VOLUME 12 NOMOR 1 JUNE 2025 ISSN 2548 – 611X

JURNAL
BIOTEKNOLOGI & BIOSAINS INDONESIA

Homepage Jurnal: http://ejournal.brin.go.id/JBBI/index

THE EFFECT OF AMMONIUM-BASED NPK FERTILIZERS ON THE GROWTH OF MANGROVE SEEDLINGS *Rhizopora mucronata* AND *Rhizopora stylosa*

Pengaruh Pemberian Pupuk NPK Berbasis Amonium terhadap Pertumbuhan Bibit Mangrove *Rhizopora mucronata* dan *Rhizopora stylosa*

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ABSTRACT

Mangroves play an important role in coastal ecosystems, but their growth is often limited by nutrient availability, particularly nitrogen, phosphorus, and potassium (NPK) availability. The use of ammonium-based fertilizers can provide additional benefits by accelerating the growth of mangrove seedlings. This study examines the influence of various doses of ammonium-based NPK fertilizers on the growth of two mangrove species, *Rhizophora mucronata* and *Rhizophora stylosa*, The study was carried out in two different places with distinct environmental characteristics, *Rhizophora mucronata* was planted near land, whereas *Rhizophora stylosa* was planted in open areas near the sea. The seedlings received dosages of ammonium-based NPK fertilizer. Periodic measurements of growth characteristics, including leaf length, root length, plant height, and SPAD (Soil Plant Analysis Development) index, were conducted and tested statistically. *Rhizophora mucronata* responded effectively to ammonium-based fertilizer treatment, increasing plant height, root length, and chlorophyll content at an optimal dose of 0.9 grams per, although shoot growth decreased. These data show that *Rhizophora mucronata* is more responsive to ammonium- based fertilizer treatments than is *Rhizophora stylosa* under the evaluated environmental conditions, although the fertilizer dosage had no significant effect.

Keywords: *Mangrove ecosystems, Seedling growth, Rhizophora mucronate, Rhizophora stylosa, Biodiversity conservation, Wetland ecology*

ABSTRAK

Mangrove memainkan peran penting dalam ekosistem pesisir, namun pertumbuhannya seringkali terbatas oleh ketersediaan hara, terutama nitrogen, fosfor, dan kalium (NPK). Penggunaan pupuk berbasis amonium dapat memberikan manfaat tambahan dalam mempercepat pertumbuhan bibit mangrove. Penelitian ini berfokus pada pengaruh pemberian beberapa dosis pupuk NPK berbasis amonium terhadap pertumbuhan dua spesies mangrove, *Rhizophora mucronata* dan *Rhizophora stylosa*. Penelitian dilakukan di dua lokasi dengan karakteristik lingkungan berbeda, yaitu *Rhizophora mucronata* ditanam di dekat daratan, sementara *Rhizophora stylosa* ditanam di area terbuka dekat laut. Parameter pertumbuhan diuji secara statistik, seperti tinggi tanaman, panjang akar, panjang daun, dan indeks SPAD (*Soil Plant Analysis Development*) diukur secara berkala. Hasil penelitian menunjukkan *Rhizophora mucronata* memberikan respons positif terhadap pemberian pupuk berbasis amonium dengan peningkatan tinggi tanaman, panjang akar, dan kadar klorofil pada dosis optimal 0,9 gram per 1,5 Kg berat tanah meskipun terjadi penurunan pada pertumbuhan tajuk. Temuan ini mengindikasikan bahwa

***Received**: 25 November 2024* ***Accepted**: 14 April 2025* ***Published**: 1 June 2025*

Rhizophora mucronata lebih responsif terhadap aplikasi pupuk berbasis amonium dibandingkan *Rhizophora stylosa* dalam kondisi lingkungan uji meskipun pengaruh dosis pupuk tidak memberikan pengaruh yang signifikan.

