

Species diversity and quality of planting stocks in selected tree seedling nurseries in Leyte, Philippines

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Abstract. Magno R, Peque DP, Oclarit JB. 2025. *Species diversity and quality of planting stocks in selected tree seedling nurseries in Leyte, Philippines. Asian J For 9: 221-231.* Smallholder nurseries are essential in supporting reforestation programs in the Philippines, especially under the National Greening Program (NGP). However, stock diversity and quality are overlooked when planting, and long-term restoration efforts can be put at risk. This study examined ten community-based nurseries across Leyte, Philippines, focusing on the range of species they grow, the physical quality of their seedlings, and how they operate. Species were inventoried and assessed using diversity indices (Shannon, Evenness, Similarity), while destructive sampling of 111 seedlings helped evaluate root-shoot balance, sturdiness, and root formation. Across all nurseries, 26 tree species were recorded, with a strong preference for native species such as *Pterocarpus indicus* (narra) and *Shorea contorta* (white lauan). The SUFA nursery showed the highest species diversity ($H' = 1.90$), and UFAB had the most balanced species distribution ($E = 0.95$). However, 8 out of 10 nurseries (80%) produced seedlings with physical defects like J-rooting, overgrowth, and poor root-shoot ratios—factors that can reduce survival and growth once planted in the field. These findings emphasize the real-world risk of using low-quality planting stocks in reforestation projects. To improve outcomes, we recommend stronger nursery accreditation systems, better access to native seeds, and capacity-building efforts to help nursery operators produce high-quality, ecologically resilient planting materials.

Keywords: J-root, *Pterocarpus indicus*, root-shoot ratio, seedling survival

INTRODUCTION

Historically, reforestation initiatives in the Philippines relied on exotic tree species, mainly mahogany (*Swietenia macrophylla* G.King) (Pagunsan 2023) and yemane (*Gmelina arborea* Roxb. ex Sm.) (Cardenas et al. 2024), due to their rapid growth and effectiveness in suppressing competing vegetation (Cordero 2022; Pagunsan 2023). In particular, *S. macrophylla* was favored because of its potential for carbon sequestration (Recelis et al. 2019) and its effectiveness in controlling soil erosion and runoff (Paimin 2017). On the other hand, *G. arborea* was used due to its resilience to environmental stressors like drought, pests and disease (Cardenas et al. 2024). Despite these benefits from exotic species, there is a growing interest in utilizing native species, a shift likely influenced by the National Greening Program (NGP) (Peque and Hölscher 2014). This national project aims to restore ecological integrity to the denuded forest landscape and improve the socioeconomic status of participating farmers, with the target of planting 1.5 billion trees across 1.5 million hectares by 2016 (Goltiano et al. 2021). Further, the NGP mandates that a portion of the budget for reforestation projects shall be allocated to cultivating indigenous tree species, promoting ecological balance and biodiversity in forestry efforts.

Cultivating planting stock in nurseries is the most effective method for establishing forestry plantations in

tropical regions (Maid et al. 2019). In nurseries, planting materials can be managed with strict quality control measures, ensuring the production of robust seedlings (Riikonen and Luoranen 2018; Passos et al. 2021). Further, Maid et al. (2019) emphasized that nursery activities such as careful seed selection, land preparation, and management of nursery stock contribute to higher survival rates and reduced mortality of seedlings. In the Philippines, NGP is the national policy that regulates seedling quality for government reforestation programs as outlined in the DENR Administrative Order 2010-11. However, implementation of this policy remains weak due to the absence of rigorous auditing and quality assurance mechanisms, resulting in the widespread distribution of substandard seedlings that compromise reforestation outcomes (Gregorio et al. 2017; Haase and Davis 2017). According to Diepeveen (2015), monitoring and evaluating reforestation efforts are essential to ensure success in restoring denuded areas. Various government, community, and private nurseries and the limited availability of quality seedlings pose a significant barrier to advancing smallholder forestry in the Philippines (Valette et al. 2020). This challenge has been documented in several studies, indicating that the forest nursery industry is poorly organized and lacks adequate support systems (Clark et al. 2023; Fulcher et al. 2023). Further, the Department of Environment and Natural Resources (DENR) distributes free seedlings, undermining local nursery markets and

preventing a profitable private nursery sector. This situation creates local seed shortages and discourages investment in quality control, ultimately affecting the success of forest landscape restoration efforts and smallholder participation (Valette et al. 2020).

