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Growth of *Dyera polyphylla* and *Shorea balangeran* Seedlings on Various Growing Media for Restoration Program

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ABSTRACT

The success of peat swamp ecosystem restoration needs to be supported by the supply of good quality native plant species, one of which is influenced by the growing media. This study aimed to evaluate the effect of cocopeat, compost, and biochar as a mixture of peat media on the growth of *Dyera polyphylla* and *Shorea balangeran* seedlings in a greenhouse for six months. The experiment was carried out using a completely randomized design with one factor, growing media (100% peat as M1 (control); 70% peat + 30% cocopeat as M2; 70% peat + 30% compost as M3; and 70% peat + biochar 30% as M4). The survival rate of both types of seedlings in all growing media treatments was 100%. Dickson Quality Index (DQI) of *D. polyphylla* seedlings on M1, M2, M3, and M4 was 0.32, 0.29, 0.46, and 0.31, respectively, and for *S. balangeran* was 0.15, 0.10, 0.09, and 0.12, respectively. Adding cocopeat, compost, and biochar could increase the nutrient content of peat media. The growing media with the best quality for *D. polyphylla* was M3, while for *S. balangeran* was M1.

1. Introduction

In recent decades, the intensity of land use in peat swamp ecosystems has increased, causing degradations, such as the construction of artificial canals, forest and land fires, deforestation, and conversion of peat swamp forests to agriculture or plantations (Dohong et al. 2018; Lampela et al. 2017; Tata and Pradjadinata 2016; Wibisono and Dohong 2017). This tendency caused the peat swamp forest cover to decrease, leading to irreversible drying of peat, fastening soil decomposition, compression, and subsidence, which increased carbon emissions (Barchia 2017; Wilson et al. 2016). The chemical, physical and biological properties of peat soil are also getting worse, which challenge the degraded peat ecosystems restoration (Graham et al. 2013; Masganti et al. 2014; Tata and Pradjadinata 2016).

The process of regeneration in degraded peat swamp ecosystems is relatively slow, with limited diversity of tree species (Dohong et al. 2018). Planting native plant species in peat ecosystems can speed up the recovery process for degraded ecosystems and increase the diversity of tree species. Native plant species can help increase local populations of other species, increase soil biological activity, balance soil nutrients, and slow the loss of biodiversity (Carvalho et al. 2022; Özyavuz et al. 2013). *Dyera polyphylla* and *Shorea balangeran* are native plant species that are widely recommended and used to restore degraded peat ecosystems (Graham et al. 2013; Lampela et al. 2017; Tata et al. 2016). *S. balangeran* grows well in various habitats, such as degraded peatlands, dry open land, flooded land, and intense peat (Atmoko 2011; Suryanto et al. 2012). *D. polyphylla* can be planted on light or moderate burnt areas, clear-cut areas, and open areas with sparse vegetations (Wibisono and Dohong 2017).

Efforts to provide and select quality seeds and seedlings from both plant species of native peat swamp ecosystems in nurseries are important to support the success of the restoration. Good quality seedlings can be carried out using fertile growing media, without any toxic materials, low-cost, and easily obtained (Marjenah et al. 2016) around the planting site, such as peat, cocopeat, compost, and biochar. The quality of seedlings can be determined based on the Dickson Quality Index (Dickson et al. 1960). Therefore, this research was conducted to determine the effect of various growing media on the growth response of *D. polyphylla* and *S. balangeran* seedlings.

2. Materials and Methods

2.1. Time and Location

The research was carried out from September 2020–April 2021. The growth of *D. polyphylla* and *S. balangeran* was observed in the greenhouse of the Center for Standardization of Environmental and Forestry Instruments (BSILHK) Bogor. Growing media analysis was conducted at the Laboratory of the Department of Soil Science and Land Resources, IPB University. In addition, plant tissue analysis was carried out at the Laboratory of the Department of Agronomy and Horticulture, IPB University.

2.2. Materials

The materials used included *D. polyphylla* seedlings, *S. balangeran* wildlings, peat media, cocopeat media, compost media, and biochar (husk charcoal) media. *S. balangeran* wildings, with an average height of 14.53 cm, obtained from Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Tumbang Nusa, Pulang Pisau Regency, Central Kalimantan and from Sungai Gelam, Muaro Jambi Regency, Jambi Province. *D. polyphylla* seedlings were 1.5 years old and taken from the Center for Standardization of Environmental and Forestry Instruments (BSILHK) Bogor and the germinated seeds were originated from Kameloh Village, Kalampangan District, Palangkaraya City, Central Kalimantan. Peat soil with sapric maturity used in this study also comes from Kameloh Village.

