

Mass and Precise Mangrove Restoration Using Aerial Drone Systems

Selected Literature and Design Review of Seed/Plantlet Anchoring Mechanisms (DRAFT)

Note: The following literature extracts (text and figures) provide the background to the development of strategies for anchoring mangrove propagules to the substrate in the intertidal areas. This document provides an outline of the pathways of establishing mangrove species originating in the Philippines and Indonesia. The review was always intended as a working document which supports the trajectory towards methodologies for establishing propagules in the intertidal areas.

Introduction

There are 3 main technical challenges with the project. The 1st relates to the design of drone seed-holding reservoirs and then the 2nd relates to the drone seed release mechanisms. The 3rd which is discussed here, relates to how the seeds remain in place in the same position where they are dropped. This is extremely important, as the mangroves need to be placed and grow at suitable distances from each other, and this in a fluid intertidal zone, where the seeds can be pushed by incoming and outgoing tides. The project is also looking at abandoned fish/shrimp ponds which could beneficially be planted to create new mangrove habitats, water cleansing biotopes, and areas which can be used by local people for harvesting local aquatic creatures to eat and/or to be sold at market.

In a terrestrial situation, where restoration is required, seeds can readily be dropped en-masse; the exact position of each seed is not so important, as the restoration relies, as nature does, on the release of large numbers of seeds, where only some will survive and grow into mature plants. Planting of mangroves, on the other hand needs to be better considered in order to reinstate the best ecological conditions for other fauna and flora to re-establish and flourish and to protect landward areas from storm surges and flooding. Thus, positioning needs to be precise and the plants that are positioned need to remain, more or less where they are first planted/seeded.



The probability of mangrove seeds if dropped en-masse all ending up in groups is high and is not a desirable scenario. Drones can be used to deliver seed accurately and systematically at appropriate distances apart.

Types

The project is investigating those mangrove species that are producing propagules which can be used including:

- *Rhizophora mucronata* (Indonesia and the Philippines)
- *Bruguiera cylindrica* (the Philippines)
- *Bruguiera gymnorhiza* (Indonesia)
- *Avicennia marina* (Indonesia)
- *Sonneratia alba* (Indonesia)

Dataset of "true mangroves" plant species traits Seed Species and Types

‘Here a dataset is presented with 2364 records of traits of "true mangroves" species, gathered from 88 references (published articles, books, theses and dissertations). The dataset contains information on 107 quantitative traits and 18 qualitative traits for 55 species of "true mangroves" (*sensu* Tomlinson 2016). Most traits refer to components of living trees (mainly leaves), but litter traits were also included’.

Data Paper

Biodiversity Data Journal 5: e22089

<https://doi.org/10.3897/BDJ.5.e22089> (29 Dec 2017)

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Academic editor: Luis Cayuela

Received: 06 Nov 2017 | Accepted: 29 Nov 2017 | Published: 29 Dec 2017

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Citation: Quadros A, Zimmer M (2017) Dataset of "true mangroves" plant species traits. Biodiversity Data Journal 5: e22089. <https://doi.org/10.3897/BDJ.5.e22089>

‘There are around 80 different species of mangrove trees worldwide (ZSL).’

Establishment Theories

Understanding dispersal mechanisms is key to mangrove establishment if one is using propagules and not planting seedlings from polybags or planting directly by digging holes.

We are attempting to follow nature in 2 ways:

1. By anchoring the propagules we allow them establish themselves from the horizontal to the vertical and in the Rhizophora create the “J” shape that occurs in nature;
2. By preparing the Rhizophora and Bruguiera species propagules so that they transition from a horizontal position to a vertical position.

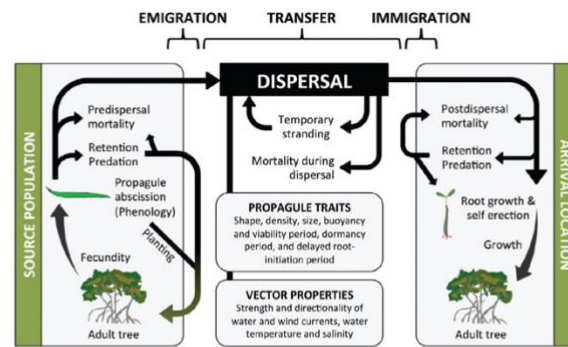
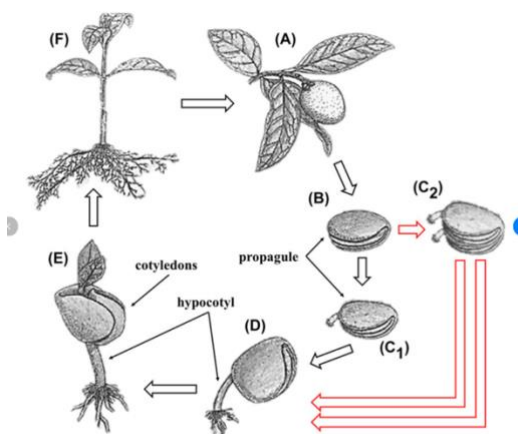


Fig. 1. Mangrove dispersal is determined by a range of factors. Fecundity and predation determine the number of propagules available for dispersal, and in combination with retention in the landscape matrix, the potential number of emigrants. Propagule traits such as buoyancy, viability and dormancy determine the timeframe within which propagules can take root and establish at a suitable location. The site of arrival depends on interactions between propagule traits (size, shape and density), hydrology, and the landscape matrix. While tides and tidal currents can transport propagules within a mangrove stand, the trajectories of propagules reaching open waters will be determined also by near-shore, coastal, and open-ocean currents, as well as by winds in the case of wind-sensitive propagules (e.g. *H. littoralis*). Whether or not a dispersal event is followed by successful establishment and early seedling development will depend on several biotic (e.g. predation, competition) and abiotic (e.g. sediment conditions, temperature, hypoxia, hydrogen sulphide concentrations, salinity, light, nutrients, tides and flooding, sea-level changes) factors. In contrast to long-distance dispersal events, which we here define as dispersal between (nearby or distant) populations, the arrival location is situated within the source population in the case of short-distance dispersal events and 'emigration' and 'immigration' do not apply. Some factors are influenced by climatic conditions (e.g. phenology) so that climate change is likely to affect dispersal and connectivity patterns. Additional anthropogenic stressors such as clearing can strongly impact the number of propagules available (e.g. fecundity) and the area of suitable habitat. More knowledge about these factors is important to understand better the resilience of mangrove species to various future scenarios of environmental change.

Growth And Reproduction

'Life by the ocean has its perks—for mangroves, proximity to the waves and tides helps with reproduction.

*For most plants, the seeds remain dormant until after they are dispersed to a favorable environment. Not mangroves. Mangrove offspring begin to grow while still attached to their parent. This type of plant reproduction is called vivipary. After mangrove flowers are pollinated the plants produce seeds that immediately begin to germinate into seedlings. The little seedlings, called propagules, then fall off the tree, and can be swept away by the ocean current. Depending upon the species, propagules will float for a number of days before becoming waterlogged and sinking to the muddy bottom, where they lodge in the soil. Propagules of *Rhizophora* are able to grow over a year after they are released from their parent tree, while the white mangrove, *Laguncularia racemosa*, floats for up to 24 days, though it starts losing its ability to take root after eight. The flotation time allows for the propagules to vacate the area where their parent grows and avoid competition with an already established mangrove' (Smithsonian).*



Reproductive cycle of *Avicennia germinans*. Propagules are produced by cryptovivipary thus remaining attached to the parent plant until germination (A and B). Propagules emerge by first developing an hypocotyl (C) and then roots (D). Epicotyl and first leaves emerge from the cotyledons (E), and subsequently the seedling develops into a sapling (F). Red arrows indicate deviations from the standard cycle as a result of polyembryony. Visible differences are the presence of two hypocotyls and a thicker, heavier mature propagule. Adapted from The mangrove ecosystem—adaptations (available at: <https://themangroveecosystem.weebly.com/adaptations.html> (Accessed: 8 September 2021)).

Avicennia marina - the roots and leaves establish extremely easily. Placed in water, the roots start emerging within a few hours after the top fuzzy skin is removed.

Species	Salinity	Predominant buoyancy pattern	Refloat	BP (days)	Buoyant after reported BP (%)	VP (days)	Viable after reported VP (%)	ODP (days)	Reference
<i>Acanthus ilicifolius</i>	S (15 ppt)	Floater	—	—	—	< 11	—	Table 2 in Ref.	Ye <i>et al.</i> (2004)
<i>Aegialitis annulata</i>	F	Sinker	No	15	0	—	—	—	Clarke <i>et al.</i> (2001)
<i>Aegialitis annulata</i>	S	Sinker	No	15	0	—	—	10 §	Clarke <i>et al.</i> (2001)
<i>Aegiceras corniculatum</i>	F	Sinker	No	5	0	—	—	—	Clarke <i>et al.</i> (2001)
<i>Aegiceras corniculatum</i>	S	Sinker	No	10	0	—	—	8 §	Clarke <i>et al.</i> (2001)
<i>Avicennia germinans</i>	F	—	Yes	110	40	ca. 45	—	< 14	Alleman & Hester (2011)
<i>Avicennia germinans</i>	R (0–8 ppt)	—	—	25	—	—	—	—	Delgado <i>et al.</i> (2001)
<i>Avicennia germinans</i>	S (18 ppt)	—	Yes	110	30	ca. 45	—	< 14	Alleman & Hester (2011)
<i>Avicennia germinans</i>	S (36 ppt)	—	Yes	110	65	ca. 45	—	< 14	Alleman & Hester (2011)
<i>Avicennia marina</i>	F	Floater	Yes	15	ca. 80	—	—	—	Clarke <i>et al.</i> (2001)
<i>Avicennia marina</i>	S	—	No	A few days	—	240	ca. 5	ca. 7	Clarke (1993)
<i>Avicennia marina</i>	S	Floater	Yes	15	100	—	—	4 §	Clarke <i>et al.</i> (2001)
<i>Avicennia marina</i>	S	Sinker	No	2	5 to 10	—	—	—	Clarke & Myerscough (1991)
<i>Avicennia marina</i>	S	Sinker	Yes	ca. 6	ca. 40	—	—	—	Clarke & Myerscough (1991)
<i>Avicennia marina</i>	S (10%)	Sinker	Yes	ca. 6	ca. 35	—	—	—	Clarke & Myerscough (1991)
<i>Avicennia marina</i>	S (12%)	Sinker	Yes	2	ca. 45	—	—	—	Clarke & Myerscough (1991)
<i>Avicennia</i> spp.	F	—	—	—	—	—	—	ca. 14	Rabinowitz (1978)
<i>Avicennia</i> spp.	S	—	No	82	Always float	82	> 65	ca. 14	Rabinowitz (1978)
<i>Bruguiera exaristata</i>	F	Floater	No	15	ca. 70	—	—	—	Clarke <i>et al.</i> (2001)
<i>Bruguiera exaristata</i>	S	Floater	No	15	95	—	—	8 §	Clarke <i>et al.</i> (2001)
<i>Bruguiera gymnorhiza</i>	F	Sinker	Yes	15	30	—	—	—	Clarke <i>et al.</i> (2001)
<i>Bruguiera gymnorhiza</i>	S	—	—	117	—	—	—	—	Guppy (1906, p. 460)
<i>Bruguiera gymnorhiza</i>	S	—	—	31	—	31	100	—	Steele (2006)
<i>Bruguiera gymnorhiza</i>	S	Floater	No	15	60	—	—	14 §	Clarke <i>et al.</i> (2001)
<i>Bruguiera parviflora</i>	F	Sinker	No	15	0	—	—	—	Clarke <i>et al.</i> (2001)
<i>Bruguiera parviflora</i>	S	Sinker	No	15	20	—	—	8 §	Clarke <i>et al.</i> (2001)
<i>Bruguiera sexangula</i>	S (34.6–35.1 ppt)	—	—	60 / 67*	10 / 0*	63	—	—	Allen & Krauss (2006)
<i>Ceriops australis</i>	F	Floater	—	—	—	—	—	—	Clarke <i>et al.</i> (2001)
<i>Ceriops australis</i>	S	Floater	—	—	—	—	—	8 §	Clarke <i>et al.</i> (2001)
<i>Ceriops decandra</i>	F	Floater	Yes	15	75	—	—	—	Clarke <i>et al.</i> (2001)
<i>Ceriops decandra</i>	S	Floater	No	15	80	—	—	8 §	Clarke <i>et al.</i> (2001)
<i>Ceriops tagal</i>	F	Floater	No	15	85	—	—	—	Clarke <i>et al.</i> (2001)
<i>Ceriops tagal</i>	S	Floater	No	15	95	—	—	14 §	Clarke <i>et al.</i> (2001)
<i>Cynometra iripa</i>	F	Floater	No	15	100	—	—	—	Clarke <i>et al.</i> (2001)
<i>Cynometra iripa</i>	S	Floater	No	15	100	—	—	23 §	Clarke <i>et al.</i> (2001)
<i>Excoecaria agallocha</i>	S	—	—	208	—	208	35	—	Steele (2006)

