Khalshi (*Aegiceras corniculatum*) – An important honey producing plant and its cultivation in the Sundarban of Bangladesh

Bulletin
5
MANGROVE SERIES

Dr. Md. Masudur Rahman
Divisional Officer

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF ENVIRONMENT AND FOREST
BANGLADESH FOREST RESEARCH INSTITUTE
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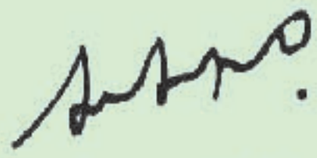
Foreword

This bulletin entitled "Khalshi (*Aegiceras corniculatum*) – An important honey producing plant and its cultivation in the Sundarban of Bangladesh" gives information about nursery and plantation techniques of the species which is known as honey plant in the Sundarban. The objective of this publication is to familiarize the mangrove foresters as well as other enterprising individuals, voluntary organizations and institutions involved in mangrove tree planting activities, under various afforestation schemes of the country. There is a growing awareness and interest for planting of *A. corniculatum* on the Sundarban and non-forest lands in the coastal areas of Bangladesh. In order to increase the vegetation cover area with this species, the tree planting activity is gaining momentum. The success of tree planting program requires sound knowledge of various aspects. The bulletin mainly deals with propagule viability, storage and germination; raising and maintenance of nursery; artificial regeneration; plant propagation; planting site and other details required for success of a nursery and plantation with *A. corniculatum*.

This bulletin holds many answers about how we can protect and manage the *A. corniculatum* plantations and how we can increase the area of healthy mangrove forest with the species in the Sundarban and in the coastal region of Bangladesh. I convey my sincere thanks to the author for preparing this important document.

I hope that researchers, foresters, students, NGOs will find this bulletin a useful publication.



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Contents

Khalshi (*Aegiceras corniculatum*) – An important honey producing plant and its cultivation in the Sundarban of Bangladesh

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Abstract

The research was carried out in experimental mangrove nurseries established at three different ecological zones of the Sundarban, Bangladesh to assess survival percentage and growth performance of *Aegiceras corniculatum* (L.) Blanto. The development of nursery and plantation technique for regeneration and popularization of the species in the Sundarban is described. Site selection, source of plant material, raising nursery and plantation, season of transplantation, technique of transplantation, etc. were considered as important factors for nursery and plantation establishment. It is observed that the best growths were recorded in moderate saline zone and significantly lower growths were recorded in strong saline zone of the Sundarban. The study has clearly identified and characterized a number of species-site relationships in the mangrove ecosystems of the Sundarban, findings that could be applied in future efforts towards the afforestation, conservation and management of the mangrove ecosystems in which local mangrove dwellers continue to extract resources on the basis of their needs and the capacity of the ecosystem to provide such resources on a sustainable basis. Mangrove afforestation with *A. corniculatum* can be an efficient and effective tool for disaster mitigation and enhanced livelihood as well as for the mitigation of climate change.

Introduction

Khalshi (*Aegiceras corniculatum*) is an important honey producing mangrove species in the Sundarban. It belongs to *Aegiceras* genus of *Myrsinaceae* family, is a crypto-viviparous species of Mangrove. It is commonly known as Black Mangrove. It is the most valuable and resourceful honey plant mainly thrives in the north-western part of Sundarban. The species forms a potential source for high quality honey and bee-wax from its flowers and the wood is used as fire wood, fencing materials, cores of mud wall etc. Siddiqi (2001) also informed that honey bees produce best quality honey from the nectar of *A. corniculatum* and wood is used for fuel and charcoal production.

River mangrove trunks were used as stakes in the culture of oysters and the trees are still a major source of pollen for beekeepers. This species provides valuable habitats for juvenile commercial and recreational fish, and is suitable for the rehabilitation and stabilization of river banks and estuaries. To increase honey production, development of apiculture and income generation it needs to expand this species. For this purpose nursery technique development, improvement of plantation technique and assessment of site suitability for plantation of this species are most essential for conservation of the species in the Sundarban because the natural population of the species has declined in a large scale.

Map of The Sundarban Showing Activities of Mangrove Silviculture Division Bangladesh Forest Research Institute, Muzgunni, Khulna.