2.3. Experimental Design

The experiments using various growing media as substrates for *D. polyphylla* and *S. balangeran* seedlings were conducted in a greenhouse. Each seedling of *D. polyphylla* and *S. balangeran* was arranged in a completely randomized design (CRD) with one factor, namely the type of growing media (**Fig. 1**). The growing media type factor is composed of four levels, namely 100% peat (M1) as control, peat 70% + cocopeat 30% (M2), peat 70% + compost 30% (M3), and peat 70% + biochar 30% (M4). The two types of media on M1, M2, and M3 are mixed evenly (**Fig. 2**). Each treatment was repeated (U) 25 times for each type of plant, so the total experimental units were 100 units (4 × 25) for each type of plant. One hundred seedlings of *D. polyphylla* and 100 seeds of *S. balangeran* were used. The seedlings were planted in polybags in size of 20 cm x 25 cm. Seedlings' maintenance included watering once a day, weeding, and eradicating plant-disturbing organisms manually.

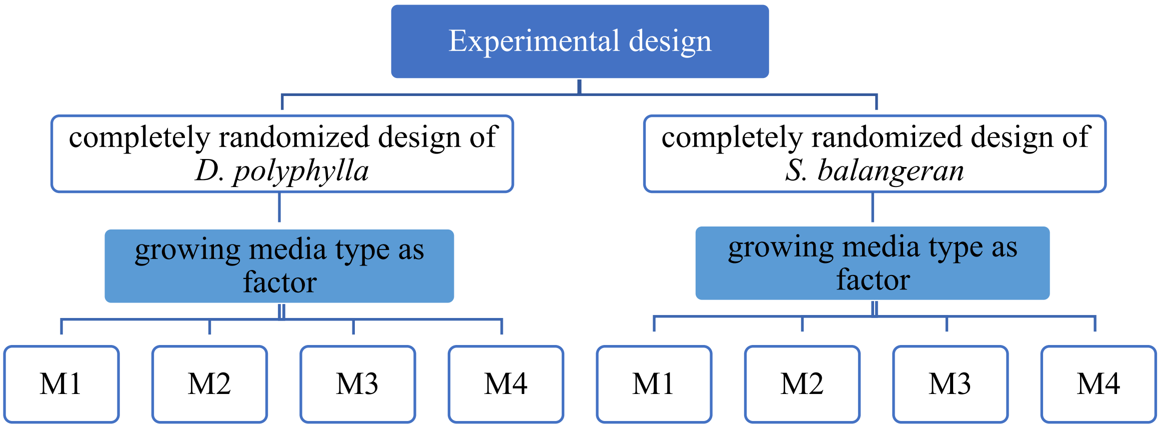

Fig. 1. Experimental design for *Dyera polyphylla* and *Shorea balangeran* seedlings.

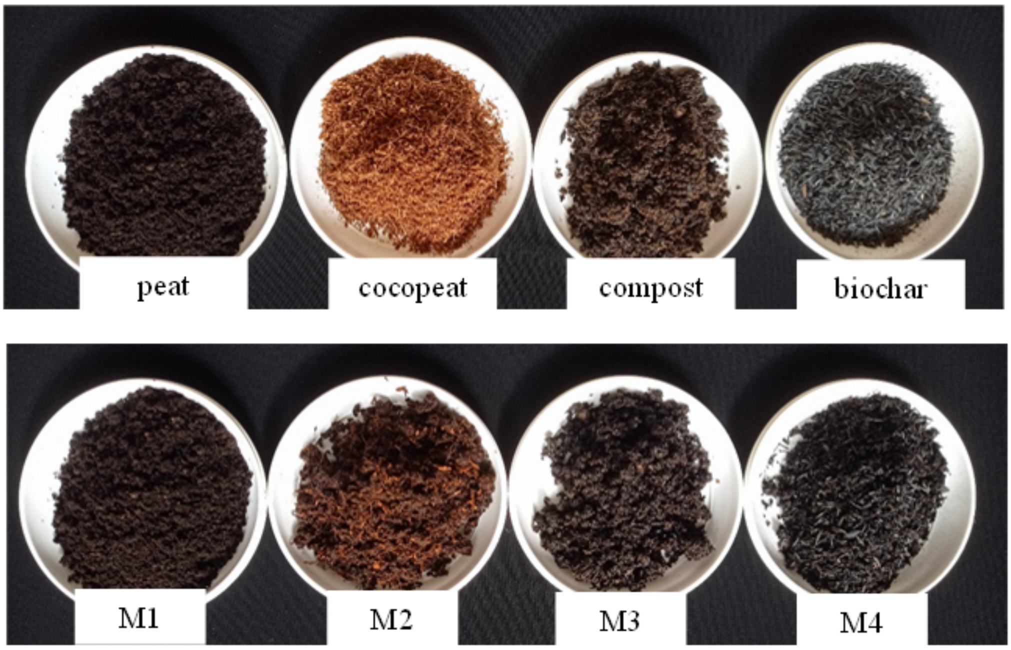

Fig. 2. The growing media, (M1) peat 100%, (M2) peat 70% + cocopeat 30%, (M3) peat 70% + compost 30%, (M4) peat 70% + biochar 30%.

