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Research Paper

High-Quality Seedlings: A Must for Successful Forest and Land Rehabilitation

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ABSTRACT: *The success of tree planting in forest and land rehabilitation programs depends heavily on the availability of high-quality seedlings produced in each nursery. Therefore, this research was conducted at the permanent nursery of the Way Seputih-Way Sekampung Watershed Management Center (WMC), Indonesia, with the aim of analyzing the physical-physiological quality of tree seedlings. Sample seedlings for each species of tree seedling were determined using systematic sampling with random start, with the number of samples according to the provisions of Indonesian National Standards 8420 (INS 8420). Data collected included: tree species, seedling height, stem diameter, stem straightness, woody stem length, number of leaves and/or LCR (live crown ratio), growth medium compactness, and seedling health conditions. Seedling quality class analysis was conducted based on the criteria listed in INS 8420, as well as seedling quality index analysis using the Dickson's formula.The results of the research showed that 8 species of tree seedlings had been observed, namely Avocado generatively, Avocado by grafting, durian, dogfruit, nutmeg, areca nut, jackfruit, and sea sengon.There were no tree seedlings classified as first quality. Two species of tree seedlings were classified as second quality, namely generative avocado seedlings and grafted avocado seedlings.Three species of tree seedlings are categorized as rejected, namely dogfruit, jackfruit, and sea sengon. Three species of seedlings could not be assigned a quality class, namely durian seedlings, nutmeg seedlings, and areca nut seedlings, as they are not yet listed in INS 8420.Two species of tree seedlings, namely generative avocado seedlings and 3-month-old areca nut seedlings, had relatively high seedling quality index values (>0.09), at 0.138 and 0.344, respectively. The other six species of tree seedlings had low seedling quality index values (<0.09). The seedling quality index may still increase in the next growth period if the availability of nutrients and water in the seedling growth media meets the needs for optimal growth.*

Keywords: *Nursery, Rehabilitation, Seedling quality, Tree seedling*

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I. INTRODUCTION

Forest and Land Rehabilitation

Indonesia is one of the countries with extensive forest areas, covering 120.5 million hectares, or 64% of Indonesia's land area (Nurofiq et al, 2020). Forest areas in Indonesia have experienced very serious deforestation over the past 70 years (Fisher et al., 2023) caused by various factors, resulting in forest vegetation cover within forest areas in Indonesia has decreased from 74% to 54% over a period of 30–40 years (Basuki et al., 2022). Deforestation results in land degradation within forest areas and becomes critical land (Rostanty et al., 2023), while critical land outside forest areas generally occurs due to inappropriate land use intensification (Hajad et al., 2025).

The total area of critical land in Indonesia in 2018 was approximately 14 million ha (Badan Pusat Statistik Indonesia, 2018; Rostanty et al., 2023). In 2024, the total area of critical land in Indonesia is estimated to remain at 12,294,321 ha, including 7,094,277 ha of critical land within forest areas and 5,200,044 ha of critical land outside forest areas (Menteri Kehutanan Republik Indonesia, 2025).Critical land is a form of degraded land (Nugraheni et al., 2021). Critical land is land that hasexperienced damage or degradation, resulting in reduced land function or even loss of land function (Budiastuti et al., 2020). Reduced land function or even loss of land function can negatively impact soil fertility, water quality, and other environmental components (Budiastuti et al., 2020; Rostanty et al., 2023).Forest and land rehabilitation is one of the priority development programs of the Indonesian Government (Rostanty et al., 2023) which has been started since the early 1950s (Nawir et al., 2007) to overcome the high rate of deforestation and reduce the existence of critical land in forest areas and outside forest areas (Basuki et al., 2022). In fact, forest and land rehabilitation is also a priority program in many countries (Maalik et al., 2025). Rostanty et al. (2023) stated that to reduce the emergence of critical land due to deforestation and land degradation, the Indonesian Government has set a target of forest and land rehabilitation of 420 thousand ha annually, or targeting an area of 2.1 million ha for the period 2020-2024 (Rostanty et al., 2023).

Forest and land rehabilitation is intended to restore, maintain, and improve forest and land functions, so that their carrying capacity, productivity, and role in supporting life support systems are maintained (Pemerintah Republik Indonesia, 1999). Forest rehabilitation in the form of reforestation in forest areas is an effort to restore and increase forest vegetation cover (Basuki et al., 2022), overcome land and environmental degradation due to deforestation, restore and improve forest functions (Afrianda & Yasin, 2023), mitigate greenhouse gas emissions, increase carbon sequestration, while protecting the environment (Fisher et al., 2023), and encourage sustainable forestry development processes (Ali et al., 2024; Rostanty et al., 2023). Meanwhile, land rehabilitation has the main objective of restoring and improving the condition of degraded land to increase productivity and sustainability, as well as increasing stocks and mitigating climate change (Mursyid et al., 2025). According to Ali et al. (2024), the implementation of reforestation programs has a real contribution in addressing various factors that cause deforestation and land and environmental degradation.

