Exploration of data on the formation of two mangrove seedling species to establish a growing stability point

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Abstract. Avicennia alba is one of the best mangrove colonies. A. alba seems to adapt well to grow stably on dynamic flat mud. A. alba species through their root growth, are able to rely on sediments quickly, resist the hydrodynamic force of waves and tidal currents within a few days and then withstand the movement of sediments in the upper sedimentary layers. While from Ceriops tagal propagules and Rhizophora mucronata, after falling from the mother tree, certain dehydration levels stimulate the initiation of root formation as a sign to show dormancy propagules. As a result, root formation is delayed when propagules float in the sea during dispersal. Meanwhile, the formation phase of mangrove propagules is faster in conditions of low salinity than in conditions of high salinity, and if during the rainy season, conditions for propagules’ information are better. However, these two species follow different strategies for the distribution and formation of mangrove zoning, and these findings contribute to the explanation of the distribution of different species.

1. Introduction

Mangrove forests have been damaged rapidly, with a total loss of 1900 million hectares in Asia from 1980 to 2005 [1-2]. Worldwide, mangrove forest areas have decreased by 0.3-0.7% per year [3]. Many mangrove forests are in the area of pond or other aquaculture cultivation systems, making mangrove forests vulnerable to runoff of nutrients and organic matter [4-5]. Mangrove forests, under pressure from climate change and changes in coastal ecosystems, are valuable ecosystems globally. Small physical disturbances such as tidal flooding and sediment dynamics caused by ocean waves constitute the main obstacles to the formation of seedlings on tidal plains [6].

The existence of mangrove forests depends on the survival of seedlings for expansion, regeneration, and maintenance. Specifically, the formation of mangrove seedlings in a dynamic biogeomorphic system is a critical phase of plant succession; if mangrove seedlings cannot colonize the surface of a tidal area, then the entire mangrove forest cannot be formed or expanded [7]. Once mangrove forests are damaged, restoration activities along the coast are challenging to succeed [8-9].

This study discusses experimental data from several studies related to mangrove seedlings' formation or stability by a combination of experiments in the greenhouse and measurements in the field. The purpose of these various studies is to assess the effect of seasonal variations in exposure to tidal or receding seawater movements on the survival and growth of seedlings of 3 mangrove species, which will be used as guidelines in mangrove forest restoration activities.
2. Materials and method
The material used in the writing of this manuscript is the result of research that has been published in the range of 2011-2015 with several other supporting scientific writings. The method itself is to access various internationally reputable journal publishers such as Elsevier, Wiley online library, Springer, and Inter-Research Science Publisher. Then the data of the various publications are reviewed and summarized.

3. Results and Discussions

3.1. Avicennia alba Experiment Data
In the Avicennia alba experiment on mangrove seedlings stability was conducted. Avicennia sp, the largest genus of mangrove pioneer trees, reaches tidal plains in tropical regions around the world because this genus is the leading mangrove zone to the sea [10]. Propagules are species of Avicennia alba, collected from Singaporean mangroves and transported to the Netherlands in a moist container within 48 hours. A. alba seedlings are directly cultivated in the climate chamber, set at 30°C and given an average of 12 hours/day from 550 μmol m⁻² s⁻¹ photosynthetic/photosynthetically active radiation (PAR). The trial was completed 13 days after receipt of direct planting. Propagules are placed on sea sand in PVC pipes, each with a height of 150 mm and a diameter of 120 mm, which have an open bottom and are coated with polyethylene bags. The sand remained flooded during the experiment. This arrangement simulates natural landings on tidal plains or is free of tidal flooding. The pot design allows us to measure the flow, both hydrodynamic pressure and sediment disturbance, which the seeds can hold before they are released from the soil.

![Figure 1. Flume arrangement shows pots (bronze-colored areas) made of PVC pipes [10].](image-url)

The seeds were sown at the time of planting, with each root primordium < 5 mm in length. For simplicity, after all the propagules have been shown, the first root is called a seedling. From the 5th to the 13th day after planting, ten pots are chosen randomly every day and become a flume experiment. After a flume experiment the root growth was measured. Flume consists of 17.5 m long oval lines and 0.6 m wide lines capable of producing currents and waves [11]. The bottom of flume allows the sediment-containing PVC pipe to flush with the bottom of the flume, leaving only the seeds open. No significant disturbances have been observed.

The water depth of the flume is maintained at 32 cm. The first root is seen after two days of simulation, and on day three, the maximum length of the root is 1 cm. At least 75% of all propagules formed roots seen on day four. At day six, hypocotyl extension is found in the first seedlings. On day eight, 24.5% of all seedlings had cotyledons expanded. After plantation the root length increases linearly between day five and thirteen.

Three thresholds need to be achieved during the manufacture of Avicennia sp. The amount of disturbance will increase from the initial stage to the end. After the seed coat has been peeled off, the
propagules begin to release their roots to grow in the sediment. In the first stage, the propagule must first have a minimum root length during a puddle-free period to survive so as not to float during the tidal inundation. Second, the roots must be long enough to resist strength by waves and tidal currents. Third, after the root has penetrated several centimeters into the sediment, only the mixing or erosion of the upper sediment layer can lead to the release of the sediment.

![Figure 2](image2.png)

**Figure 2.** Schematic representation of 3 thresholds that need to be achieved *A. alba* [10]

Based on observations, which divides three thresholds during seedling establishment [10]. First, *A. alba* propagules require a minimum period free from inundation after stranding. Second, root development must reach the required duration to avoid the interaction with the waves and currents forced on the seedlings by the hydrodynamic forces. Third, the root length must be adequate to tolerate soil depletion intrusion across the seedlings, which may be induced by combining sediments or surface erosion.