2.4. Observation and Growth Measurement

Observations were carried out for six months. Several variables were observed, including survival rate, height, diameter, total dry weight, shoot-root ratio, root length, growing media analysis, macronutrient contents test, and seedling quality index. The survival rate is calculated based on the ratio of viable seedlings to the number of seedlings and then multiplied by 100%. Seedling height was measured using a ruler from the base of the stem (1 cm above the media) to the point of growing apical shoots. The seedling diameter was measured using a caliper at the base of the stem, which had been marked 1 cm above the surface of the media. The total dry matter (TDM) was obtained based on the sum of the weight of the shoots and roots of the seedlings after each part was dried in the oven (Memmert UN55) to a constant weight at 80°C for 48 h. The weight of shoots and roots was measured using an analytical balance. The shoot-to-root ratio (SRR) was obtained based on the ratio of the dry weight of shoots to roots. Root length was measured using a ruler from the root neck to the root tip at the end of the observation. The growing media was analyzed at the Laboratory of Soil Science and Land Resources IPB University to determine the characteristics of the growing media, including pH value, macronutrient content (C, N, P, K, Ca, and Mg), base saturation, cation exchange capacity (CEC), and soil ash content. An macronutrient contents test was carried out at the end of the observation at the Laboratory of the Department of Agronomy and Horticulture IPB University. Seedling quality was measured using the Dickson Quality Index (DQI) (Dickson et al. 1960) and was calculated using Equation 1.

$$DQI = \frac{TDM}{\frac{SH}{SBD}+\frac{SDM}{RDM}} \quad (1)$$

where TDM is the total dry matter (gram), SH is shoot height (cm), SBD is stem base diameter (mm), SDM is the dry shoot matter (g), and RDM is root dry matter (g).

Environmental conditions in the greenhouse during the observation were also measured, which included air temperature, relative air humidity, and light intensity. Measurements of air temperature, relative air humidity, and light intensity were carried out three times in the morning, afternoon, and evening to obtain daily average data and were repeated six times each month to obtain monthly average data. Air temperature and relative humidity were measured using a thermohygrometer (TFA, Germany), while light intensity was measured using a light meter (Sanfix LXD1330).

2.5. Data Analysis

The experiment is a completely randomized design (CRD) and the linear equation model used is as follows (Mattjik and Sumertajaya 2006):

$$Y_{ij}= \mu+ \sigma_i+ \varepsilon_{ij} \quad (2)$$

where Y_{ij} is an observation on the treatment *i* repetition *j*, μ is the general average, τ_i is the effect of treatment *i*, ε_{ij} is a random effect on the treatment, *i* is the number of treatments (1, 2, 3, 4), and j is the number of repetition (1, 2, ……, 25). If the τ_i value for one or more treatments is not equal to zero, it can be concluded that the growing media treatment significantly affects seedling growth.

The data was processed using Microsoft Office Excel software and IBM SPSS Statistic 25. First, the normality test and homogeneity test were carried out on the data. Data that is not normal and/or homogeneous is transformed. Next, the data were analyzed using analysis of variance (ANOVA) at a confidence level of 95% to determine the effect of the growing media on the growth of *D. polyphylla* and *S. balangeran*. If there is a significant effect on the experimental variable, then it is continued with the post hoc test of Duncan's Multiple Range tests with a 95% confidence level. Pearson's linear correlation analysis was applied between all observed variables.

3. Results and Discussion

3.1. Environmental Factors, Edaphic Factors, and Survival Rate

Survival rate as an indicator of plant adaptability in surviving the conditions in which it grows is influenced by environmental factors and edaphic factors (Setiawan et al. 2015). **Table 1** shows the microclimatic conditions in the greenhouse as environmental factors.

Table 1. Microclimatic conditions in the greenhouse from September 2020 to January 2021

Month	Air temperature (°C)	Relative air humidity (%)	Light intensity (Lux)
September	28.16	77.53	1293.89
October	27.47	79.28	459.48
November	27.69	75.83	1806.06
December	26.33	80.17	1254.72
January	26.44	82.33	1175.61

Environmental factors (air temperature, relative air humidity, and light intensity) fluctuated during the six months of observation of seedling growth (**Table 1**). During the observation, the air temperature in the greenhouse ranged from 26.33–28.16°C, the relative air humidity ranged from 75.83–82.33%, and the light intensity ranged from 459.48–1806.06 Lux.