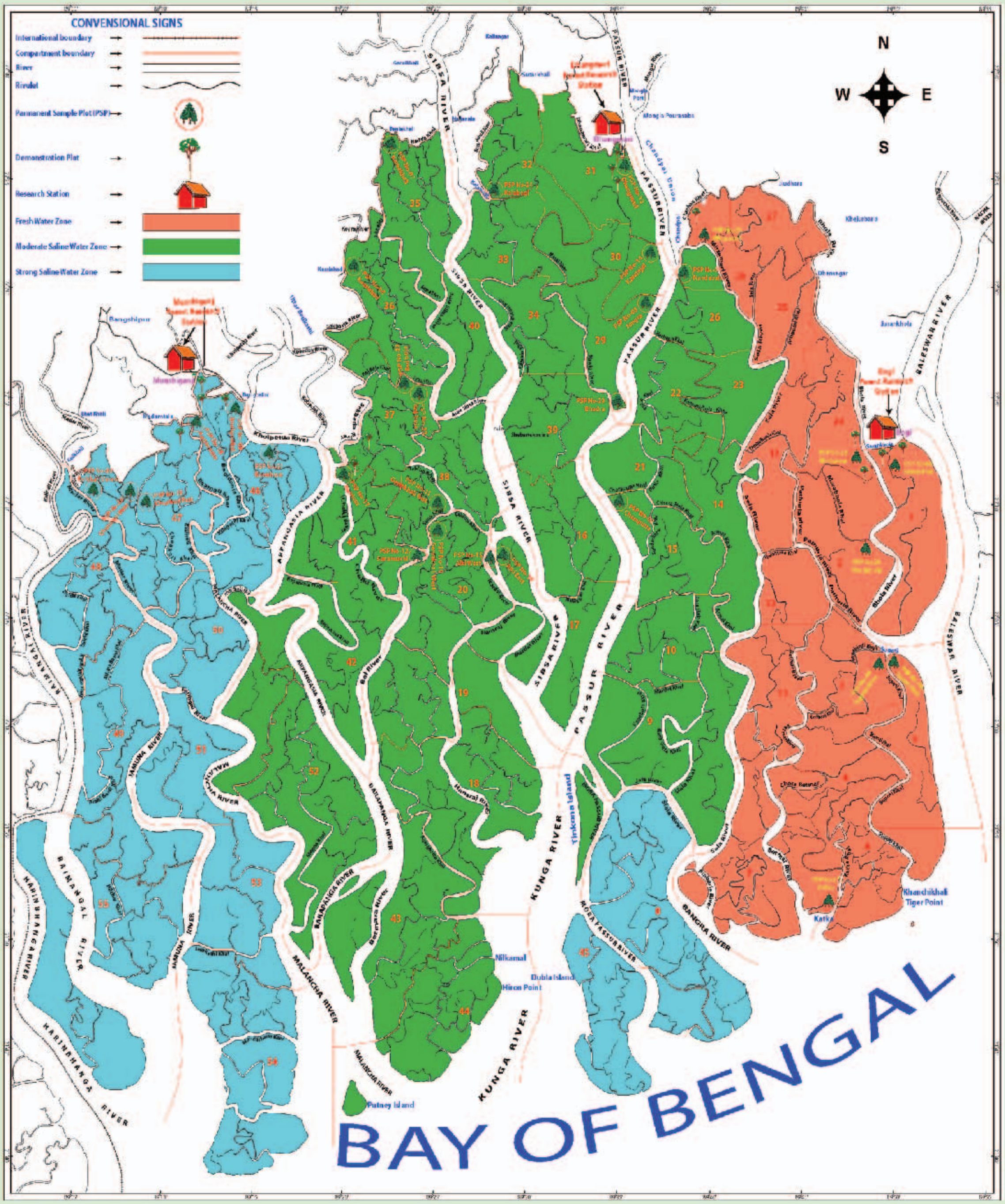


Figure 1. Salinity Wise Map of the Sundarban

Description and Adaptation

Mangroves have shallow root systems but they have adapted in a remarkable way to withstand the conditions of the nutrition, absorption of water and oxygen in anaerobic muddy soil and for anchorage on an unstable substratum. The mangroves have adapted to their environment through:

- ❑ Mechanical fixation in loose soil.
- ❑ Respiratory roots and aerating devices.
- ❑ Vivipary.
- ❑ Specialized means of dispersal and
- ❑ Development of xerophytic structures in relation to soil salinity.

Aegiceras corniculatum is a tropical woody shrub that grows in the intertidal zone throughout the Sundarban. It is a common mangrove of western part of the Sundarban considered as strong saline zone, occurring along banks in the upper tidal reaches of creeks and rivers where it is frequently encountered as an under storey beneath stands of black mangrove. It may also form pure, dense stands in the centre and landward zones of mangrove forests. It is noted that 'mangrove' has two different interpretations: it can refer to an individual plant or to an assemblage of plants that contains many species (Tomlinson, 1986; Saenger, 2002). According to the 2010 World Atlas of Mangroves, there are a total of 73 species and hybrids, which are considered to be true mangroves – those that have adapted to mangrove environments and are rarely found elsewhere. Thirty-eight of these species might be considered 'core species' that typify mangroves and dominate in most locations. The remainder are either not so abundant or are found mostly on the fringes of

Figure 2: A five years old *Aegiceras corniculatum* plant bearing propagules at strong saline zone of the Sundarban

mangrove habitats. Its gregarious growth occurs on the banks of tidal streams and intertidal zones, often forming pure zones along the muddy flats. It appears to be a pioneer species in some sites along with *Sonneratia apetala* and *Avicennia sp*. This species is often found as single-stemmed evergreen shrub or small tree in association with *Ceriops decandra*, *Avicennia officinalis*, *Excoecaria agallocha*, *Xylocarpus mekongensis*, *Kandelia candel*, *Sonneratia apetala* and *Acanthus ilicifolius* at the moderate to strong saline areas in the Sundarbans. A five years old *Aegiceras corniculatum* plant bearing propagules is shown in Figure 2.

Despite being species poor, mangroves are one of the most productive ecosystems (Kathiresan K and Bingham BJ, 2001). Mangroves perform many important ecosystem services, protecting coastal assets and providing breeding grounds for thousands of species of fish and other species; their conservation and management, therefore, are important parts of sustainable development. The species is hardy and has become adapted to harsh environments where water and salinity levels fluctuate. Pneumatophores, or breather roots, form a network that collects silt and debris, and controls erosion. Pneumatophores are a major adaptation to the stresses of intertidal habitat. They allow root respiration in anaerobic, waterlogged soils. The pneumatophores are also excellent nursery areas for crustaceans in the marsh plant community. Md. Masudur Rahman (2016) recorded that the height of *A. corniculatum* in Sundarban varies from 2m to 4m and individual tree can reach up to 6m, but is usually much shorter. The bark is rough and dark grey or black. Leaves are spoon-shaped with a rounded tip, and are glossy green above and paler green below. They occur alternately along the stem, while the surface is covered with minute salt glands that excrete salt from the plant. Clusters of white flowers may appear with a smell similar to rotten bananas. The species with its foliage, fragrant white flowers and curious crescent-shaped yellow fruits in bunches looks elegant and is at once identifiable in the field. The single-seeded fruit is small, curved, elongated and fleshy. Propagules germinate on the tree (vivipary). Roots along the soil surface are exposed to air at low tide and help the uptake of oxygen. Prominent lenticels (air pores) at the base of each trunk also help with atmospheric gas exchange. *A. corniculatum* is able to regulate its internal salt concentration and grow in a wild range of salinities, but its ability to increase leaf area is limited under high salinity. Youssef and Saenger (1998) informed that *A. corniculatum* is one of the very few salt-secreting mangrove species that displays strong performance and growth across a wide range of environmental conditions, including the Australian tropics and subtropics. This plant is a valuable component of the marsh ecosystem. It is a very important true mangrove species.

Medicinal Uses

Mangroves and associated plants provide a wide domain for therapeutic application in recent years, most yet to be explored. Bandaranayake (2002) informed that extracts from mangrove plants and associates has been used worldwide for medicinal purposes and have been recorded around 349 metabolites which turns out to be a rich source of steroids, diterpenes and triterpenes, saponins, flavonoids, alkaloids and tannins.

Banerjee et al (2008) reported that the leaves of *A. corniculatum* are rich in flavonoids with proven anti-inflammatory and antioxidant property. Roome *et al* (2011) recorded that *A. corniculatum* extract has analgesic properties. Gurudeeban et al (2012) determined that *A. corniculatum* leaf suspension showed moderate reduction in blood glucose (from 382 ± 34 to 105 ± 35), glycosylated hemoglobin, a decrease in the activities of glucose-6 phosphatase and fructose 1, 6-bisphosphatase, and an increase activity of liver hexokinase achieved through the oral administration of extract on 100 mg/kg. Roome *et al* (2014) observed that *A. corniculatum* extracts has shown remarkable effect as an anti-arthritic and anti-inflammatory agent to combat with chronic inflammatory diseases, that provides significant justification for its folklore medical use against rheumatism interfering with inflammatory and cellular immune responses. Bandaranayake (1998) learned that due to the medicinal values, different parts of mangrove plants have been used for ages by the local people as folk medicine for curing many diseases. Evaluation of physiological and toxic effects, solvent used for extraction, route of administration and acute or chronic effect of *A. corniculatum* leave extract are quite diversified, which is encouraged by delineating the beneficial applications and confines various assessments.