Many upland farmers engage in small-scale forestry and agroforestry, relying on seedlings from these small-scale nurseries (Suryanto et al. 2021). Agroforestry systems, in particular, are noted for their ability to enhance soil quality and mitigate environmental issues such as soil erosion and nutrient loss, making them a sustainable choice for upland farmers (Legaspi et al. 2021). The use of native forest tree species (NFTs) in these systems is also gaining attention, although their full potential remains underutilized due to limited awareness and availability (Piñón et al. 2024). Unfortunately, most of these nurseries do not produce high-quality seedlings due to technical, institutional, and policy support constraints, lack of necessary skills and knowledge of farmers, and limited access to high-quality germplasm and insufficient resources for nursery operations (Takoutsing et al. 2014; Gregorio et al. 2017; Starfinger et al. 2023; Yousaf et al. 2024; Legesse et al. 2024).

Although there has been a growing interest in small-scale forestry in recent years (Shyamsundar et al. 2022; Nambiar 2021), government support has not sufficiently strengthened the sector, leaving many smallholder farmers with inconsistent access to high-quality planting materials (Tumaini et al. 2023). As a result, reforestation efforts are hampered by high mortality rates and poor field performance of planted trees. A significant contributor to this problem is the inadequate technical capacity of local nurseries, which often suffer from limited infrastructure, poor-quality germplasm, and weak quality control systems (Gregorio et al. 2017). Despite the critical role that community nurseries play in achieving the goals of the National Greening Program, empirical data on the diversity, physical quality, and production constraints of seedlings in these nurseries, especially in the context of specific provinces like Leyte, Philippines remain sparse. This study addresses that gap by systematically assessing

seedling species composition, quality, and operational challenges in ten community nurseries in Leyte, Philippines, thereby contributing updated insights into nursery-level dynamics that influence reforestation success (Valette et al. 2020; Clark et al. 2023).

MATERIALS AND METHODS

Study area

A total of 10 selected nurseries in Leyte were visited, all operating under the jurisdiction of the Community Environment and Natural Resources Office (CENRO) in Baybay City and Ormoc City (Figure 1; Table 1). The selection aimed to represent nursery operations involved in the National Greening Program (NGP) and other local initiatives. Records from these nurseries were obtained through collaboration with CENRO officials. The People's Organizations (POs) involved were primarily participants of the NGP, except the Patag Nature Conservation Group (PNCG) based in Brgy. Patag, Baybay City. This diversity in organizations provided a comprehensive overview of nursery practices in the region.

Procedures

Key informants, including the PO President, Vice President, and knowledgeable members, were interviewed using a semi-structured interview schedule. This approach facilitated in-depth discussions about nursery operations, challenges faced, and management practices. The research team conducted personal observations of seedling production and management practices within the nurseries. This hands-on approach allowed a better understanding of the operational standards and conditions affecting seedling quality. Information was meticulously recorded regarding the sources of planting stocks, the number of species cultivated in each nursery, and cultural management practices. This data was essential for assessing species diversity and the quality of seedlings produced.