Forest and land rehabilitation is carried out through reforestation and afforestation (Pemerintah Republik Indonesia, 1999).Reforestation is an effort to restore land in a forest area that has experienced deforestation to become forest again, while afforestation is an effort to improve agricultural land or degraded community land by planting trees in part or in a certain area to become forest (Maalik et al., 2025).According toIndriyanto (2010) dan Maalik et al. (2025),reforestation is the activity of planting trees in a forest area, while afforestation is planting trees on degraded land or critical land outside the forest area. Referring to the definitions of reforestation and afforestation, the main activity of forest and land rehabilitation is tree planting (Afrianda & Yasin, 2023; Indriyanto, 2010).

Deforestation within forest areas in Lampung Province in 2024 covered 21,000 ha and deforestation outside forest areas covered 16,580 ha (Direktorat Jenderal Planologi Kehutanan, 2024). This ongoing deforestation certainly leads to the emergence of critical land that is never resolved. The area of critical land within the working area of the Way Seputih-Way Sekampung Watershed Management Center of Lampung Province is 389,323 ha, which includes 293,872 ha within forest areas and 95,451 ha outside forest areas (Menteri Kehutanan Republik Indonesia, 2025). This prompted the watershed management center to build a permanent nursery to support the forest and land rehabilitation program in Lampung Province.Nursery development is one stage in a series of forest and land rehabilitation activities (Indriyanto, 2010), aimed at providing a sufficient number of high-quality seedlings to achieve the objectives of tree planting activities (Indriyanto, 2022). The success of tree survival and growth indicates the success of a tree planting program (Indriyanto, 2022)which is influenced by high-quality seedlings and, of course, the number of seedlings available is sufficient to meet needs (Grossnickle & MacDonald, 2018).

Function of Tree Nursery

Seedling production is a basic requirement in every tree planting and forest development program, so the existence of a nursery allows for seedling production as needed (Keneni & Zeleke, 2025). A nursery is a building and/or activity in order to provide seedlings in sufficient quantities and of high quality (Indriyanto, 2022). Keneni & Zeleke (2025)state that a nursery is a place designed and managed to produce tree seedlings that grow well until they are ready to be planted. According to Lamhamedi et al. (2023), a nursery is part of the chain or stage of forest development that functions to provide tree seedlings of high physical-physiological quality.

As previously stated, forest and land restoration is a significant challenge (Preece et al., 2023; Rostanty et al., 2023)and a complex process, with each stage requiring effective implementation to achieve successful forest development(Grossnickle & MacDonald, 2018).Therefore, nursery development is essential as a means of providing high-quality seedlings (Guimaraes et al., 2024; Indriyanto, 2022; Lamhamedi et al., 2023).Dumroese et al. (2005)argued that establishing nurseries is crucial for implementing technology to produce high-quality seedlings. Furthermore, Dumroese et al. (2005)stated that nurseries serve as research facilities and support successful reforestation and reforestation. Private nurseries, for example, can also foster seedling entrepreneurship by selling seedlings to the government or communities in need (Irawan et al., 2015).

Many factors influence the success of forest and land rehabilitation. Forest and land rehabilitation through tree planting must consider the benefits of trees according to the planting objectives, such as economic or social benefits, as well as ecological or conservation benefits (Le et al., 2013).According to (Indriyanto, 2010),tree species selection is crucial for the success of various tree planting objectives. Reforestation failure often occurs when planting uses inappropriate tree species (Preece et al., 2023). Another factor contributing to the success of tree planting is the availability of seedlings in sufficient quantities and of adequate quality (Indriyanto, 2022; Sisay et al., 2020). According to Grossnickle & MacDonald (2018)and Rostanty et al. (2023), one of the key factors determining the success of forest and land rehabilitation programs is the provision of high-quality seedlings in sufficient quantities for tree planting. High-quality seedlings are needed to develop high-quality tree planting (Irawan et al., 2015), improve seedling survival and growth after planting (Harayama et al., 2023),and reduce plant management costs (Keneni & Zeleke, 2025).