Kata Kunci: *Ekosistem Mangrove, Pertumbuhan bibit, Rhizophora mucronata, Rhizophora stylosa, Konservasi biodiversitas, Ekologi lahan basah*

INTRODUCTION

Mangrove forest ecosystems exist at the interface between terrestrial and marine environments. This ecosystem is characterized by high salinity, strong winds, high temperatures, muddy sediments, tidal fluctuations, and anaerobic soils (Kathiresan and Bing- ham 2001). These ecosystems provide significant environmental and economic value to many tropical and subtropical countries (Hochard *et al.* 2019). Additionally, compared with other ecosystems, mangroves are well known for their high ability to generate biomass. The intensive decomposition of organic matter makes mangroves a critical ecological link, serving as a food source and nursery for various species such as fish, shrimp, and crabs (Imran and Efendi 2016).

Mangrove forests play a crucial role in carbon sequestration, storing higher carbon levels than most other forests do globally (Rachmawati *et al.* 2014). In fact, mangroves can hold up to three times more carbon than terrestrial tropical forests, with sediment layers storing as much as 956 Mg C Ha^{-1} (Kusumaningtyas *et al.* 2019). By acting as a buffer between land and water ecosystems, mangroves help filter heavy metal pollutants (such as Mn, Fe, Zn, Cu, Cr, Pb, and Cd) from terrestrial sources through mechanisms such as rhizodegradation, phytoextraction, and phytovolatilization. The ability of these bacteria to absorb up to 100% of heavy metals in tropical coastal environments underscores their importance in maintaining environmental quality (Piwowarska *et al.* 2024).

As an archipelagic nation with extensive coastal areas, Indonesia is home to vast mangrove forests. However, these forests have significantly declined. According to data from the Indonesian Central Bureau of Statistics as of December 2023, the country's mangrove ecosystem spans 3.32 million hectares, yet the FAO (2007) reported that Indonesia has lost approximately 40% of its mangrove coverage over the past 30 years. The primary causes include human activities such as agriculture, aquaculture, and sand

mining, which have led to coastal erosion, tidal flooding, and damage to fish and shrimp ponds (Karminarsih 2007). One of the significant mangrove areas is in Karawang Regency, particularly in Cilamaya Wetan District (Muarabaru village) and Cilamaya Kulon District (*Desa Sukajaya*). These areas are predominantly inhabited by *Rhizophora mucronata* and *Rhizophora stylosa* species. *R. mucronata* thrives on soft, muddy substrates, which are supported by the root morphology that penetrates the soil, often positioning *R. mucronata* in terrestrial ecosystems. Moreover, *R. stylosa* grows well on sandy substrates, positioning *R. stylosa* in aquatic ecosystems because of its stilled root structure and resistance to salinity stress.

To support the sustainability of the *Rhizophora* sp. mangrove ecosystem in these areas, optimizing seedling growth is essential, particularly by supplying essential nutrients such as nitrogen, phosphorus, and potassium (NPK) to support vegetative growth, root development, and plant health. Trisnawati *et al.* (2017) revealed that a dosage of 12 grams per 10 kg of medium resulted in optimal seedling mangrove growth. However, further studies on the effectiveness of NPK-based fertilizers for *R. mucronata* and *R. stylosa* are still lacking. Owing to the frequent waterlogging in mangrove ecosystem, selecting the appropriate nitrogen form for NPK fertilizer is especially crucial.

Ammonium ions ($NH4^{+}$) are the most readily absorbed form of nitrogen by mangrove plants under anaerobic conditions

(Reef *et al.* 2010), where nitrification is inhibited due to the lack of oxygen, affecting chemical processes in the soil, including nutrient absorption by plants. Additionally, ammonium not only enhances vegetative growth but also supports root development in plants exposed to waterlogged conditions. With increased root absorption capacity, plant growth can be more efficient in term of acquiring the necessary nutrients. These characteristics make ammonium a more suitable form of nitrogen for mangrove ecosystems.