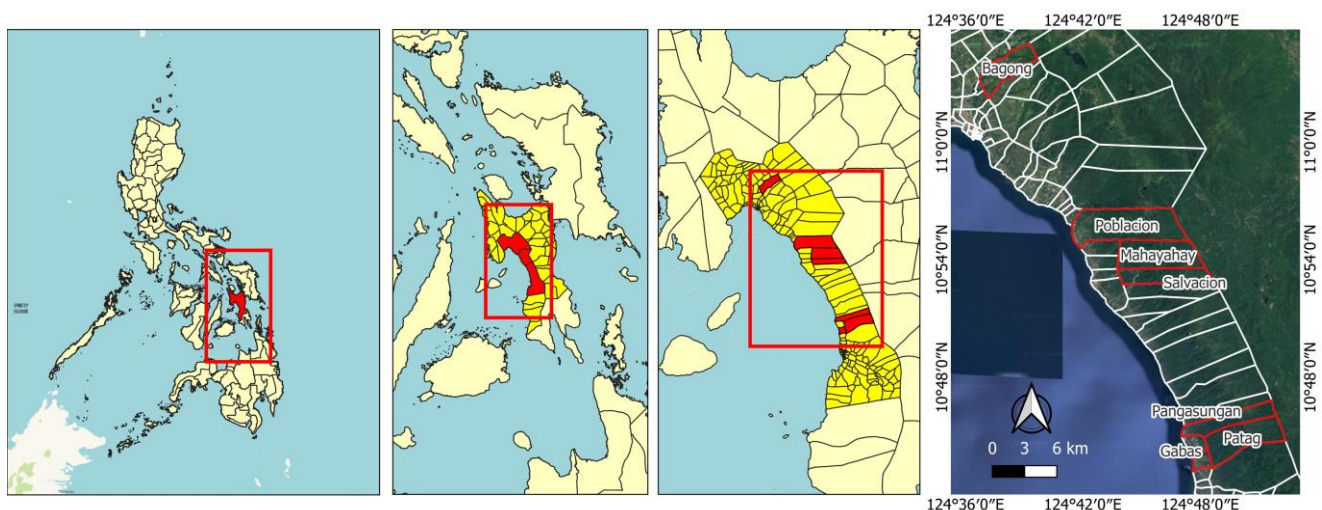


Figure 1. Locations of selected nurseries visited in Leyte, Philippines under the Jurisdiction of CENRO Baybay and CENRO Ormoc

Table 1. List of nurseries visited in the study

Nursery	Location Details	CENRO Assigned	NGP Implementer	
			Yes	No
Cienda San Vicente Farmers Association (CSVFA)	Cienda, Baybay City, Leyte	Baybay	✓	
Patag Nature Conservation Group (PNCG)	Patag, Baybay City, Leyte	Baybay		✓
Patag Reforestation Association (PRA)	Patag, Baybay City, Leyte	Baybay	✓	
Patag Gabas Guadalupe Farmers Association (PAGGFA)	Patag, Baybay City, Leyte	Baybay	✓	
Patag Nature Conservation Association (PNCA)	Patag, Baybay City, Leyte	Baybay	✓	
Aktibong Grupo sa Mag-uuma sa Mahayahay (AGSAM1)	Salvacion, Albuera, Leyte	Ormoc	✓	
Aktibong Grupo sa Mag-uuma sa Mahayahay (AGSAM2)	Mahayahay, Albuera, Leyte	Ormoc	✓	
Sibugay Upland Farmers Association (SUFA)	Soob, Albuera, Leyte	Baybay	✓	
Ecological Farmers Association (ECO-FARMERS)	Pangasugan, Baybay City, Leyte	Baybay	✓	
United Farmers Association of Bagong (UFAB)	Bagong, Ormoc City, Leyte	Ormoc	✓	

**Figure 2.** Rooting system of sample seedlings

Data sampling

A sample of seedlings was subjected to destructive sampling to evaluate physical quality. Key metrics such as total height and root collar diameter were measured to calculate the sturdiness quotient (SQ). Seedlings with an SQ greater than 6 were classified as lanky and less likely to survive in planting sites, while those with an SQ less than six were deemed healthy. The rooting systems of sampled seedlings were documented (Figure 2). Roots and shoots were collected, oven-dried for 24 hours, and weighed to determine the root-shoot ratio. A ratio of 1 was considered indicative of high-quality planting stocks, while ratios greater than 1 indicated an imbalance. Constraints encountered during nursery production were documented through interviews and observations. This qualitative data provided insights into the operational challenges that affect seedling quality, including technical, economic, and knowledge-related barriers.

Data analysis

Data collected from the interview was organized and analyzed in Microsoft Excel. Seedling diversity was determined using the Shannon Index of diversity:

$$H = \sum_{N-1}^n pi \ln pi$$

Where: H' is the Shannon index, pi is a proportional abundance of the i^{th} species or is equal to n_i/N , n is the number of individuals in each species, and N is the total number of individuals for all species. The distribution of the kinds of seedlings between nurseries was determined using the Index of Evenness (E_H):

$$E_H = \frac{H'}{\ln S}$$

Where: H' is the Shannon diversity index and S is the total number of species in the community. Likewise, the similarity of seedlings present in nurseries was determined using the Sorensen Similarity Index:

$$S = \frac{2c}{a + b}$$

Where: S is the similarity index, c is the number of species common to both sites, a is the number of species in site one, and b is the number of species in site two. The root-shoot (R:S) ratio was computed as;