Establishment

Aegiceras corniculatum grows in the intertidal zone throughout the Sundarban. It can establish in nature from propagule that floats and can travel some distance on the tides. Propagule can germinate quickly and establish young seedlings in good habitat. Mangrove communities can often reestablish by natural volunteer propagule recruitment if natural hydrologic patterns are restored. The long distant dispersal of their propagules, largely through water, play important role in their geographical distribution and high inter-population genetic diversity (Geng *et al*., 2008). Propagule may be propagated in the nursery from wild collected propagule. Propagule collected in the wild will not survive more than three to four weeks. Freshly collected propagule should be soaked in water and the propagule planted into polybag with prepared soil.

Solar Energy Collectors

The leaves of *Aegiceras corniculatum* contain chlorophyll which is the molecule that absorbs sunlight and uses its energy to synthesise carbohydrates and sugars from CO_2 and water. These enriched leaves ultimately fall into the mud under the trees where some types of bacteria rot the leaves while others take nitrogen from the air and water and convert it into nitrates and nitrites. The products of these different bacteria combine to produce a rich "soup". Thus the energy of the sun is transferred into the Bay and the mud is enriched and so produces much sea life.

Carbon Sequestration and Carbon Storage in Mangrove Forests

Mangroves take part in the global carbon cycle by holding organic carbon in biomass, soils and sediments. In recent years, the mangrove carbon sequestration capacity has been studied worldwide due to the increase of the concentrations of greenhouse gasses implicated in global warming and climate change. Mangroves play a significant role in sequestering of carbon and reducing greenhouse gases. Mangrove forests are highly productive, with carbon production rates equivalent to tropical humid forests. Patil *et al* (2012) studied that mangroves growing near the coast play an important role in carbon sequestration by acting as sink for carbon. Salt marshes, mangroves, and sea grass beds play two important roles:

- **Carbon sequestration**—the process of capturing carbon dioxide from the atmosphere, measured as a rate of carbon uptake per year
- **Carbon storage**—the long-term confinement of carbon in plant materials or sediment, measured as a total weight of carbon stored

Alongi (2012) informed that mangroves are among the most carbon-rich biomes, containing an average of 937 tC ha(-1), facilitating the accumulation of fine particles, and fostering rapid rates of sediment accretion (similar to 5 mm year(-1)) and carbon burial (174 gC m(-2) year(-1)). Mangroves account for only approximately 1% (13.5 Gt year(-1)) of carbon sequestration by the world's forests, but as coastal habitats they account for 14% of carbon sequestration by the global ocean.

Kambale & Tripathi (2010) observed that carbon sequestration also provides associated ecosystem co benefits such as increased soil water holding capacity, better soil structure, improved soil quality nutrient cycling and reduced soil erosion. Tateda (2005) learned that the below ground content of mangroves is 4 to 18 times higher than the carbon content of tropical rainforest. This indicates positive action in mangrove conservation and rehabilitation would contribute immensely to sequestration of CO_2.

Ecological Zonation of the Sundarban Reserved Forest

There are three ecological zones in the Sundarban such as less saline (LS), moderate saline (MS) and strong saline (SS) zone based on the degree of salinity and floristic composition. The floristic composition of the Sundarban is defined by the distributions of three species, *H. fomes, E. agallocha* and *C. decandra*. All three occur throughout the Sundarban but in different proportions depending on salinity. *H. fomes* is the characteristic species of the less saline zone, *E. agallocha* of the moderate saline zone and *C. decandra* of the strong saline zone. Karim (1988) classifies salinity boundaries based on pre-monsoon and post-monsoon levels of major rivers in the Sundarban. Three zones were recognized based on dry season salinity levels of river water. These are oligohaline (0-5 ppt), mesohaline (5-18 ppt) and polyhaline (>18 ppt). Different salinity zones of the Sundarban are shown in Figure 1.

Climatic Condition and Site Characteristics

Climatic conditions of the Sundarban is humid with annual rainfall of about 1640-2000 mm. Highest temperature in the Sundarban occur in April and May upto 40^{0}C and lowest temperature is 12^{0}C in December and January. The rainfall is typically monsoon during May to October and dries during November to April. The mean annual rainfall is about 1700 mm in most of the Sundarban area. The predominant features of the climate in the Sundarban are the southeast monsoon which effectively divides the year into three distinct seasons: i) monsoon season—June to October, ii) cool season—November to February and iii) dry season—March to June. Maximum and minimum average relative humidity (RH) in the Sundarban is 100% and 23% respectively. The low RH values usually registered from December to April when air temperature is still relatively low while the average high monthly RH occurs from May to November. The soils of the Sundarban are alluvial in nature, no distinct profile and hydromorphic with varying degree of gluing in the sub-soil horizon (Bhuiyan 1994). In general, soil fertility decreases from east to west and from north to south (Choudhury 1968). The soil of the Sundarban is slightly saline, silty caly loam and the sub-soil consists of alternate layers of clay and sand, and it is uniform throughout the forests. The mean organic mater content in the topsoil is 0.62% and pH range is 7.0-8.0 throughout the Sundarban. Hasan *et al.* (1988) have classified soils having <2.0 mmhos of electrical conductivity as less saline, 2.0-4.0 mmhos of electrical conductivity as moderate saline and >4.0 mmhos of electrical conductivity as strong saline.

Materials and Methods

Experiments with *Aegiceras corniculatum* were laid out in three salinity zones of the Sundarban such as in the less saline zone (Compartment Nos. 01), the moderate saline zone (Compartment Nos. 31) and the strong saline zone (Compartment No. 46). The experimental plantations of Khalshi were raised by planting nursery raised seedlings in polybags in Randomized Complete Block Design (RCBD) at 1.0m x 1.0m spacing with seven replications in each saline zone. The number of seedlings were planted in each plot is 81(9 x 9). Thus a total of 567 (81 x 7) seedlings were planted in each saline zone. Experimental plantations were initially protected by fencing against browsing up to the period it reached beyond the browsing height. Growth and survivability data of planted *A. corniculatum* 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 any difference existed in the species and between different saline zones.

Nursery Techniques for *Aegiceras corniculatum* (L.) Blanto

A mangrove nursery is a place for raising and tending mangrove seedlings until they are ready for planting or for sale to other mangrove planters. This ensures good quality seedlings at the right quantity by the time they are needed.

