International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page:www.iscientific.org/Journal.html

© International Scientific Organization

Salinity-dependent study on mangrove seedling existence and development

Shivang Desai[1]*, Ashutosh Awasthi[2] andGarima Khaspuriya[3]

[1]*Parul University,PO Limda, Vadodara, Gujarat, India*
[2]*Teerthanker Mahaveer University, Moradabad, Uttar Pradesh, India*
[3]*Vivekananda Global University, Jaipur, India*

Abstract

Six widespread Mangrove survival of seedlings, the species *Avicennia marina, Bruguiera gymnorrhiza, Rhizophoraapiculata, R. mucronata, A. officinalis*, and *B. sexangula* were chosen over 30 weeks in low (3-5psu), intermediate (15-17psu), and high salinity conditions (33–36psu). High salinity seedlings performed considerably worse than those maintained under low and moderate salt regimes regarding rates of survival, total shoot height, average rates of growth, total leaf area, and average dry weight (p 0.05). The low-salinity method offered every ideal circumstance for seedlings of all species to establish themselves and flourish until they were 15-20 weeks old. Yet, the identical seedlings fared better with mild salinity at 15-20 weeks of age, suggesting that mangrove seedlings' physiology and salt tolerance differ with age. The results indicated must feed seedlings low-salt water until they are four to five months old, after which they should be given moderately salty water for best growth and Survival. This has practical implications for bringing up mangrove nursing species for planting.

Keywords: Bruguiera, Avicennia, early growth, nursery, mangroves, planting, salinity, Survival, Rhizophora

Full length article **Dr. Shivang Desai*, e-mail:shivang.desai24451@paruluniversity.ac.in

1. Introduction

The plant communities in mangrove forests are unique found only in arid biotopes comparable to estuaries,lagoons, and protected bays' intertidal zones in tropical as well as subtropical locations global. They may flourish under harsh environmental circumstances, including high temperatures, low air humidity, frequent tidal inundations with concomitant silt hypoxia, high salinity, and significant fluctuations in those parameters. The worldwide mangrove cover is still decreasing despite the ecological functions and economic advantages provided by mangrove ecosystems [1]. The primary causes of this continual loss are mangrove forest conversion to different land uses such dumping grounds, roads, industries, shrimp farms, and urban development. Mangrove conservation is now a top focus, involving extensive initiatives to restore the forest. The Indian government, for instance, has a busy mangrove restoration program initiative that was sparked in part by the tsunami that hit the Indian Ocean in 2004. The rehabilitation initiative attempts to offer protection against natural disasters like ocean surges. These planting campaigns, however, frequently lack reliable scientific evidence. Notwithstanding the high failure rates of numerous projects in India, governments, national and international non-governmental organizations, and coastal communities have all expressed a strong interest in mangrove restoration initiatives [2]. According to various studies, the main factors contributing to the failure of mangrove restoration were a lack of knowledge about the key ecological factors influencing mangrove health, including ecological salinity needs, acceptable hydrology and topography, and the proper species composition. One of about key elements affecting mangroves' development, dispersion, production, and health is salinity. It has been demonstrated that mangrove restoration operations at various sites affect the Survival and development of planted mangrove seedlings. Due to freshwater and saltwater imports, flooding, groundwater seepage, and evaporation, it regularly displays substantial geographical and temporal changes [3]. Understanding species-specific reactions to salt is crucial for mangrove planting initiatives. According to several research, seedlings from at least certain species develop the fastest when exposed to moderate salinity, such as 17.5psu. Some research, however, claims that water with a significantly lower salinity boosts production, growth, and Survival. Species differences and the capacity to maintain high water usage efficiency influence the salinity range that mangrove plants can withstand in the wild. Examples include *Avicennia marina*, which has a very high tolerance to salt, *Rhizophora mucronata*, which has a comparatively high tolerance to salt; and species with a moderate to poor tolerance for salt, including *Aegicerascorniculatum*, *Sonneratiacaseolaris*, and *Bruguiera sexangula* [4]. There is no documentation of the emergence also expansion species mangrove, particularly those accustomed a high salinity, as several about the subjects examined that is article that were exposed to such low salinity conditions regularly. According to some data, a mangrove species' ideal salinity may change with age, especially in the early stages of life. There aren't any studies that directly compare how various species' sensitivities to salt vary with age. If the tolerance to various salinity regimes is investigated over a longer length of time, this may be assessed accurately. Consequently, the primary goal of the current investigation was to investigate how Mangrove species frequently used in India planting initiatives vary in reaction to salt during their early growth stage to improve the efficiency of raising seedlings in nurseries for planting [5]. The mangrove ecosystem is a transitional habitat between terrestrial and marine zones and is impacted by high salinity soil and water, tidal waves, and water inundation. In terms of the physical, ecological, and socioeconomic elements, mangrove forests are significant. Ecotourism is one socioeconomic purpose of mangrove forests that may be improved [6]. The establishment of mangrove seedlings is mechanical disturbance provided [7] with waves and sediment movements. It has not yet been determined how different tolerant species of sediment movements are. Determined the differences in the size of propagule, stage of succession, and kind of embryonic development permissible sediment dynamics. The paper [8] Congested tourist visits can potentially harm ecotourism as a whole. Hence, it's crucial to understand the area's potential so tourist and conservation efforts can work harmoniously. Analysis of Maron Mangrove Edu Park's (MMEP) carrying capacity. The Clungup Mangrove Conservation Area (CMC) community at Clungup Beach, Malang Regency, applied ecotourism to the biocultural landscape. Although the method still needs some improvement and optimization, the community is immediately impacted by its effects, such as improved revenue, preserved natural conditions, and improved environmental consciousness [9]. Among the richest mangroves country in the global, Indonesia, accept put forth mangrove that is most ambitious restoration goal of any country (600,000 ha), which must be accomplished to accomplish numerous Objectives for Sustainable Development by 2024 (SDG 1-3, 6, 13 and 14). Nonetheless, attempts to restore and rehabilitate mangroves have often had low success rates and have been performed [10]. Threats to India's mangrove environment include over-harvesting pollution, the growth of invasive alien species, the use of mangrove products, habitat loss for buildings, climate change, and global warming. Successful restoration techniques are used at Kalpitiya, Pambala, and Negombo [11]. The pace at which certain mangrove species' seeds germinate. A hydro time model was used to describe how the medium's water potential and the rate at which seeds germinate. At 15, 25, and 35°C, seed germination was investigated in a NaCl light/dark gradient. To determine if these species act following the hydro time model's guiding principles, germination time courses and germination data were generated [12]. India's mangrove ecology, management, and conservation are provided [13]. India's mangrove management might be a key example for other countries as it was the first to conserve its mangrove forests formally in 2015. Mangroves, including a few small, thick mangrove forests, are occasionally present throughout India's coastal region. The paper [14] provided a crucial nursery environment a food source for animals other than fish and crabs. Urbanization and industrialization stresses brought on by anthropogenic forces, also swift climatic variation, mangrove forests in tropical are currently among the most vulnerable ecosystems on earth, which accept resulted in a loss of ecosystem services and livelihoods along the coast globally. The paper [15] suggested that the growth and geographic spread of mangrove forests are significantly influenced by the climate and edaphic factors. Six mangrove forests, three on the west coast and three on the east, have species composition and structural characteristics that vary with temperature and substrate salinity. In three distinct salinity treatments, low, moderate, and high, the growth and survival of seedlings were evaluated over a 30-week period. Six common mangrove species *R. mucronata,Rhizophoraapiculata, A. officinalis,Avicennia marina,*and *B. sexangula,Bruguiera gymnorrhiza* were chosen.