Nurhasybi et al. (2019)stated that planting trees using high-quality seedlings can produce plants with a high level of adaptation, rapid initial growth, and a desirable appearance. Meanwhile, the use of poor-quality seedlings is a reason for planting failures in land rehabilitation (Grossnickle & MacDonald, 2018). Low-quality seedlings are unable to withstand environmental stress and various other plant-damaging factors, so their ability to survive and grow is also low (Guimaraes et al., 2024),increasing mortality and early growth in the field (Moreira et al., 2023)**.**

Seedling quality includes genetic, physical, and physiological qualities (Irawan et al., 2015; Indriyanto, 2022).The genetic quality of tree seedlings can be seen from certified seed sources (Irawan et al., 2015), while the physical and physiological quality of tree seedlings at the nursery can be seen based on their morphological (physical) and physiological characteristics (Guimaraes et al., 2024)because these two characteristics are closely related.The physical quality of seeds is the quality of seeds based on the morphological characteristics of the seeds (Haase, 2008).Morphological characteristics of seeds are based on the shape of seedling organs indirectly as a manifestation of physiological responses to environmental factors (Haase, 2007), for example stem shape, leaf shape, and root system (Guimaraes et al., 2024; Indriyanto, 2022). Meanwhile, the physiological quality of seeds is the quality that is influenced by the activity of the plant's physiological processes, so that its physiological characteristics are visible (Haase, 2008), for example, the dimensions of seedling height, stem diameter dimensions, number of leaves, dry weight, and seedling quality index (Guimaraes et al., 2024; Indriyanto, 2022).

The diversity of seedling quality in nurseries can affect the success of forest and land rehabilitation programs. Santoso et al. (2024)stated that of the 11 tree seedlings produced at PT Bukit Asam's nursery, none were of the first-quality (prime quality) category, 6 were of the second-quality category, and 5 were of the poor-quality (rejected) category. The percentage of normal seedlings varied between tree species, ranging from 0 to 90% (Santoso et al., 2024). Then, Muin et al. (2022)stated that of the 10 species of tree seedlings studied in the nursery belonging to the Siantan WMPFC (Watershed Management and Protected Forest Center), West Kalimantan, only 7 species of tree seedlings were of high quality. Yustika et al. (2022)also stated that the tree seedlings produced in the PT Natarang Mining nursery showed that all tree seedlings were of low quality (rejected quality). The percentage of normal seedlings in the PT Natarang Mining nursery also varied between tree species, namely 0.73–79.80% (Yustika et al. (2022).

The nursery owned by the Way Seputih-Way Sekampung WMC (Watershed Management Center) in Tanggamus Regency, Lampung Province, Indonesia, is one of the permanent nurseries built to support forest and land rehabilitation programs in Lampung Province. Each nursery is expected to meet the required number of seedlings and high-quality seedlings to support forest and land rehabilitation programs(Dumroese et al., 2005; Irawan et al., 2015).Therefore, the research was conducted on seedlings produced at the permanent nursery owned by the Way Seputih-Way Sekampung WMC in Tanggamus Regency (Indonesia) to analyze the quality of the resulting tree seedlings. The results are expected to serve as a reference for improving the quality of tree seedlings in the future (Sisay et al., 2020).

II. METHODS

Research Location

The research was conducted at a permanent nursery owned by the Way Seputih-Way Sekampung Watershed Management Center (WMC), Tanggamus Regency, Lampung Province, Indonesia. This nursery is one of two permanent nurseries owned by the Indonesian Government in Lampung Province. The nursery is located in Kota Agung Selatan Village, Kota Agung District, Tanggamus Regency, Lampung Province, Indonesia. The location of the research site can be seen in Figure 1.

Figure 1. Map of the research location at the permanent nursery belonging to the Way Seputih-Way Sekampung WMC, Tanggamus Regency, Lampung Province, Indonesia.

The permanent nursery belonging to the Way Seputih-Way Sekampung WMC in Tanggamus Regency is located at an altitude of 90 m asl and covers an area of 1 ha. The annual seedling production capacity is 1,000,000 seedlings (Dewan Perwakilan Rakyat Republik Indonesia, 2020).The seedlings produced include both forest timber and multi-purpose tree species (MPTS), but the number of tree species produced varies each year.The nursery facilities include a nursery administration office building, a vehicle parking area, a gazebo (shelter), a nursery media preparation room, a germination room in the form of a transparent plastic greenhouse with an iron frame, a water installation equipped with sprinklers, and seedling weaning beds. The seedling weaning beds measure 5 m x 1 m with a capacity of 800-1,200 seedlings per bed, depending on the size of the container used.Most of the seedling weaning place (bedengan; term in Indonesia) are roofed with shading nets measuring approximately 50-70%. Most of the seedling weaning media is made of a mixture of topsoil (3 parts) + cocopeat (2 parts) + rice husk charcoal (1 part) + goat manure (1 part). A small portion uses topsoil. All seedlings are made in the form of container seedlings (potted seedlings) using polybags of various sizes, including 5 cm diameter and 11 cm height, 7.5 cm diameter and 10 cm height, 7 cm diameter and 10.5 cm height, 10 cm diameter and 20 cm height, and 9 cm diameter and 21 cm height.

Equipment

The equipment used for this research consists of a measuring tape, ruler, caliper, knife, scissors, baseboard for taking notes, tally sheet, pen, global positioning system (GPS), lux meter, thermohygrometer, soil pH-moisture meter (soil survey instrument), and camera.