Site Selection and Preparation of Mangrove Nursery

Location of the nursery site should be selected within a protected intertidal area means that watering occurs naturally, and the mangrove seedlings are better acclimatized to the mangrove conditions where they are to be planted. The water quality should be good and the area should be fenced with barbed wire, to prevent grazing by feral cattle inhabiting the mangrove forests. It should be connected by road and waterways, to reduce the cost of transportation of seedlings from the nursery to the plantation site. It should be provided with water pumping facility, especially during summer. The optimal size of polythene bag is 6cm X 9cm, these can be easily relocated, and should have holes to allow drainage. Only muddy soil which is clayey should be used for preparing the nursery bags. The soft clayey mud available in the mud flats during low tide should be collected. The soil mixed with cow dung in the ratio of 8:1. Polythene bags filled with the prepared mud soil should be kept ready before sowing. The bags are arranged in a nursery bed of size 1.2 m x 12.0 m, a shed should be given on the bed and fenced to protect the seedlings from the sun, rain and animals. Water should be sprayed in the nursery regularly. The seedlings are allowed to grow in the nursery for nine months. The shed over the seedlings should be removed three months after raising the nursery to allow seedlings the direct sunshine and rain. Raising mangrove seedlings in nurseries before planting out can increase the survival and growth of mangrove planting. This allows the seedling to develop a healthy root system before planting. The major requirements for a mangrove nursery site are

- areas with periodic inundation
- access to good quality salt and fresh water
- pumps for pumping saline water from the creeks for the saplings
- access to road/creek to mobilize transport and labour to the planting sites
- good quality propagation stock.

Propagules Collection and Management

Propagules of Khalshi (*Aegiceras corniculatum*) were collected from healthy, mature, and vigorously growing trees in the morning time from the Sundarban mangrove forest. When harvesting propagules for planting it is highly recommend they be removed directly from the donor trees at the time that coincides with the natural drop. We discourage the use of propagules that have been collected from the ground or washed-up on a shoreline since our experience has demonstrated these sources to result in low planting yield. Propagules are really delicate living plants and must be carefully collected, cleaned and protected to keep them alive and healthy.

The following should be considered when collecting propagules:

- Should know the fruiting season for the species
- Collect propagules from healthy mature trees or under healthy mature trees that are free from pest and diseases
- Collect seeds which are mature and healthy not rotten and with insect damage
- Collect large propagules - they grow with more vigour than small propagules
- Collect propagules in the morning and keep in the shade – prolonged exposure to the sun will kill them
- Place propagules in jute sacks or appropriate bag for transporting
- Never leave propagule in the rain or wet area for prolonged period they will rot and loss viability
- Never collect propagules in plastic bags. Plastic containers can get warm quickly and the heat can kill the propagules. Many propagules kept together in very large bags can generate heat that may kill the propagules
- Store propagules in large open baskets in a dry, cool and shaded area
- Always label collected propagules stating the following: species; collection date; location (place) of collected; collector's name.

While storing the propagules, they should be kept in the shade for two to five days. The fruiting season of the species in Sundarban is between September and October. The collected propagules were examined for incidence of diseases or pests. The mature fruits of *A. corniculatum* can be easily identified by change in the colour from green to light brown.

Raising Seedlings and Management

The propagules were sown in polythene bags in the nursery within a week of collection, as delay in sowing reduces the rate of germination. The calyx region of the fruit should be inserted to a depth of about two to three cm. It is vital that the seedlings remain moist. Seedlings must be kept wet at all times. Seedlings should be watered once or twice a day with seawater mix. This suppresses fungal infections, and acclimatizes the seedlings to saline conditions. The seedlings were periodically checked for pest or wood borer damage as the sprouting propagules are susceptible to caterpillar damage. Caterpillars are the major pests and in case of a severe attack, contact insecticides may be applied. Initially the casualties should be replaced with propagules/ seedlings. The seedlings from the beds should be shifted periodically for three months after sowing. Shifting of bags with seedlings helps in preventing rooting into the soil. A micronutrient mixture may also be added to enhance the growth of the seedlings. The recommended provision of the seedlings are as height should be 30 - 40 cm, number of leaves at least 6 and age 8 - 9 months. Planting of only high quality seedlings can have a profound effect on planting yield.

Seedlings with physical damage such as broken or bruised tissues have a much lower probability of survival. A physical handling of the seedlings should confirm them to be hard with complete resistance to pressure. Any seedlings with soft spots or tissues that easily yield to physical pressure should be discarded. Although seedlings that have been rooted in fresh or ground water can develop normally, they can suffer high mortality when transplanted into the salt or brackish conditions of lagoons and estuaries.

Hardening of Seedlings before Plantations

Aegiceras corniculatum cultivated with fresh or ground water may suffer stress and go into shock when directly introduced to salt conditions. Therefore, seedlings that have been prepared for plantation must be acclimated in a transitional process to the salinity levels at the actual plantation site prior to introduction. Life is harder for the seedlings when they are outplanted. Seedling must be tough to survive. In order to achieve good survival, they must be acclimatized to the harsher conditions in the field. This is called hardening-off. Hardening off is done by:

- Reducing water one month before seedlings is outplanted. This is necessary to prepare the plants for the harsher environment at outplanting.

- Water plants by giving half the amount every alternate day. Plants should be wetthoroughly one day followed being moist the next day. Be careful not to allow the soil to dry-out and let the leaves dry up.

Do not try to harden plants in a shorter period. It may make it difficult for the plant to adjust to the outplanting conditions and the may grow poorly.

Seedling Preparation for Plantations

It is very important to prepare the seedlings for plantations.

- Choose only hardened plants for plantations
- Water plants thoroughly the day before plantations.
- On planting day carefully pack seedlings in the transporting vehicle.

Record Keeping and Planning

Maintaining accurate records is one of the most important activities in the nursery. Accurate records can help save the nursery unnecessary spending and assists making the nursery well-organized. The record keeping can take many forms and should be simple and easily understood by the nursery operator. This will further assist with the planning process of nursery management.

Post Nursery Operations

When all the seedlings are already sent out, the nursery should be prepared for the next batch of seedlings. Some repair of the infrastructure and retooling of equipment may be necessary. Likewise, cleaning and sanitation of the nursery should be done to prevent infestation of the incoming seedlings.

Propagule morphology and germination performance of *Aegiceras corniculatum* in different salinity zones of the Sundarban were shown in Table 1. Germination percentage in less, moderate and strong saline zone were recorded 76, 85 and 79 respectively. Propagule collecting time is same for all salinity zones of the Sundarban from September to October. Siddiqi *et al.* (1993) recorded the fruits of *Aegiceras corniculatum* ripen in July-August and about 100% germination success is secured. Seedlings of *Aegiceras corniculatum* at mangrove nurseries in different salinity zones of the Sundarban are shown in Figure 3, 4, 5, 6 & 7.

Table 1. Propagule morphology and Germination performance of *Aegiceras corniculatum* in different salinity zones of the Sundarban.