A similar study regarding the application of NPK fertilizer on mangrove seedlings has been conducted by Rahman *et al*. (2020). However, the study did not specifically focus on ammonium-based NPK fertilizer. Additionally, the research did not include testing on *R. mucronata* and *R. stylosa* species.

`Therefore, research on the response of *R. mucronata* and *R. stylosa* to The effectiveness of ammonium based NPK fertilizers in promoting mangrove seedling growth must be assessed. This study aimed to evaluate the effects of different ammonium based NPK fertilizer dosages on these two species and identify which species presented the best growth response. The results of this study can serve as a recommended fertilization dosage, particularly for the NPK 15-15-15 formula. Furthermore, by providing an optimal fertilization dosage, it is anticipated that the quality of mangrove seedlings will improve, the availability of high-quality seedlings will be accelerated, and the local community's economy will be enhanced.

MATERIALS AND METHODS

Study Area and Setting

A nursery trial was conducted from January to May 2023 at the Plantation Trial Unit at Bengkel Mangrove Indonesia, located in Muara village, Cilamaya Wetan District, Karawang Regency, with geographic coordinates -6.194499, 107.611809. This location was chosen for its diverse mangrove ecosystems, which encourage research into mangrove seedling development by examining two species with distinct environmental adaptations: *Rhizophora mucronata*, typically found in landward zones, and *Rhizophora stylosa*, which thrives in open coastal areas near the sea.

Materials

Mud soil collected from the study site was used as the primary planting medium. The mangrove seedlings were *R. mucronata* and *R. stylosa*. Ammonium-based NPK fertilizer with a 15-15-15 formulation was applied for fertilization, while water was used for irrigation.

The equipment involved included 15 × 10 cm polybags for planting, measuring tapes to measure plant height, ovens, SPAD meters, plastic bags 30 L, measuring cups, cutting tools, and digital scales for weighing fertilizer and plant samples.

Methods

The experimental design was a completely randomized design (CRD) with four treatments and three replicates, resulting in 12 experimental units for each species. The experiment involved different NPK fertilizer treatments: P1 = control (no fertilizer); P2= 0.3 g fertilizer; P3 = 0.6 g fertilizer; P4 = 0.9 g fertilizer. Each treatment was applied to polybag which filled with 1.5 kg of soil.

The procedures consisted of site preparation, initial soil analysis, medium preparation, seedling planting, fertilizer treatment, and maintenance through watering and weeding. The observed parameters included plant height, root and shoot length, leaf count, and leaf greenness measured with a SPAD meter. Data analysis was conducted via One Way ANOVA to assess differences among the treatments.

RESULTS AND DISCUSSION

The statistical analysis results for *Rhizophora mucronata*, as displayed in Table 1, reveal p-values of 0.8 for root length, 0.93 for shoot length, 0.72 for SPAD leaf 3, and 0.7 for SPAD leaf 4. Since all p-values exceed 0.05, it can be concluded that there are no significant differences between the treatments for any of these measured parameters.

Table1. Statistics Data Analysis of *R. Mucronata*

Parameter	Treatment	Mean ± SD	P value
Root Length	Control	20.67 ± 3.33 a	0.8
	0.3 gr	18.33 ± 4.54 a	
	0.6 gr	19.5 ± 0.90 a	
	0.9 gr	21.25 ± 2.25 a	
Shoot Length	Control	74.25 ± 3.54 a	0.93
	0.3 gr	71.33 ± 1.01 a	
	0.6 gr	73.5 ± 3.69 a	
	0.9 gr	73.17 ± 0.80 a	
SPAD Leaf 3	Control	55.82 ± 1.47 a	0.72
	0.3 gr	54.68 ± 1.38 a	
	0.6 gr	53.23 ± 4.02 a	
	0.9 gr	57.06 ± 1.53 a	
SPAD Leaf 4	Control	55.71 ± 3.20 a	0.7
	0.3 gr	54.31 ± 2.29 a	
	0.6 gr	55.43 ± 3.77 a	
	0.9 gr	57.38 ± 1.55 a	