Table 2. Buoyancy and viability characteristics of propagules from selected mangrove species. Typically, dispersal experiments are conducted using sea water (S), fresh water (F), or river water (R). Salinity values are provided in parentheses when provided in the respective source. Although some studies report minimum, median and mean values for the buoyancy period (BP) and viability period (VP), we here only considered maximum values for these propagule traits. Obligate dispersal period (ODP) refers to the post-abscission period during which a propagule is yet to initiate root growth. For detailed information on the number of propagules considered, the reader is referred to the respective source(s)

Van der Stocken et al., 2019

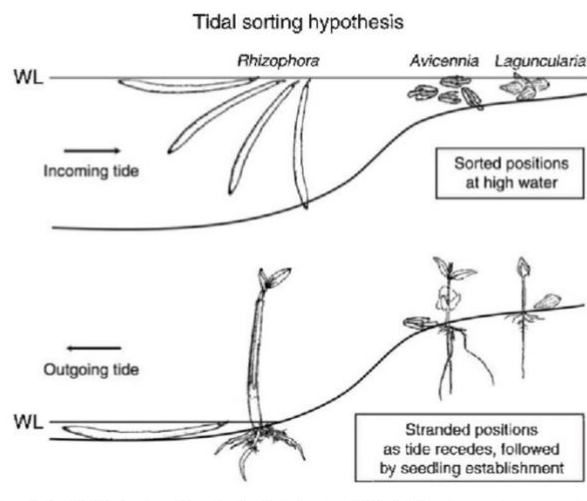
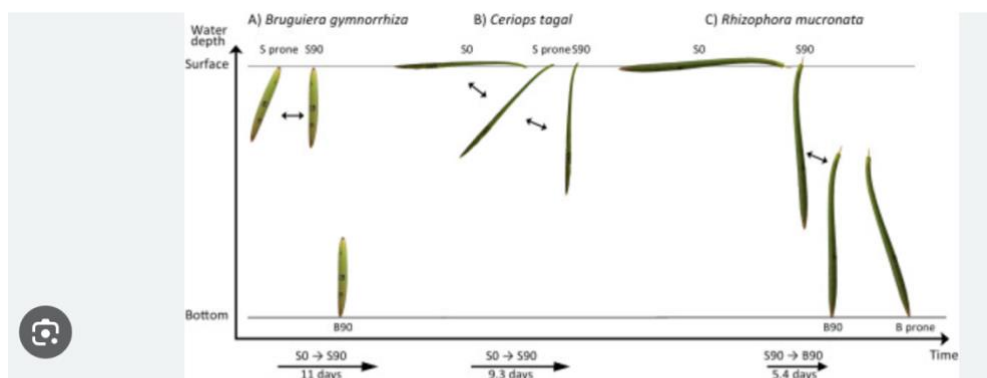
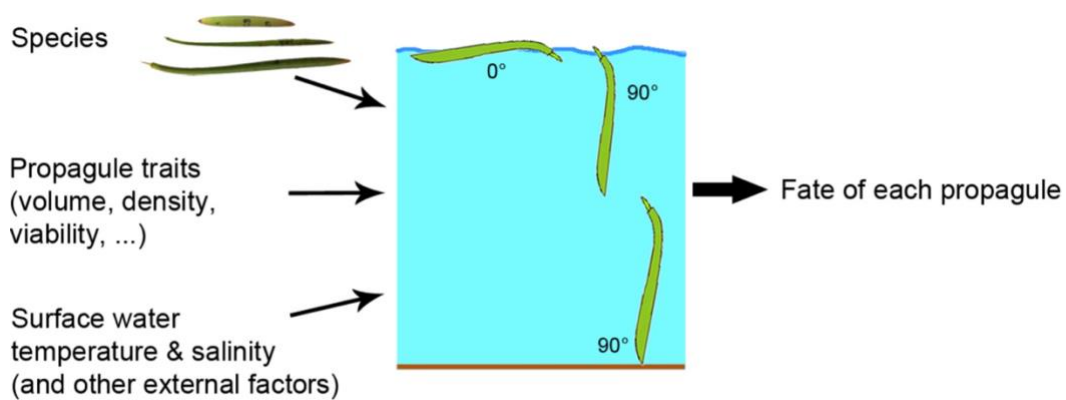


Figure ? Sousa et al., 2007.



Towards an unknown fate: The floating behaviour of recently abscised propagules from wide ranging Rhizophoraceae mangrove species -...

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Tonne et al., 2017.

On the issue of vivipary in botany, i.e., where the seeds germinate whilst still attached to the parent plant or within a seed pod such as in *Rhizophora* species, within, Tomlinson (2016) notes, *‘the “plunk” hypothesis...unsupported by any direct observation, was that the mature seedling shape provides a self-planting missile (“torpedo” in some descriptions), so that the released seedling, with or without the fruit, plunges directly into the underlying soft mud so that it remains straight and becomes anchored by the formation of adventitious roots. This idea, the “plunk” hypothesis as named by Egler (Reference Egler1948), was easily debunked by him and subsequent authors (Lawrence, Reference Lawrence1949; LaRue and Muzik, Reference Larue and Muzik1951). First, the propogule is as likely to fall into tidal water as mud; second, it is an elementary observation that Rhizophora seedlings mostly float (in a horizontal or erect position), and thus are carried away from the parent tree by tidal influence, as Rumphius described...Yamashiro (Reference Yamashiro1961), working with Kandelia in southern Japan (the northernmost mangrove “forest” in the world), demonstrated that initially attached marked seedlings, after they have fallen naturally, are transported within 30 days at least 50 m away from the mother tree. Out of 1854 marked seedlings, 1627 (87.76 percent) were “lost”; that is, were carried beyond the 50 m study plot. Only 31 (1.67 percent) were collected under the mother tree....Figures for trees in different tidal regimens were comparable. As stated earlier, the absence of an understorey in a mature Rhizophora forest is explained by the inability of seedlings to grow to maturity in shade....The development of a basal hook, as first illustrated by Rumphius (Fig. 1.2), had been well described and further illustrated (Egler, Reference Egler1948; Lawrence, Reference Lawrence1949; LaRue and Muzik, Reference 391Larue and Muzik1954). An illustration by Ding Hou in his account in Flora Malesiana (Reference Ding Hou1958) shows the hook in Rhizophora mangle, although this is not an Asian species. It was generally agreed that the hook is the result of the process that re-erects the seedling and allows it to become erect. Some writers were content to illustrate a series of disinterred seedlings to represent the process (Lawrence, Reference Lawrence1949), but LaRue and Muzik (Reference 391Larue and Muzik1954) observed, over an extended period, the process in R. mangle sown horizontally in shallow flats, hence measuring how long erection took. Tomlinson and Cox (Reference Tomlinson and Cox2000) conducted similar experiments in Hawaii on all four genera of mangrove Rhizophoraceae (Bruguiera, Ceriops, Kandelia, and Rhizophora), which showed that all became erected by formation of a basal hook. The experiments were repeated in Florida on R. mangle; that is, in its native location (Fisher and Tomlinson, Reference Fisher and Tomlinson2002), and were*

the substance of a refutation of previous mistaken observations (Fisher and Tomlinson, Reference Fisher and Tomlinson 2012).

None of the early observers seemed to have considered the mechanism by means of which the hook is developed and the seedling axis erected, other than the assumption that it was by a “push” from the lower side in contact with the substrate; that is, by unequal extension growth of the lower surface. There was no anatomical observation of the structure. In contrast, Tomlinson and Cox (Reference Tomlinson and Cox 2000) showed that the movement was caused by a “pull” via the development of tension fibers (gelatinous fibers) in the secondary xylem produced eccentrically within the hook; that is, on the upper surface and opposite to where the adventitious roots occur most commonly. These observations were confirmed by Fisher and Tomlinson (Reference Fisher and Tomlinson 2002). This shows the efficacy of tension wood even in circumstances of a mechanical disadvantage – rather like pulling a flagpole erect by applying lift at the base rather than the apex. The mechanics would indeed be aided at high tide by flotation. Once the seedling is erect, the work of tension fibers is done; further but still limited development of secondary xylem throughout the hypocotyl persists without their continued formation, but the hook endures because the hypocotyl as a whole undergoes little further secondary thickening, so that the hook is visible on older seedlings (e.g., Fig. 1.3). We must recall Rumphius’ illustration of the later stages of trunk development (Fig. 1.1) and realize that secondary growth of the axis increases most rapidly in a distal direction and in association with the aerial roots formed in succession up the trunk. The hook persists unobscured by this later growth and as the vestige of the initial erection process. Later-formed roots in a distal direction become progressively wider by secondary thickening, in reverse order of their age, to form the massive flying buttresses of the mature tree (Plate 13A). The function of the hook is therefore seen as a mechanism that facilitates the rapid erection of an axis that otherwise is regularly inundated by the tide. Consequently, the plumule is positioned as early as possible in a completely aerial environment, something like a swimmer’s snorkel. This adaptation is anticipated in the necessarily viviparously extended hypocotyl. Gas exchange in plumular leaves is promoted as they are least inundated. The hypocotyl alone is less able to promote adequate gas exchange because it is distinctly devoid of extensive stomatal development, which in part explains how it can float for an extended period without becoming waterlogged, part of its earlier adaptive construction. The development of reaction fibers in a viviparous seedling axis requires no unusual mechanism because they occur routinely and eccentrically in the tilted seedlings of terrestrial plants, where they have been used extensively in studies of reaction wood

formation. They occur, for example, in tilted seedlings of other mangroves (e.g., in Avicennia and Laguncularia). The eccentric production of tension fibers is thus a normal condition of seedling growth, but in the elongated seedlings of the Rhizophoraceae, it is clearly restricted to the base of the axis where the adventitious roots are also eccentrically developed by contact of the lower surface with the substrate, and where secondary xylem is first produced. The association of secondary growth with root formation seems physiologically as well as functionally efficient. Hence, vivipary is explained. (Tomlinson 2016)'

Summary

Summarizing this information produces the hypothesis based on the following observations and logical extensions.