Sl. No.	Parameter	Salinity Zone		
		Less saline zone	Moderate saline zone	Strong saline zone
1.	Propagule collecting time	September-October	September-October	September-October
2.	No. of seeds/fruit	1	1	1
3.	No. of propagule/kg	1,150-1,300	1,000-1,100	1,250-1,500
4.	Length of propagule (cm)	5.0	6.5	4.0
5.	Propagule storage time (days)	26	20	32
6.	No. of propagules sown	3000	3000	3000
7.	Initiation of germination (days)	12	14	18
8.	Completion of germination (days)	24	28	35
9.	Germination percentage (%)	76	85	79
10.	Average height after 9 months (cm.)	24	44	36

Figure 3: Propagules of *Aegiceras corniculatum* sown in poly-bags at mangrove nursery in the Sundarban

Figure 4: One month old seedlings of *Aegiceras corniculatum* at mangrove nursery in the Sundarban

Figure 5: Nine months old seedlings of *Aegiceras corniculatum* at mangrove nursery in strong saline zone of the Sundarban

Figure 6: Nine months old seedlings of *Aegiceras corniculatum* at mangrove nursery in moderate saline zone of the Sundarban

Figure 7: Nine months old seedlings of *Aegiceras corniculatum* at mangrove nursery in less saline zone of the Sundarban

Plantation Techniques for *Aegiceras corniculatum* (L.) Blanto

Mangrove plantation establishment and management involve a number of stages ranging from site selection and preparation, outplanting, care and maintenance and monitoring and evaluation. In all of these stages, appropriate technologies have to be consistently applied to ensure success. The experimental plantations with *Aegiceras corniculatum* can be successfully planted out at any stage from propagules to seedlings up to nine months old. The seedlings require more shade than is available in an open nursery or field environment. It grows more successfully in a partial shaded environment. The following procedure should be done in the planting of *A. corniculatum* in the field:

- Ensure tides allow access below Highest Astronomical Tide (HAT) for the species to be inundated sufficiently or for the workers to access the planting site and plants;

- Dig a hole to an appropriate size for the seedling — at least 100 % more by volume than the polybag size so that less compacted soils can be placed around the seedlings roots;

- Dislodge the seedling from the polybag with minimal disturbance by placing one hand over the top of the soil and inverting the polybag into the other hand;

- Gently place the plant into the hole with the roots below ground level;
- Cover the base with surrounding soil and press until upright stability is achieved;
- Stake the plant with a single, short stake, if required (or use other protective measures).

It is best for plantation until seedlings have developed six leaves. By then they have usually grown a strong tap root as well as the earlier network of fine roots. The adventurous tap root will force its way into the mud and anchor the plant. It is very important not to disturb the mud where the seedling is to be planted. It is observed that planting seedlings at a density of at least one seedling per $1m^2$ is successful. This allows room for the seedling to grow healthy and allows access if thinning is required. Replanting success can be expected as long as both the plant and the site are in reasonable condition and the change from the nursery environment is not extreme in terms of light, salinity, temperature or hydrological conditions. Where there is a marked difference in any or all of the above conditions then a period of at least one month for gradual acclimatization is recommended. Raising plantations with *A. corniculatum* can be done by selecting appropriate sites and based on the frequency of tidal inundation. The plantations should be started from the area closer to the low tide line where the regular inundation is assured. The plantation should be done better using polybag seedlings.

Care and Maintenance of Plantations

Plantations are cared for in several stages depending on their age, rate of growth etc. Below are the major phases of care for plantations in natural forests:

- Like any newborn, the first 2 years after their establishment are probably the most intense phase of care for plantations.
- Generally, from the 3rd through the 4th years the level of care is somewhat less.
- The 5th year sees an increase in care because this is the first thinning if growth has been normal and the economic size of desired products is attained.
- The subsequent years need relatively low maintenance in longer maturing.

Maintenance activities in the early years

Care taken in establishment and maintenance operations during the early years of a plantation can help to make a plantation more resistant to insects and fungi. In general, maintaining a young plantation involves:

- Regular visits
- Removal of debris
- Installation or fence repair
- Uprooting and replacement of sick or dead plants

Maintenance Activities in Subsequent Years

When the trees attain economic size, thinning of the stand should be done to allow better growth. Thinning is the cutting of trees to reduce competition from sunlight, nutrients and soil moisture in order to improve the quality of the stand.

Pruning is another maintenance activity that takes place after the initial year or two of intensive maintenance. It is defined as the cutting of unnecessary branches and stems. Pruning is done to enhance height and trunk diameter growth rate. The nutrients that otherwise would be absorbed by the branches will now be utilized by the upper part of the tree, thus increasing growth rate. Pruning should be conducted with some restraint to avoid adverse effect on trees. The following are some pruning rules:

- Do not cut more than 30% of the live crown over a 1-2 year period. Over pruning will adversely affect plant growth because of sudden reduction of leaves that are active in photosynthesis.

- Paint stub preferably with tar to prevent fungal attack.

- Cut smaller branches close to the trunk to increase better height and growth.

- For bigger branches, make an undercut 10 centimeters from the trunk. The upper cut should be close to the trunk to avoid bark splitting.

- Use a pruning saw (a saw attached to a long pole) to reach branches up to 5 meters in height.

Maintenance of forest plantations includes protecting the plants from detrimental climatic conditions, fire, insects and fungi, and animals. Maintenance may include measures that are silvicultural, chemical, biological or mechanical.

Table-2. Site descriptions of the experimental plots for *Aegiceras corniculatum* species in different salinity zones of the Sundarban.

Sl. No.	Salinity zone	Year of plantation	Area of plantation (ha)	Spacing	Soil texture	Soil pH	Soil salinity (m mhos)	Water salinity (ppt)	Inundation condition	Initial vegetation
1.	Less saline zone	2012	0.5	1mx1m	Silty-clay-loam	6.7	0.9	3.0	Inundated by all tides	Dense cover of shun grass(*Saccharum spontaneum*), bhola(*Hibiscus tiliaceous*), nal khagra(*Phragmites karka*), hogla(*Typha elephantine*), kutum kata(*Caesalpinia crista*), dhanshi(*Myriostachya wightiana*) and kewa katta(*Pandanus foetidus*)
2.	Moderate saline zone	2012	0.5	1mx1m	Silty-clay	7.2	2.9	11.0	Inundation by all tides in monsoon	Dense cover of gila lata(*Derris trifoliate*), chanda lota(*Dalbergia candenatensis*), tiger fern(*Acrostichum aureum*), dhanshi(*Myriostachya wightiana*) and kewa katta(*Pandanus foetidus*)
3.	Strong saline zone	2012	0.5	1mx1m	Silty-clay	7.8	4.8	27.0	Inundation by all tides in monsoon; seldom in non-monsoon	Scattered hargoja(*Acanthus ilicifolius*), tiger fern(*Acrostichum aureum*), hanthal(*Phoenix paludosa*), dhanshi(*Myriostachya wightiana*) and kewa katta(*Pandanus foetidus*)

Three experimental sites were selected for *Aegiceras corniculatum* species trials in three salinity zones of the Sundarban. Site descriptions and initial vegetations of experimental plots in different locations of the Sundarban are shown in Table-2.

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. Through weeding was done before raising plantation. The experiment was laid out in Randomized Complete Block Design (RCBD) with seven replications in all three sites. The experimental areas were fenced with wooden stakes mainly of goran to protect the planted seedlings from browsing of the deer or trampling by the wild boars. Especially the area should be protected from pigs, as these will push over young seedlings in their foraging activities.