Table 2. Chemical characteristics of the growing media

Characteristic	Variation of Growing Media							
	M1	Value	M2	Value	M3	Value	M4	Value
C-organic (%)	49.12	VH	46.59	VH	47.6	VH	40.89	ST
N-total (%)	0.93	VH	0.97	VH	1.13	VH	1.07	VH
P-available (ppm)	46.6	VH	76.6	VH	589.9	VH	249.4	VH
P-total (ppm)	127.2	VH	334.7	VH	968	VH	573.2	VH
K ($cmol^{(+)}$/kg)	0.47	M	5.34	VH	2.28	VH	4.39	VH
Ca ($cmol^{(+)}$/kg)	2.77	L	4.14	L	16.45	H	14.17	H
Mg ($cmol^{(+)}$/kg)	3.78	H	5.91	H	6.35	H	7.65	H
CEC ($cmol^{(+)}$/kg)	118.91	VH	130.2	VH	100.68	VH	89.46	VH
Alkali saturation (%)	6.53	VL	15.6	VL	25.95	L	31.09	L
Ash content (%)	15.31	H	19.67	H	17.94	H	29.51	H
pH (H_2o)	3.13	VA	3.38	VA	3.93	VA	4.05	VA

Notes: M1 = 100% peat soil, M2 = 70% peat soil + 30% cocopeat, M3 = 70% peat soil + 30% compost, M4 = 70% peat soil + 30% biochar, CEC = cation exchange capacity, VL = very low, L = low, M = medium, H = high, VH = very high, VA = very acid (Eviati and Sulaeman 2009).

The edaphic factor in the form of growing media is the primary source for plants to meet the nutrient needs for growth. **Table 2** shows that the treatments tested improved the chemical characteristics of degraded peat soil. Mixing sapric mature peat media with cocopeat, compost, or biochar can increase pH, ash content, base saturation (KB), and nutrients N, P, K, Ca, and Mg. On the other hand, the addition of biochar or compost or cocopeat to sapric mature peat media reduced the C-organic content of the growing media. The addition of cocopeat increased the highest K element content, compost increased the highest N, P, and Ca elements content, while biochar increased the highest Mg element content. The highest pH value was obtained from peat media mixed with biochar (4.05).

Table 3. The survival rate of *Dyera polyphylla* and *Shorea balangeran* seedlings six months after planting in a nursery

Variation of Growing Media	Number of seedlings	Number of live seedlings	Survival rate (%)
D. polyphylla			
100% peat soil (control)	25	25	100
70% peat soil + 30% cocopeat	25	25	100
70% peat soil + 30% compost	25	25	100
70% peat soil + 30% biochar	25	25	100
S. balangeran			
100% peat soil (control)	25	25	100
70% peat soil + 30% cocopeat	25	25	100
70% peat soil + 30% compost	25	25	100
70% peat soil + 30% biochar	25	25	100

All *D. polyphylla* and *S. balangeran* seedlings treated with growing media for six months of observation in the greenhouse resulted in a 100% of survival rate (**Table 3**). The results show that both types of plants can adapt well to all growing media and greenhouse environments. Several studies related to *D. polyphylla* and *S. balangeran* in nurseries and in the field showed that both species grow best under microclimate conditions where air temperatures ranging from 22–33°C, relative air humidity between 57.9-86%, and light intensity ranging from 317–56,802 Lux (Graham et al. 2013; Khalil et al. 2019; Mardhatillah et al. 2019; Santosa 2010; Tata et al. 2022; Utami et al. 2008). These values were pretty similar to the microclimate conditions in the greenhouse during this study. The balance of temperature and humidity can encourage the opening of stomata to carry out photosynthesis, thereby increasing plant growth (Nassar et al. 2018). Light as a source of energy for plants to carry out photosynthesis also affects plant growth (Lakitan 2018). The increase in light intensity can increase the photosynthetic rate to some extent, but the value varies among species and varieties (Modarelli et al. 2022).

3.2. Growth of Dyera polyphylla and Shorea balangeran

The results of the variance analysis showed that the treatment of the growing media affected all observed variables except for the variable root length in *D. polyphylla* seedlings and variable diameter growth in *S. balangeran* seedlings (**Table 4**). Each treatment of the growing media resulted from various responses to each variable and seedlings' species of *D. polyphylla,* which was grown using peat and compost (M3), had the best height growth, diameter growth, TDM, SRR, and DQI and the second-best root length values compared to other growing media. Conversely, *S. balangeran,* which is grown on peat media (M1), had the best growth for diameter, TDM, SRR, root length, and DQI, as well as the second-best height growth compared to other growing media.