- 1. Vivipary is a mechanism generated by absence of a dormant phase in the development of the embryo in the fruit.*
- 2. All subsequent features are normal features of a seedling with epigeal germination (the presumed ancestor).*
- 3. The seedling develops an extended hypocotyl with marked polarity while still attached to the parent plant and capable of penetrating the pericarp of the fruit (i. e., it germinates).*
- 4. The elongated seedling is detached (usually from the fruit) and dispersed, often widely, by flotation, its epidermal features preventing waterlogging.*
- 5. It is stranded, most usually in a horizontal position, becoming anchored via adventitious roots formed on the surface in contact with the substrate.*
- 6. Secondary xylem is rapidly developed but in an asymmetric condition, as an evident gravimorphic response.*
- 7. Gelatinous fibers are produced on the upper side, normal fibers on the lower side.*
- 8. Gelatinous fibers function as tension fibers and contract, creating a tension that shortens the axis on the upper side and erects the seedling axis relatively rapidly.*
- 9. This raises the plumular end of the seedling, so that if inundated (as is periodically possible in a tidal environment), the shoot can function more rapidly in an aerial environment and in a gaseous environment, gas exchange facilitating photosynthesis.*
- 10. The erect seedling can function at a competitive level in a high light environment, but once erect, it is no longer subject to an eccentric gravimorphic stimulus.*

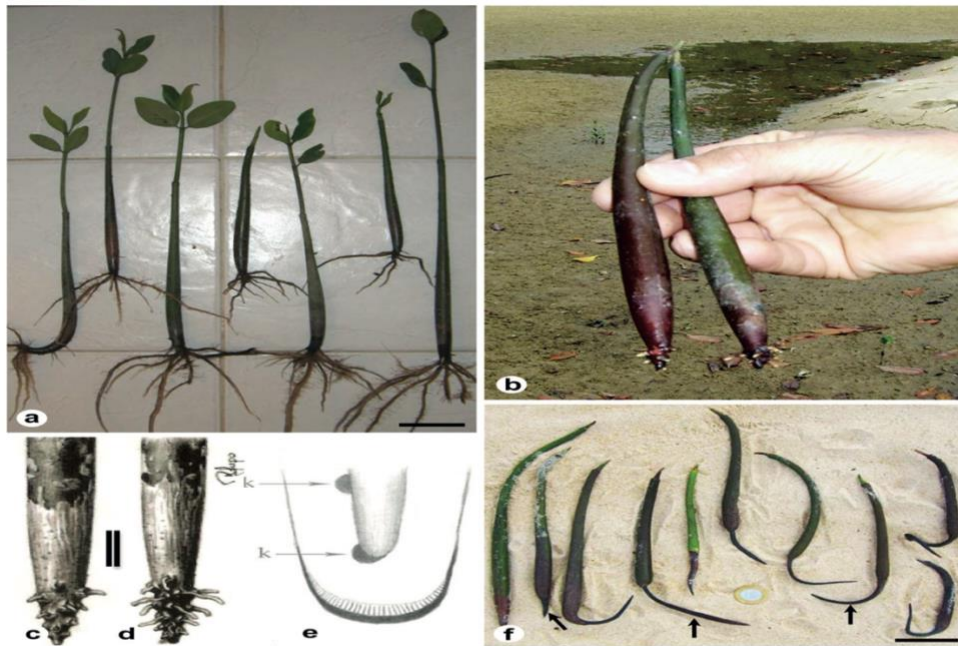


Figure 3 - (a-f): *Rhizophora mangle* at Porto de Galinhas (a-d) and at Porto Seguro, Bahia (f); - J-shaped plant (on left) and six self-planted (straight) ones. b - d - Self-planted propagules, with the beginning of adventitious root formation; e - Copy of Fig. 25 - i. Plate IX-X from Warming (1883); f - Propagules washed up on the beach at Taperapuã, showing later growth from the lower apex (arrows).

Propagules of *Rhizophora* are shaped like rods with pointed ends and superficially resemble giant green beans (fig. 6). They are elongated, floating hypocotyls, produced by extensive vivipary on the parent tree. The cotyledons, fused into a ring, are left behind in the fruit when dispersal begins (Gill and Tomlinson 1969). These propagules are large (fig. 1, table 2), those of *R. harrisonii* being somewhat longer and heavier than those of *R. mangle*. They are remarkably hardy and long-lived. Davis (1940) reports that propagules of *R. mangle* that were kept floating or submerged for 12 months and more grew when planted. LaRue and Muzik (1954) report that propagules kept on a laboratory bench for 68 days lost a third of their weight but grew when planted.

How do these propagules establish in the wild? Egler (1948) suggests that the propagules strand in a horizontal position, root, and then erect themselves. Egler found J-shaped hypocotyls on wild seedlings, indicating that they become erect after rooting. Davis (1940) feels that, as the propagules float vertically,

Dispersal of Mangrove Propagules 49

Rabinovitz 1978 discussing *Rhizophora harrisonii*

In both fresh and salt water, half of the propagules produced roots in 40 days (fig. 14c). The extrapolated minimum time to produce roots is ten days. In buckets of mangrove soil, propagules root in less than two weeks.

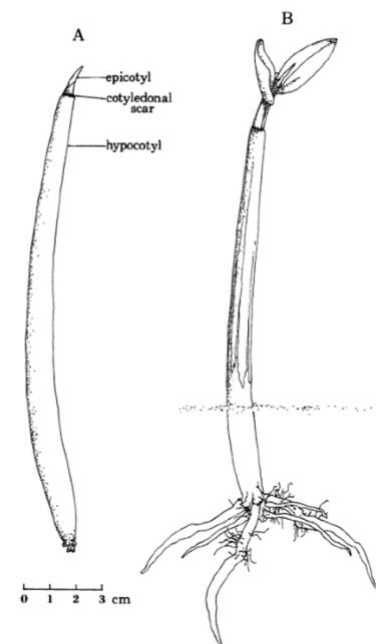


FIGURE 6. *Rhizophora mangle*: a, propagule, and b, seedling.

their sharp tips embed themselves in the substrate by abrasion. LaRue and Muzik (1951) say that they fall from the tree and implant themselves in the soil like little spears; they note that most seedlings bear straight hypocotyls, indicating that they rooted while erect. One can plant propagules either by sticking them into the soil vertically (fig. 6) or by anchoring them horizontally. Wild seedlings probably root both ways, but I feel that the spear technique is the more uncommon.

Pelliciera rhizophorae.—*Pelliciera* is a monotypic genus in the Theaceae and the only mangrove of the family (Robyns 1967). *P. rhizophorae* is restricted to the eastern Pacific, ranging from southern Costa Rica to northern Ecuador. In spite of its small range, it is common where found. Howe (1911) has been

For plants to reproduce successfully, it is crucial that their seeds be adapted to survive the environmental conditions in which they disperse and establish. The buoyant dispersal units (propagules) of viviparous mangrove species seem perfect adaptations for dispersal and establishment within the mangrove environment. However, much remains unknown about the structural changes mangrove propagules undergo between abscission from the parent tree and establishment. Mature propagules of two viviparous mangrove species (*Rhizophora mucronata* and *Ceriops tagal*) were submitted to experimental conditions in order to test: (i) how substrate influences propagule mass and volume during dispersal; (ii) if stranding of propagules on solid soil triggers root development and thus establishment. Our results showed that **dehydration stimulates root formation and propagule establishment** and that the establishment phase is faster at lower rather than higher salinity. Furthermore, it was found that the larger propagules of *R. mucronata* were less vulnerable to dehydration than those of *C. tagal*, that their root growth started later and that, once initiated, their roots grew faster. This indicated that *Rhizophora* propagules are better suited for long distance dispersal than those of *Ceriops* and that ***Rhizophora* has an advantage for establishment in the lower part of the intertidal zone**, where inundation is more frequent and propagules need to anchor more rapidly. This study therefore points out that two co-living species of the same family have different dispersal and establishment strategies, thereby contributing to the understanding of their local and global distribution and of the species-specific dynamics within mangrove forests.

Choosing Suitable Mangrove Species

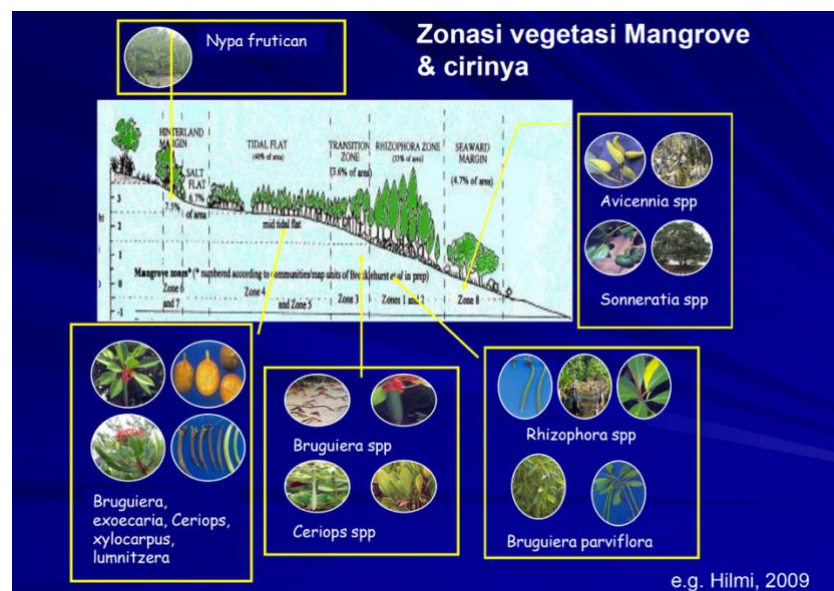
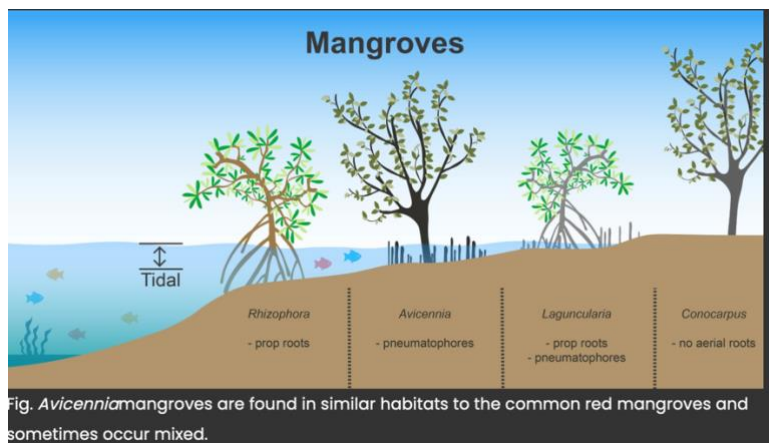


Figure from IPB lect – Zone 7 and 8 are of interest: 7) *Rhizophora* spp. and *Bruguiera parviflora*, 8) *Avicennia* spp. and *Sonneratia* spp.