Table 2. Statistics Data Analysis *R. Stylosa*

Parameter	Treatment	Mean ± SD	P value
Root Length	Control	16.08 ± 3.88 a	0.77
	0.3 gr	13.25 ± 1.52 a	
	0.6 gr	13.25 ± 4.98 a	
	0.9 gr	14.58 ± 2.18 a	
Shoot Length	Control	63 ± 3.07 a	0.7
	0.3 gr	62.08 ± 1.28 a	
	0.6 gr	60.92 ± 4.19 a	
	0.9 gr	65.38 ± 4.35 a	
SPAD Leaf 3	Control	51.05 ± 0.93 a	0.75
	0.3 gr	51.84 ± 4.97 a	
	0.6 gr	48.62 ± 4.03 a	
	0.9 gr	50.3 ± 3.67 a	
SPAD Leaf 4	Control	51.21 ± 1.69 a	0.63
	0.3 gr	53.26 ± 3.36 a	
	0.6 gr	51.08 ± 2.74 a	
	0.9 gr	50.98 ± 1.32 a	

The data presented in Table 2 display the statistical analysis results for *Rhizophora stylosa*. The p-values recorded were 0.77 for root length, 0.7 for shoot length, 0.75 for SPAD leaf 3, and 0.63 for SPAD leaf 4. All four p-values exceed 0.05, suggesting that there are no statistically significant differences among the treatments for these measured parameters.

Plant height serves as a critical indicator of vegetative growth, and is often utilized for its simplicity in measurement and its ability to reflect treatment effects on plant development. The species-specific responses of *R. mucronata* and *R. stylosa* to ammonium-based NPK fertilizer are presented in Figures 1 and 2, respectively. In *R. mucronata*, the application of a 0.9 g/Soil weight fertilizer resulted in increased seedling height, whereas *R. stylosa* presented an inverse response, with a greater height increase in the control treatment (19.4 cm) than in the fertilized treatment, with an average increase of 18 cm.

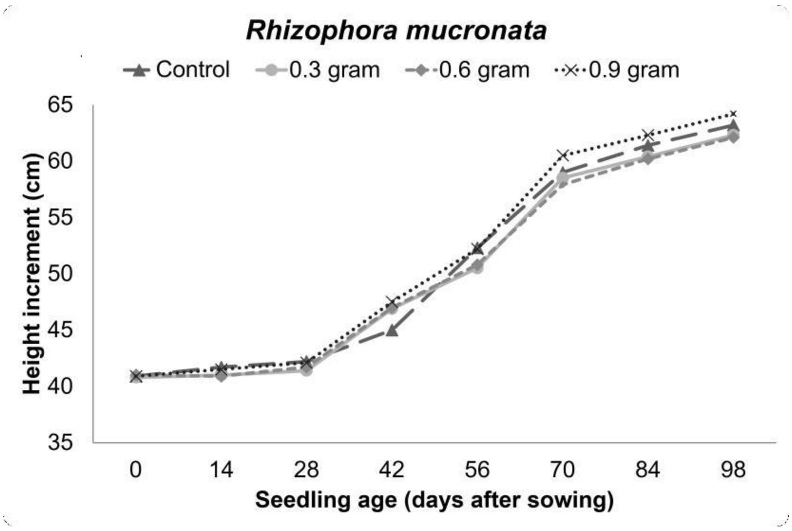

Figure 1. Plant height growth of the mangrove *R. mucronata* up to 98 days after planting (DAP)