Data Acquisition

The research was conducted for 5 months, from July to October 2025. Data collection was carried out by direct survey at the nursery location. The data collected included the species of tree seedlings, the condition of the number of seedling stems, the condition of the straightness of the seedling stems, the health condition of the seedlings, the woody condition of the seedling stems, the height of the seedlings, the diameter of the seedling stems, the compactness of the growing media, the number of leaves and/or live crown ratio (LCR), the age of the seedlings, the materials for the seedling growing media, the container size, the pH of the growing media, and data on environmental conditions (air temperature, air humidity, and solar radiation intensity).

Determination of sample seedlings for each species of tree was carried out on the seedling weaning place of each species of tree using systematic sampling with random start with the number of samples according to the provisions in Table 1.

Table 1. Determination of the number of sample seedlings for observation the physical-physiological condition variables of the tree seedlings

Number	Total number of seedlings was observed (individual)	Number of sample seedlings (individual)
1.	<1,000	10
2.	1,000 until <10,000	100
3.	10,000 until <50,000	200
4.	50,000 until <100,000	500
5.	100,000 until <1,000,000	1,000
6.	≥1,000,000	2,000

Source:Badan Standardisasi Nasional (2018) ; Direktorat Jenderal Rehabilitasi Lahan dan Perhutanan Sosial (2009)

Based on this procedure, the seedling samples for observing the physical-physiological quality variables of seedlings of each tree species are presented in Table 2.

Table 2. Trees species, total number of seedlings, and number of seedling samples studied in the nursery belonging
to the Way Seputih-Way Sekampung Watershed Management Center (WMC), Tanggamus Regency,
Lampung Province, Indonesia.

Number	Tree species		The number of seedling (individual)	The number of sample seedling (individual)
	Local name	Botanical name		
1.	Avocado generatively	*Persea americana* Mill.	800	10
2.	Avocado by grafting	*Persea americana* Mill.	600	10
3.	Durian	*Durio zibethinus* Murr.	3,000	100
4.	Dogfruit	*Pithecellobium lobatum* Benth.	5,000	100
5.	Nutmeg	*Myristica fragrans* Hout.	3,000	101
6.	Areca nut	*Areca catechu* L.	8,000	105
7.	Jackfruit	*Artocarpus heterophyllus* Lamk.	800	12
8.	Sea sengon	*Paraserianthes falcataria* (L.) Nielsen	22,000	200

Analysis of Data

1. Physical-physiological Conditions of Seedlings

General requirements for the physical-physiological quality of seedlings include: the number of seedlings, the straightness of the stems, the health condition, and the percentage of woody stem length to the total height of the seedlings. Seedlings that meet the general requirements are then verified again to determine whether they meet the specific requirements for the physical-physiological quality of tree seedlings, including seedling height, stem diameter, compactness of the growing medium, number of leaves and/or LCR (live crown ratio), and age of the seedlings.

Seedlings that meet the general requirements for physical-physiological quality are called normal seedlings, while seedlings that do not meet the general requirements for quality seedlings are called abnormal seedlings (Indriyanto, 2022). The criteria for normal seedlings are seedlings that have a single stem or a stem that does not fork, an upright and straight stem, healthy or not attacked by pests and diseases, normal leaf color, and a percentage of woody stem length of 50% of the total height of the seedlings (Badan Standarisasi Nasional, 2018).The percentage of normal seedlings number was calculated using the following formula(Badan Standardisasi Nasional, 2018).

$$\text{Percentage of normal seedling number} = \frac{\text{the number of normal seedling}}{\text{the number of sample seedling}} \times 100\% \quad (1)$$

The special condition variables for the physical-physiological quality of seeds are analyzed using the following formulas (Badan Standardisasi Nasional, 2018).

a. Percentage of seedlings number which height meets the standard (BST).

$$\mathrm{BST} = \frac{\text{the number of seedling which height meets the standards}}{\text{the number of sample seedling}} \times 100\% \quad (2)$$

b. Percentage of seedlings number which stem diameter meets the standard (BSD).

$$\mathrm{BSD} = \frac{\text{the number of seedling which stem diameter meets standards}}{\text{the number of sample seedling}} \times 100\% \quad (3)$$

c. Percentage of seedlings number which growth medium is compact or intact (BMK)

$$\mathrm{BMK} = \frac{\text{the number of seedlings which growth is compact}}{\text{the number of sample seedling}} \times 100\% \quad (4)$$

d. Percentage of seedlings number which leaf amount or LCR meets the standard (BSJD).

$$\mathrm{BSJD} = \frac{\text{the number of seedlings which leaf amount or LCR meets standards}}{\text{the number of sample seedling}} \times 100\% (5)$$

e. Average percentage of seedlings for each tree species that meets special requirements (RPK).