Jungle Leaves

Avicennia marina

<https://www.asergeev.com/pictures/archives/compress/2014/1488/28.htm>

Avicennia marina or alba (<https://www.istockphoto.com/photo/mangrove-seedling-gm144286041-3790700?searchscope=image%2C51>)

A close-up photograph of a mangrove seedling, likely Avicennia marina or alba, showing its characteristic prop roots emerging from the soil and submerged in shallow water. The plant has green leaves and a small, developing flower or fruit at the top of a short stem. The background is slightly blurred, focusing attention on the seedling.

Avicennia alba

Figure 1

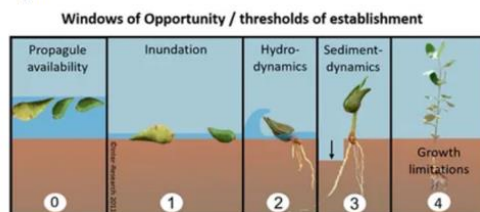


FIGURE 1. Windows of opportunity that propagules should encounter (or threshold of establishment that propagules should overcome) before they can colonize a site. EMR makes use of measures that extend the window of opportunity for natural establishment (**0–3**). Mangrove planting is either aimed at overcoming propagule limitation (**0**) or at skipping the thresholds of propagule establishment (**1–3**) by using larger seedlings or saplings that would, to a certain extent, be able to withstand conditions that are too harsh for smaller seedlings. Finally, saplings need to overcome limitations of growth (**4**) such as predation, disease or other stressors to grow into reproductive young trees (**panels 0 and 4** are additions to [Balke et al. \(2011\)](#)’s Windows of Opportunity figure).

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Environ. Sci., 07
February 2022 Sec.
Interdisciplinary Climate
Studies Volume 9 - 2021
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[https://doi.org/10.3389/fe
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nvs.2021.69001)



Rhizophora mucronata



Sonneriata alba fruit and seeds

Seed Preparation

Sonneratia alba

Seed Propagation for *Sonneratia alba*



1. FRUIT COLLECTION, SEED EXTRACTION AND PROCESSING

- Select quality parent trees with mature fruits (usually in July-September); and collect fruits through handpicking, shaking, or using poles to shake twigs and branches. Apply force that is just enough for the mature fruits to fall.
- Macerate the collected fruits by pressing the center of the fruit and separating the seeds from the pulp. Then soak the seeds in freshwater or preferably rainwater to determine the viable seeds (those that float) from the non-viable ones (those that sink). Then wash the collected viable seeds thoroughly with freshwater or rainwater.
- To break seed dormancy, sun dry the seeds for 1-2 hours depending on light intensity, as too much drying may negatively affect seed viability.

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Buduan et al., 2017 – Some key points for *Sonneratia alba*:

- Fruit usually July-September
- macerate fruit, extract seeds
- soak seeds in freshwater, better rainwater

- viable seeds are ones that float
- then wash viable seeds again
- sun dry for 1-2 hours to break dormancy depending on light intensity

2. SEED GERMINATION

• Germinate seeds in areas with a soft muddy substrate (i.e. abandoned fishponds, or open areas in-between mangrove trees), with a few growing Pagatpat wildings (indicator of suitability), and can be reached by tidewater. Where there's none, construct a seedbed laid with canvas/tolda then fill up with excavated

soft mud substrate. Allow the mud to dry for an hour to let the nutrients/acid evaporate before sowing the seeds.

• During low tide, scatter the seeds in the mud and cover them with black bean net (mesh #23) to prevent from being washed away by tidewater. Hold the net with stones or pegs along the edges. The seeds germinate in 3-5 days.



3. SEED SOWING AND GROWING

• Handpick the germinating seeds along with the mud substrate and broadcast in growing beds. Ideally, it is an abandoned pond with minimum of 15 cm deep mud substrate devoid of vegetation and can be reached by high tide.

• Scatter the seeds sparsely with density of max. 50 seedlings/m² to avoid overcrowding and facilitate mud balling and transplanting later on.

• Allow at least 4 months for the seeds to grow as seedlings. Install barriers and signboards to protect from human disturbance.



Buduan et al., 2017, Some key points for *Sonneratia alba* establishment

- Is it better to drop prepared seed that has yet to sprout or drop recently sprouted seed? It is probably better to try both? Unsprouted and then sprouted and see which ones do best. In a separate test
- To prepare for sprouting:
 1. construct a seedbed with suitable mud
 2. dry out mud for an hour to evaporate nutrients and acids? (to me this would just concentrate them?)
 3. rehydrate mud?
 4. Add seeds
 5. Cover with No.23 black mesh – this may not be need as this is used to stop seeds drifting away in tidal areas
 6. Seeds should germinate in 3-5 days.

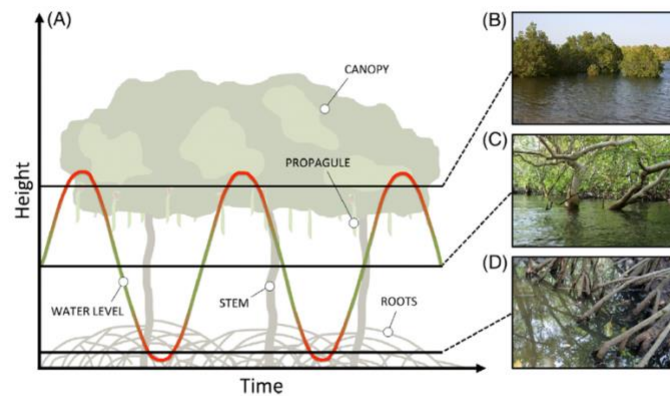


Fig. 3. Schematic illustration of dispersal barrier density variation over a tidal cycle (sinusoidal signal, simplified), using *Rhizophora* as an example case (A). Temporal changes in water level may increase (red) or decrease (green) barrier density and hence the potential for dispersal. Steric hindrance is particularly high when the water level reaches the canopy (B) or when the water level is within the vertical reach of the root structure (D). Steric hindrance is lower in the vertical reach where tree stems present a physical barrier that is less dense (C).

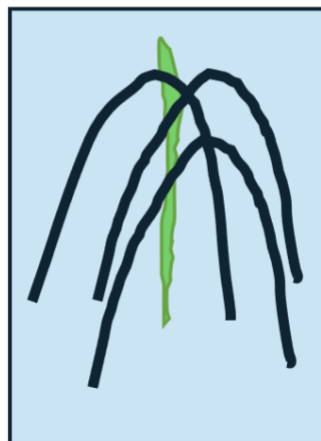
Van der Stoken et al., 2019.

Tom van der Stoken notes that when the waters are above root level and below canopy level that is the best chance; *Rhizophora* propagules have to float away on the tide. However, it should be considered that when propagules first drop, they lie flat, and this also enhances their chances to pass unhindered on top of the water. They eventually turn vertical, and if they were vertical, they would be hindered by roots and branches as shown in the diagram below for created this project.

Horizontal
propagule can
more readily
pass through
roots



Vertical
propagule
cannot pass
through roots as
readily

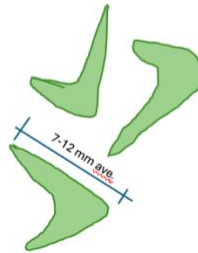
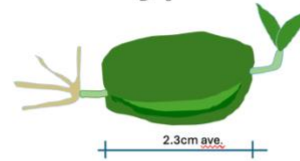


External morphology of 3 seed types

1. *Rhizophora* type:
Average length 23.1 cm (De Rijk et al., 2012), note hook at the bottom. The roots 1st appear just above this hook



2. *Avicennia* type: Average diameter 2.3cm Seed usually single, compressed. Capsule subglobose, broadly ellipsoid or ovoid, usually not beaked when mature, 1.2–3 cm. long, 0.7–2.5 cm. wide, velvety scaly-tomentose. The roots emerge from one side and the leaves the other



3. *Sonneratia alba*: 7-12mm long, irregular flattened. Th seeds are quite rough and thorn like

The external morphology of the 3 seed types dictates different methods for containing the propagules on the drone, the associated release mechanism and the anchoring system that needs to be attached to the different propagules to keep them in place in the intertidal areas and/or ponds.

1. The literature notes that where the conditions are right, such as in soft mud areas, and when the tide is out, some *Rhizophora* spp. propagules fall vertically and insert themselves into the mud. These propagules are long and cylindrical, and have a hard tip, with a small hook on the end. This can only happen within the canopy of the trees themselves. Thus the majority of *Rhizophora* spp. propagules drop horizontally onto the mud, or into water, when the tides are in and then they can be carried to other locations where if the conditions are right the propagules hook themselves into the substrate and set roots (see Figures ??/ below).
2. *Avicennia* spp. look like small discs, with a hard outer shell which is discarded to reveal a number of slightly domed sheaths from in which the roots and leaves appear from opposite ends.
3. *Sonneriata alba* seeds (see Figure ?) are enclosed in a fruit. They are arranged radially around the centre of the fruit. When the fruit breaks open or is deliberately peeled, the seeds are positioned side by side around the centre

Anchoring Systems - Learning from the Literature and Nature

It is imperative that in both the intertidal and pond areas, the propagules of all three species remain in the location where they have been programmed to be dropped. This thus allows for the spatial design of restored mangrove forests to suite various key objectives which may include a variety of priorities, such as:

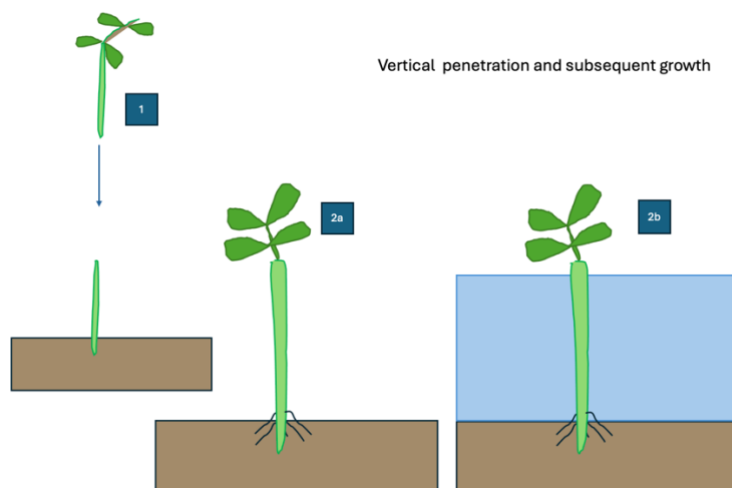
- Flood and surge control;
- Increasing marine and terrestrial biodiversity;
- Water cleansing biotope;
- Local harvesting of marine animals for consumption and sale on local market;
- Nursery areas for fish;
- Etc.

The type of anchoring mechanism will be largely determined by the morphology of the propagules, their shape and weight and also how they root into the substrates once they are in a suitable condition to root and start sprouting stems and leaves.

