

Mangrove Seeds and Their Role in Climate Adaptation and Coastal Ecosystem Management

SADR UL ANAM¹, ABDUL KAREEM VETTAN², POOJA SURESH³
AND JASMIN LAILA RASHEED^{3*}

¹Wageningen University and Research, Wageningen, The Netherlands

²Khor Kalba Mangrove Centre for Education and Conservation, Kalba Environment & Protected Area Authority, Govt. of Sharjah, UAE

³Dhameer Quality Consultancy LLC, Ajman, UAE

*jasmin.dhameer@gmail.com

(Received August 2025; Revised September 2025; Accepted September 2025)

ABSTRACT: Mangroves represent specialized coastal ecosystems that play a crucial role in shoreline stabilization, carbon storage, and biodiversity conservation. Their seeds and propagules possess unique physiological and morphological adaptations that enable successful germination and establishment under saline and waterlogged conditions. Understanding these biological traits is essential for developing efficient propagation and restoration strategies. This article examines the seed biology of mangroves, the environmental parameters influencing their germination, and practical approaches for seed handling and establishment. Methods including pre-sowing treatments, nursery techniques, and recent innovations such as drone-assisted dispersal are discussed with reference to their application in the United Arab Emirates. By integrating conventional and advanced propagation methods, the study highlights the importance of mangrove seed-based approaches in enhancing restoration success and contributing to climate-resilient coastal management.

Keywords: Mangrove seeds, germination biology, seed propagation, salinity tolerance, nursery techniques, UAE

INTRODUCTION

Mangroves are exceptional plants with specialized adaptations that enable them to thrive in intertidal zones constantly inundated with brackish or saline water. Their unique root systems, salt-excreting leaves, and oxygen-absorbing capabilities allow survival under conditions lethal to most terrestrial plants. These adaptations make mangroves crucial for stabilizing coastlines, preventing erosion, and buffering against storm surges and sea-level rise [1].

Mangrove seeds are biologically unique. Many species display vivipary, germinating while still attached to the parent tree, producing propagules ready to establish immediately after dispersal. These seeds are highly salt-tolerant, buoyant for long-distance dispersal, and can remain viable in water for extended periods, facilitating colonization of suitable habitats [2].

Mangroves play a key role in climate-resilient ecosystems, acting as blue carbon sinks and providing habitats for fish, crustaceans, and other wildlife [3, 4]. They support local livelihoods through fisheries, ecotourism, and sustainable resource use. International

initiatives, such as the UN Decade on Ecosystem Restoration (2021–2030), highlight the importance of mangrove conservation [5].

The UAE hosts significant mangrove forests, with Abu Dhabi accounting for approximately 85% of the nation's mangroves, dominated by *Avicennia marina*. These forests provide breeding grounds for fish, turtles, and other aquatic species, protect coastlines, and support projects like the Dubai Mangrove Project [1, 3].

Despite their ecological and socio-economic importance, limited documentation exists on effective propagation and seed management in the UAE. This study provides a comprehensive overview of mangrove seed production, including collection, preparation, germination, and planting techniques, aiming to support large-scale restoration and sustainable management of UAE mangrove forests.

Conditions Required for Mangrove Growth

Mangroves thrive under a narrow range of environmental conditions supporting their survival and unique adaptations. Temperature is critical, with the coldest



Figure 1



Figure 2

month's average remaining above 20 °C and seasonal variation below 5 °C to avoid disruption of physiological processes such as photosynthesis and salt regulation [4].

Soil texture is important; mangroves prefer finely textured substrates, such as silty clay or loam, which retain moisture and provide anchorage for extensive roots. Coarse or sandy soils may limit water retention and nutrient availability, reducing seedling establishment. Hydrological and coastal dynamics, including wave action and tidal currents, also influence propagule survival. Sheltered shores, estuaries, and tidal flats are preferred [4].

Salinity further defines mangrove distribution. These facultative halophytes tolerate brackish and saline water through root filtration and leaf salt excretion. Moderate salinity promotes growth, while extremes may reduce survival, highlighting the need for careful restoration planning.