$$\mathrm{RPK} = \frac{\mathrm{BST+BSD+BMK+BSJD}}{4} \quad (6)$$

2. Quality of Forest Plant Seedlings

The quality standards for forest plant seedlings in Indonesia were grouped into three classes, namely first quality, second quality, and rejected (do not meet the first quality or second quality) (Badan Standardisasi Nasional, 2018). The first quality is forest plant seedlings that meet general requirements with a quantity percentage > 95% and meet special requirements with a quantity percentage > 90%. The second quality is forest plant seedlings that meet general requirements with a total percentage of 75 – 95%, and meet special requirements with a total percentage of 70 – 90%. Rejected seedling are seedlings that are not included in the first or second quality class because the percentage of the number of seedlings that meet the general requirements is <75% and the percentage of the number of seedlings that meet the special requirements is <70%. First and second quality seedlings can be certified by the Forest Plant Seed Center or by a Certification Agency under the Directorate General of Land Rehabilitation and Social Forestry (Indriyanto, 2022).

3. Seedling Quality Index

The seedling quality index is one of the index that can indicate the physiological quality of seedlings. The seedling quality index is calculated using the the Dickson'sformula proposed by Bickelhaupt as follows (Indriyanto, 1999).

$$\text{Seedling quality index} = \frac{\text{crown dry weight (g)} + \text{root dry weight (g)}}{\frac{\text{seedling height (cm)}}{\text{seedling diameter (cm)}} + \frac{\text{crown dry weight (g)}}{\text{root dry weight (g)}}}$$

III. RESULT AND DISCUSSION

1. Physical-physiological Conditions of Seedlings

Seedlings from eight tree species studied at the Way Seputih-Way Sekampung WMC nursery in Tanggamus Regency, Lampung Province, Indonesia, exhibited varying physical and physiological conditions within eah species and between species. Variations in the physical and physiological conditions of the seedlings are shown in Table 3.

Table 3. Physical and physiological conditions of the seedlings of the jungle wood and MPTS (multi-purpose tree
species) groups at the permanent nursery belonging to Way Seputih-Way Sekampung WMC,
Tanggamus Regency, Lampung Province, Indonesia

Number	Species of tree seedlings	Seedling height (cm)	Seedling stem diameter (mm)	Leaf amount (strands) /LCR(%)	Percentage of healthy seedlings (%)	Percentage of seedlings whose media is intact(%)	Age of seedlings (month)
A.	Group of jungle trees						
	1. Sea sengon	7.0—54.0	1.1—4.1	LCR 31.6—98.9	99.5	99.0	1
B.	Group of MPTS						
	1. Avocado generatively	23.0—47.4	5.2—7.2	3—19	100.0	80.0	3
	2. Avocado bygrafting	26.0—41.0	5.2—8.2	8—18	100.0	100.0	3
	3. Durian	26.0—64.9	2.2—6.2	3—19	84.0	81.0	2
	4. Dogfruit	5.4—20.3	1.2—3.2	2—10	95.0	85.0	2
	5. Nutmeg	7.0—27.4	2.1—4.2	2—9	88.1	89.1	2
	6. Areca nut	8.0—42.2	3.2—9.1	1—4	82.9	75.2	3
	7. Jackfruit	23.0—79.5	3.1—5.2	2—7	83.3	75.0	3

The physical-physiological condition components of the seedlings include seedling height, seedling stem diameter, number of leaves or LCR, seedling health, compactness/intactness of the growing media, and seedling age. Seedling height, seedling stem diameter, and number of leaves or LCR are common parameters in measuring growth and are relevant for ranking seedling growth quality(Haase, 2007).

Based on the data in Table 3, the physical-physiological conditions of seedlings vary greatly. Variations in physical-physiological conditions occur within a single tree seedling species, as well as between tree seedling species. For example, one-month-old sea sengonseedlings have varying seedling heights ranging from 7.0 cm to 54.0 cm, stem diameters varying from 1.1 mm to 4.1 mm, and LCRs varying from 31.6% to 98.9%.Likewise, other species of tree seedlings, such as avocado seedlings generatively, avocado by grafting, durian, dogfruit, nutmeg, areca nut, and jackfruit have variations in seedling height, seedling stem diameter, and variations in the number of leaves or LCR.The variation in physical-physiological conditions of seedlings for a given tree species is thought to occur due to the diversity of individual trees used as sources of plant material or seed. Meanwhile, the variation in physical-physiological conditions between tree seedling species occurs due to differences in the growth characteristics of each tree species.

The percentage of healthy seedlings and the percentage of seedlings with intact growth media also varied between tree seedling species. The highest percentage of healthy seedlings (100%) was found in generatively grown avocado and grafted avocado seedlings, while the lowest percentage of healthy seedlings (82.9%) was found in areca nut seedlings. The highest percentage of tree seedlings with intact/compact growth media (100%) was found in grafted avocado seedlings, and the lowest percentage (75.0%) was found in jackfruit seedlings.