Rhizophora Type

The average length of *Rhizophora mucronata* propagules is 23cm. The pencil or bean shape of *Rhizophora spp.* and the way it commonly fixes itself into the substrate appears to suggest that the propagules need to be dropped

1. When the tide is out;
2. The front end is weighted, so that the tip could partially penetrate the substrate and that it would not move as tides come in and out;
3. The top end could have a floating device, which could help with buoyancy if this is required.



Diagrammatic representations of how *Rhizophora* species propagules seed themselves naturally if they drop vertically and penetrate the substrate and remain in position. This can only happen when the tide is out and the mud is soft enough.

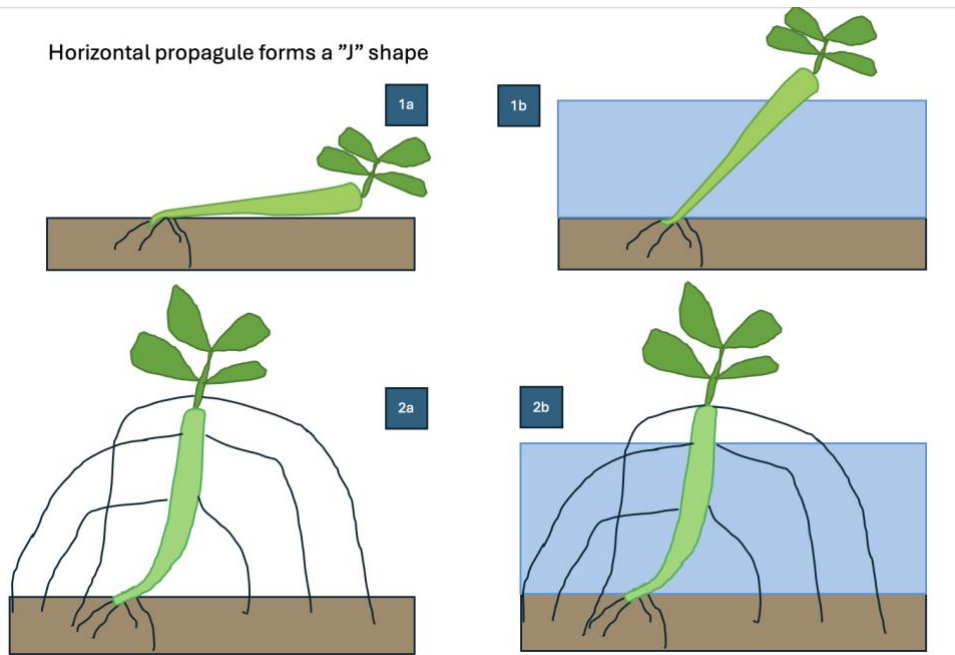
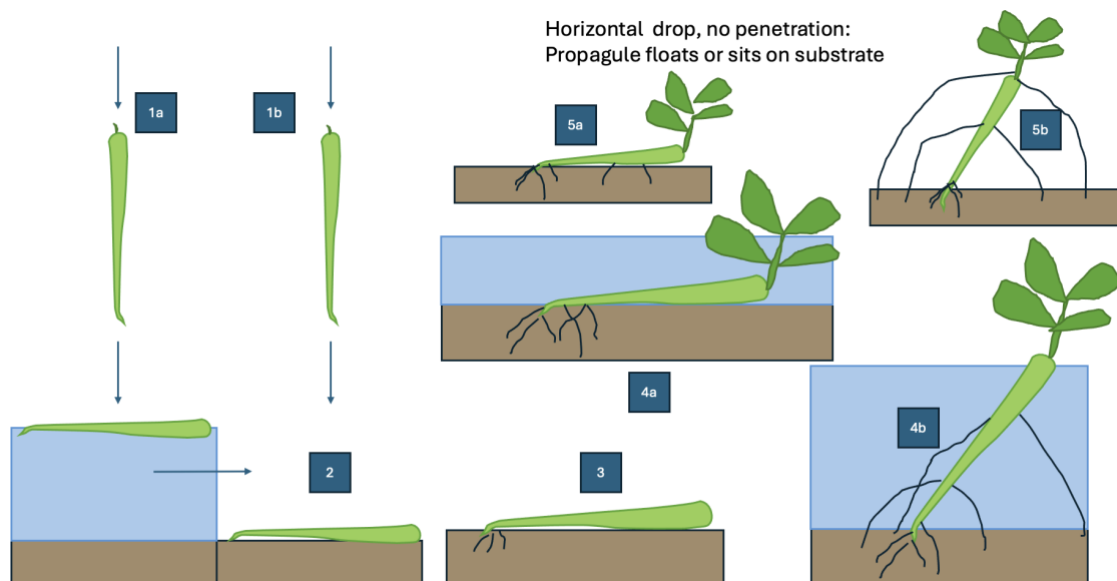


Figure ? Diagrammatic representations of how Rhizophora species propagules seed themselves naturally but forming a "J" shape – The literature suggest this is the main way that they grow



Diagrammatic representations of Rhizophora species propagules following horizontal drop – chances are that propagules will shift in the tide. 1a) Propagule drops onto water and lies horizontally and remains horizontal until 2) when the tide is out or it drops onto the mud and remains horizontal and 3) roots start to grow from tip. 4a) and 4b) roots fix the propagule at bottom and when tide is in the propagule is fixed but it floats towards verticality. Eventually the propagule remains semi-vertical in position at all times and has a typical "J" shaped form.

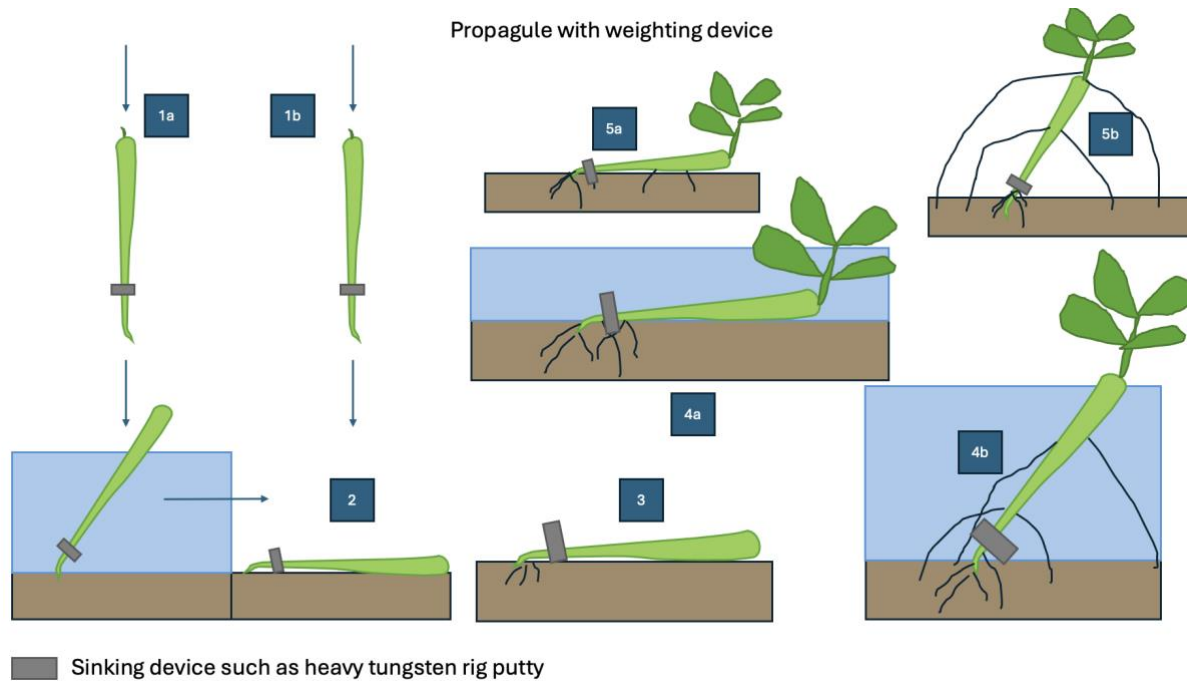
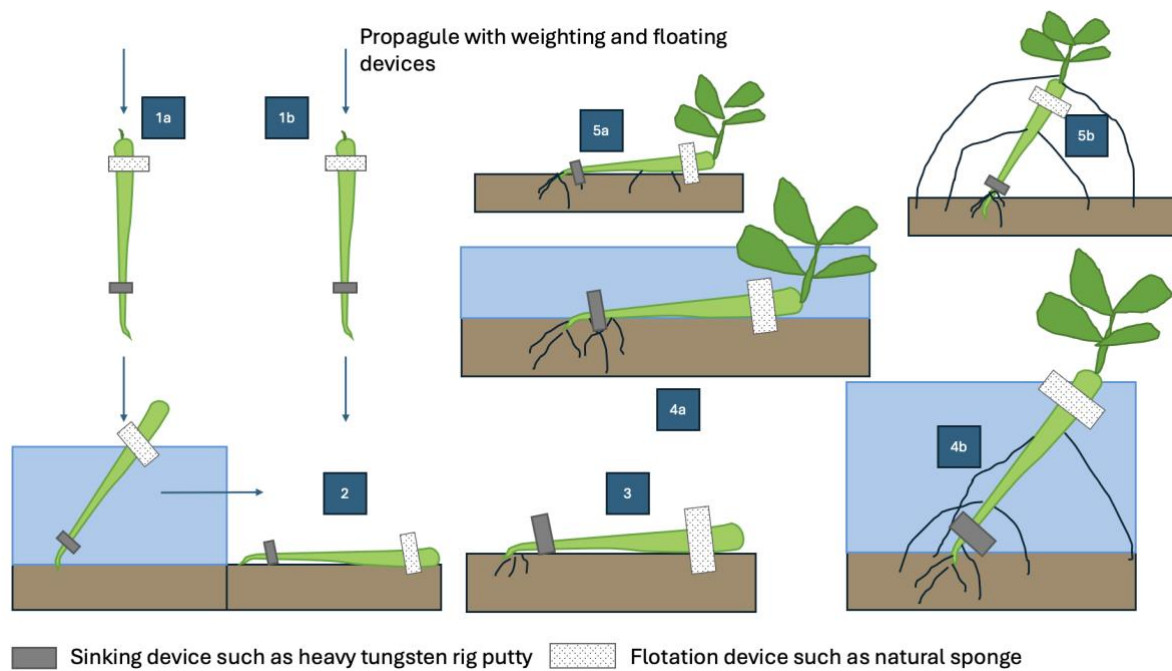


Figure ? Diagramatic representations of *Rhizophora* species propagules following horizontal drop with weighting device to maintain position

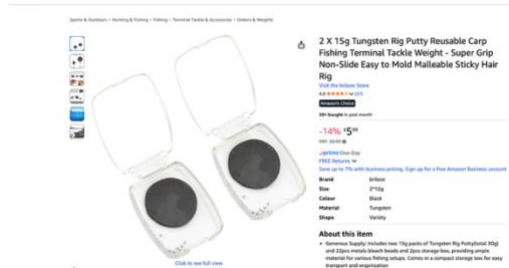


Diagramatic representations of *Rhizophora* species propagules following horizontal drop with weighting device to maintain position and floating device to assist in vertical growth

Weighting Mechanisms

Note all materials considered need to be non-toxic

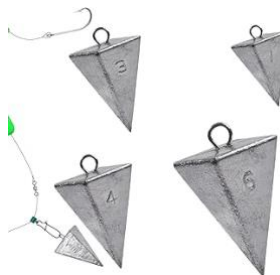
Tungsten Rig Putty



EARLY BLACK FRIDAY 50pcs Carbon Steel Egg Sink...