Factors to Consider While Planting Mangrove Seeds

Timing and weather conditions

Successful mangrove establishment depends on precise timing and careful handling of seeds. The optimal planting season coincides with warm, humid conditions during the wet season. High rainfall and naturally elevated soil moisture during this period enhance germination rates

and root establishment. Planting outside this window, particularly in dry or cooler seasons, often leads to delayed sprouting, stunted growth, or seedling mortality [4].

Seed preparation and germination

Seed preparation and germination are equally important for ensuring successful propagation. Mangrove seeds may exhibit dormancy, which must be overcome for uniform germination. Pre-treatment such as soaking seeds in water for 24–48 hours softens the seed coat and improves water uptake. Mixing seeds with compost or peat moss provides nutrients and aeration. Seeds should be sown 1–2 cm deep in a well-drained seedling medium and maintained at 25–30 °C with indirect sunlight. Additional measures, such as periodic brackish water irrigation and microbial inoculation, can further enhance germination and early growth [5, 6].

Nutrient-rich soil

Although mangroves can survive in relatively poor and waterlogged soils, their growth and development are optimized when key macronutrients are available. Nitrogen, phosphorus, and potassium (NPK) play essential roles in photosynthesis, root development, and overall biomass accumulation. Typical optimal concentrations for mangrove growth are nitrogen 50–100 ppm, phosphorus 20–50 ppm, and potassium 100–200 ppm [7]. Trace elements like magnesium, calcium, and iron also influence seedling vigor and salinity resistance. Nitrogen promotes leaf and shoot development, phosphorus supports strong root systems and energy transfer within cells, and potassium regulates water balance and stress tolerance. In addition to these macronutrients, trace elements such as magnesium, calcium, and iron can influence seedling vigor and resistance to salinity stress. Fertilization may be necessary in degraded or highly saline soils to ensure sufficient nutrient availability, particularly for restoration projects where fast establishment of propagules is desired.

pH and salinity levels

Mangroves are adapted to a wide range of soil pH conditions, from slightly acidic to alkaline environments. Most species thrive in a pH range of 6.0–8.0, although some, such as *Laguncularia racemosa*, can tolerate pH values as high as 9.0, and *Rhizophora mangle* may survive in soils as acidic as pH 5.0. Soil salinity is equally

critical for mangrove growth, as these facultative halophytes have evolved mechanisms to tolerate brackish and saline water. Optimal salinity for most mangrove species ranges from 5 to 20 parts per thousand (ppt), though certain species can withstand levels up to 40 ppt. Salinity influences water uptake, nutrient availability, and overall physiological processes, including leaf succulence and salt excretion. Understanding the combined effects of pH and salinity is particularly important for restoration planning, as mismatched conditions can reduce seedling survival and long-term establishment [7].

SELECTING THE RIGHT SPECIES

- **Red mangrove (*Rhizophora mangle*)** – thrives in damp, muddy environments.
- **Black mangrove (*Avicennia germinans*)** – prefers drier, sandy soils.
- **White mangrove (*Laguncularia racemosa*)** – grows in swamps and saltwater marshes.

Water Requirements of Mangroves

Mangroves possess remarkable adaptability that enables them to thrive across a spectrum of water conditions, including freshwater, saltwater, and brackish environments. Their growth is strongly influenced by tidal cycles, which regulate nutrient exchange, oxygenation of the rhizosphere, and flushing of accumulated salts [8]. Tides also play a crucial role in dispersing propagules and in maintaining the hydrological balance necessary for root aeration. While mangroves can tolerate periods of inundation, consistent water levels are essential for seedling establishment and survival. Prolonged drought or excessive flooding can impair nutrient uptake, damage delicate root tissues, and increase mortality rates. Consequently, careful site selection and hydrological management are critical considerations in successful mangrove restoration projects.

Steps in Planting Mangrove Trees

The process of planting mangroves involves several carefully coordinated steps to ensure maximum survival and establishment. The first stage is ground preparation, which typically includes the removal of invasive or non-native plant species and the maintenance of muddy, moist soil conditions conducive to root anchorage. This step is vital as invasive weeds often compete aggressively for nutrients and water. The second stage is the selection of propagules, where healthy, mature seeds that are brown

or purple in color, straight, and fully developed are chosen for planting. The physiological maturity of propagules directly influences their germination success and subsequent growth performance.

