

Growth and adaptability of *Pterocarpus indicus*, *Delonix regia*, and *Melaleuca cajuputi* in post-coal mining

Khairuddin Khairuddin^{1*)}, Restu Juniah², Ratih Wijayanti^{1,3}, Asia Afriyani^{1,3}

¹Doctoral Program of Environmental Science, Graduate School, Universitas Sriwijaya, Palembang 30139, South Sumatera, Indonesia

²Department of Mining Engineering, Faculty of Engineering, Universitas Sriwijaya, Ogan Ilir 30662, Indonesia

³Environmental Science Study Program, Faculty of Science and Technology, Universitas Serasan, Muara Enim 31311, South Sumatra, Indonesia

*)Email address: kh_noor26@yahoo.com

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ABSTRACT

Reclamation of post-mining coal land requires effective revegetation strategies to accelerate ecosystem recovery and establish sustainable vegetation. The purpose of this study was to evaluate the effects of fertiliser dose on the vegetative growth of *Pterocarpus indicus*, *Delonix regia*, and *Melaleuca cajuputi* grown in post-mining reclamation soil. The experiment was conducted using plants cultivated in polybags containing reclamation soil and subjected to different fertilizer doses. Growth was evaluated based on plant height, stem diameter, and number of leaves, while data were analysed using analysis of variance (ANOVA) at a 5% significance level. The results showed that increasing the fertiliser dose up to 5 kg produced the best overall growth, with mean plant height, stem diameter, and number of leaves reaching 82.80 cm, 3.76 cm, and 188.22, respectively. Fertiliser dose significantly affected the growth of *P. indicus* and *M. cajuputi* ($P < 0.05$), whereas *D. regia* showed a relatively stable response to increasing fertilizer doses. Overall, a 5 kg fertilizer dose was the most effective treatment for promoting vegetative growth under the tested reclamation-soil conditions. These findings provide a basis for optimizing fertilizer application and selecting suitable plant species for revegetation of post-mining coal land.

Keywords: fertiliser dosage, pioneer, plants, restoration, revegetation

INTRODUCTION

The environmental crisis caused by coal mining has become a serious global issue, as it leads to the physical, chemical, and biological degradation of soil, as well as a decline in the quality of terrestrial ecosystems. Post-mining land is generally nutrient-poor, acidic, and has low levels of microbial activity, which plays a crucial role in the nutrient cycle (Toren, 2002; Hadi, 2025; Lestari et al., 2019; Herdiansyah et al., 2020). Restoration efforts should not only rely on technical approaches but also be supported by ecological strategies through revegetation-based reclamation (Hadi, 2025). This approach emphasizes using fast-growing species tolerant of extreme conditions in degraded soils to accelerate canopy restoration,

improve soil health, and sustainably enhance ecosystem function.

Revegetation of post-mining land is not just an aesthetic restoration endeavor, but also an ecological rehabilitation process that strives to enhance edaphic conditions, stabilize the soil surface, and produce a microclimate balance that enables ecological succession (Navarro-Ramos et al., 2022). The success of this process is largely determined by the selection of strategic plant species (Hapsari et al., 2020). Ideal plant species must demonstrate adaptability to nutrient-deficient substrates, resistance to environmental stress, and a functional role in improving the structural integrity and ecological functionality of the soil system (Silva et al., 2019).

Pterocarpus indicus (Angsana), *Delonix regia* (Falmbuyan), and *Melaleuca cajuputi* (Kayu

Putih) are three types of tropical trees that exhibit rapid growth, high tolerance to marginal soil conditions, and significant ecological potential in land rehabilitation processes (Yuningsih et al., 2021b). The species *Pterocarpus indicus* (Wong, 1982) and *Delonix regia* (Yuningsih et al., 2021a) belong to the Fabaceae family, which is known to have a symbiotic association with nitrogen-fixing bacteria, thereby increasing nutrient availability and sustainably improving soil fertility. Meanwhile, *M. cajuputi* acts as a pioneer species commonly found on dry and nutrient-poor land (Davidson, 1993; Rusdiana et al., 2013; Yuningsih et al., 2021a). Its morphological and physiological adaptations, such as xerophytic leaf structure and water use efficiency, enable it to survive extreme environmental pressures while contributing to soil stabilization and forming a microclimate that supports post-mining ecosystem recovery (Juniarto et al., 2025).