The average height before planting (nine months old seedlings) of the species for less saline zone, moderate saline zone and strong saline zone were 24cm, 44cm, and 36cm respectively (Table-1). Planting was carried out over an area of 1.5ha in three experimental sites of the Sundarban. Growth performance of five years old experimental plantations of *A. corniculatum* at different saline zones of the Sundarban are shown in Figure 8 & 9. Scientists from SAARC countries visited experimental sites of the Sundarban (Figure 10).

Figure 8: Five years old experimental plantations of *Aegiceras corniculatum* at strong saline zone of the Sundarban

Figure 9: Five years old experimental plantations of *Aegiceras corniculatum* at moderate saline zone of the Sundarban

Figure 10: Scientists from SAARC countries visited experimental sites of the Sundarban in September 2015

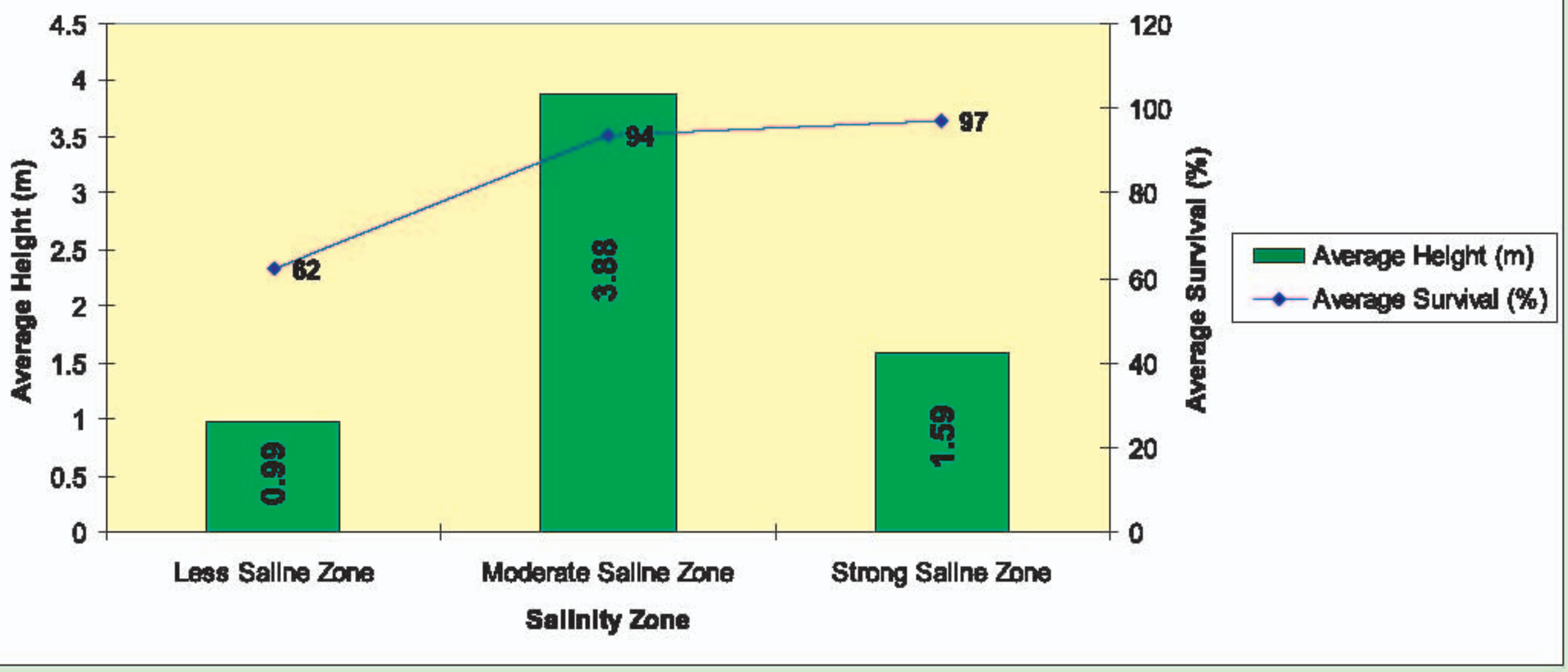
The mean total height (m), mean survival %, mean annual height increment, regression co-efficient, t-test and F-test of *A. corniculatum* of 1 to 5 years old monoculture plantations under strong, moderate and less saline zone in the Sundarban were shown in Table 3. Considering the average total height values (Table-3) were analyzed to assess the mean annual height increment, regression co-efficient, t-value and F-value.

Table 3: Growth performance of *Aegiceras corniculatum* in different saline zones of the Sundarban

Age (year)	Strong saline zone (Compt.-46)		Moderate saline zone (Compt.-31)		Less saline zone (Compt.- 24)	
	Mean total height (m) ±SE	Mean survival (%)	Mean total height (m) ±SE	Mean survival (%)	Mean total height (m) ±SE	Mean survival (%)
1	0.47±0.06	100	1.27±0.07	94	0.33±0.01	63
2	0.63±0.03	97	1.75±0.03	94	0.38±0.03	62
3	1.37±0.02	97	2.40±0.06	94	0.68±0.02	62
4	1.52±0.02	97	2.95±0.23	94	0.82±0.03	62
5	1.59±0.03	97	3.88±0.03	94	0.99±0.02	62
Mean annual height increment (m)	0.32	_	0.78	_	0.20	_
Growth Rate (Regression Co-efficient)	0.313	_	0.641	_	0.176	_
Plantations between strong and moderate saline zone	$t_{.05}$ (8) = 2.61*		_		_	
Plantations between moderate and less saline zone	_		$t_{.05}$ (8) = 3.85*		_	
Plantations between less and strong saline zone	_		_		$t_{.05}$ (8) = 1.85	
Analysis of variance (ANOVA)	$F_{.05}$ (2) = 9.67*					

The t-tests analysis were done on the mean total height data of *A. corniculatum* planted in less, moderate and strong saline zones of the Sundarban. Plantations between strong and moderate saline zone the calculated value of t is $t_{.05}$ (8) = 2.61*, which is significant, i.e, there is significant difference at the 5% level in the mean total height between the plantations of strong and moderate saline zone. Similarly, plantations between moderate and less saline zone the calculated value of t is $t_{.05}$ (8) = 3.85*, which is significant, i.e, there is significant difference at the 5% level in the mean total height between the plantations of moderate and less saline zone. But, plantations between less and strong saline zone the calculated value of t is $t_{.05}$ (8) = 1.85, which is insignificant, i.e, there is no significant difference at the 5% level in the mean total height between the plantations of less and strong saline zone. Where tabulated value was $t_{.05}$ = 2.306 with 8 d.f.