Seedling health is the physical and physiological condition of seedlings related to their ability to survive and grow in areas where pests and diseases are present or absent, as well as other limiting factors. Healthy seedlings are seedlings that have normal color, do not show any nutrient deficiencies, do not have dead shoots, are not attacked by pests and diseases (Badan Standardisasi Nasional, 2018),or are attacked by pests and diseases with a percentage of organ damage ≤ 5% (Asmaliyah et al., 2010).The compactness of a seedling growth media is the degree to which the media and roots aggregate perfectly, forming a cohesive mass. A cohesive or intact media is defined as a compact mass where the media and roots have aggregated to form a compact, unblemished mass (Badan Standardisasi Nasional, 2018).

As described in the research methods, that the general requirement for quality seedlings is that they must be of a normal category. Normal seedlings are defined as having a single and straight stem, a maximum height of 1.5 m, healthy seedlings, and woody stems with a woody stem length >50% of the seedling height (Badan Standardisasi Nasional, 2018; Indriyanto, 2022).The percentage of normal seedlings found at the research site is presented in Table 4.

Table 4. Percentage of amount of normal seedlings (seedlings that meet general physical-physiological quality requirements) in the nursery owned by the Way Seputih-Way Sekampung WMC, Tanggamus Regency, Lampung Province, Indonesia

Number	Species of tree seedlings	The number of sample seedling(individual)	The number of normal seedling (individual)	Percentage of amount of normal seedlings (%)
1.	Avocado generatively	10	9	90.0
2.	Avocado by grafting	10	10	100.0
3.	Durian	100	76	76.0
4.	Dogfruit	100	94	94.0
5.	Nutmeg	101	81	80.2
6.	Areca nut	105	86	81.9
7.	Jackfruit	12	10	83.3
8.	Sea sengon	200	162	81.0

Eight species of tree seedlings that were observed during the research at the permanent nursery belonging toWay Seputih-Way Sekampung WMC, all contained seedlings that were categorized as normal seedlings.The number of normal seedlings varies between tree species. The percentage of normal seedlings in each tree species varies from 76.0% to 100.0%.Based on the percentage of the number of normal seeds in each species of tree seedling, all species of tree seedlings meet the general requirements for physical-physiological quality.According toDirektorat Jenderal Rehabilitasi Lahan dan Perhutanan Sosial (2009), the percentage of normal seedlings as a general requirement for the physical-physiological quality of tree seedlings is 75%.At the time the research was conducted, there were four species of trees whose seedlings had not yet reached 3 months, namely sea sengon, durian, dogfruit, and nutmeg.According to Insusanty & Ikhwan (2022), normal seedlings that are more than 3 months old are generally suitable for planting in the planting area.Furthermore, Insusanty & Ikhwan (2022)stated that tree seedlings are suitable for planting if the seedling stem is woody, single and sturdy, healthy, the growing medium is compact, and the height and diameter of the seedling stem are sufficient.In general, a minimum seedling height of 25 cm has reached sufficient conditions (Badan Standardisasi Nasional, 2018; Direktorat Jenderal Rehabilitasi Lahan dan Perhutanan Sosial, 2009).

Tree seedlings produced in nurseries, in addition to having to meet general requirements (seedlings fall into the normal seedling category), must also meet special requirements.The variables determining the specific requirements for tree seedlings include the height of the seedling, the diameter of the base of the seedling stem, the number of leaves or LCR, and the compactness of the media which must meet standards (Badan Standardisasi Nasional, 2018).The percentage of amount of seedlings that meet the special physical-physiological quality requirements according to SNI 8420 is presented in Table 5.

Table 5. Percentage of amount of seedlings that meet the specific physical-physiological quality requirements for
each species of tree seedling at the permanent nursery belonging toWay Seputih-Way Sekampung WMC, Tanggamus Regency, Lampung Province, Indonesia

Number	Species of tree seedlings	The number of sample seedling (individual)	Percentage of amount of seedlings that meet special requirements (%)
1.	Avocado generatively	10	70.0
2.	Avocado by grafting	10	75.0
3.	Durian	100	Not yet registered in SNI 8420
4.	Dogfruit	100	35.5
5.	Nutmeg	101	Not yet registered in SNI 8420
6.	Areca nut	105	Not yet registered in SNI 8420
7.	Jackfruit	12	54.2
8.	Sea sengon	200	50.8

Based on Table 5, there are 3 species of tree seedlings that are not listed in SNI 8620-2021, so the percentage of seedlings that meet the specific physical-physiological quality requirements for tree seedlings cannot be analyzed.The three species of seedlings in question are durian tree seedlings, nutmeg tree seedlings, and areca nut tree seedlings.These three species of seedlings also cannot be analyzed based on the equivalence of criteria that exist in their close relatives (similarity of genus and plant family).There are 5 species of tree seedlings that have been analyzed for fulfilling the special physical-physiological quality requirements, namely generative avocado tree seedlings, avocado tree seedlings by grafting, dogfruit tree seedlings, jackfruit tree seedlings, and sea sengon tree seedlings.According to Direktorat Jenderal Rehabilitasi Lahan dan Perhutanan Sosial (2009),the percentage of the number of seedlings for each species of tree seedling is related to the specific physical-physiological quality requirements of the seedlings, which must be at least 70%.