The following sections of the article are organized: The materials and techniques are summarized in Section II; Section III presents the recommended results and discussion in more depth. Section III concludes the study and offers suggestions for more research.

2. Materials and methods

2.1 Selection of species

To assess mangrove planting initiatives, an assessment of every complex of brackish water bodies, including lagoons and estuaries, throughout India's coastline between October 2012 and February 2014 was completed. When that assessment was done, every species of mangrove employed in planting initiatives was discovered. A significant portion of the mangrove seedlings planted were provided by R. apiculata B.L.and Rhizophora mucronata Lamk. The remaining plants were propagules or seedlings of *Bruguiera gymnorrhiza Lamk, Avicennia marina Vierh., A. officinalis L.*, and *B. sexangulaPoir*. The majority about plants that were implanet had received nursery care. These six varieties of mangroves were selected for the current investigation a result.

2.2 Experimental design

From natural mangrove sites, Cryptoviviparous fruits, in which the embryo develops to drop to the ground after breaking but not the fruit wall, through the seed coat. were collected also used as planting materials. Sand, organic matter, and sieved loam soil were combined in a 1:1:1 (v/v) ratio to create sandy soil. The produced soil mixture was placed inside plastic pots with the collected propagules, which were then stored until the first two leaves appeared, in a nursery, and then washed with new water —considering that they would have the same vigor, seedlings whose first two leaves that unfolded during the same brief period were used in the experiment. Each species' 27 young seedlings, perfectly around the same breadth, were moved individually into a giant plastic bag containing same soil combination.