*A. alba* is one of the most successful mangrove colonies to adapt, *Avicennia* sp seems to adapt well to grow and form colonies on dynamic flat mud. *Avicennia* sp, can anchor quickly, resist the hydrodynamic force of wave and current in a few days, then withstand the movement of sediments in the upper sedimentary layer. Events from windows of opportunity (for example, depending on tides and weather) and the availability of propagules (e.g., fruit season) are likely to be essential for successful colonization and ecosystem stability.

![Figure 3](image3.png)

**Figure 3.** Maximum root length (cm) of *Avicennia alba* [10].
The mass formation of the *Avicennia* sp, the genus can be spotted in the even-aged *Avicennia* sp, standing on a tidal plain. The mudflat remains empty in front of the older mangrove where the threshold cannot be exceeded. This experiment underlines the importance of coastal hydrodynamics and produces sediment dynamics in mangrove regeneration and colonization.

### 3.2. *Ceriops tagal* and *Rhizophora mucronata* Experiment Data

Experimental designs using by *C. tagal* and *R. mucronata* propagules, collected on the seaside and forest side, two successive experiments were carried out. At first experiment, the propagules were positioned horizontally under one of three experimental conditions (seawater, moist mud and dry sand). After four time intervals, (6\textsuperscript{th}, 12\textsuperscript{th}, 18\textsuperscript{th} and 24\textsuperscript{th} days), the propagule was transferred to the second experiment and to the right place in a hydroponic setting with the three hydroponic treatments (seawater with salinity 17-18 ppt, seawater with salinity 34-35 ppt or seawater with salinity 17-18 ppt with an increase in relative atmospheric humidity) [12].

Experimental arrangements are carried out ex-situ, close to mangrove forests in almost the same environmental conditions (except when changed experimentally), especially in light, day of observation, and temperature. Characteristics of hypocotyl propagule length, mid-length diameter, weight, volume, and buoyancy behavior are measured for the first time between 12 and 48 hours after field collection before the propagules are placed in the greenhouse. For each species, 138 propagules were collected and used in two consecutive experiments.

![Figure 4. Design of experimental simulation [12].](image)

In the first step, all samples except nine seedlings from each species and forest location (towards the sea and land) were set in a horizontal position under one of the following conditions of experimentation. In seawater, in mud moisture (gathered in one seaside location where propagules of *R. mucronata* are collected) and on dry sand (collected at one location towards the mainland where *C. tagal* propagules are collected) under open-air conditions near sampling location. Schematic representation of an experiment arrangement simulates at time between propagule absorption and seedling formation (first experiment) and straight after formation (second experiment). Propagule *R. mucronata* and *C. tagal* were placed in a horizontal position under three conditions of experiment that species could undergo dispersal (seawater, moist mud and dry sand). After the propagules are set in vertical position in the water to simulate the potential effects with various salt concentrations, with...
different salt concentrations of positions in the tidal zone and in their habitats with or without an increase in relative atmospheric humidity to simulate the potential effects of rainfall. Measurements made in each experiment figures and table of experimental results are displayed [12]. The results help explain the distribution of the two species in mangrove forests because *C. tagal* is more sensitive to dehydration and therefore relies on faster formation than *R. mucronata*, making both species unsuitable for long periods of dispersion and is more common on the opposite side. The most towards the sea from mangrove forests.

In the two species studied, there was a significant Small difference for the collected propagules from the ocean and forest sides at the time of *C. tagal* collection: land propagation that was longer than *R. mucronata*: more extended sea propagation. After being set in a vertical position at hydroponic arrangement for 24 days, the seedlings of the two species studied that the longest roots had been in low salinity.

![Figure 5](image-url)

**Figure 5.** Root lengths of *C. tagal* and *R. apiculata* after 24 days [12].

Propagule *C. tagal* is also positively affected by an increase in atmospheric relative humidity. These results indicate that rain is having a positive effect on root growth and therefore, root growth could be the fastest during the rainy season if soil salinity is reduced by intrusion of rainwater and higher air humidity. Mangrove species balance must be struck between rejuvenation through direct formation in dynamic environments and long-distance travel to build broader survival. As the result of *C. tagal* and *R. mucronata*, which represent the most typical family of mangrove throughout the world, this balance can be affected by the local distribution of the species, by the characteristics of propagation and by local environmental conditions. The survival strategy of propagules after amputation differs mainly between the two species, interfere with their chances of scattering along longer distances. This circumstance will be of use for further developing the mangrove propagation distribution model and understanding the dynamics of mangrove vegetation and discovering whether other mangrove species follow one of the strategies identified in this study by the species studied here follows the same strategy in other locations.
4. Conclusions

_A. alba_ seems to adapt well to grow stably on dynamic flat mud. _A. alba_ species through root growth, able to rely on sediments quickly, resist the hydrodynamic force of waves and tidal currents in just a few years can withstand sedimentary movements in the upper sedimentary layer. While from _C. tagal_ propagules and _R. mucronata_, after falling from the mother tree, certain dehydration levels stimulate to initiate root formation as a sign to show dormant propagules. As a result, the root formation is delayed when propagules float in the sea during dispersal. Meanwhile, the formation of mangrove propagules is faster under low salinity conditions than under high salinity conditions, and if during the rainy season, conditions for the formation of propagules are better. However, these two species studied follow different strategies for the distribution and formation of mangrove zonation, and those findings contribute to explaining how different species are distributed. Research on the threshold for mangrove seedlings' stability shows that gradual changes from natural interruptions such as hydrodynamics and sediment dynamics can cause sudden changes in the success of mangrove seedling stability.

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