Determination of the physical-physiological quality class of tree seedlings that produced at nurseries in Indonesia has been regulated in the Regulation of the Director General of RLPS Number P.05/V-SET/2009 and SNI 8420-2018. The results of the physical-physiological quality classification of tree seedlings at the research location are presented in Table 6.

Table 6. Seedling quality classes at the permanent nursery owned byWay Seputih-WaySekampung WMC, Tanggamus Regency, Lampung Province, Indonesia

Number	Species of tree seedlings	Percentage of amount of normal seedlings (%)	Percentage of amount of seedlings that meet special requirements (%)	Quality class of seedling
1.	Avocado generatively	90.0	70.0	Second quality
2.	Avocado by grafting	100.0	75.0	Second quality
3.	Durian	76.0	Not yet registered in SNI 8420	Cannot be determined yet
4.	Dogfruit	94.0	35.5	Reject
5.	Nutmeg	80.2	Not yet registered in SNI 8420	Cannot be determined yet
6.	Areca nut	81.9	Not yet registered in SNI 8420	Cannot be determined yet
7.	Jackfruit	83.3	54.2	Reject
8.	Sea sengon	81.0	50.8	Reject

Based on the results of determining the quality class of tree seedlings as presented in Table 6 above, it can be stated that of the 8 species of tree seedlings, there are 2 species of tree seedlings that are categorized as second quality, 3 species of tree seedlings whose quality class cannot be determined, and 3 species of tree seedlings are categorized as rejected.Two species of tree seedlings that fall into the second quality class category are genertively grown avocado seedlings and avocado seedlings by grafting which at the time of the study were 3 months old.

Three species of seedlings whose quality class cannot be determined are durian tree seedlings, nutmeg tree seedlings, and areca nut tree seedlings. The species of durian tree seedlings, nutmeg tree seedlings, and areca nut tree seedlings are not listed in SNI 8420, nor are there any tree genera and families listed in SNI 8420. If the species of tree seedlings is not listed in SNI 8420, then the determination of the seedling quality class can use the criteria of other species of tree seedlings that are still in the same genus and/or one family (Badan Standardisasi Nasional, 2018).

Three species of tree seedlings are categorized as rejected (low-quality seedlings), namely dogfruit, jackfruit, and sea sengon tree seedlings. These three species of tree seedlings have met the general requirements, namely the percentage of normal seedlings of ≥ 75%, but the percentage of seedlings that meet special requirements is < 70%, so they are categorized as rejected. Tree seedlings are categorized as low-quality (reject) allegedly because the seedlings are still too young, it could also be due to other causal factors such as the quality of the media and the size of the seedling container, and others, so that the quality of seedling growth is not optimal, and the growth of the crown and roots is not balanced.

Good and balanced seedling growth will produce high-quality seedlings. Seedling quality can be determined by the seedling quality index. The seedling quality index is also used as a variable that can indicate the physiological quality of tree seedlings (Moreira et al., 2023). The results of the seedling quality index analysis are presented in Table 7.

Table 7. Quality index of tree seedlings at the permanent nursery owned by Way Seputih-Way Sekampung WMC, Tanggamus Regency, Lampung Province, Indonesia

Number	Species of tree seedlings	Polybag size (diameter x height)	Composition of seedling growing media	Acidity of growing media (pH)	Seedling quality index
1.	Avocado generatively	10 cm x 20 cm	A	4.5—6.5	0.138
2.	Avocado by grafting	9 cm x 21 cm	A	6.0—6.5	0.079
3.	Durian	7.5 cm x 10 cm	A	5.0—6.5	0.036
4.	Dogfruit	7.5 cm x 10 cm	A	4.5—6.5	0.056
5.	Nutmeg	7.5 cm x 10 cm	A	5.0—6.5	0.028
6.	Areca nut	7 cm x 10.5 cm	A	5.0—6.5	0.344
7.	Jackfruit	5 cm x 11 cm	B	5.5—6.5	0.026
8.	Sea sengon	7.5 cm x 10 cm	A	5.0—6.5	0.019

Remark:
A= a mixture of topsoil, cocopeat, rice husk charcoal, goat manure with a ratio of 4:3:1:1.
B= top soil

Good physiological processes influence good growth. The seedling quality index can be used as an indicator of seedling growth quality and seedling quality. It can even be used to indicate seedling readiness for planting in the field or in planting areas (Irawan & Hidayah, 2017).Seedlings are considered to have good growth quality if the seedling quality index is at least 0.09 (Irawan & Hidayah, 2017; Purwanto et al., 2023).