The three salinity treatments in this study have names based on the salinity range that naturally occurs in Indian lagoons and estuaries; lagoons and estuaries in India have salinities more than fortypsu. The pretty uncommon, especially during drought situations. The average seawater pressure is 36 psu. Low salinity, moderate salinity, and high salinity were the three salinity treatments employed. For irrigation of pots with mangrove seedlings, separately, mixed old tap water with these salinities to create the water with seawater or by storing water a few days in open containers before to use to get rid of extra chlorine. According into an entirely random design, pots containing seedlings were dispersed on individual 7.5 cm-deep plastic trays placed outside benches. The salinity-appropriate water for each pot was watered each pot twice daily. The water collected on trays and drained from pots were added tanks originally used. Every three days, the salinity of the water in the tanks was assessed using a portable refractometer and adjusted as necessary based on the preliminary investigation findings. Commercial fertilizer was treated once per month with the same amount per pot. From 11.45 and 14.30 hours, the greenhouse saw an average light level of 49400.5, with a standard deviation of 780.3.

2.3 Data collection

Each mangrove species' number of surviving seedlings was counted once every week. Once every two weeks, the shot elevation was measured to crypto-viviparous plants, starting with each's tip seedling to the soil hypocotyl apex to the point of every seed about viviparous seedlings. The height of the central axis was multiplied by the sum of all branch lengths, and the result was regarded as the total shot height. Every week, the quantity of leaves on each seedling is likewise counted. Although this is a crucial earlier lifestyle time during the sapling and seedling process, all live seedlings were taken after 30 weeks of development. To preserve as much of the root system as possible, the soil was carefully cleansed by submerging plants after being taken from their plastic containers. The height of the essential axis was multiplied by the sum of all branch lengths, and the result was regarded as the total shot height. Every week, a seedling's total number of leaves likewise counted. Although a seedling's total number of leaves in the sapling also seedling process, all live seedlings were taken after 30 weeks of development. To preserve as much of the root system as possible, the soil was carefully cleansed by submerging plants after being taken from their plastic containers. After being thoroughly cleaned, plants were divided into their leaves, stems, roots, and hypocotyls. Except for hypocotyls, the current weights of each plant's other three sections were calculated, and the entire leaf area of each manually operated plant was calculated using mm graph paper (the area covered by each leaf's outline after it had been spread over the form with a pencil was the leaf space). The parts were oven-dried at 80 degrees celsius to determine their dry weights. Individual plant weight differences among fresh and dry states were used to assess water quantity, and the % water quantity was computed as described:

$$Percentage\ water\ content = \frac{Fresh\ weight - dry\ weight}{Fresh\ weight} \times 100 \quad (1)$$

Thecumulative shoot height, mean percentage, mean dry weight,water content, and mean total leaf region of seedlings produced down varied salinity conditions do also investigated. Each of these two factors was looked at independently in cases where there were significant interactions between them, and Tukey tests were used to identify level differences. To enable visual interpretation of substantial variations across all factors examined, information was given with 95% confidence intervals.

2.4 Data Analysis

Two-way ANOVA was used to examine the four parameters translate to shot height (elevation just at the end of the investigation), among the permanent element species and salt phases, the average total leaf area, average dry weight, and average percentage of water. The remaining were inspected to see whether any modifications were necessary.

3. Results and Discussions

3.1 Rates of Survival

Figure 1 shows that low salinity treatments had much higher mangrove seedling survival rates than did moderate and high salinity treatments. The better average survival rates were seen in low and moderate salinity environments after the research period. The therapy with high salinity showed similarly lowest percentages of Survival. Across the three treatments, there were qualitative differences in the survival curve forms. For most species exposed to excessive salinity, Survival dropped at steady rates. For all kinds, except for the two Avicennia species, a low- and moderate-salinity treatment's chance of survival, however, exhibited early minor decreases followed by relative consistency.

3.2 Growth performances

The six species' shoot heights each of the three salinities exhibited minimal growth before the fifth week, although increases following that were evident, as shown in Figure 2. Throughout the research period, the shoot heights of all the organisms' seedlings cultivated in rose high salinity slower than the matured in low and moderate salinity. The final two species of Rhizophora'sspp heights. Seedlings and the *B. gymnorrhiza* seedlings cultivated in the medium salinity treatment washigher compared to people that are lowly salinity treatment. Figure 3 shows how the rate of growth varies by species. The species of Bruguiera and Avicennia generally had every most effective and lowest growth rates, respectively, whereas Rhizophoraspp had growth rates that fell in the middle.

Many differences in the rise in the rates of the six species, but there were also some similarities. For instance, in 6 species individually, mean growth rate of people raised in high salinity conditions remained lower during the course of the research than that of those raised in moderate along with low salinity conditions. The pattern about variance in the growth rates of all six species underwent a shift in mid or 3rd half of the experimentation phase. Around the 15th to 20th week of the moderate salinity therapies, the growth rates started to outpace those of the deep salinity treatment. All six mangrove species cultivated below the lowest salinity treatment saw more excellent mean growth rates than those grown below the medium salinity treatment before the change in optimum salinity. Except for B. gymnorrhiza, all species grew much more quickly in moderate salinities after the difference in the ideal salinity.