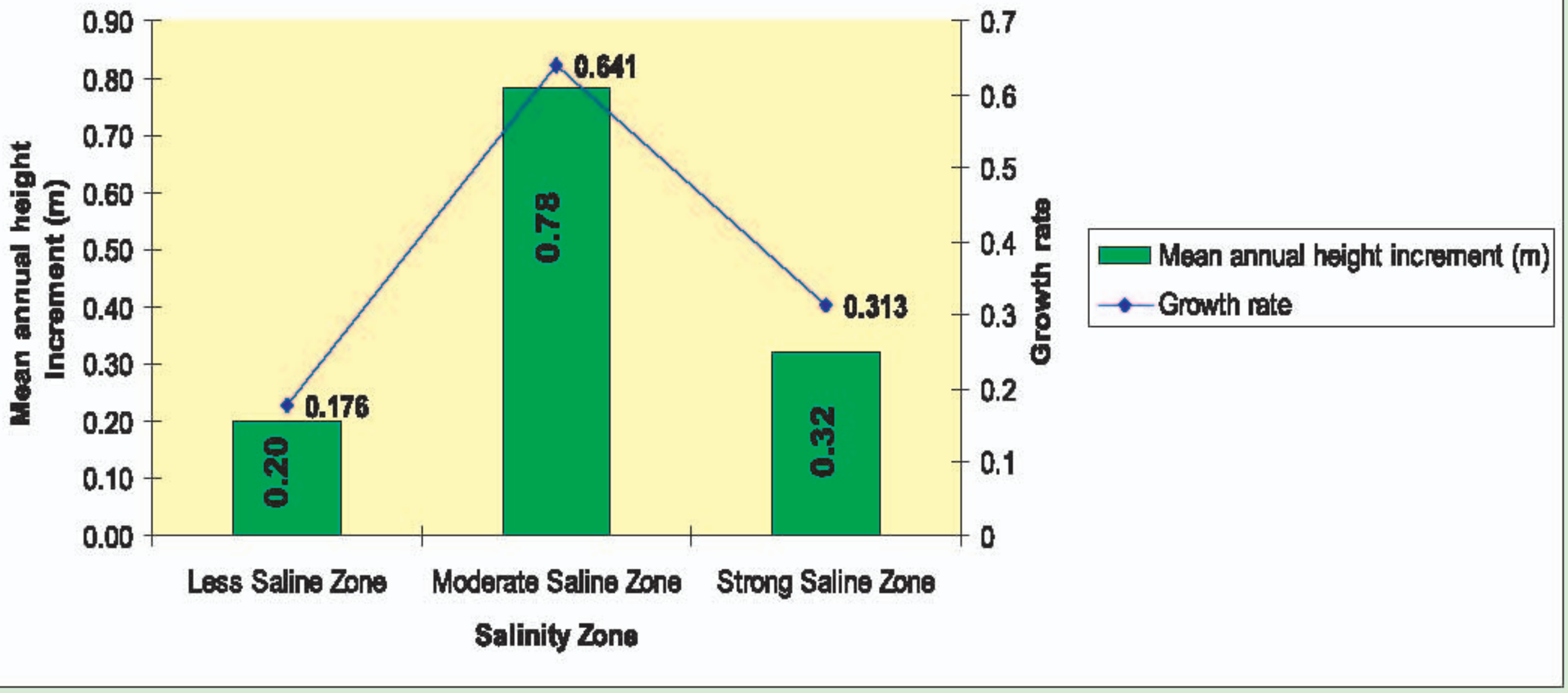
Figure 11 : Growth performance of *Aegiceras corniculatum* at five years old plantations in the Sundarban



Analysis of variance (ANOVA) shows the calculated value of F is $F_{.05}$ (2) = 9.67* , which is significant at the 5% level, i.e, there is significant difference in the mean height growth of *A. corniculatum* plantations among strong, moderate and less saline zone in the Sundarban. Where tabulated value was $F_{.05}$ = 3.89 with 2 d.f.

It is recorded that the average total height and survival percentage of *A. corniculatum* at five years old plantations for less, moderate and strong saline zones were 0.99 ±0.02, 3.88 ±0.03 and 1.59 ±0.03 as well as 62, 94 and 97 respectively in figure 11.

Figure 12 : Mean annual heihgt increment and growth rate of five years old *Aegiceras corniculatum* plantations in the Sundarban



The mean annual height increment of *A. corniculatum* at five years old plantations for less, moderate and strong saline zones were 0.20m, 0.78m and 0.32 m as well as growth rate (regression co-efficient) were 0.176, 0.641 and 0.313 respectively in figure 12.

Salinity effects on biochemical components of the mangrove *A. corniculatum* were studied by Parida & Das (2005). *A. corniculatum* is a salt secretor mangrove and was tested for salt induced biochemical changes in hydroponically grown plants. They also found that this particular salt secreting mangrove can be sustained and propagated under low salinity conditions. Patel & Pandey (2009) identified *A. corniculatum* is highly salt tolerant at germination stage, growth of seedlings is significantly promoted by low salinity and higher salinities inhibited its growth. Mishra & Das (2003) find out the high salt consentration (≥ 300 mM) suppressed activity of antioxidative enzymes without losing the ability to secrete salt. Parida *et al* (2004) analyzed that the salt secreting mangrove *A. corniculatum* can be sustained and propagated under low salinity conditions. Shan Liang *et al* (2008) reported that individual genes or whole genomes of mangroves have confirmed conclusions drawn from studies on anatomy, physiology and biochemistry, and have further indicated that specific patterns of gene expression might contribute to adaptive evolution of mangroves under high salinity. Mangroves are woody plants that inhabit intertidal zones with high salinity (Shan *et al.*, 2008; Parida and Jha, 2010) and can tolerate a wide range of salinities under natural conditions (Suarez *et al.*, 1998). Like other halophytes, mangroves decrease their water and osmotic potentials to maintain leaf turgor at high salinity (Naidoo, 1987; Khan *et al.*, 2000a,b). The level of salinity required for optimal growth varies

from 10 to 50 % seawater (Downton, 1982; Clough, 1984; Naidoo, 1987; Lin and Strenberg, 1992, 1995; Ball and Pidsley, 1995 and Patel N. T. *et al.*, 2010) and a decline in growth occurs with a further increase in salinity.

In our experiment we observed that the best growths were recorded in moderate saline zone and significantly lower growths were recorded in strong saline zone of the Sundarban. They occur in estuaries and along rivers and prefer more silty-clay habitats rather than thick mud that lack oxygen. They have special adaptations for growing in low moisture and high salt conditions. In estuarine and coastal environments, salinity levels of interstitial and flooding waters are often widely variable being affected by tidal fluctuations, seasonal rainfall and river flows. *A. corniculatum* is a salt secretor mangrove which can afford a moderate level of salinity.

Table 4. Phenology of raised *Aegiceras corniculatum* species in different salinity zones of the Sundarban.