Tree growth is an irreversible process of increasing the size or volume and the number of cells (Sagala et al. 2022). The seedling stems' height and diameter represent the plant's primary and secondary growth forms. Height and diameter are two morphological parameters often used as standards for determining the quality of seedlings in planting activities. According to Lampela et al. (2017), seedling height will affect their survival at the beginning of planting in the field, which is related to increased tolerance to floods, prolonged drought, and high soil surface temperatures in degraded peatlands. Likewise, the seedlings' diameter indicates an extensive root system and stem volume (Nurhasybi et al. 2019). *D. polyphylla* seedlings, which were grown on M3 media, were able to grow with the best growth rates in height and diameter (**Table 3**). M3 media also provided the best TDM, SRR, and DQI averages for *D. polyphylla* seedlings compared to other growing media (**Table 3**).

Table 4. Effect of growing media treatment on growth seeds of *Dyera polyphylla* and *Shorea balangeran* in 6 months treatment

Variable	Variation of growing media			
	M1	M2	M3	M4
D. polyphylla				
Growth of height (cm)	1.68 ± 0.32b	1.88 ± 0.38b	2.82 ± 0.45a	1.18 ± 0.29c
Growth of diameter (mm)	1.7 ± 0.30b	1.72 ± 0.25b	2.20 ± 0.30a	1.79 ± 0.28ab
Total dry matter (gram)	2.81 ± 0.65b	2.57 ± 0.63b	4.15 ± 0.90a	2.45 ± 0.60b
Shoot root ratio	5.44 ± 0.56a	5.13 ± 0.58a	5.52 ± 0.64a	4.24 ± 0.56b
Root length (cm)	14.29 ± 1.99a	14.96 ± 2.67a	17.66 ± 2.33a	17.70 ± 2.09a
Dickson Quality Index	0.32 ± 0.09ab	0.29 ± 0.09b	0.46 ± 0.11a	0.31 ± 0.09ab
S. balangeran				
Growth of height (cm)	6.21 ± 1.58b	6.14 ± 1.33b	9.18 ± 1.61a	6.05 ± 1.15b
Growth of diameter (mm)	1.46 ± 0.17a	1.38 ± 0.11a	1.32 ± 0.13a	1.41 ± 0.15a
Total dry matter (gram)	2.09 ± 0.46a	1.21 ± 0.27b	1.28 ± 0.37b	1.22 ± 0.23b
Shoot root ratio	5.79 ± 1.18a	4.88 ± 0.65a	5.80 ± 0.80a	3.31 ± 0.32b
Root length (cm)	17.37 ± 1.88a	11.08 ± 2.03c	12.55 ± 1.70bc	15.13 ± 2.08ab
Dickson Quality Index	0.15 ± 0.03a	0.10 ± 0.02bc	0.09 ± 0.02c	0.12 ± 0.02ab

Notes: mean ± standard deviation followed by the same letter are not significantly different according to Duncan's test at a 95% confidence interval. M1 = 100% peat soil, M2 = 70% peat soil + 30% cocopeat, M3 = 70% peat soil + 30% compost, M4 = 70% peat soil + 30% biochar.

The M3 media had the highest nitrogen and phosphorus content among other growing media (**Table 2**). They produced the highest nitrogen and phosphorus content in *D. polyphylla* leaf tissue tests grown using this medium (**Table 5**). Nitrogen is generally absorbed by plants as nitrate and ammonium (Munawar 2011; Sagala et al. 2022; Sahwalita et al. 2012). Both play a role in the formation of chlorophyll needed for photosynthesis and affect the products of photosynthate (Sahwalita et al. 2012). The photosynthate is then sent to the tissues that need it, such as the tissues in the shoots, to form buds that develop into leaves and stems so that plant height also increases (Sahwalita et al. 2012). In addition to nitrogen, phosphorus also plays a role in stem development. According to Sahwalita et al. (2012), the growth response of seedling diameter tends to increase with the addition of phosphorus. Phosphorus, which is generally absorbed by plants in the form of $H_2PO_4^-$ and HPO_4^- is an essential constituent of plant cell membranes, especially young cells such as shoot and root tissues, which have fast cell division activity and high metabolism (Sagala et al. 2022; Sahwalita et al. 2012). It accelerates seedlings' growth into mature plants. The high content of nitrogen and phosphorus in M3 media plays an essential role in increasing the growth of shoots and roots of seedlings and indirectly contributing to the increase in TDM.

Table 5. The effect of growing media treatment on the nutrient content of N, P, K, C, Ca, and Mg of *Dyera polyphylla* and *Shorea balangeran* seedlings