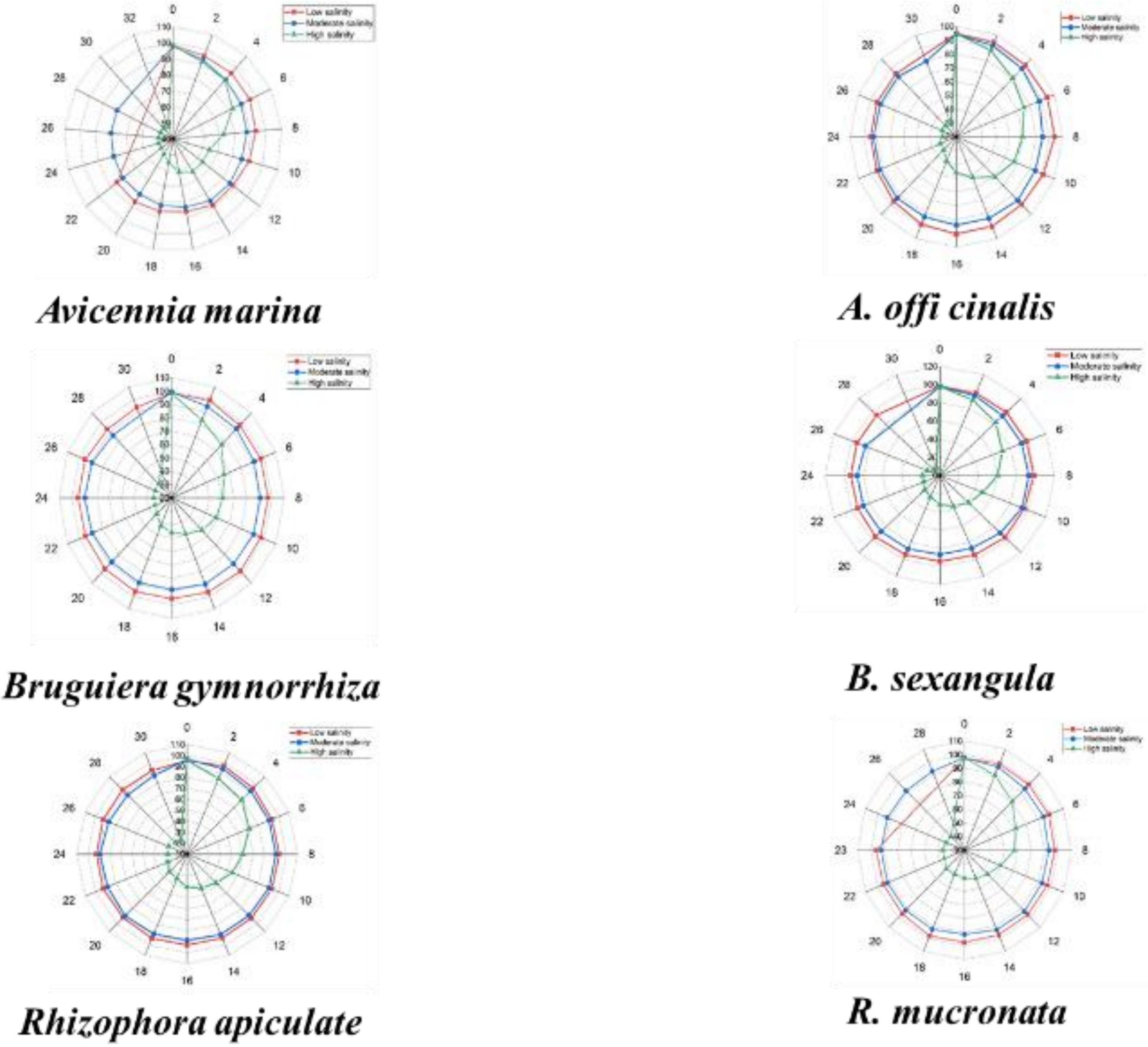

Figure 1: Mean (within 95% confidence interval) percentage of mangrove seedlings that survived against age in six distinct salinity regimes

Table 1: Mean dry weight (g)

