculture Division, Bangladesh Forest Research Institute, Khulna

**Venue:** **Date:**

| Sl No. | Time Schedule | Subject | Name & designation of lecturer |
|---|---|---|---|
| 1. | 10.00-10.10 | Reciting from the Holy Quran | |
| 2. | 10.10-10.30 | Introductory session | Dr. Masudur Rahman, Divisional Officer |
| 3. | 10.30-11.00 | Address to the course Coordinator | Dr. Masudur Rahman, Divisional Officer |
| 4. | 11.00-11.30 | Address to the Divisional Officer | Dr. Masudur Rahman, Divisional Officer |
| 5. | 11.30-12.00 | Tea Break | |
| 6. | 12.00-1.00 | Technical Session: Seed Collection, seed Storage and Seed preservation for Nursery raising. | Dr. A.S.M. Helal Siddiqui, Senior Research Officer |
| 7. | 1.00-1.30 | Launch Break & Prayer | |
| 8. | 1.30-2.30 | Necessary of Tree plantation: What seedlings, where and how to plant? | Dr. A.S.M. Helal Siddiqui, Senior Research Officer |
| 9. | 2.30-3.00 | Nursery Raising System | Dr. Masudur Rahman, Divisional Officer |
| 10. | 3.00-3.30 | Plantation Raising System | Dr. Masudur Rahman, Divisional Officer |
| 11. | 3.30-4.00 | Necessity for mangrove forest conservation and development of public awareness. | Dr. Masudur Rahman, Divisional Officer |
| 12. | 4.00-4.15 | Tea Break & Asar Prayer | |
| 13. | 4.15-5.00 | Desertification and our responsibility: Recent concept. | Dr. A.S.M. Helal Siddiqui, Senior Research Officer |
| 14. | 5.00-5.30 | Closing | |

Mangrove Silviculture Division of the Bangladesh Forest Research Institute, Khulna, conducted one-day long training program among the local farmers on "Sundarban Conservation and Plantation Techniques" at 6 Upazillas in four districts adjacent to the Sundarban during project period. The overall goal of the training program was for the development of mangrove ecosystems by increasing homestead forest of the people living adjacent to the Sundarban which will ultimately decrease pressure on the Sundarban and developing the public awareness for forest conservation. A total number of 175 farmers were participated in the training program among them 70 were female and 105 were male (Table-10).

**Table-10. Training/Workshop among the local farmers living adjacent to the sundarbans**

| Sl. No. | Subject of Training | Date of Training | Name of District | Name of Upazilla | Name of location | Number of participants |
|---|---|---|---|---|---|---|
| 1. | Sundarban conservation and plantation techniques | 03/01/18 | Bagerhat | Sharankhola | Vill.- Bogi | 25 |
| 2. | | 04/01/18 | Bagerhat | Mongla | Vill.- Kanainagor | 25 |
| 3. | | 05/01/18 | Satkhira | Shymnagor | Vill.- Munshigonj | 25 |
| 4. | | 03/02/18 | Jessore | Keshobpur | Vill.- Madardanga | 25 |
| 5. | | 04/02/18 | Khulna | Koira | Vill.- Amadi | 25 |
| 6. | | 06/02/18 | Bagerhat | Sharankhola | Vill.- Sharankhola | 25 |
| 7. | | 04/03/18 | Khulna | Rupsha | Vill.- Nandhonpur | 25 |

The figures 34-39 show the pictorial view of training in different locations. The participants accepted the information regarding nursery and plantation techniques very eagerly. They expressed their feelings that the Sundarban must be conserved for their survival. It is very fruitful for the farmers. The training program will increase practical knowledge for raising nursery and plantation. The training programs also improve to raise their home garden. The program will reduce the pressure on the forest resources of the Sundarban. So, it will help to conserve the biodiversity as well as ecosystems of the Sundarban.


Figure-34. Training workshop on Sundarban conservation and plantation techniques at Sharankhola, Bagerhat


Figure-35. Training workshop on Sundarban conservation and plantation techniques at Kanainagor, Mongla, Bagerhat


Figure-36. Training workshop on Sundarban conservation and plantation techniques at Munshigonj, Shamnagor, Shatkhira


Figure-37. Training workshop on Sundarban conservation and plantation techniques at Motherdanga, Keshobpur, Jessore


Figure-38. Training workshop on Sundarban conservation and plantation techniques at Amadi, Koira, Khulna


Figure-39. Training workshop on Sundarban conservation and plantation techniques at Nandonpur, Rupsha, Khulna

## 12. Research highlight/findings:

- Nursery and planting techniques differ significantly among different mangrove species. Nursery and planting techniques for *K. candel* species were determined. Incorporating *K. candel* species for coastal green engineering is to use multi-species planting on certain prearranged environmental engineering structures and other biodegradable structures. These innovative structures may help to boost mangrove formations, accrete sediments and perhaps even enriching recruitment of seedling.
- The training program for the development of mangrove ecosystems by increasing homestead forest of the people living adjacent to the Sundarban which will ultimately decrease pressure on the Sundarban and developing the public awareness for forest conservation.