£8.96 780 sold

RRP £10.91



Lead free weights: Carbon steel, plant weights strips, aluminium, bullet shaped, pyramid shaped, long tailed/grip for strong currents

Using a fluid gel for planting

The best method is creating a cornstarch-based gel that you can apply with the seeds. This method is used by horticulturists for "fluid seeding" and works great for wet or sandy surfaces.

Instructions for cornstarch gel

1. **Prepare the gel:** Mix one tablespoon of cornstarch with one cup of water in a pot.
2. **Heat the mixture:** Cook over low to medium heat, stirring until the gel thickens to a toothpaste-like consistency.
3. **Cool the gel:** Let the mixture cool completely before using.
4. **Mix in the seeds:** Stir your seeds into the cooled gel, distributing them evenly.
5. **Apply to the sand:** Use a small plastic bag with a corner snipped off to pipe the gel and seeds onto the wet sand.

Seed-safe alternatives

- **Create seed tape:** For more precise placement, make your own seed tape using water-soluble school glue or a flour and water paste.
 1. Place dots of glue or paste onto strips of a paper towel.
 2. Press the seeds into the dots.
 3. Let the tape dry, then lay it on the wet sand and cover it with a thin layer of sand.

PVA Bags or netting



Appendix - AI Information – Google AI mode

Accessed 24/10/25 at 11:15

Question: how do *Sonneratia alba* seeds grow?

Answer:

Sonneratia alba seeds grow through a process called epigeal germination, where the seeds are dispersed by tides and establish themselves in soft, muddy intertidal zones. Unlike some other mangrove species that are viviparous (germinate while still on the tree), *S. alba* seeds undergo germination after falling from the fruit.

The natural growth cycle

1. **Seed dispersal:** The fruits of *S. alba* are indehiscent (do not split open) and buoyant, allowing them to be carried away by ocean currents.
2. **Germination:** Once the fruit settles in a soft, muddy intertidal flat, the seeds inside germinate. The fruit can be periodically inundated by brackish water during this stage.
3. **Establishment:** As a pioneer species, *S. alba* is well-adapted to colonizing newly formed mudflats and shorelines. It thrives in high-salinity conditions and needs to be regularly touched by saltwater.
4. **Growth and adaptation:** The seedlings develop finger-like roots called pneumatophores, which help anchor the tree in unstable soil and bring oxygen to the roots in the low-oxygen mangrove environment.

Sonneratia alba - PROTA4U

Comment on this plant. ... Leaves opposite, simple and entire; stipules absent; petiole 3–15 mm long; blade elliptical to ovate, 3...



PROTA4U

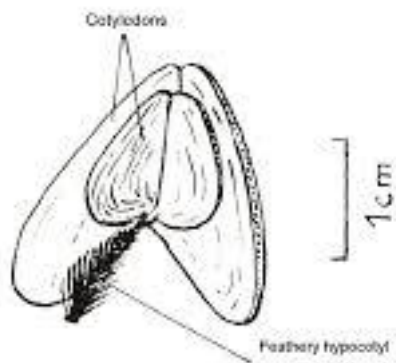


Mangrove planting and sustainability

Salinity varies between seasons, when there is a lot of rainfall salt water is diluted. In dry seasons, with no rain and high evap...



Pan African Conservation Education



Avicennia germinans seed, that has started germinating.
Drawing from Lotoubozy, Manual of forest botany, tropical Africa.

Nursery and replanting methods

For mangrove restoration projects, *S. alba* seedlings can be grown in a nursery setting or planted directly from seeds in a "wild" nursery.

Direct scattering

This method is often considered more successful than raising seedlings in a traditional nursery.

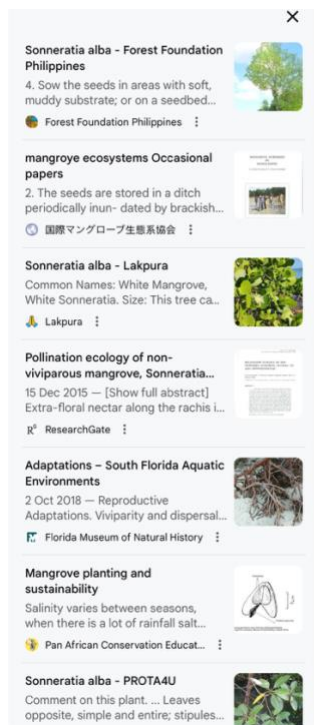
- **Seed preparation:** Collect mature fruits and extract the angular, smooth seeds from the pulp. Soak the seeds in water overnight (around 12 hours).
- **Sowing:** Scatter the soaked seeds directly onto a designated "wild" field site with a soft, muddy substrate that receives daily tidal inundation.

- **Transplanting:** After 5–6 months, or when seedlings have at least 4–10 leaves, they can be carefully uprooted and transplanted to their permanent location during the wet season.

Nursery bag cultivation

If using a nursery, the process is as follows:

- **Sowing:** Sow seeds in a bed of soft mud and cover with a protective net. Germination can occur in as little as 3–5 days.
- **Initial transplant:** When seedlings develop 2–3 leaves (typically within one to two weeks), transplant them into individual bags filled with mud.
- **Growth period:** Let the seedlings grow in the bags for 4–5 months, watering regularly with a mix of mud and saltwater.
- **Hardening:** Before planting out, remove any artificial shading to help the young trees acclimatize to full sun.
- **Final transplant:** Plant the mud-balled seedlings in the restoration area, ensuring smaller seedlings are adjacent to existing mangroves and taller ones are in seafront areas.



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Question: how do *Rhizophora* seeds grow?

Answer:

Rhizophora propagules grow through a process called viviparity, where a seed germinates while still on the parent tree, developing into a long, torpedo-shaped seedling called a propagule. Once mature, it falls into the water and floats, often for a long time, before the heavy, bottom end becomes waterlogged and causes it to float vertically. This orientation, aided by currents and tides, helps it to self-plant into the substrate or to be swept into a suitable muddy area where it can take root. Once the bottom of the propagule is embedded, the roots will begin to grow, followed by the shoot and leaves.

he growth process unfolds in three main stages:

1. Viviparous development on the parent tree

- **Germination on the parent:** The *Rhizophora* propagule, also known as a "sea pencil," is not a dormant seed. The embryo germinates and grows while still attached to the parent mangrove tree.
- **Embryo maturation:** Over several months, the embryo grows, protrudes from the fruit, and develops into a long, elongated, cigar-shaped seedling called a propagule. This provides it with a substantial store of nutrients from the parent plant.
- **Detachment:** Once the propagule is fully mature, it detaches from the parent fruit. The end that will form the roots is heavier, which helps it to either drop straight down into the mud below or float away.

6. Vivipary: Special Type of Germination

Apr 20, 2025 — in this video we will learn about VV parry. this is a special type of germination seen in plants. very specific plants...



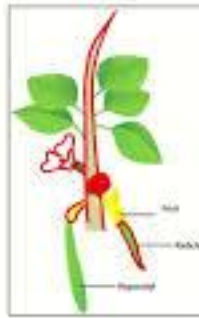
YouTube·Srijan Education

Vivipary: Special Type of Germination

Vivipary germination is found in mangrove plants such as *Rhizophora* and *Sonneratia* which are found in marshy lands and on sea coasts.

The seeds germinate inside the fruit and are nourished by it while the fruit is still attached to the parent plant.

Vivipary → young ones
of seed



Red Mangrove

These germinated seeds (called propagules) look like green and brown cigars, and can be seen hanging from Red Mangrove trees in su...



environment.bm

2. Dispersal and orientation

- **Floating horizontally:** If the tide is high when the propagule falls, it floats off horizontally and can be carried by currents for long distances—sometimes for over a year. This mechanism allows *Rhizophora* to colonize new areas.
- **Switching to vertical:** As it drifts, the propagule can actively adjust its buoyancy. The heavier root end gradually takes on more water, causing the seedling to eventually orient itself vertically in the water column. This change is triggered when it encounters suitable brackish water, increasing its chances of successfully rooting.

3. Rooting and growth into a seedling

- **Anchoring:** Once the propagule is floating vertically, it can anchor itself in the soft, muddy sediment of the intertidal zone. If it falls vertically into the mud at low tide, it can "self-plant". If it lands on its side, it has the ability to take root and straighten itself.
- **Establishing roots:** The propagule quickly develops adventitious (prop) roots from its base to anchor firmly in the shifting, low-oxygen mud. These iconic arching roots provide stability against waves and tides.
- **Developing shoots:** Once anchored, the embryonic leaves at the top of the propagule can begin to unfurl and grow, allowing the young plant to photosynthesize and continue its development into a mangrove sapling.

×

My mangrove obsession, and the basics of Mangrove care.

3 Apr 2019 — Rather, we acquire mangroves as propagules- buoyant seedlings which grow...

Tannin Aquatics



Reproduction of the mangrove species *Rhizophora stylosa* Griff. at ...

The elongated propagules produced by Rhizophoraceae species can establish by self-planting into the substrate, or after...

ScienceDirect.com

Rhizophora mangle - Wikipedia

As a viviparous plant, *R. mangle* creates a propagule that is in reality a living tree. Though...

Wikipedia



#559: HUNDREDS OF RED MANGROVES - Update Monday

19 Nov 2018 — in a way where they w...

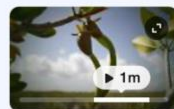
YouTube · Greg Jones (Greg's Fishroom)



Life Cycle of the Red Mangrove

30 Apr 2015 — this is very rare. but wit...

YouTube · Odyssey Earth



-
- Accessed 24/10/25 at 11:25
 - Question: how do *Avicennia alba* seeds grow?
 - Answer:

Avicennia alba seeds germinate while still on the tree, a process called vivipary, so they sprout before falling to the mud. Once detached, the germinated seeds (propagules)

immediately start to grow, with the root emerging from the thicker end and the shoot from the thinner end. They have hooked hairs to help them attach to the muddy substrate and grow into tangled groups, establishing the mangrove roots quickly in the intertidal zone.

Germination process

- **Viviparous germination:**

The seeds begin to sprout while still inside the fruit, with the embryo developing and breaking through the seed coat before it falls from the parent tree.

- **Immediate growth:**

The germinated seed, also called a propagule, can start growing as soon as it lands on the mud.

- **Root and shoot development:**

The root emerges first from the thicker end of the seed, while the shoot grows from the thinner end.

- **Establishment in mud:**

The seedlings often have hooked hairs to help them get established in the soft, muddy environment of the intertidal zone, forming tangled groups.