Salinity regime	Mean dry weight (g) of different mangrove species					
	A.*officinalis*	*A.marina*	*B.sexangula*	*B. gymnorrhiza*	*R.mucronata*	*R. apiculata*
Low	26.6 $\pm$5.0^a	26.9 $\pm$2.7^a	27.2 $\pm$5.8^a	31.3 $\pm$5.7^a	32.6 $\pm$3.7^a	27.1 $\pm$ 2.4
Medium	25.3 $\pm$2.7^a	31.2 $\pm$4.0^b	24.0 $\pm$3.8^a	32.4 $\pm$4.3^a	31.4 $\pm$3.4^a	31.3 $\pm$2.1^a
High	8.5 $\pm$1.8^b	10.4 $\pm$2.6^c	5.6 $\pm$2.5^b	9.7 $\pm$2.5^b	11.6 $\pm$1.6^b	11.1 $\pm$1.5^b

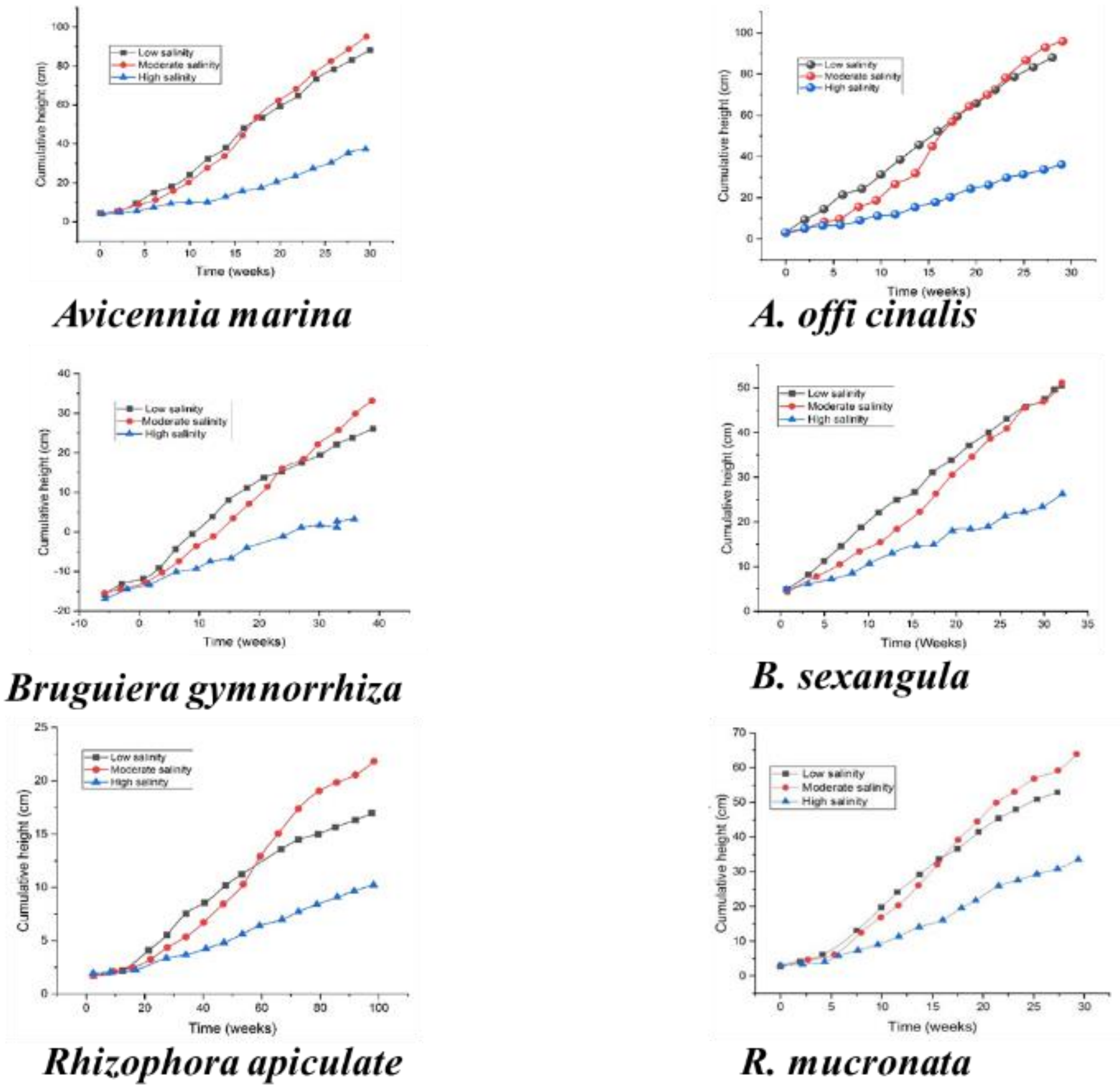

Figure 2: Mean cumulative shoot height versus age of seedlings from six different species of mangroves under varying salinity regimes throughout development

Table 2: Mean total leaf area (cm^2)