**B. Implementation Position**

**1. Procurement:**

| Description of equipment and capital items | PP Target | | Achievement | | Remarks |
|---|---|---|---|---|---|
| | Phy (#) | Fin (Tk) | Phy (#) | Fin (Tk) | |
| (a) Office equipment | | | | | |
| (b) Lab &field equipment | | | | | |
| GPS | No.1 | 25,000 | No.1 | 25,000 | |
| Portable $P^H$ Meter | No.2 | 25,000 | No.2 | 25,000 | |
| Top pan balance | No.4 | 25,000 | No.4 | 25,000 | |
| Field Compass | No.4 | 20,000 | No.4 | 20,000 | |
| Digital Camera | No.1 | 25,000 | No.1 | 25,000 | |
| Total | | | | 1,20,000 | |

**2. Establishment/renovation facilities:** Not applicable

| Description of facilities | Newly established | | Upgraded/refurbished | | Remarks |
|---|---|---|---|---|---|
| | PP Target | Achievement | PP Target | Achievement | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

**3. Training/study tour/ seminar/workshop/conference organized:** Not applicable

| Description | Number of participant | | | Duration (Days/weeks/ months) | Remarks |
|---|---|---|---|---|---|
| | Male | Female | Total | | |
| (a) Training | | | | | |
| (b) Workshop | | | | | |

## C. Financial and physical progress

**Fig in Tk**

| Items of expenditure/activities | Total approved budget | Fund received | Actual expenditure | Balance/ unspent | Physical progress (%) | Reasons for deviation |
|---|---|---|---|---|---|---|
| A. Contractual staff salary | 250435 | 247220 | 247220 | | | |
| B. Field research/lab expenses and supplies | 1965000 | 2371027 | 2371027 | | | |
| C. Operating expenses | 560000 | 262347 | 262347 | 230 | | Deposited in Agrani Bank, Daulatpur Branch, Khulna for account closing. |
| D. Vehicle hire and fuel, oil & maintenance | 900000 | 686618 | 686618 | | | |
| E. Training/workshop/ seminar etc. | 440000 | 425216 | 425216 | | | |
| F. Publications and printing | 200000 | 121439 | 83000 | 38439 | | Refund to Director, NATP, BARC by Check No. CDB 4040323 Agrani Bank for PCR printing. |
| G. Miscellaneous | 64565 | 61563 | 61563 | | | |
| H. Capital expenses | 120000 | 111600 | 111600 | | | |
| Total | 45,00,000 | 42,87,030 | 42,48,591 | | | |

## D. Achievement of Sub-project by objectives: (Tangible form)

| Specific objectives of the sub-project | Major technical activities performed in respect of the set objectives | Output(i.e. product obtained, visible, measurable) | Outcome(short term effect of the research) |
|---|---|---|---|
| To develop mangrove vegetation in the coastal areas and to improve carbon sink.<br><br>To promote climate smart and sustainable management | Selection of promising seedlings at nursery stage for plantation.<br><br>Site selection and site preparation for experimental plantation. | A total of 56,000 seeds/ propagules of 14 mangrove species (*Amoora cuculata, Avicennia officinalis, Bruguiera gymnorhiza, Bruguiera sexangula, Heritiera fomes, Kandelia candel, Nypa fruticans, Rhizophora mucronata, Sonneratia caseolaris, Xylocarpus granatum, Xylocarpus mekongensis,* | Mangrove ecosystem are enriched and silvicultural techniques are improved for major mangrove species.<br><br>Mangrove forest gene resources are conserved.<br><br>Management strategies for sustainable yield and protective services from mangrove ecosystems are developed. |

| | | | |
|---|---|---|---|
| of coastal ecosystems through application of innovative approach for ecosystems rehabilitation.<br>Raising awareness among mangrove dwellers through capacity building programs. | Selecting villages adjacent to the Sundarban for conducting training for awareness. | *Cerbera manghas*, *Bruguiera sexangula and Xylocarpus granatum***)** from the Sundarban were collected.<br>A total of 42,000 seedlings with the collected seeds/ propagules were raised and maintained.<br>A total of 16.8 ha experimental plantations in the Sundarban were raised and maintained.<br>Seven training for awareness development about the ecological roles, economic importance and cultural significance of mangrove ecosystems among the local people living adjacent to the Sundarban were conducted. | Devise management objectives to encompass the total ecosystem with the subsequent preparation of composite or integrated plans applicable to prudent management of the total terrestrial, coastal and marine resources.<br>Awareness of the local people are increased. Scientific information are generated for sustainable mangrove forest management for future planning. |