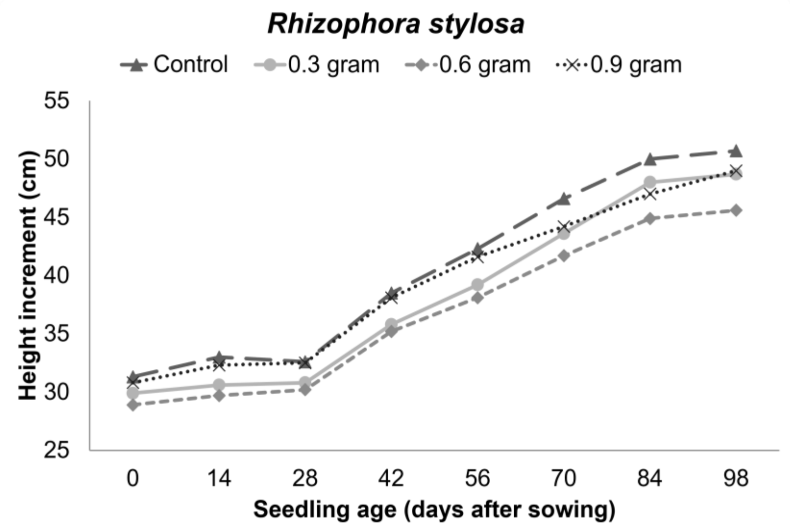

Figure 2. Plant height growth of the mangrove *R. stylosa* up to 98 days after planting (DAP)

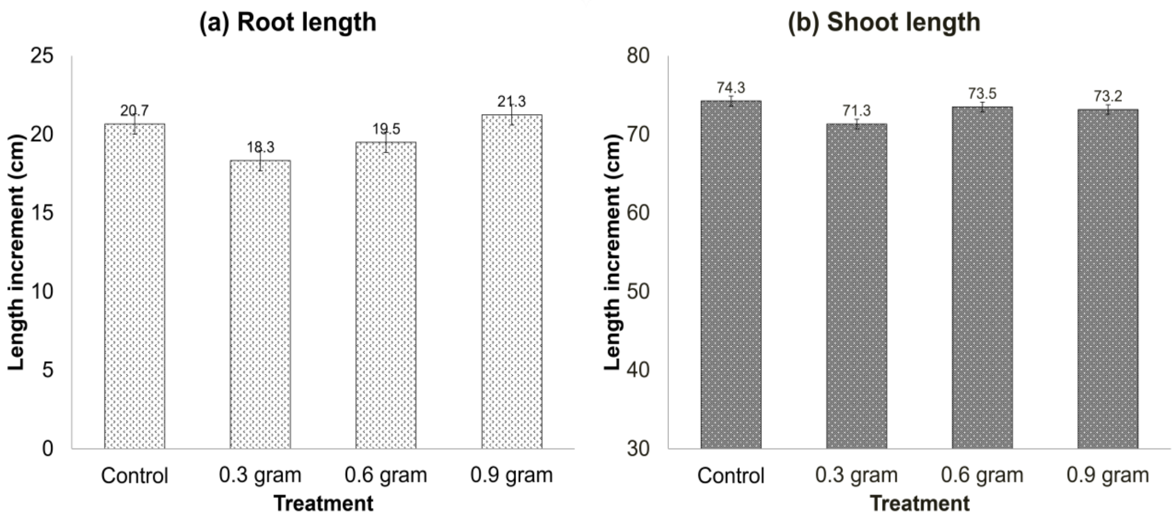

Figure 3. Root length growth (a) and shoot growth (b) of mangrove *R. mucronata*

This differential response between species may be attributed to variations in root growth dynamics. The data in Figure 3 indicate that *R. mucronata* presented an average root growth of 19.95 cm, notably surpassing *R. stylosa*, which exhibited an average root growth of 14.32 cm. According to Indriyanto (2006), root development significantly influences overall plant growth rates. In the present study, *R. stylosa* exhibited characteristic stilt root morphology with branching potential below ground. The limited spatial area for seedling development may have impeded optimal root growth.