Salinity regime		Total leaf area (cm^2) of different mangrove species				
	A.officinalis	*A.marina*	*B.sexangula*	*B. gymnorrhiza*	*R.mucronata*	*R. apiculata*
Low	102.7 $\pm 8.6^a$	403.5 $\pm 7.0^a$	201.2 $\pm 15.8^a$	110.0 $\pm 9.7^a$	232.6 $\pm 8.7^a$	214.1 $\pm$ 2.4
Medium	25.3 $\pm 2.7^a$	106 .2 $\pm 4.0^b$	201.0 $\pm 3.8^a$	132.4 $\pm 9.3^a$	31.4 $\pm 11.4^a$	255.3 $\pm 8.1^a$
High	45.5 $\pm 5.8^b$	43.3 $\pm 6.6^c$	5.6 $\pm 6.5^b$	55.7 $\pm 51.5^b$	115.6 $\pm 18.6^b$	89.1 $\pm 6.5^b$

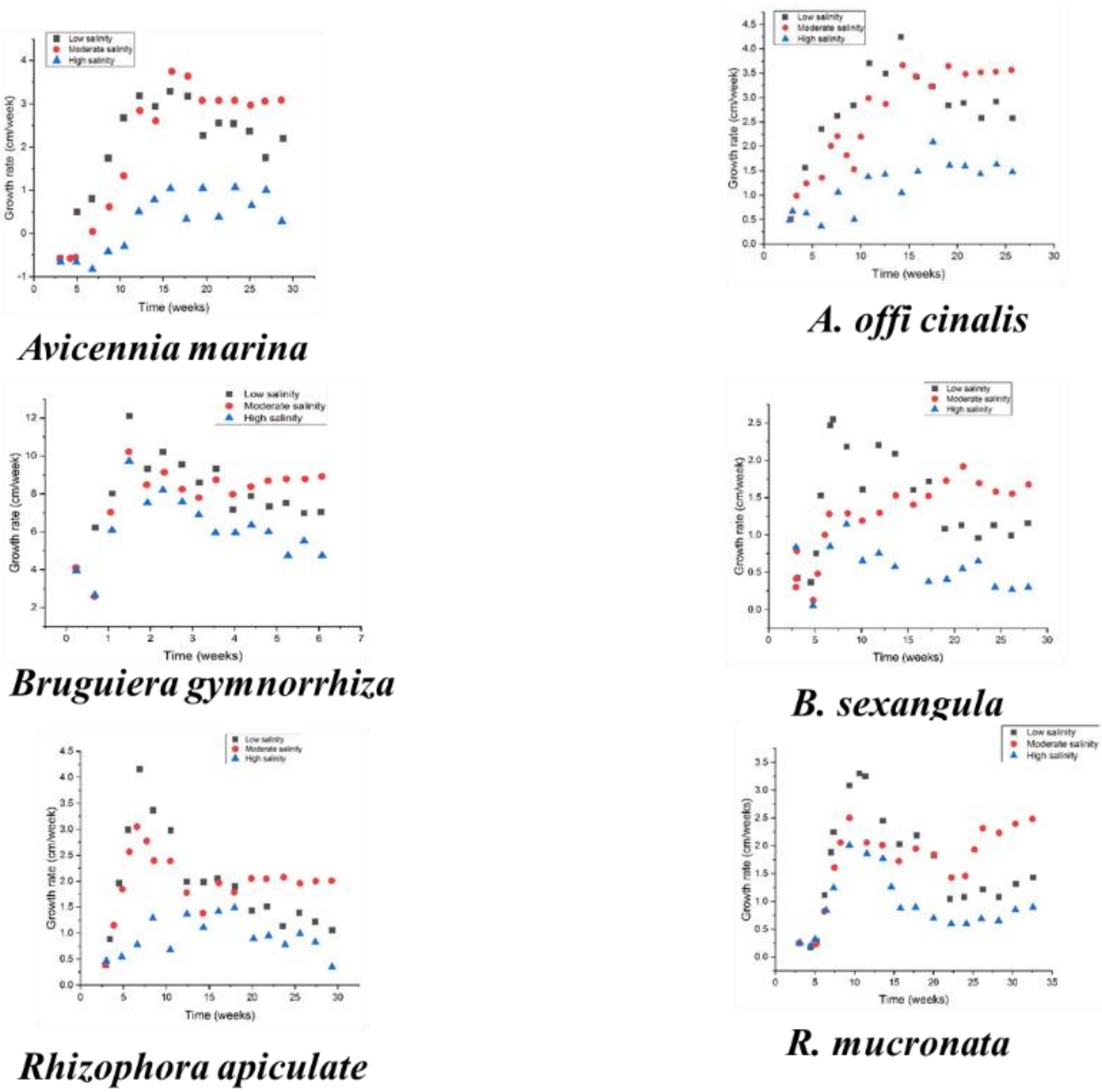

Figure 3: The weekly increment in shoot height or mean growth rate of three different mangrove species grown in a greenhouse at low, moderate, and high salt levels.