**E. Materials Development/Publication made under the Sub-project:**

| Publication | Number of publication | | Remarks (e.g. paper title, name of journal, conference name, etc.) |
|---|---|---|---|
| | Under preparation | Completed and published | |
| Technology bulletin/ booklet/leaflet/ flyer etc. | 04 bulletins | | i. Mangrove museum - a nucleus for conservation, training and educating people about the value of Sundarban mangrove forest of Bangladesh Bulletin 7, Mangrove Series. Mangrove Silviculture Division. BFRI.<br>ii. Improvement and Conservation of Climate Resilient Mangrove Ecosystems in the Sundarban of Bangladesh. Bulletin 8, Mangrove Series. Mangrove Silviculture Division. BFRI.<br>iii. Chronology of Natural Regeneration of Mangrove Plant Species in the Sundarban of Bangladesh. Bulletin 9, Mangrove Series. Mangrove Silviculture Division. BFRI.<br>iv. Establishment of Mangrove Arboretum in the Sundarban Mangrove Forest of Bangladesh. Bulletin 10, Mangrove Series. Mangrove Silviculture Division. BFRI. |
| Journal publication | | 01 | Enrichment of mangrove ecosystems through *Kandelia candel* (L.) Druce species in the Sundarban Mangrove Forest of Bangladesh. Int. J. Bus. Soc. Sci. Res. 6(4): 01-08. |
| Information development | | | |
| Other publications, if any | | | |

## F. Technology/Knowledge generation/Policy Support (as applied):

**i. Generation of technology (Commodity & Non-commodity)**

*Kandelia candel* grows well in medium saline zone when planted at 2m x 2m spacing.

ii. **Generation of new knowledge that help in developing more technology in future**

The above technology will help developing more technology for conservation and sustainable management of major mangrove species in the Sundarban.

**iii. Technology transferred that help increased agricultural productivity and farmers' income**

The training program for the development of mangrove ecosystems by increasing homestead forest of the people living adjacent to the Sundarban which will ultimately decrease pressure on the Sundarban and developing the public awareness for forest conservation.

**iv. Policy Support**

Generated technology/ information may help in future planning for sustainable mangrove forest management.

## G. Information regarding Desk and Field Monitoring

**i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):**

A workshop on desk monitoring of Agro-forestry base CRG sub-projects held on 23.09.2018 at BARC Dhaka organized by the Project Implementation Unit NATP phase-2. The project progress was presented in the workshop and received positive remarks from the discussion. It was suggested to complete rest of the research activities on time due to the short period of time. Accordingly, it was completed all the activities during the project allocated time.

**ii) Field Monitoring (time& No. of visit, Team visit and output):**

| Visit/Team Visit | No. of Visit | Time | Output |
|---|---|---|---|
| Dr. Khurshid Akhter, Director, Bangladesh Forest Research Institute | 1 | 17/02/2018 | Visited mangrove nursery and experimental plantation at Munshigonj in the strong saline zone of the Sundarban. |
| Dr. Rafiqul Hayder, Project Director, RBRTC Project, Bangladesh Forest Research Institute | 1 | 30/03/2018 | Visited mangrove nursery and experimental plantation at Dhangmari of the Sundarban. |
| Monitoring team of Bangladesh Agriculture Research Council | 1 | 07/04/2018 | Visited mangrove nursery and experimental plantation at Dhangmari in the moderate saline zone of the Sundarban. |

## H. Lesson Learned/Challenges

The Sundarban's mangrove is a unique ecosystem and represents a genetic resource of its own and component of the global mangrove genetic heritage. The abnormal change of ecosystem may have a far reaching effect on the future sustainability of the ecosystem leading to ecological degradation of the area. Further studies on mangrove species are needed to assess the performance of various species in the different areas of the Sundarban to improve the mangrove ecosystems.

## I. Challenges

- Insufficient infrastructure like, nursery seed, staff quarter, *etc.* Two research stations' offices have been ruined by river erosion. Infrastructure like, nursery seed, staff quarter, *etc.* should be developed.
- Insufficient development of manpower. Promotion and recruitments should be regularized.
- Working hour reduces due to tides
- Difficult to collect seeds/propagules from the remote areas of the Sundarban

Signature of the Principal Investigator
Date ……..

Seal

Counter signature of the Head of the organization/authorized representative
Date ……..
Seal