Root and shoot lengths were also evaluated as metrics of the plants ability to access and allocate soil nutrients. The mangrove species *R. mucronate* presented greater root elongation under the 0.9 g fertilizer treatment (Figure 3a), with the root length increasing to 21.3 cm compared with 20.7 cm in the control. In contrast, *R. mucronata* shoot growth was greatest in the control treatment (Figure 3b). Mulyani (2006) described *R. mucronata* root systems as comprising taproots that branch extensively and thicken secondarily, facilitating nutrient storage. Ammonium uptake by roots tends to stimulate root elongation, acting as an initial adaptive mechanism for survival under extreme coastal conditions. This root elongation enhances water and nutrient absorption while stabilizing seedlings in muddy substrates. However, this adaptation can suppress shoot growth due to potential ammonium ion accumulation, which disrupts nutrient balance by reducing the uptake of calcium (Ca) and magnesium (Mg), thereby impeding photosynthesis and shoot expansion (Coleto *et al.* 2023).

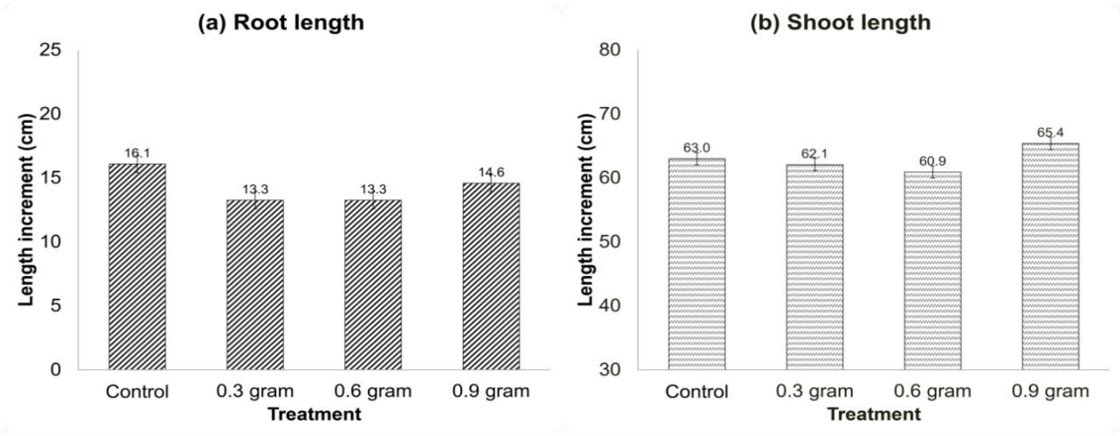

Figure 4. Root length growth (a) and shoot growth (b) of mangrove *R. stylosa*

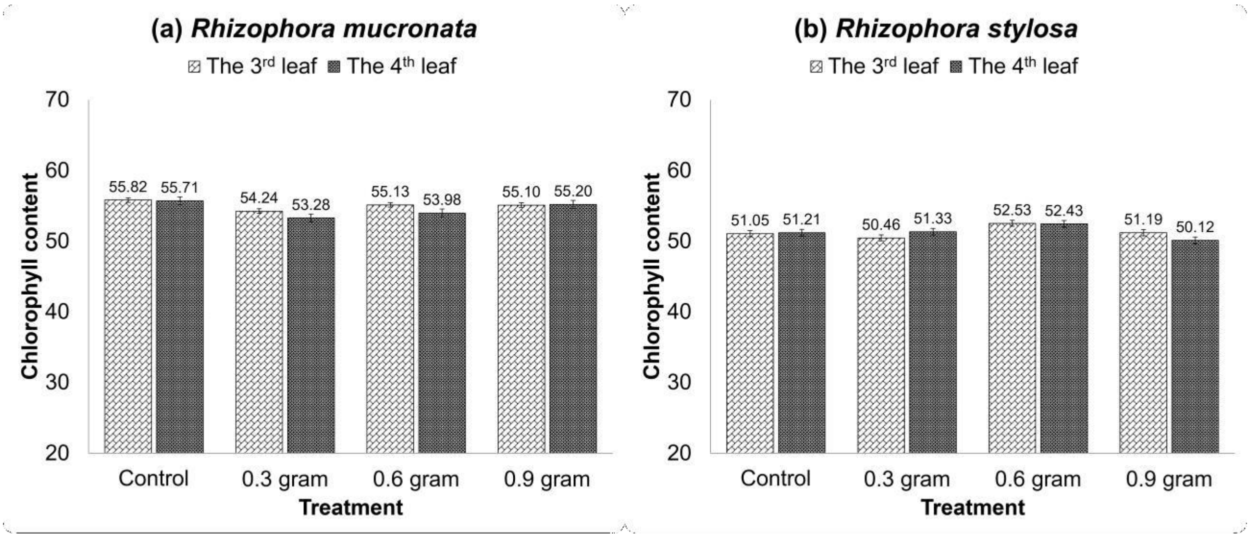

Figure 5. SPAD

In contrast to *R. mucronata*, *R. stylosa* root growth was non-responsive to fertilizer treatments (Figure 4a), but shoot elongation increased by 2.4 cm at the 0.9 g dose (Figure 4b). These findings suggest that *R. stylosa* may prioritize structural adaptations in root morphology, such as pneumatophores, which maintain respiratory function under submerged conditions (Alongi 2002). In this species, the applied ammonium fertilizer appears to support shoot development, given the critical role of nitrogen in protein and chlorophyll biosynthesis (Li and Zhou 2008). Study conducted by Rahman et al. (2020) demonstrated that increasing the dosage of NPK fertilizer positively impacts the growth of the mangrove species *Excoecaria agallocha*.

The chlorophyll content, a reliable indicator of nutrient status, was also measured to assess the physiological response to ammonium-based NPK fertilizer. The data, displayed in Figure 5, indicate that *R. mucronata* seedlings presented no significant