Nutrient content (%)	Variation of growing media			
	M1	M2	M3	M4
D. polyphylla				
N	1.94 ± 0.02[a]	1.93[a]	1.99 ± 0.04[a]	1.87 ± 0.19[a]
P	0.12 ± 0.01[b]	0.16 ± 0.01[a]	0.17 ± 0.02[a]	0.16 ± 0.01[a]
K	1.22 ± 0.04[ab]	1.24 ± 0.04[ab]	1.12 ± 0.13[b]	1.40 ± 0.03[a]
C	46.49 ± 0.69[a]	47.96 ± 1.61[a]	44.20 ± 2.64[a]	46.14 ± 2.42[a]
Ca	0.83 ± 0.01[a]	0.73 ± 0.07[a]	0.77 ± 0.08[a]	0.80 ± 0.04[a]
Mg	0.35 ± 0.01[a]	0.25 ± 0.01[b]	0.24[b]	0.34 ± 0.05[a]
S. balangeran				
N	1.75 ± 0.03[b]	1.76 ± 0.02[b]	1.91 ± 0.12[ab]	1.96 ± 0.06[a]
P	0.11 ± 0.01[c]	0.13[bc]	0.16[b]	0.22 ± 0.03[a]
K	0.63 ± 0.02[b]	0.91 ± 0.04[a]	0.71 ± 0.04[b]	0.91 ± 0.09[a]
C	44.76 ± 2.22[ab]	47.07 ± 0.71[a]	46.83 ± 0.87[ab]	43.35 ± 0.58[b]
Ca	0.49 ± 0.03[a]	0.43 ± 0.02[a]	0.68 ± 0.18a	0.61 ± 0.03[a]
Mg	0.13 ± 0.01[b]	0.11[b]	0.17 ± 0.01[a]	0.17 ± 0.01[a]

Notes: mean ± standard deviation followed by the same letter are not significantly different according to Duncan's test at a 95% confidence interval. M1 = 100% peat soil, M2 = 70% peat soil + 30% cocopeat, M3 = 70% peat soil + 30% compost, M4 = 70% peat soil + 30% biochar.

Table 6 shows that TDM is positively related to seedling height and diameter (0.744 and 0.756), according to the results of a study conducted by Marjenah et al. (2016) and Hidayat et al. (2020). Usually, TDM also correlates with the survival rate of seedlings and their growth in the field; however, to produce seedlings with the best adaptation and growth, TDM must have a balanced SRR value (Nurhasybi et al. 2019).

Nurhasybi et al. (2019) stated that SRR measures the balance between the transpiration area (shoots) and the water absorption area (roots). A lower SRR value indicates a more extensive root system so that it has better survival, growth, and adaptation to drought after planting (Binotto et al. 2010; Marjenah et al. 2016). Conversely, a high SRR value can increase the stress of seedlings on dry sites prior to root development because they have a larger transpiration area than the root surface area (Marjenah et al. 2016; Nurhasybi et al. 2019). However, according to Santosa et al. (2013), a high SRR value indicates that the growing media used can provide sufficient water and nutrients to increase photosynthetic capacity and more significant growth potential, resulting in a large increase in total biomass production (Santosa et al. 2013). These conditions indirectly indicate that the roots provide water and nutrients to increase the growth of high seedlings (Santosa et al. 2013). In this study, M3 media resulted in the highest SRR value, while the lowest SRR value was produced by seedlings on M4 media.

The M3 media also resulted from the highest average yield of *D. polyphylla* seedling quality index (DQI) compared to other growing media. According to Sudomo et al. (2010), a better seedling quality index will increase the chances of successful planting in the field. The M3 media produces the best quality seedlings because compost addition improves the characteristics of degraded peat soil. The analysis of the growing media (**Table 2**) shows that mixing compost with peat media can increase the highest N, P, and Ca content and the second-best organic C, Mg, alkaline content, and pH compared to other mixtures. Improvement of these characteristics is indirectly able to meet the needs of nutrients to increase the growth of *D. polyphylla* seedlings so that the quality of the seedlings increases.

Table 6. Pearson correlation coefficients among Dickson quality index and other observed variables in *Dyera polyphylla* and *Shorea balangeran* seedlings

		D. polyphylla	***S. balangeran***
Growth of height vs	Growth of diameter	0.563**	0.570**
	Total dry matter	0.744**	0.573**
	Shoot root ratio	0.15	0.373**
	Root length	0.176	0.088
	Dickson quality index	0.650**	0.365**
Growth of diameter vs	Growth of height	0.563**	0.570**
	Total dry matter	0.756**	0.527**
	Shoot root ratio	-0.174	0.173*
	Root length	0.344**	0.175
	Dickson quality index	0.788**	0.485**
Total dry matter vs	Growth of height	0.744**	0.573**
	Growth of diameter	0.756**	0.527**
	Shoot root ratio	-0.033	0.422**
	Root length	0.285**	0.377**
	Dickson quality index	0.960**	0.900**
Shoot Root Ratio vs	Growth of height	0.15	0.373**
	Growth of diameter	-0.174	0.173*
	Total dry matter	-0.033	0.422**
	Root length	-0.244*	0.024
	Dickson quality index	-0.273*	0.043
Root length vs	Growth of height	0.176	0.088
	Growth of diameter	0.344**	0.175
	Total dry matter	0.285*	0.377**
	Shoot root ratio	-0.244*	0.024
	Dickson quality index	0.355**	0.398**
Dickson Quality Index vs	Growth of height	0.650**	0.365**
	Growth of diameter	0.788**	0.485**
	Total dry matter	0.960**	0.900**
	Shoot root ratio	-0.273*	0.043
	Root length	0.365**	0.398**

Notes: ** correlation is significant at the 0.01 level (2-tailed), * correlation is significant at the 0.05 level (2-tailed).