The promise of these three plant species has long been acknowledged in revegetation and marginal land restoration initiatives, but their growing performance on post-mining land remains limited. Furthermore, quantitative and

comparative data on the effectiveness of each plant's growth under these conditions remain limited. The study's findings are expected to provide a scientific foundation for selecting appropriate species to promote the achievement of sustainable reclamation in former mining regions. The objective of this research was to experimentally assess the growth and adaptability of *P. indicus*, *D. regia*, and *M. cajuputi* on reclaimed mining site.

MATERIALS AND METHODS

Research Area

Soil sampling was carried out in one of the mining concession sites in South Sumatra. Geographically, the mining region was located at 03°43' South Latitude and 103°07' East Longitude (Figure 1). This location was within an active mining operation zone spanning approximately 134.7 hectares, with a humid tropical climate and agroclimatic conditions. The investigation activity lasted three months and included planting, growth tracking, and data analysis.



Figure 1. Soil sampling in the West Bank region

Soil Analysis

The growth material used for all treatments in the research was tested in the laboratory prior to planting. Soil samples were collected from a six-month-old post-coal mining reclamation site (Nutayla et al., 2023) This also provided a supply of topsoil for the polybag media. The zig-zag approach was used to sample compositely from five typical places in the reclamation area at depths ranging from 0-20 cm. The five subsamples were homogeneously blended to create a composite sample that reflected the overall features of the initial soil medium. The soil samples were then air-dried, sieved using a 2 mm sieve, and placed in sterile containers for examination.

The investigation was carried out at the Soil Science Laboratory, Faculty of Agriculture, Sriwijaya University, to assess the soil's chemical characteristics and basic fertility as preliminary considerations for the growth medium. The factors analyzed were soil metal concentration, pH (H₂O), KCL pH, organic carbon (%), total nitrogen (total N), accessible phosphorus (available P), cation exchange capacity (CEC), and soil texture.

Experimental Desain

This research employed a factorial randomized block design (RBD) including two variables: plant type and fertilizer dosage. The first factor (A) was plant kind, including three levels: *P. indicus*, *D. regia*, and *M. cajuputi*. The second variable (B) was the organic fertilizer dosage, with four treatments: 0 kg (control), 1 kg, 3 kg, and 5 kg per polybag (Figure 2).

There were 12 treatment combinations, each replicated three times, yielding a total of 36 experimental units. A control treatment (without fertilizer application) was included with three replicates for comparison. Consequently, this study used 36 polybags, with plant observations conducted every 7 days post-planting (DAP).

Preparation and Planting

The plant seedlings included in the study were sourced from accredited local nurseries. Seedling selection criteria included plant age, with a minimum height of 30–50 cm, erect stems, and robust root systems free of signs of pathogen

infection. Chosen seedlings were thereafter acclimatized for 7 days prior to planting to guarantee their physiological stability under the experimental environmental conditions. The planting medium was formulated using soil from post-coal mining reclamation that had received preliminary treatment by mechanical processing and the application of fundamental soil amendments. Prior to planting, each polybag was administered varying quantities of compost fertilizer, specifically 1 kilogram, 3 kg, and 5 kg, which were subsequently blended uniformly with the soil to modify the soil pH and enhance nutrient accessibility.

Planting was executed at a spacing of 0.5 × 0.5 meters between polybags to preserve growth space and reduce competition among plants (Nutayla et al., 2023). Throughout the research duration, all experimental units were administered consistently. Watering was conducted bi-daily (morning and evening) with contaminant-free water. Weed management was performed manually weekly, and preventative measures against pests and illnesses were implemented based on field symptoms. Consequently, any discrepancies noted during the trial are anticipated to represent the unadulterated impact of the therapy, uninfluenced by uncontrolled environmental factors.

Vegetation Data and Analysis

Quantitative data were collected using direct observation and evaluated using analysis of variance (ANOVA) to evaluate the impact of different fertilizer dosages on plant growth characteristics. The analysis used SPSS software version 25.0, and the results were displayed in tables with narrative explanations. Following significant ANOVA findings, Duncan's Multiple Range Test (DMRT) was conducted at a significance threshold of $P < 0.05$ to ascertain statistical differences across treatments.