Compared with that in the control, the chlorophyll content in the fourth leaf was relatively greater under fertilized conditions. Conversely, chlorophyll levels in *R. stylosa* increased following fertilizer application, particularly at the 0.6 g dose. Although height and shoot length increased at the 0.9 g dose, the chlorophyll concentrations in *R. stylosa* were lower than those in the control. This observation aligns with the dilution effect hypothesis (Jarrell and Beverly 1981), where rapid growth results in increased green tissue mass, but chlorophyll production does not increase proportionally, thereby causing variation in the chlorophyll concentration per unit leaf area.

Finding of the research highlight the importance of ammonium based NPK fertilizer in enhance *Rhizophora mucronata* growth, offering a cost-effective and species-specific strategy for mangrove restoration. These findings enable fertilizer manufacturers to develop tailored products, support sustainable practices, and improve ecosystem services, benefiting both environmental conservation and local economies.

CONCLUSION

The application of ammonium-based NPK fertilizer at the optimal dose of 0.9 g/polybag resulted in the best growth response in *R. mucronata*, with increases in plant height, root length, and chlorophyll content, whereas *R. stylosa* presented a weaker response. Overall, *R. mucronata* exhibited better growth responses to varying doses of ammonium-base NPK fertilizer.

This research provides valuable insights into the use of ammonium-based NPK fertilizers for enhancing mangrove seedling growth, particularly for *R mucronata*. While the findings have significant implications for mangrove restoration and addressing degradation, the study's limitations and research gaps highlight the need for further investigation into long-term effects, broader species coverage, and ecological impacts. Addressing these gaps will enable the development of more effective and sustainable mangrove restoration strategies.

ACKNOWLEDGEMENT

The authors express their sincere gratitude to the Indonesia Fertilizer Research Institute (IFRI), PT Pupuk Indonesia (Persero), and Research Division of Pupuk Kujang Cikampek for their significant contributions to this research. Thanks are also extended to the Corporate Social Responsibility (CSR) program for supporting mangrove seedling activities under the Creating Shared Value (CSV) program. We also acknowledge Cipta Pesona Desa as a partner who contributed to the successful implementation of this project.