Table 3: Mean percentage water content (%)

Salinity regime	Percentage water content (%) of different mangrove species					
	A.marina	*A.officinalis*	*B. gymnorrhiza*	*B.sexangula*	*R. apiculata*	*R.mucronata*
Low	11.5 ± 4.1^a	79.7 ± 4.6^a	81.0 ± 2.7^a	771.2 ± 3.8^a	11.1 ± 2.4	71.6 ± 2.7^a
Medium	$60 .2 \pm 4.2^b$	45.3 ± 2.7^a	132.4 ± 2.3^a	201.0 ± 1.8^a	255.3 ± 4.5^a	62.4 ± 11.4^a
High	63.3 ± 4.6^c	45.5 ± 5.8^b	75.7 ± 5.5^b	75.6 ± 1.5^b	89.1 ± 6.5^b	71.6 ± 12.6^b

Towards the conclusion of the research period, the rise rates of low salinity allowed the seedlings to grow regime had begun to decline. As shown in Table 1, the mean dry weights (total biomass) and mean leaf area of each of the six species' 30-week-old saplings planted in the high salinity therapies were less than those raised in the other two treatments. The high salinity treatments caused the seedlings of all six species to grow will have mean dry weights that were roughly half individuals raised in conditions of low and moderate salinity.

Moreover, as shown in Tabs. 1, 2, there were no appreciable variations in between low and medium salinity environments, mean dry weight or mean leaf area. Table 3 shows that, except for A. officinalis and R. mucronata, each species produced in a low salinity environment had a mean water content that was greater than saplings raised in the other two salinity regimes.

Because it was necessary to expose the slowly evolving reactions of mangrove seedlings, during a lengthy period of 30 weeks, the present research studied reactions of mangrove seedlings in less, medium, and greater salinity environments. In this experiment, mangrove seedlings were built below a high salinity regime. As a result, growth performances, such as mean dry weight, mean total leaf area, and cumulative shoot height, were reduced along decreased preservation rates. However, many additional studies have shown that optimum expansion rates should happen in concentrations ranging from 5 to 75 percent saltwater, consistent with the most significant growth at moderate salinity. Based on this research, a large number of ecologists and planting experts advice average salinity requirements into produce with mangrove seedlings the best development also vigor in plant nurseries and planting locations. Low salinity is suitable for establishing mangrove seedlings quickly using a more significant effect.

Nevertheless, after 15–20 weeks, things started to shift, and all six of the examined mangrove species reported their maximum growth rates when given a moderately salty treatment. This circumstance persisted until the experiment's conclusion, suggesting that after 4-5 months of growth, the salinity most conducive to mangrove seedlings' optimal growth shifts from low to moderate. The indicated A. marina seedling weights grown at a medium salinity towards the experiment's conclusion were higher compared to those raised in low-salinity environments. The pathways of growth imply the different animals would have displayed equivalent variations providing more space. Although same total leaf area is low and moderate salinities can be found, the higher biomass in the typical salinity treatment buildup may be caused by the increased leaf chlorophyll content under reasonable salinity circumstances compared to a low saline environment. The procedure was repeated twice for verification, and the findings proved identical in each experiment. In this research, the shift in the optimal salinity for improved performance is used to describe this changing response to salinity.

Thus, seedlings need relatively greater salt levels roughly 4-5 months after initial establishment to achieve and sustain optimal growth and metabolic activities. Mild salinity may specifically assist water intake in maintaining optimal plant water status. This is further corroborated by the observation that, after the 20th week of growth, in the salt concentration environment, there was a tendency for the six species of mangrove seedlings' development rates to slow down.

4. Conclusions

The finding is that cheap salinity requirements are better suited for early organization and have a greater survival rate for mangrove seedlings. By the age of around five months, the examined mangrove species, however, tend to require moderately saline environments. This implies that needs for salt differ according to every maturity of mangrove seedlings, and that an slightly above proportion about salt necessary approximately five months after the founding. High salinity harms growth and causes poor survival rates. Mangrove seedlings are frequently moved while the salinity is low during the rainy season once they are placed in nurseries, believing they would have a greater rate of survival. Rhizophora is effectively employed in mangrove planting in moderate environments, according to the survival rate, growth features, and water conservation technique. Different genus, including Avicennia, might serve as nursing organisms in highly salty situations. The fundamental problem that mangrove seedlings are often cultivated and managed in nurseries, where they will be typically watered with fresh or brackish water according on availability, disregarding the water's salinity, is addressed in this work. This approach might cause seedling death at an early stage.