Based on the data listed in Table 7, it can be stated that the eight species of tree seedlings found at the research location have different seedling quality indices between tree seedling species. Two species of tree seedlings, namely generatively avocado tree seedlings and areca nut tree seedlings at the age of 3 months, have quite high seedling quality index values (> 0.09), respectively, at 0.138 and 0.344. The other six species of tree seedlings have seedling quality index values that are still low (< 0.09). The low seedling quality index values are thought to be influenced by many factors, such as seedling age, growing media, container, and propagation method.

The seedling quality index can be further increased as long as the nutrient and water supply for seedling growth is adequately met. Every tree species, at any growth phase, requires adequate nutrient, water, and environmental conditions within a suitable tolerance range for optimal survival and growth (Indriyanto, 2017).The seedling quality index is closely related to seedling biomass, a result of net photosynthesis, which reflects the quality of seedling growth (Indriyanto, 1999).Furthermore, Indriyanto (1999)stated that a high seedling quality index indicates a balance in the translocation of photosynthesis results to the seedling's crown organs (stems and leaves) and to the roots. The balance in the translocation of photosynthesis results to the seedling organs causes the seedling to have a growth balance between the crown and the roots. Therefore, the seedling quality index is formulated as directly proportional to the total dry weight of the seedling, and inversely proportional to the seedling's sturdiness (the ratio of seedling height to stem diameter) and the ratio of dry weight of the crown to the roots (Putri, 2008).

The availability of nutrients for seedling growth depends on the growing media used and the container used (Indriyanto, 2022).The use of organic materials is important to improve the quality of the growing media, but the container used must also be adequate to accommodate the growing media. The size of seedling containers at the research sites varied (Table 7), meaning that root growth space varies.The smaller the container used for growing seedlings, the less space there is for root growth, and the less capacity the growing media has to provide nutrients and retain water, which can negatively impact seedling growth later in life. The quality of the growing media is one of the most important factors influencing the development of seedling morphological characteristics (Boja, N. & Borz, 2021). In general, the space in a seedling growing media affects the amount of water and air available, as well as root penetration. A growing media that is too dense will not support root development, hindering root penetration and nutrient uptake, thus disrupting seedling growth (Boja, N. & Borz, 2021).

Root system development is influenced by the availability of nutrients for growth and the size of the container. Container size determines the capacity of the seedling growth media, the amount of nutrients bound and available in the growing media, the amount of water bound in the growing media, and the growth space capacity of the seedling roots. The availability of nutrients and water in the seedling growth media significantly influences the physiological processes of the seedling (Haase, 2007).

The acidity (pH) of the growing media varied significantly between 4.5 and 6.5 (Table 7). This is thought to be due to the presence of organic matter that has not been properly decomposed, resulting in suboptimal nutrient availability and root absorption. Juliansyah et al. (2022)suggest that plants can grow well in soil acidity conditions of 5.5–7.5.Growing media that is too acidic or too alkaline will affect seedling growth. This condition will result in some nutrients being unable to be absorbed by the plant roots because they are bound or trapped, even if the growing media is supplemented with organic matter or fertilizer.

IV. CONCLUDING REMARK

Conclusion

There were no tree seedlings classified as first quality. Two species of tree seedlings were classified as second quality, namely generative avocado seedlings and grafted avocado seedlings, which were three months old at the time of the research. Three species of tree seedlings are categorized as rejected.Three species of seedlings could not be assigned a quality class,namely durian seedlings, nutmeg seedlings, and areca nut seedlings, as they are not yet listed in Indonesian National Standards 8420 (INS 8420).

Two species of tree seedlings, namely generative avocado seedlings and 3-month-old areca nut seedlings, had relatively high seedling quality index values (>0.09), at 0.138 and 0.344, respectively. The other six species of tree seedlings had low seedling quality index values (<0.09). The seedling quality index may still increase in the next growth period if the availability of nutrients and water in the seedling growth media meets the needs for optimal growth.

Recommendation

Considering that not all species of tree seedlings are listed in Indonesian National Standards 8420 (INS 8420), it is therefore recommended to use the seedling quality index as a complement in the analysis of the physiological quality of tree seedlings prepared for planting in the field or in the planting area.

It's recommended to use well-decomposed organic matter as a topsoil mixture to improve the quality of the seedling growing media. It's recommended to add no more than 30% organic matter to prevent the growing media from becoming too porous and allowing it to easily aggregate with the seedling's root system.

It's recommended to use polybags of the appropriate size to increase the seedling growth capacity and allow for root growth, thus improving seedling quality. Therefore, research is needed to determine the effect of using various polybag sizes on the seedling quality index.

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