RESULTS

Characteristics of Coal and Bokashi Fertilizers

An evaluation of bokashi fertilizer quality was performed to determine its adherence to the organic fertilizer quality standards outlined in

Minister of Agriculture Regulation No. 70/SR.140/10/2011, specifically regarding the nutrient content of organic fertilizers as soil conditioners, with a focus on pH, nitrogen (N), phosphorus (P), and potassium (K) parameters (Table 1). The testing findings demonstrate that bokashi fertilizer was an appropriate organic nutrition source for post-mining soil.

Table 1. Nutrient profile of bokashi fertilizer

Variables	Fertilizer Quality Standards	Fertilizer Content
pH H ₂ O	04–9	7.51
N (%)	>4	3.290
P (%)	>4	1.264
K (%)	>4	1.365

The research indicates that bokashi fertilizer possesses a neutral pH of 7.51, aligning with organic fertilizer quality criteria, so rendering it safe for use on diverse soil types. Nonetheless, the nitrogen (3.29%), phosphorus (1.26%), and potassium (1.36%) levels remain beneath the threshold (>4%), signifying a deficiency in critical macronutrients. This situation indicates that bokashi serves primarily as a soil conditioner by enhancing organic matter and microbial activity, rather than as a principal nutrient source; hence, its application should be supplemented with other fertilizers to fulfil plant nutritional needs successfully.

Characteristics of Post-Coal Mining Soil

Post-coal mining terrain undergoes chemical and physical deterioration resulting from topsoil depletion and reduced organic matter. Laboratory study of chemical and physical characteristics (Table 2) reveals the soil fertility condition and the primary limiting factors for land restoration according to soil assessment standards (Soil Research Center, 1983) (Hardjowigeno, 1995).

The chemical test results of post-mining soil indicate severely deficient nutritional conditions, marked by extremely low concentrations of organic carbon (0.78%) and total nitrogen (0.06%). The low C/N ratio (12) signifies a comparatively rapid rate of organic matter breakdown; nevertheless, this was not complemented by sufficient organic substrate supply. The phosphorus content (9.56 ppm) and exchangeable potassium (0.25 me/100 g) are very low, indicating a deficiency of important

minerals for plant development. Despite magnesium being measured at a high level (5.01 me/100 g), its beneficial effects are minimal due to the predominance of very acidic soil conditions (pH H₂O 4; pH KCl 3.38) and a base saturation of just 20.53%. The pronounced acidity is directly associated with the oxidation of sulfide minerals, especially pyrite, leading to the formation of sulfuric acid, which reduces cation exchange capacity (CEC) and limits the availability of macro- and micronutrients.

Table 2. Chemical and physical characteristics of post-mining soil

Soil Parameters	Result	Information
Chemistry		
C-organic (%)	0.78	Very low
N-total (%)	0.06	Very low
C/N ratio	12	Low
Available P (ppm)	9.56	Very low
K ₂ O HCl Olsen (ppm)	2.41	Very low
K ₂ O HCl 25% (mg/100g)	41.68	Tall
K (me/100 g)	0.25	Very low
Na (me/100 g)	0.21	Very low
Mg (me/100 g)	5.01	Tall
Ca (me/100 g)	3.16	Very low
Base Saturation (%)	20.53	Very low
pH KCL (1:1)	3.38	Highly acidic
pH H ₂ O (1:1)	4	Highly acidic
Physics		
Texture		Clay sand
Sand (%)	20.08	
Dust (%)	23.9	
Clay (%)	45.5	
Permeability (cm/h)	2.83	
Porosity (%)	53.21	

The soil had a sandy clay texture, characterized by a clay fraction dominance of 45.5%. This state renders the soil dense, exhibiting relatively poor permeability (2.83 cm/hour), hence restricting water movement. The overall porosity of 53.21% theoretically suggests adequate pore space for water and air flow; nonetheless, the uneven distribution of macro and micro pores may lead to drainage and aeration issues.

Effects of Growth and Diversity Assessment in Land Reclamation

Plant Development exhibited diverse responses to fertilizer dosage treatments, regarding height, stem diameter, and leaf count. This consistent increasing trend verifies that plants may utilize supplementary nutrient inputs to facilitate biomass growth, particularly during the mid to late vegetative growth phase.