To enhance mangrove planting, it can be suggested to first rinse until they are 4 to 5 months old, nursery plants are watered with low-salt, then moderate-salt. The age of every nursery plants should be considered when choosing the optimal time of year to transfer them to the field. Imagine that mangrove propagules are employed right away for planting, as is typical for mangrove restoration projects. In that case, this should be done as soon as possible because low salinity conditions are preferred during early establishment, before the rainy season. To ensure accurate synchronization of seedling physiology and environmental factors, it is advised to have a thorough awareness seasonally salinity variations into each specific authorizing location. Planting seedlings might reduce the need for the wetter months to coincide, with the evolving sensitivity as reported here for salinity.

References

[1] M.J. Wu, B. Xu, and Y.W. Guo, (2022). Unusual secondary metabolites from the mangrove ecosystems: Structures, bioactivities, chemical, and bio-syntheses. Marine Drugs, 20(8), p.535.

[2] C.E. Lovelock, E. Barbier and C.M. Duarte, (2022). Tackling the mangrove restoration challenge. PLoS biology, 20(10), p.e3001836.

[3] A.M. Ellison, A.J Felson and D.A. Friess, (2020). Mangrove rehabilitation and restoration as

experimental adaptive management. Frontiers in Marine Science, 7, p.327.

[4] G.J.W Webb, C. Manolis, M.L. Brien, S.A. Balaguera-Reina, and S. Isberg, (2021). Crocodylus porosus. The IUCN Red List of Threatened Species 2021: e. T5668A3047556.

[5] S. Raguraj, S. Kasim, N. MdJaafar and M.H. Nazli, (2022). Growth of tea nursery plants is influenced by different rates of protein hydrolysate derived from chicken feathers. Agronomy, 12(2), p.299.

[6] M.J. Bersaldo, G.P. Dalagan, C.J. Felix, and M.L. Orbita, (2023). Growth dynamics and Survival of mangroves (Rhizophoraceae) seedlings in Guang-guang, Mati City, Davao Oriental, Philippines. Aquaculture, Aquarium, Conservation & Legislation, 16(1), pp.534-545.

[7] R. van Hespen, Z. Hu, Y. Peng, Z. Zhu, T. Ysebaert, and T.J. Bouma, (2022). Identifying trait-based tolerance to sediment dynamics during seedling establishment across eight mangrove species. Limnology and Oceanography, 67(10), pp.2281-2295.

[8] H. Poedjiastoeti, H. Widyasamratri, and C.D. Arista, (2022). Analysis of The Carrying Capacity of Tourism Area in Maron Mangrove Edu Park (MMEP) Semarang. In IOP Conference Series: Earth and Environmental Science (Vol. 955, No. 1, p. 012020). IOP Publishing.

[9] R. Parmawati, and R. Hardyansah, (2022). The Role of Ecotourism in Biocultural Landscape to Harmonize Nature and Human towards Sustainable Development: Clungup Mangrove Conservation Area as a Case Study. In Conserving Biocultural Landscapes in Malaysia and Indonesia for Sustainable Development (pp. 99-109). Singapore: Springer Singapore.

[10] S.D. Sasmito, M. Basyuni, A. Kridalaksana, M.F. Saragi-Sasmito, C.E. Lovelock, and D. Murdiyarso, (2023). Challenges and opportunities for achieving Sustainable Development Goals through restoration of Indonesia’s mangroves. Nature Ecology & Evolution, pp.1-9.

[11] M. Vierros, 2017. Communities and blue carbon: the role of traditional management systems in providing benefits for carbon storage, biodiversity conservation and livelihoods. Climatic Change, 140(1), pp.89-100..

[12] X. Chen, Z. Wei, D. Chen, and X. Hu (2022). Base water potential but not hydrotime predicts seedling emergence of Medicago sativa under water stress conditions. PeerJ, 10, p.e13206.

[13] P. Ragavan, S.K. Dubey, J.C Dagar, P.M Mohan, P.M, K. Ravichandran, R.S.C Jayaraj and T.S., Rana, (2019). Current understanding of the mangrove forests of India. Research developments in saline agriculture, pp.257-304..

[14] E.S. Bindiya, P.M. Sreekanth, and S.G. Bhat, (2023). Conservation and Management of Mangrove Ecosystem in Diverse Perspectives. In Conservation and Sustainable Utilization of Bioresources (pp. 323-352). Singapore: Springer Nature Singapore.

[15] D.A Friess, M.F Adam, J.B Adams,. and C.E Lovelock,. (2022). Mangrove forests under climate change in a 2 C world. Wiley Interdisciplinary Reviews: Climate Change, 13(4), p.e792..