Once suitable propagules are selected, they are planted with approximately one-third of their length buried in mud and the remaining two-thirds exposed above the soil surface. This method enhances root penetration while allowing the shoot to establish photosynthetic activity. In some cases, external support such as bamboo stakes may be provided to keep the young plants upright against tidal currents or strong winds. Post-planting management is equally important and involves regular monitoring of environmental conditions such as sunlight exposure, salinity, and water availability. Seedlings must also be protected from natural predators, including crabs and grazing livestock, which can significantly reduce survival rates.

Types of Planting

Different planting strategies are employed depending on ecological, logistical, and socio-economic considerations. One emerging method is drone-assisted seed dispersal, which allows for large-scale mangrove planting in remote or inaccessible areas. This technology enables rapid coverage of degraded landscapes while reducing labor costs and human effort, making it particularly useful for large restoration projects [9].

A more conventional technique is the hand sowing of seeds directly into intertidal zones. This method is cost-effective and requires minimal equipment, making it suitable for community-driven restoration efforts [10]. However, the success of direct sowing depends heavily on careful site selection and appropriate timing with tidal cycles to prevent seed wash-off.

Another widely practiced approach is the transplantation of nursery-raised saplings. In this method, young mangroves are cultivated under controlled conditions and

later transplanted into the field during low tide. Proper spacing, usually one to two meters apart depending on species, is crucial to avoid overcrowding and to allow healthy canopy development. While labor-intensive, this method offers the advantage of higher survival rates since saplings are already partially established and resilient to environmental stress [11].

REFERENCES

1. SPALDING M, M KAINUMA, L COLLINS (2010). World Atlas of Mangroves. Earthscan, London.
2. AL-MAYAH AA, WM AL-ASADI (2023). Germination percentage of Emirati and Iranian grey mangrove *Avicennia marina* (Forssk.) Veirn seeds and their growth rates in Basrah. College of Science, University of Basrah (unpublished report). ResearchGate upload, Sep 19, 2023.
3. ALSHAMSI AA, M SHETEIWY, KA EL-TARABILY, S ABUQAMAR (2023). Enhancement of mangrove growth performance using fish emulsion and halotolerant plant growth-promoting actinobacteria for sustainable management in the UAE. *Mar Pollut Bull*, 199:115916. doi:10.1016/j.marpolbul.2023.115916.
4. ENVIRONMENT AGENCY – ABU DHABI, MINISTRY OF CLIMATE CHANGE AND ENVIRONMENT, E NATURE – WWF (2024). Mangrove Restoration Guidelines for the United Arab Emirates. Abu Dhabi, UAE.
5. UNITED NATIONS ENVIRONMENT PROGRAMME, F A ORGANIZATION (2020). United Nations Decade on Ecosystem Restoration 2021–2030: Strategy. Nairobi, Kenya.
6. AZAD MS, NK PAUL, MA MATIN (2011). Effect of pre-sowing treatments on seed germination of *Albizia procera* (Roxb.) Benth. *Res J Agric Biol Sci*, 7(2): 183-186.
7. KŁUPCZYŃSKA EA, TA PAWŁOWSKI (2021). Regulation of seed dormancy and germination mechanisms in a changing environment. *Int J Mol Sci*, 22: 1357.
8. REEF R (2010). Nutrition of mangroves. *Tree Physiol*, 30: 1148-1160.
9. COLDREY JJ, A MURPHY, S MURPHY (2024). Evaluating stakeholder perceptions on drone use in forest restoration. *People Nat*, 6(2): 10660. doi:10.1002/pan3.10660.
10. ENVIRONMENT AGENCY – ABU DHABI (2022). Guidelines for Hand Sowing of Mangrove Seeds in UAE Coastal Areas. Abu Dhabi, UAE.
11. MINISTRY OF CLIMATE CHANGE AND ENVIRONMENT (2022). Best Practices for Transplanting Nursery-Raised Mangrove Saplings in the UAE. Abu Dhabi, UAE.