In contrast, the control treatment (0 kg) and low dosage (1 kg) exhibited sluggish development, with a tendency to fall after 28

days post-sowing until the conclusion of the observation period (Figures 2, 3, and 4).

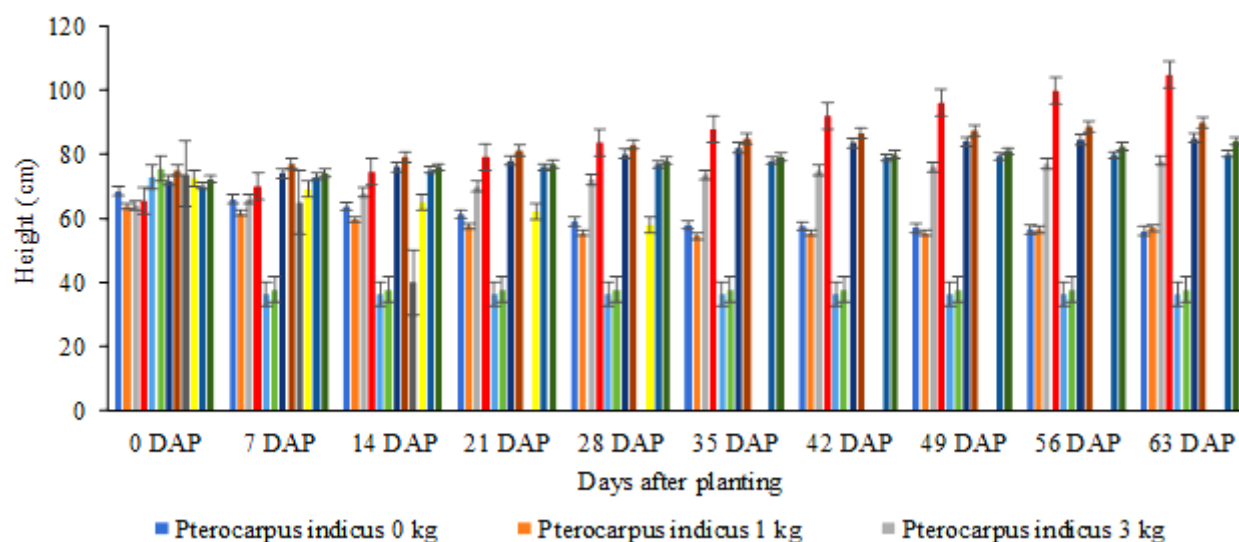


Figure 2. Plant height growth

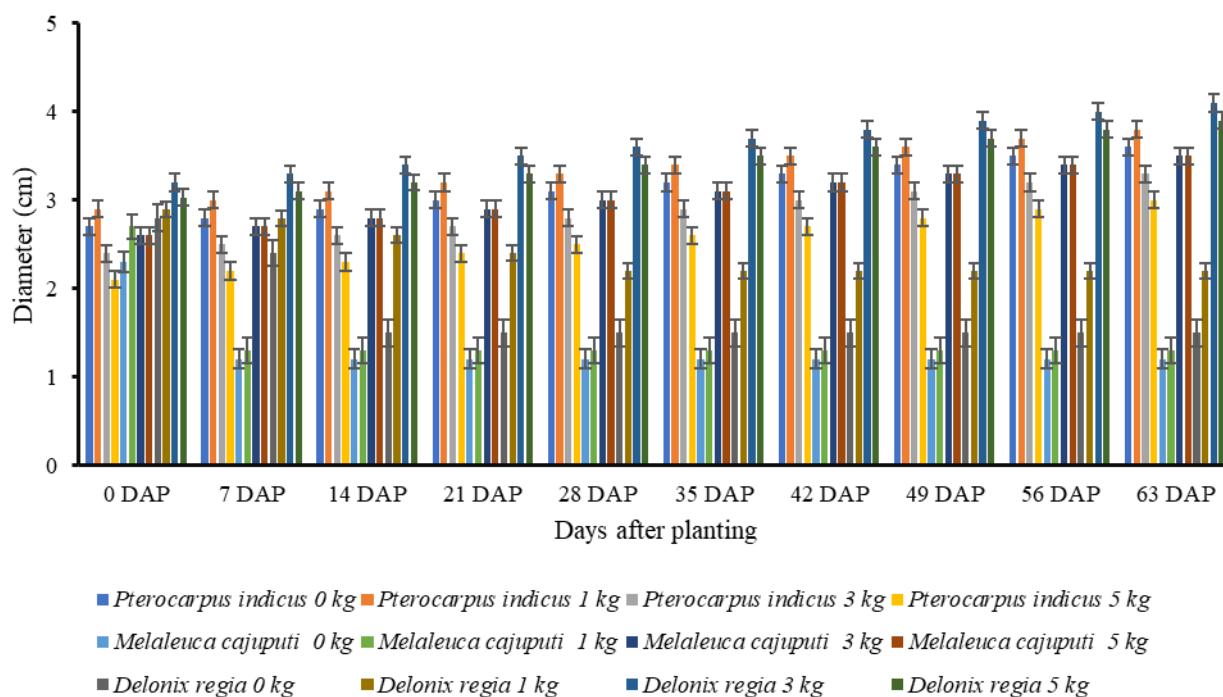


Figure 3. Growth in plant diameter

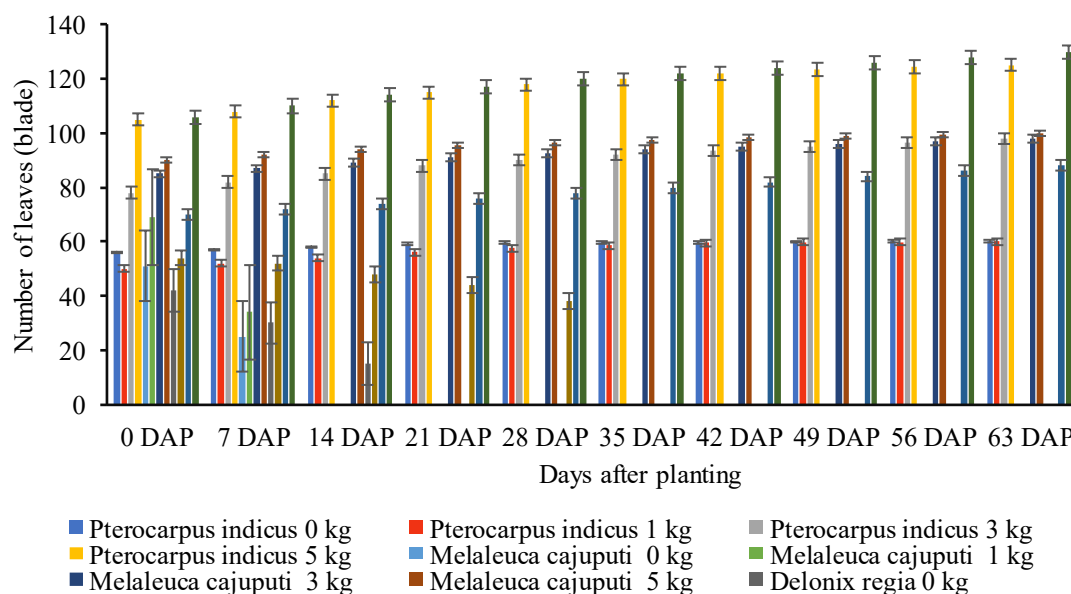


Figure 4. Growth in the number of plant leaves

Plant height growth varied distinctly across species and fertilizer dosage treatments. *P. indicus* exhibited a steady growth pattern across all dosages, with a notable enhancement at a dosage of 5 kg (65.6 cm–105 cm at 63 days after planting). Conversely, in the control treatment (0 kg) and low dosage (1 kg), growth exhibited a stationary pattern, even showing a tendency to fall after 28 days post-planting until the conclusion of the observation period. *M. cajuputi* had a comparable reaction, achieving an ultimate height of just 51 cm in the control group, which increased to 90 cm at a dosage of 5 kg. Simultaneously, *D. regia* exhibited the most pronounced development, with the maximum dosage (5 kg) yielding a height of 106 cm, whilst the control group only reached 42 cm before perishing in the fifth week. Overall, elevated fertilizer applications enhanced height growth across all three plant species, with the ultimate growth hierarchy being *D. regia* > *P. indicus* > *M. cajuputi* (Figure 2).