The growing media that gave the second-best average DQI for *D. polyphylla* was M1 (0.32), supported by the second-best average TDM (2.81) and SRR (5.44) even though growth in diameter (1.7) and root length (14.29) were the lowest compared to the other growing media. Peat as a growing media (M1) has the lowest nutrient content and pH than other growing media. Even so, the growth of *D. polyphylla* as a native peat swamp forest plant can still grow well. *D. polyphylla* has grown using M2 and M4 showed lower DQI values. The condition of the seedlings in each treatment can be seen in (**Fig. 3**).

Fig. 3. The *Dyera polyphylla* seedlings condition of each treatment, (a) seedlings condition of M1 treatment, (b) seedlings condition of M2 treatment, (c) seedlings condition of M3 treatment, (d) seedlings condition of M4 treatment.

In contrast, *S. balangeran* seedlings showed the best growth performance on M1 media. *S. balangeran,* which was planted using M1 media, showed the best growth in diameter, TDM, SRR, root length, and DQI, as well as the second-best height growth value compared to other seed-growing media. Peat media (M1) has the lowest N, P, K, Ca, and Mg nutrient content characteristics among other growing media (**Table 2**), as well as base saturation, ash content, and pH. Seedlings planted on peat media (M1) had the lowest N, P, and K nutrient content and the second lowest C, Ca, and Mg elements compared to others. These results indicate that peat-growing media can better support many growth parameters of *S. balangeran* seedlings, even though most of the media's nutrient content is low. The growing media that gave the second-best average DQI for *S. balangeran* was M4 (0.12). Statistically, the results of the DQI of M1 were not significantly different from the DQI of M4. Even so, the average growth of height, TDM, and SRR of S. balangeran grown using M1 were lower than the others. These three parameters are very important in the selection of seedlings for restoration. Tall seedlings will better tolerate inundated peatland conditions (Lampela et al. 2017). The TDM value positively correlates with their growth in the field, but this needs to be supported by a balanced SRR value (Nurhasybi et al. 2019). The condition of the seedlings in each treatment can be seen in (**Fig. 4**).