The cryptovivipary process

1. **Embryo development:** After insects pollinate the small, yellow-orange flowers, the fruit begins to develop. Inside the fruit, the single seed germinates and grows into an embryo.
2. **Internal growth:** The embryo develops and breaks through its seed coat, but remains enclosed within the fruit wall. This is the key characteristic of cryptovivipary, distinguishing it from true vivipary, where the seedling emerges from the fruit while still on the tree.
3. **Maturation and dispersal:** When the pale green, conical fruit matures and drops into the water, it is already a fully germinated and ready-to-grow seedling, or "propagule". These propagules are buoyant and can be dispersed by the sea.
4. **Establishing a new plant:** The buoyant propagule floats until it reaches a suitable location, such as a newly formed mud bank or tidal river bank. It then lodges itself in the soft mud and quickly establishes a root system to anchor itself before it can be washed away by the tides.

Advantages for mangrove survival

This unique reproductive strategy has evolved to overcome the challenges of a marine environment:

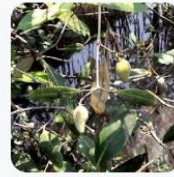
- **Rapid establishment:** By germinating while still attached to the parent, the seedling avoids the period of dormancy typical of most plants. It can begin growing roots immediately upon finding a suitable patch of mud.
- **Energy and resource advantage:** The parent tree provides the developing embryo with a secure, nutrient-rich environment for its initial growth stage, increasing its chances of survival once it's on its own.
- **Coping with harsh conditions:** The propagule is better prepared to handle the anaerobic (oxygen-poor) and saline conditions of the mangrove mudflats than a typical dormant seed would be.
- **Widespread colonization:** Floating propagules can be carried by currents far from the parent plant, allowing the mangrove to colonize new areas. *Avicennia alba* is a "pioneer species" that is one of the first plants to establish itself in new muddy areas.



Avicennia alba - Wikipedia

* Description. *A. alba* forms a low, dense bushy crown often branching...

Wikipedia



What's a Mangrove? And How Does It Work?

Some mangroves flourish along riverbanks far inland, as long as the...

American Museum of Natural His...



Avicennia alba Blume - Singapore

7 Oct 2025 — *Avicennia alba* Blume. ... *Avicennia alba*, also known as Api...

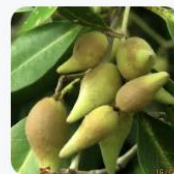
National Parks Board (NParks)



Avicennia alba (Api api): Sea dispersed

17 Dec 2018 — *Avicennia alba* (Api api): Sea dispersed. ... The local nam...

seedsofborneo.com



Pollination biology of the cryptoviviparous *Avicennia* species ...

9 Aug 2025 — Floral biology, sexual system, breeding system, pollinators...

ResearchGate



Avicennia alba | MangroveWatch World Mangrove iD-2.1

22 Sept 2024 — Species Note Text. *Avicennia alba* is a significant pione...

Atlas of Living Australia



Avicennia alba Blume - AVICENNIACEAE - Dicotyledon - Cirad

Diagnostic characters : Small tree, up to 5 m tall, much branched; bark greyish-black, lenticelled;...

is there anything that can stick to mud or sea sand

Yes, many substances, animals, and plants can stick to mud or sea sand, relying on the particles' small size and properties when wet

. For example, when mud particles are wet, they become cohesive and cling to other objects through partial vacuum forces. Sea sand is less cohesive, but with added substances, it can also bind together.

Everyday substances and adhesives

- **PVA/School Glue:** When mixed with water and sprayed onto sand, it forms a hard coating, similar to an M&M shell, that prevents the sand from shifting. This technique is often used for sand sculpting or crafting.
- **Joint Compound:** Some construction workers add wood or PVA glue to drywall or joint compound to improve its binding strength, especially over glossy paint.
- **Landscape Adhesives:** Products like gravel or mulch glue are designed to bond outdoor landscaping materials, including sand and pebbles, into place.
- **Natural Glue:** Plant-based glues made from potato or wheat starch are biodegradable and effective adhesives for many materials, including paper and other crafts.
- **Mortar and Cement:** These materials are essentially high-powered adhesives designed to bind sand and other aggregates together, making them "stick" and harden to create durable structures.

Animals

- **Sand Mason Worms:** These worms construct protective, tree-like tubes out of sand and shell fragments that stick together with a mucus-like secretion.
- **Bivalves:** Mussels, clams, and cockles use powerful feet to bury themselves deep into the mud and sand of the seabed.
- **Limpets:** These cone-shelled creatures clamp firmly onto rocks and sand with their muscular foot.
- **Lugworms:** These worms live in U-shaped burrows on sandy shores and produce worm-castings, or coiled piles of sand, on the surface.

- **Crustaceans and Worms:** Numerous other creatures, from small worms to large sandworms, live an

Plants

- **Psammophytes:** This category of plants is specially adapted to grow in sandy soils, often in deserts or near the coast.
- **Creeping Thyme:** This plant, along with others like Creeping Phlox and Sedum, works as a natural groundcover that can take root in shallow, sandy, or stony soil, helping to bind it together.
- **Marsh and Wetland Plants:** Species like cattails and willows are suited for wet, muddy soils and use extensive root systems to stabilize the ground.

Are you looking to use something to stick mud or sand together for a specific project?.

how can I glue a seed onto sea sand or mud?

For planting seeds in sand or mud, using a natural, water-soluble glue like a flour paste is the safest and most effective method

. This avoids introducing toxins that could harm the seeds or the environment, while providing a temporary, biodegradable bond.

How to make and use flour paste

This DIY method is often used to create seed tapes for small seeds, but it also works for placing individual seeds.

1. **Mix the paste:** Combine one part flour with two parts water and stir until it forms a thick, smooth paste similar in consistency to white school glue. You can adjust the ratio to get the desired thickness.
 2. **Apply to the surface:** Use a paintbrush or toothpick to apply a small dot of the flour paste onto the sand or mud where you want the seed to stick.
 3. **Place the seed:** Carefully place one seed onto each dab of glue.
1. **Allow to set:** Let the paste dry completely. The seeds will be firmly attached, and the glue will naturally break down as you water the area.

What happens if you. . . Making a Seed Tape - Handout

• Mix the seed 'glue'. (Seed glue is 1 part water and 2 parts flour.) • Cut a length of seed tape (toilet paper). • With a pen, pl...

Virginia Cooperative Extension



5 Gardening Hacks for Seed Sowing Success - GrowVeg.com

Apr 22, 2016 — "to sow small seeds in pots: I pour some out onto a paper plate, put some water in a cup, take a wooden toothpick and ...



GrowVeg.com

Other useful methods

Beyond traditional gluing, these techniques can also help with seed placement in sandy or muddy conditions:

- **Mix seeds with sand:** For spreading very small seeds evenly over a large area, mix them with a larger quantity of clean sand. You can then scatter the mixture by hand.
- **Seed balls:** In a technique called seed bombing, seeds are mixed with compost and clay to form small balls. The balls can be thrown or placed and will break down over time, protecting the seed as it germinates.
- **Germination in paper:** Some gardeners start seeds in wet paper towels or on layers of toilet paper with non-toxic glue before transplanting them into soil.

This method provides a very controlled germination process before introducing the seedling to the final planting environment.

Do you need to stick seeds onto a surface that is either sand or mud, or do you have one in particular in mind?

can I create a suction onto sea sand

It is difficult to create a lasting suction force directly onto sea sand due to its high permeability, which allows water to flow in and break the vacuum seal

. However, engineers have developed specialized techniques for creating temporary, controlled suction forces for specific purposes, such as installing offshore foundations.

How engineers create temporary suction on sand

In large-scale offshore projects, engineers use hollow cylinders called **suction caisson** to anchor structures to the seabed, including in sandy soil. This is how they work:

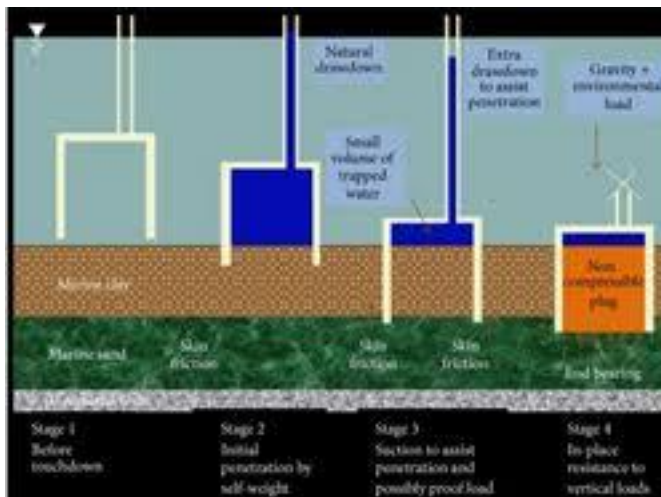
1. **Caisson placement:** A large, hollow, steel cylinder, open at the bottom and sealed at the top, is lowered to the seabed.
2. **Water pumping:** Water is pumped out from inside the cylinder to create a negative pressure (a vacuum) relative to the surrounding sea pressure.
3. **Penetration:** The pressure difference, or suction, forces the caisson to penetrate deep into the sand, effectively holding it in place.

Suction caisson - Wikipedia

Suction caisson. ... Suction caissons (also referred to as suction anchors, suction piles or suction buckets) are a form of fixed ...



Wikipedia



INSTALLATION OF SUCTION CAISSONS IN SAND

The installation of a caisson by suction is possible due to the generation of a differential pressure between the interior chamber...



Simulador de puntajes UCSC



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Challenges for creating suction on sand

The high permeability of sand, compared to finer-grained soils like clay, presents several challenges:

- **Water inflow:** Sand's large pore spaces allow water to rush in and equalize the pressure, making it difficult to maintain a strong, long-term vacuum.
- **Leakage:** The suction caisson's base must be effectively sealed against the seabed to prevent leakage and create a pressure differential.
- **Stability:** If the suction is applied improperly or too forcefully, it can disrupt the sand's structure and cause "piping," which is when water flows rapidly into the caisson and undermines its stability.

Everyday alternatives for handling wet sand

If your goal is to simply clean or collect wet sand, you do not need to create suction. Other methods are more effective:

- **Siphon vacuum:** A simple siphon with a wide hose is effective for cleaning debris from wet sand, such as in an aquarium. By holding the tube slightly above the sand, you can remove debris without disturbing the heavier sand particles.
- **Sand shrimp pump:** This hand-operated device uses a manual suction action to pull up sand and small creatures for collection. By covering a thumb hole, a quick suction force is created as the pump is pulled up.

What is the specific application for which you are trying to create suction on sand?
Is there anything that will stick to wet sand?

Yes, several types of adhesives and binding agents are specifically designed to stick to wet sea sand, even underwater.

. These materials are formulated with waterproof polymers that displace moisture and create a strong, lasting bond.

Construction and marine-grade adhesives

These industrial-strength products are designed for demanding, wet environments:

- **MS Polymer-based adhesives:** Products like

[EVO-STIK Strong Stuff Waterproof Adhesive](#)

are high-performance, single-component adhesives that bond effectively to damp surfaces and can even be applied underwater.

- **Marine-grade epoxy sealants:**

[3M Marine Adhesive Sealant 5200](#)

is a tough, flexible polyurethane sealant that adheres permanently to marine surfaces, resists saltwater, and absorbs the stress of vibration and shock.