Stem diameter increased for all plant species 63 days after planting (Figure 3). *D. regia* had the highest diameter growth, especially at the 5 kg dose, which reached approximately 4.0 cm at 63 days after planting. *P. indicus* showed moderate growth with an optimum dose of 3 kg, while higher doses did not provide significant

increases. *M. cajuputi* had the slowest diameter growth and a relatively small response to treatment. Differences in response between species indicate that dose effectiveness is strongly influenced by the physiological characteristics of each plant, so the optimum dose needs to be adjusted to the type of plant used.

At the same time, the number of leaves varied notably across plant species and fertilizer dosage treatments (Figure 4). In *P. indicus*, the untreated group yielded only 60 leaves by the conclusion of the observation period, but the application of 5 kg of fertilizer elevated the leaf count to 125. In *M. cajuputi*, the control plants (0 kg) lasted only to 25 leaves in the second week before succumbing, as did the 1 kg dosage, which reached 34 leaves; conversely, the 3 kg and 5 kg doses supported growth to 98 and 100 leaves by day 63. *D. regia* exhibited the most pronounced leaf growth, with the control group yielding just 30–42 leaves at the beginning of observation before succumbing on the 21st day post-planting, whereas the 3 kg and 5 kg fertilizer treatments augmented the leaf count to 88 and 130, respectively. High dose treatments (3–5 kg) gave the most beneficial results in leaf proliferation, with *D. regia* exhibiting the most pronounced response.

Evaluation of Plant Growth Using ANOVA and Duncan's Test

The influence of plant species and fertilizer dosage on vegetative development was examined by analysis of variance (ANOVA) (Table 3). The analytical results indicated that the fertiliser dosage and its interaction with plant type significantly influenced all observed growth metrics, but the response levels varied among species. In *Pterocarpus indicus*, the dose of fertilizer and its interaction with plant type exhibited a very significant effect ($P < 0.01$), showing that variations in dosage resulted in substantial variances in growth. *M. cajuputi* had a comparable impact, with both the primary factor and its interaction being significant ($P < 0.01$), signifying that the interplay between fertiliser dose and species traits substantially influenced the growth rate. In *D. regia*, only the fertilizer dosage component was significant ($P < 0.05$), but the main effects of the plant and their interaction were not, suggesting a more stable growth response to dosage variation. The results affirm that fertilizer dosage was a critical determinant of plant development, with *M. cajuputi* and *P. indicus* exhibiting the most pronounced response, whilst *D. regia* demonstrates a more stable adaptability to nutrient fluctuations.

Table 3. Results of ANOVA tests on *P. indicus*, *M. cajuputi*, and *D. regia* plants

Variabel	F-Count	Sig.
<i>Pterocarpus indicus</i>	2.29	0.12
Dosage	29.48	0.00
<i>Pterocarpus indicus</i> x fertilizer dosage	8.93	0.00
<i>Melaleuca cajuputi</i>	15.49	0.00
Dosage	26.47	0.00
<i>Melaleuca cajuputi</i> x fertilizer dosage	10.18	0.00
<i>Delonix regia</i>	1.61	0.22
Dosage	3.28	0.03
<i>Delonix regia</i> x fertilizer dosage	0.74	0.62

Table 4 showed the average height, diameter, and number of leaves for various types of plants and fertilizer doses. The data showed a pattern of increased growth as the fertilizer dose increased and illustrated differences in physiological responses between plant types to nutrient availability. The data in the table indicates that changes in plant kinds and fertilizer dosages led to substantial variances in vegetative development, encompassing plant height, stem diameter, and leaf count. According to the

average data, *D. regia* exhibited the greatest plant height (75.44 cm), succeeded by *M. cajuputi* (74.09 cm) and *Pterocarpus indicus* (71.86 cm). *Pterocarpus indicus* exhibited a notable increase in leaf count, averaging 143.25 leaves, far surpassing *M. cajuputi* (58.58 leaves) and *D. regia* (57.83 leaves). Simultaneously, the examination of the fertilizer dosage factor revealed a uniform.