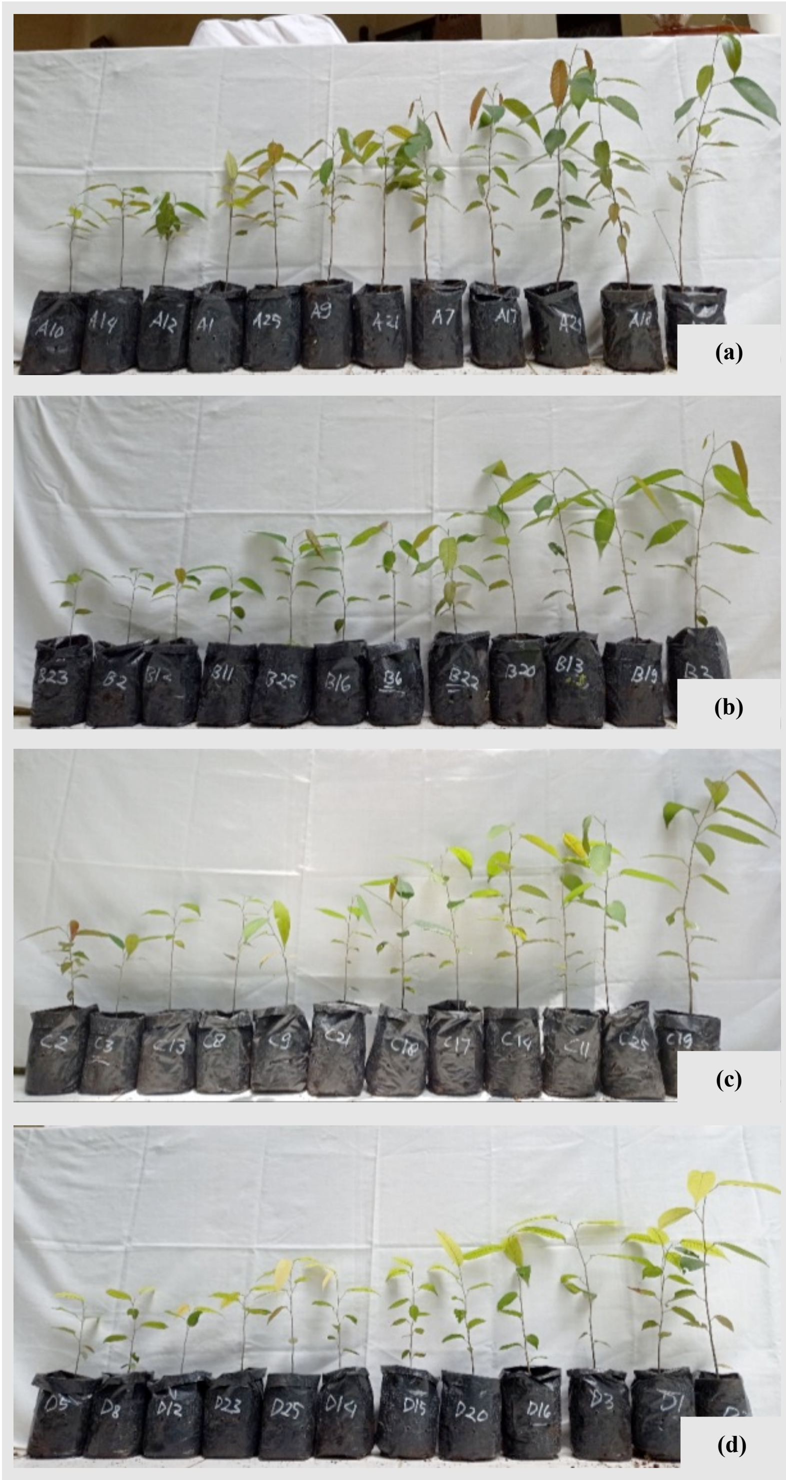

Fig. 4. The *Shorea balangeran* seedlings condition of each treatment, (a) seedlings condition of M1 treatment, (b) seedlings condition of M2 treatment, (c) seedlings condition of M3 treatment, (d) seedlings condition of M4 treatment.

S. balangeran adapts well to various soil and environmental conditions such as ultisols or latosols, degraded peatlands, dry open land, flooded land, and intense peat (Atmoko 2011; Suryanto et al. 2012). *S. balangeran* develops adventitious roots to adapt to flooded conditions (Tata et al. 2022). The presence of nine types of endophytic molds on the leaves and twigs of *S. balangeran* also helps it control pests and diseases naturally (Istikorini and Sari 2022). *Shorea balangeran* is naturally distributed in tidal areas and swamps on the islands of Sumatra and Kalimantan, namely in Bangka Belitung, West Kalimantan, South Kalimantan, and Central Kalimantan (Arsad 2016; Suryanto et al. 2012). In several locations in Bangka Belitung Province, *S. balangeran* can grow naturally on acid to very acid soils (pH 3.8–5) with moderate CEC values (18.4-22.6), moderate base saturation values (40- 47.8), low to high C content (1.9-3.2), low to moderate N (0.2-0.3), shallow to moderate P (6.6-15.6), high K (0.7-0.8), low to moderate Ca (1.9-3.2), and high Mg (2.3-3.1) (Wardani and Susilo 2016).

The characteristics of peat soil used as media (M1) have been analyzed (**Table 2**). It can be seen that the peat media (M1) contains high C-organic, N, P, Ca, and Mg content. These results indicate that peat media is suitable as a growing media for *S. balangeran* seedlings for restoration activities because it can optimally support its growth in the nursery. However, other alternative seed-growing media also need to be considered to reduce the extraction of peat soil in the field.

Peat soil extraction is one factor that destabilizes peat ecosystem carbon stocks (Wilson et al. 2016). The addition of cocopeat or compost, or biochar as a mixture for peat media for nurseries can reduce ecosystem damage due to extraction activities because the need for peat soil is reduced. Using these materials also benefits efforts to improve the characteristics of degraded peat soils. This study showed that mixing peat and cocopeat, peat and compost, and peat and biochar resulted in an average DQI value of 0.10, 0.09, and 0.12. Some researchers state that seedlings are ready to be planted in the field with a DQI > 0.09 (Marjenah et al. 2016; Muin et al. 2022; Sudomo and Santosa 2011). Based on these standards, all growing media treatments used in this study resulted in good DQI values for preparing seedlings to be planted in the field.

4. Conclusions

The peat soil, which is mixed with cocopeat, compost, or biochar, can improve the chemical characteristics of growing media for the growth of seedlings and significantly increase of pH, ash content, base saturation, and nutrient content of N, P, K, Ca, and Mg. The growing media treatment affected all variables observed, e.g., height growth, diameter growth, total dry matter, shoot root ratio, root length, and DQI, except for the variable root length of *D. polyphylla* seedlings and the variable diameter of *S. balangeran* seedlings. The growing media for the best seedling quality index (DQI) for *D. polyphylla* was 70% peat and 30% compost (M3), while for *S. balangeran* seedlings was 100% peat (M1).

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