- **Pond and aquarium sealants:**

[AquaForte Superstrong Fix & Seal](#)

is an adhesive sealant specifically made for wet applications in ponds and aquariums, making it perfect for repairing leaks or bonding materials i

Landscaping and smaller-scale projects

For projects like stabilizing a sand path or creating decorative features, other products are effective:

- **Polymeric sand:** This is a mix of sand and waterproof polymers that is activated by water. When applied to wet sand or between pavers, it hardens into a solid yet flexible bond, preventing erosion and keeping the sand in place.

- **Mulch or gravel glue:** Products like

Nature Bond

or

Vuba Easihold

are spray-on binders designed to stabilize loose landscaping materials, including sand. They are non-toxic, dry clear, and are safe for use around plants and pets.

- **Modified PVA or SBR-based additives:** For sand/cement mixes, liquid additives containing SBR (Styrene Butadiene Rubber) can improve adhesion and create a water-resistant mortar. For smaller DIY projects, some enthusiasts have success mixing PVA (wood) glue with sand after using isopropyl alcohol to break the water's surface tension.

What are you planning to do with the wet sea sand?

I want to stick seeds to wet sea sand

For your specific project, using a seed-safe, non-toxic, and biodegradable gel is a much better choice than traditional glue for sticking seeds to wet sand

. This ensures the seeds can germinate and grow without harm.

Using a fluid gel for planting

The best method is creating a cornstarch-based gel that you can apply with the seeds. This method is used by horticulturists for "fluid seeding" and works great for wet or sandy surfaces.

Instructions for cornstarch gel

1. **Prepare the gel:** Mix one tablespoon of cornstarch with one cup of water in a pot.
2. **Heat the mixture:** Cook over low to medium heat, stirring until the gel thickens to a toothpaste-like consistency.

3. **Cool the gel:** Let the mixture cool completely before using.
4. **Mix in the seeds:** Stir your seeds into the cooled gel, distributing them evenly.
5. **Apply to the sand:** Use a small plastic bag with a corner snipped off to pipe the gel and seeds onto the wet sand.

Seed-safe alternatives

- **Create seed tape:** For more precise placement, make your own seed tape using water-soluble school glue or a flour and water paste.
 1. Place dots of glue or paste onto strips of a paper towel.
 2. Press the seeds into the dots.
 3. Let the tape dry, then lay it on the wet sand and cover it with a thin layer of sand.
- **Aquascaping glue:** For a project where you need to attach seeds to a fixed object underwater in a terrarium, a cyanoacrylate-based gel like

[Seachem Flourish Glue](#)

is an option. This is safe for aquatic life and bonds to wood, rocks, and gravel in seconds, but it's not meant for planting on the seabed.

Important considerations

- **Salt tolerance:** Seeds need freshwater to germinate. Your seeds will need to be tolerant of salt and other coastal environmental conditions, including wind and poor nutrients.
- **Sand quality:** The type of sand matters. Fine, compacted sand, like play sand, can stifle germination when wet.
- **Biodegradability:** Most commercially available glues are not biodegradable and can leach chemicals into the environment, potentially harming plants and wildlife. The cornstarch gel and flour paste methods are biodegradable and safer for planting.

Can you provide more information about the type of seeds and your project?

mangrove seeds

You should not glue

mangrove seeds to wet sea sand, as it is unnecessary and could prevent them from growing. Mangrove seeds, or propagules, are naturally adapted to float in saltwater and embed themselves in muddy or sandy soil on their own.

How mangrove propagules naturally plant themselves

- **Viviparity:** Unlike most plants, mangrove seeds start germinating while still attached to the parent tree, producing a seedling called a propagule.
- **Buoyancy:** Once the propagule matures and detaches, it is buoyant and floats horizontally in the ocean currents.
- **Sinking and anchoring:** When the propagule encounters a suitable shallow, muddy, or sandy bottom, it changes its internal density, causing it to float vertically. This helps the propagule anchor itself tip-first into the seabed to take root.

The correct way to plant mangrove seeds

For mangrove species like the Red Mangrove (*Rhizophora*), the propagule is planted directly into the substrate.

1. **Select the right spot:** Choose a site free from strong waves and with a mix of mud and sand.
2. **Insert the propagule:** Push the propagule into the soil or mud, about 7 to 8 cm deep.
3. **Allow it to grow:** With proper lighting and water conditions, the propagule will continue to grow its roots and leaves.

Growing mangroves in a container

If you want to grow a mangrove in a controlled environment like a tank, you can use sand as a substrate.

1. **Use a container:** Place a layer of sand in a container with seawater and position the propagule upright.
2. **Anchor it:** For some species, you may need to anchor it with a weight or tie it to something so it doesn't move before its roots establish.
3. **Ensure air exposure:** The leaves and part of the trunk must remain above the water line.

Are you trying to plant a specific type of mangrove seed?

Avicennia alba

Similar to other mangroves, you should not glue *Avicennia alba* seeds to sand or mud. This species is also adapted to propagate naturally without assistance. *Avicennia alba* grows best in muddy or sandy soil on tidal flats.

How *Avicennia alba* propagates naturally

- **Cryptovivipary:** The seeds begin to germinate while still on the tree, and the embryo breaks through the seed coat before the fruit opens.
- **Water dispersal:** The fruits are buoyant and distributed by water.
- **Germination on site:** Once they land on a suitable tidal flat, the seedlings can establish themselves. The root radical penetrates the soil, and the cotyledon grows upward.
- **Aerial roots:** As the plant matures, it develops pencil-like aerial roots, called pneumatophores, that stick up from the soil to help the plant breathe in the anaerobic mud.

How to plant *Avicennia alba*

If you want to plant *Avicennia alba* in a controlled environment, such as a nursery, you can follow these steps:

1. **Prepare the seeds:** Soak the seeds in freshwater for 24 hours to help germination. You may also want to remove the fruit cover, which is susceptible to fungus.
2. **Use a good soil mix:** Plant the seeds in a pot with a mix of one part sand to one part potting soil.
3. **Place the seed properly:** Gently push the seed's radicle (the small root) into the soft mud so it is about one-third of the way covered.
4. **Create a tidal effect:** In your pot, maintain a water level that simulates tidal flooding and draining to provide the right conditions for the seedling.
5. **Acclimate the seedling:** Gradually increase the water salinity to help the seedling adapt to its saltwater environment.

Are you looking to plant *Avicennia alba* in a natural habitat or in a container?

what about *Sonneratia* seeds

You should not glue

Sonneratia seeds to wet sea sand, as it is unnecessary and could harm the germination process. Like other mangroves, *Sonneratia* seeds have natural adaptations for dispersing and anchoring themselves in muddy or sandy environments.

How *Sonneratia* seeds naturally disperse and germinate

- **Buoyant fruit:** The small seeds are contained within a buoyant fruit. This allows the fruits to float away from the parent tree, reducing competition for resources.
- **Seed release:** The fruit eventually ripens and decays, releasing the seeds. This usually happens when the fruit reaches an area of appropriate water salinity, a key trigger for germination.
- **Germination on site:** Once freed from the fruit, the seeds are ready to germinate when they land on a suitable substrate like mud or fine sand. Some species, like *Sonneratia caseolaris*, show higher germination rates in finer sand.

Quadrant II – Transcript and Related Materials

Seed Dispersal in Mangroves. Mangroves are found in the tropical, subtropical and intertidal regions of the world. They grow in sa...



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Substrate Preferences of The Germination Growth of *Sonneratia Caseolaris* Under Nursery Conditions. This undergraduate thesis studi...



How to plant *Sonneratia* seeds

For propagating *Sonneratia* in a controlled environment like a nursery, you can follow these steps:

1. **Select ripe fruit:** Harvest the fruits when they are ripe.
2. **Extract the seeds:** Gently press the fruits to detach the small seeds from the stalks.
3. **Prepare a seedbed:** Use a mix of materials like sand, potting soil, and compost to provide the right balance of nutrients and drainage.
4. **Sow the seeds:** For fine sand, simply broadcasting the seeds over the surface is effective. Press them lightly into the surface and cover them with a thin layer of soil.
5. **Replicate tidal conditions:** Use freshwater for initial watering, then gradually introduce brackish or saltwater to mimic the natural tidal environment. Ensure the soil remains moist.

What about *Rhizophora* seeds

You should not glue

Rhizophora seeds (also known as propagules) to sand or mud. Like other mangrove species, they are viviparous, meaning the seed germinates and grows into a ready-to-plant seedling while still attached to the parent tree. These propagules are naturally adapted to float in water and embed themselves without human intervention.

How *Rhizophora* propagules naturally plant themselves

- **Viviparity:** The long, green, cigar-shaped propagule grows from the fruit while still hanging from the branch.
- **Water dispersal:** When the propagule matures, it drops into the water and can float for a year or more. Initially, it floats horizontally and travels with the currents.
- **Anchoring:** When the propagule finds a suitable shallow, muddy, or sandy bottom, it changes its buoyancy to float vertically. This helps it lodge tip-first into the seabed and take root.

How to plant *Rhizophora* propagules

For planting in a controlled environment like an aquarium, nursery, or a restoration project, you should simply insert the propagule directly into the substrate.

For a natural habitat or nursery:

1. **Select a site:** Choose a spot in a tidal area with a mix of mud and sand.
2. **Insert the propagule:** Gently push the propagule tip into the soft substrate, about one-third of its length, until it is firmly anchored.

For an aquarium or container:

1. **Anchor it in the water:** Tie the propagule to a floating object or a rock to hold it upright. In a tank, many people use zip ties to attach it to the side or a rock.
2. **Let the roots grow:** Allow the roots to extend naturally down into the substrate. The propagule will also be happy growing with its roots suspended in the water.
3. **Ensure air exposure:** The leafy end of the propagule must remain above the water line.

In a natural habitat



Planting *Rhizophora* propagules in their natural habitat involves selecting a suitable intertidal area and pushing the seedling directly into the mud or wet sand. You should not use any adhesive, as this could harm the propagule and is not necessary for it to take root.

Steps for planting *Rhizophora* in a natural habitat

1. **Site selection:** Choose a protected area of a tidal flat where the water currents are not too strong and there is a mix of mud and sand. Look for areas where other mangroves are already established. The ideal sites are often found in estuaries or along tidal creeks.
2. **Inspect the propagule:** Use healthy propagules that are green and firm. Avoid any that look yellowed, shriveled, or damaged by pests.

3. **Plant the propagule:** Gently push the propagule's pointed end into the soft substrate. The planting depth should be about 2.5–5 cm, or roughly one-third of its length.
4. **Ensure stability:** The propagule should be secure enough to resist being washed away by tides but not so deeply planted that it prevents root growth.
5. **Timing:** Plant during low tide when the mud or sand is exposed. This will make it easier to access the planting site and ensure proper placement.

Mangrove restoration booklet - Panda.org

Method: 1) Make sure you have a healthy propagule, (sea pen) 2) Place it in the ground to its natural marker, about 2 inches. 3) R...



Panda.org



🔗 Curious about the nitty-gritty of mangrove planting? ... - Instagram

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Instagram

What to expect after planting

- **Natural rooting:** The propagule will develop new roots from the buried end.
- **Establishment:** The plant will eventually establish its distinctive stilt-root system, which helps it anchor and access oxygen in the anaerobic soil.
- **Long-term process:** Planting is often the first step in a mangrove restoration project. The long-term success of the new mangrove forest will require ongoing monitoring and maintenance.

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