REFERENCES

Alongi DM (2002) Present state and future of the world's mangrove forests. Environ Conserv 29:331-349 doi:10.1017/S0376892902000231

Badan Pusat Statistik. (2025). Luas Penutupan Lahan Indonesia Di Dalam Dan Di Luar Kawasan Hutan Tahun 2014-2023 Menurut Kelas (Ribu Ha). Available at: https://www.bps.go.id/id/statistics-table/1/MjA4NCMx/luas-penutupan-lahan indonesia-di-dalam-dan-di-luar-kawasan-hutan-tahun-2014-2023-menurut-kelas--ribu-ha-.html. Accessed 18 March 2025.Coleto I, Marín-Peña AJ, Urbano-Gámez JA, González-Hernández AI, Shi W, Li G, Marino D (2023) Interaction of ammonium nutrition with essential mineral cations. J Exp Bot 74: 6131-6144 doi:10.1093/jxb/erad215

Hochard JP, Hamilton S, Barbier EB (2019) Mangroves shelter coastal economic activity from cyclones. Proc Natl Acad Sci 116:12232-12237 doi:10.1073/pnas.1820067116

Imran A, Efendi I (2016) Inventarisasi mangrove di pesisir Pantai Cemara Lombok Barat. JUPE 1:105-112

Indriyanto (2006) Ekologi hutan. Bumi Aksara, Jakarta

Jarrell WM, Beverly RB (1981) The dilution effect in plant nutrition studies. Adv Agron 34:197-224 doi:10.1016/S0065-2113(08)60887-1

Karminarsih E (2007) Pemanfaatan ekosistem mangrove bagi minimasi dampak bencana di wilayah pesisir. JMHT 3:182-187

Kathiresan K, Bingham BL (2001) Biology of mangroves and mangrove ecosystems. Adv Mar Biol 40:81-251 doi:10.1016/S0065-2881(01)40003-4

Kusumaningtyas MA, Hutahaean AA, Fischer HW, Pérez-Mayo M, Ransby D, Jennerjahn TC (2019) Variability in the organic carbon stocks, sources, and accu- mulation rates of Indonesian mangrove ecosystems. Estuar Coast Shelf Sci 218:310-323 doi:10.1016/j.ecss.2018.12.007

Li J, Zhou J (2008) Effect of interactions between carbon dioxide enrichment and NH_4^+/NO_3^- ratio on pH of culturing nutrient solution, growth and vigor of tomato root system. Front Agric China 2:296-300 doi:10.1007/s11703-008-0046-y

Mulyani S (2006) Anatomi tumbuhan. Kanisius, Yogyakarta

Piwowarska D, Kiedrzyńska E, Jaszczyszyn K (2024) A global perspective on the nature and fate of heavy metals polluting water ecosystems, and their impact and remedi- ation. Crit Rev Environ Sci Technol 54:1436-1458. doi:10.1080/10643389.2024.2317112

Rachmawati D, Setyobudiandi I, Hilmi E (2014) Potensi estimasi karbon tersimpan pada vegetasi mangrove di wilayah pesisir Muara Gembong Kabupaten Bekasi. JFMR 10:85-91 doi: 10.20884/1.oa.2014.10.2.22

Rahman, M. M., Khan, M. N. I., & Hoque, A. K. F. (2020). "Effects of NPK fertilization on the growth and biomass production of mangrove seedlings in the Sundarbans, Bangladesh." Journal of Forestry Research, 31(5), 1789-1798. doi:10.18801/jbar.200119.205

Reef R, Feller IC, Lovelock CE (2010) Nutrition of mangroves. Tree Physiol 30:1148-1160 doi:10.1093/treephys/tpq048

Trisnawati, Wardati, Yulia AE (2017) Pertumbuhan bibit mangrove (*Rhizopora* sp.) pada medium hidraquent yang diberi beberapa dosis NPK. Jurnal Online Mahasiswa Fakultas Pertanian Universitas Riau 4:1-10