Table 4. Duncan test results for plant growth

Plant Type	Observed Variables		
	Height (cm)	Diameter (cm)	Number of Leaves (strands)
<i>Pterocarpus indicus</i>	71.86	3.60	143.25
<i>Melaleuca cajuputi</i>	74.09	2.68	58.58
<i>Delonix regia</i>	75.44	2.98	57.83

Fertilizer Dosage	Observed Variables		
	Height (cm)	Diameter (cm)	Number of Leaves (strands)
0 kg (Control)	67.07	2.22	19.55
1 kg	68.28	2.82	23.11
3 kg	77.05	3.56	115.33
5 kg	82.80	3.76	188.22

Trend of enhancement across all growth parameters. Unfertilized plants (0 kg) exhibited an average height of 67.07 cm, but fertilization at a dosage of 5 kg elevated plant height to 82.80 cm, reflecting an increase of around 23.5% relative to the control group. A comparable augmentation was seen in stem diameter, which ascended from 2.22 cm to 3.76 cm, and in leaf count, which surged from 19.55 leaves to 188.22 leaves. This trend indicates that sufficient nutrients significantly enhance metabolic activity and plant biomass development.

DISCUSSION

This study's results indicate a robust correlation among growing media conditions, fertilizer application rates, and plant physiological traits concerning vegetative development dynamics. Preliminary soil research shows that while macronutrient levels remain moderate, fertilizer application significantly improves development by increasing nutrient availability. Fertilizer significantly enhances the physical and chemical characteristics of soil, elevates cation exchange capacity, and facilitates nutrient absorption, particularly nitrogen,

phosphorus, and potassium, which are vital for plant cell division and differentiation. The results of this study are corroborated by Šimanský et al. (2022), which asserts that the utilization of organic fertilizers significantly enhances the availability of vital nutrients in the soil, particularly in facilitating cell division and differentiation in plants. A mix of fertilizers and organic amendments is essential to enhance the physical qualities of soils with low organic matter content, improve structure, increase cation exchange capacity, and sustainably retain water and nutrients.

Vegetative growth, including increases in plant height, stem diameter, and leaf count, follows a pattern that correlates with increasing fertilizer dosages. This result substantiates the notion that early-stage plant growth is significantly affected by the availability of nutrients that facilitate photosynthesis and the production of new tissues (Kusumawati, 2021). The greatest fertilizer dosage resulted in enhanced plant development, evidenced by higher metabolic activity and improved biomass accumulation (Šimanský et al., 2022; Nutayla et al., 2023). In contrast, at low concentrations, growth is often sluggish, and dieback ensues due to deficiencies in critical nutrients that impede the synthesis of chlorophyll and photosynthetic enzymes (Nutayla et al., 2023).

The height growth of *P. indicus* and *M. cajuputi* exhibited a positive correlation with escalating fertilizer dosages, peaking at 5 kg. *D. regia* had a superior reaction, suggesting that this species possesses enhanced nutrient absorption efficiency. The results align with prior research indicating that the presence of vital nutrients, particularly nitrogen, phosphorus, and potassium, significantly influences cell elongation and the development of new tissue (Ye et al., 2019). The disparities in plant height growth responses to different treatment dosages are believed to be associated with fluctuations in the availability of macronutrients in fertilizers, which are crucial for both vegetative and generative development stages of plants. This aligns with the perspective of Jiaying et al. (2022), who underscored that optimal plant growth necessitates the availability of essential nutrients in appropriate quantities and proportions, particularly nitrogen (N),

phosphorus (P), and potassium (K), which are pivotal for plant metabolism and tissue development.

The disparities in stem diameter among treatments were increasingly evident. *M. cajuputi* exhibited static growth at low dosages from the beginning, whereas high doses sustained stem expansion throughout the study period. The results substantiate that sufficient food availability influences both longitudinal and lateral development via cell division and cambial expansion (Kozłowski & Pallardy, 1997). *D. regia* had the greatest stem diameter at a dosage of 3 kg, signifying an optimal fertilizer threshold, beyond which additional increments in dosage do not consistently correlate with growth. The expansion of stem diameter correlates with plant height as a result of nutrition and photosynthate translocation via the xylem and phloem. The translocation of photosynthetic products to various organs activates cambium activity, resulting in an increase in stem diameter to facilitate nutrient distribution within the plant (Taiz et al., 2018).