Sl. No.	Salinity zone	Flowering age of the plant (year)	Flowering time	Fruiting period	Propagule dropping time
1.	Less saline zone	3	April to June	July-August	September-October
2.	Moderate saline zone	3	April to June	July-August	September-October
3.	Strong saline zone	4	April to June	July-August	September-October

The timing of flowering is one of the most widely investigated aspects of the phenology of plant life cycles. Flowering time, fruiting period and propagule dropping time of *A. corniculatum* is same for all salinity zones of the Sundarban. Occurrences of flowering for this species from April to June, fruiting period from July to August and propagule dropping time from September to October were recorded. *A. corniculatum* plants occur flowering at the age of three in less and moderate saline zones but for strong saline zone flowering occurs at the age of four (Table 4).The sweet smelling white flowers attract pollinating insects. The flowers of the species attracted several diurnal and nocturnal visitors. But flowers of this species were found to be in bloom both at night and during the day.

Figure 13: A beehive near the experimental plantations of *Aegiceras corniculatum* at moderate saline zone of the Sundarban

Pandit and Choudhury (2001) documented that in case of *Aegiceras comiculatum,* 16 species of Lepidoptera, 9 species of Hymenoptera, 2 species of Diptera, 1 species of Coleoptera and 3 species of birds as flower visitors. Of these, 7 species of lepidopterans were nocturnal visitors and all the visitors were pollinators expect for coleopterans, which are nectar thieves. Pandey & Pandey (2014) recorded that *A. corniculatum* complete the floral cycle in 21 days on west coast of India and also found that the significant variation in the nectar availability during morning, afternoon and evening hrs influences the frequency of pollinators and potential pollinators of *A. Corniculatum.* In our observation *A. corniculatum* is the best honey producing mangrove plants in the Sundarban and mainly *Apis dorsata* is found foraging on *A. corniculatum. A. dorsata* built a hive near the plantations of *A. corniculatum* in the Sundarban (Figure 13). From the flowers they grow bundles of banana shaped propagules. It is observed that the floral biology of *A. corniculatum* strongly favors cross breeding. However, the asynchrony in flowering processes in inflorescences increases the possibility of geitonogamy. The pollination efficiency of pollinators and their availability also influence the reproductive biology of the species. For long term *in situ* conservation of this species, the pollinator resource needs to be conserved.

Pests and Potential Problems

There are no known pests that could threaten *Aegiceras corniculatum* stands in the wild and in the plantations.

Environmental Concerns

Aegiceras corniculatum is a valuable component of the intertidal ecosystem. Loss of the species is a concern as it is a woody species that persists and assists in habitat development and in breaking wave energy and it provides nesting habitat for birds and insects. Its flower nectar forms one of the best sources of honey.

Monitoring

Once the initial planting of *Aegiceras corniculatum* has been completed, it is important to monitor the progress of seedlings or transplants. Replacement of individuals that die will be necessary. The trees need to be regularly maintained for the first two years. Maintenance consists in removing debris (remove material in the area that may move around over the seedlings at high tide, including nypa palm fronds) and dead plants, replacing dead and lost plants. After two years, the plants are generally self-sustaining and can be thinned out where required. After the establishment of a mangrove plantation, it is essential to monitor progress. Actions include monitoring growth of mangrove species that develop level of mortality of seedlings, any pests or diseases, rubbish accumulation, human disturbance, and overall success of the study.

Aegiceras corniculatum Plantations – New Hope for the Mangrove Dwellers

The UN Atlas notes that about 44% of the earth's population inhabits coastal areas throughout the globe. This indicates that without adaptable and sustainable management systems, the coastal resources and ecosystems including mangroves continuously will be pressured by the rapid economic development to support people's livelihoods into the future. New plantations of *Aegiceras corniculatum i. e.* mangroves are needed to combat these challenges and these should be promoted and implemented by both government programs and community initiatives. The conservation and restoration of mangroves would be for the betterment of society, and ultimately the future earth. New plantations of mangrove will create new hope to address global challenges.

Figure 14: Raising new experimental plantations of *Aegiceras corniculatum* at moderate saline zone of the Sundarban

Figure 15: Five years old experimental plantations of *Aegiceras corniculatum* at moderate saline zone of the Sundarban

Figure 16: Five years old experimental plantations of *Aegiceras corniculatum* at strong saline zone of the Sundarban

Figure 17: A beehive near the experimental plantations of *Aegiceras corniculatum* at moderate saline zone of the Sundarban

The pictures (Figure 14, 15 & 16) indicate new plantations of *Aegiceras corniculatum* at moderate saline zone of the Sundarban. Future new mangrove plantations will be expanded continuously as part of a large-scale plan for conserving *A. corniculatum* species, the best honey producing mangrove plants and rehabilitating coastal environments. Local experience and the knowledge gained from propagating *A. corniculatum* should be disseminated in the coastal region to combat future environmental challenges. Plantations of *A. corniculatum* can offer protection from damage to coastal environments from natural disasters and as adaptation to potential threats to climate change impacts such as storms, cyclones, intense precipitation and tidal surges. Conserving and restoring mangrove areas should be mainstreamed into coastal development agendas as a strategy for adapting to climate change. In terms of marketable ecosystem services, mangroves also filter chemical and organic pollution from the water, which keeps the waters on reefs and seagrass beds cleaner. There has been scant monetization of such regulating services, but these could potentially finance conservation activities. Other co-benefits of maintaining mangroves are their function as a nursery for juvenile fish and shrimp as well as habitat for crabs, oysters, clams, estuarine crocodiles and snakes. Different kinds of birds use mangroves as resting and breeding grounds. *A. dorsata* built a big hive near the plantations of *A. corniculatum* in the Sundarban (Figure 17). By restoring the tangible and intangible benefits of mangroves, local mangrove dwellers would survive and sustain their livelihoods when met with future challenges and this would offer hope for future generations and the earth. These apparent benefits for local communities could lead the people to self mobilize in mangrove conservation and rehabilitation programs.

Conclusion

The development of nursery and plantation technique for regeneration and popularization of the *Aegiceras corniculatum* in the Sundarban is described. The nursery and plantation experiments, including using planting method, time and qualities of seedlings in different salinity zones and silty-clay-mud lands were carried out to study the sylvicultural technologies. Only large ripe propagules should be planted. They should not be planted out until they have six leaves at which stage they are more likely to survive. A strong root system will have developed by this stage. When planting, it has needed to plant one seedling per square meter corresponding to 10,000 seedlings per hectare. Sites with substantial wave action may require denser planting. With an average success rate of 80%, it is recommended to collect approx 30% more propagules than indicated by the size and the conditions of the planting site. The study is seen as highly efficient in that it has generated benefits (direct economic and ecological benefits, protective benefits for assets) to the coastal communities. There are no conservation measures specific to this species, but its range may include all over the Sundarban and the coastal areas. Continued monitoring and research is recommended, as well as the inclusion of mangrove areas in marine and coastal protected areas.

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