The quantity of leaves exhibited the most distinct pattern in illustrating variations across treatments. The demise of *M. cajuputi* and *D. regia* at minimal dosages reflects the limited adaptability of both species to nutrient-deficient environments. At the week's onset following planting, leaf growth in *M. cajuputi* and *D. regia* subjected to fertilizer treatment was superior to the control group, suggesting that nutrient availability from organic fertilizer effectively supported the plants' physiological activity. After fourteen to twenty-one days, indications of necrosis and chlorosis manifested on certain leaves, signifying physiological stress resulting from nutritional imbalance or adverse climatic circumstances (Sawyer, 2004). The symptoms resulted from disruptions in plant metabolic activity, affecting physiological and biochemical processes (Singh et al., 2016).

The rise in leaf count at a dosage of 5 kg indicates a favourable physiological reaction attributable to appropriate food availability, consequently augmenting the photosynthetic surface area and enhancing the efficacy of vegetative development in plants. This aligns with the findings of Wenshi et al. (2020) that

adequate nutrition availability enhances the rate of photosynthesis by increasing both the quantity and surface area of leaves, thereby promoting total biomass development. *D. regia* exhibited the most pronounced growth response to fertilizer treatment in comparison to *P. indicus* and *M. cajuputi*. This is believed to be associated with variations in physiological adaptability and nutritional absorption capabilities among animals.

Pterocarpus indicus, while exhibiting consistent growth, could not attain the same degree of enhancement as *D. regia*. Simultaneously, *M. cajuputi* exhibited sluggish development and elevated death rates under limited fertilizer circumstances, potentially attributable to increased particular nutritional demands or constraints in the juvenile root system's nutrient absorption capacity (Jiaying et al., 2022). Analysis of variance (ANOVA) demonstrated that both plant type and fertilizer dosage substantially influenced all growth indicators. The interplay between the two had a substantial effect, suggesting that fertilizer efficacy is contingent upon the genetic traits of each plant. Certain plant species demonstrated enhanced physiological efficiency in nutrient utilization, particularly in facilitating stem elongation and leaf development. The variations in response suggest that fertilization tactics must be customized to each species' adaptation capabilities to environmental circumstances and growth substrates. The average observational data indicate that an increase in fertilizer dose correlates with enhanced vegetative development across all plant types. This pattern suggests that nutrient richness in the growth media enhances physiological activities, including photosynthesis, transpiration, and carbon absorption. Consequently, the appropriate fertilizer dose enhances growth and strengthens plants' ability to adapt to variable environmental conditions. It is crucial to recognize that excessive fertilizer application may lead to ionic imbalances in the soil; therefore, fertilizer use must be calibrated to get optimal efficiency. This study's results affirm that plant vegetative development is significantly affected by the interplay between environmental variables, particularly soil nutrient availability, and the plants' genetic features. A slight augmentation in fertilizer application

substantially enhances height, diameter, and leaf count, while its efficacy is greatly contingent upon the kind of plant being farmed. These findings corroborate the fundamental principle of plant ecophysiology that optimal development is attained through a balance between nutrient intake and the physiological ability of plants to assimilate them.

CONCLUSION

This study demonstrates that plant vegetative development is affected by the interplay of environmental factors, nutrient availability, and species-specific physiological traits. Elevating the fertilizer dosage to 5 kg yielded ideal growth in height, diameter, and leaf count. *D. regia* exhibited the highest adaptable growth response in comparison to *Pterocarpus indicus* and *M. cajuputi*, signifying superior physiological efficiency. The ANOVA test results indicate that the interaction between plant type and fertilizer dose significantly affects the growth parameters of *Pterocarpus indicus* and *M. cajuputi*, with a significance level of $P < 0.05$. Conversely, fertilizer dose significantly influenced the growth of *D. regia* ($P < 0.05$), and it showed a consistent response to dose variation, while the interaction between plant type and fertilizer was not significant ($P > 0.05$). Duncan's test findings indicated that the optimal fertilizer application for average plant height, stem diameter, and leaf count was 5 kg, yielding a plant height of 82.80 cm, a stem diameter of 3.76 cm, and a leaf count of 188.22.

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