$$R:S = \frac{\text{dry weight of root}}{\text{dry weight of shoot}}$$

And seedling sturdiness quotient (SQ) was computed as:

$$SQ = \frac{\text{Total Height (cm)}}{\text{Root collar diameter (cm)}}$$

RESULTS AND DISCUSSIONS

Nursery operations

Most of the nurseries visited during the study were operating at a relatively large scale, producing more than 10,000 seedlings per batch. However, a few nurseries operated on a significantly smaller scale, highlighting disparities in production capacity and resource access among different organizations. For instance, the Cienda San Vicente Farmers Association (CSVFA) and the Ecological Farmers Association (ECO-FARMERS) produced fewer than 10,000 seedlings per batch, indicating more modest operations. Interestingly, many People's Organizations (POs) managing these nurseries were relatively new and operated under temporary setups. These nurseries often lacked essential infrastructure such as greenhouses, seedbeds, hardening beds, and chambers for

freshly collected planting materials, which are critical for successful nursery operations. Another issue observed was the location of some nurseries. Several were situated far from their target planting sites, making it challenging to transport seedlings without causing stress or damage. Regarding pricing, most nurseries sold seedlings for ₱10.00 to ₱20.00 each. However, when an oversupply of seedlings had aged, they were sometimes sold at a lower price, around ₱5.00 per seedling. While most buyers were based locally in Leyte, a few nurseries had established partnerships with NGOs outside the province.

Seedlings grown in the nursery

Across the surveyed nurseries in Leyte, 26 tree species were cultivated, including native, exotic, and fruit-bearing types (Table 2). Native species comprised the majority. Among these, species such as narra (*Pterocarpus indicus* Willd.), dao (*Dracontomelon dao* (Blanco) Merr. & Rolfe), kalumpit (*Terminalia macrocarpa* Decne.), and white lauan (*Shorea contorta* S.Vidal) exhibited large interquartile ranges (IQRs) in seedling counts, indicating high variability across nurseries (Figure 3). In contrast, species like tindalo (*Azelia rhomboidea* (Blanco) Fern.-Vill.), mahogany (*Swietenia macrophylla* G.King), and molave (*Vitex parviflora* A.Juss.) showed relatively compact IQRs,

suggesting more consistent seedling numbers. Several species, including bitanghol (*Calophyllum inophyllum* L.), yakal saplungan (*Hopea plagata* (Blanco) S.Vidal), cacao (*Theobroma cacao* L.), puso-puso (*Litsea glutinosa* (Lour.) C.R. Rob.), banai-banai (*Radermachera pinnata* Seem.), rambutan (*Nephelium lappaceum* L.), yakal (*Shorea astylosa* Foxw.), and ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit), displayed x-marked outliers, representing nurseries with unusually high or low seedling counts compared to others.

Narra (*P. indicus*) recorded the highest number of seedlings in a single nursery, indicated with the upper whisker approaching 30,000 (Figure 3). Similarly, kalumpit and dao showed extended upper whiskers, reflecting higher seedling counts in a few nurseries. Species such as guyabano (*Annona muricata* L.), bayok (*Pterospermum diversifolium* Blume), and hambabalud (*Barringtonia acutangula* (L.) Gaertn.) had very low or zero values in most nurseries. Some species showed only a single data point or outlier, indicating presence in only one or two nurseries. Exotic species were fewer, with mahogany and acacia (*Acacia mangium* Willd.) being the most commonly grown. Fruit-bearing trees were also limited, with only five species, coffee (*Coffea arabica* L.), rambutan, cacao, jackfruit/nangka, and guyabano, found across all sites.

Table 2. Top five species of seedlings grown in the surveyed nurseries in Leyte, Philippines

PO Nursery	Species (highest-lowest density in the nursery)
CSVFA	White lauan, bitanghol, kalumpit, bagtikan, yakal saplungan
PNCG	Kalumpit, dao, molave, mahogany, sudiang
PRA	Mahogany, white lauan, kalumpit, bahay, narra
PAGGFA	Narra, kalumpit, coffee, sudiang, dao
PNCA	White lauan, cacao, coffee, mahogany
AGSAM 1	Narra, mahogany, acacia, puso-puso, bayok
AGSAM 2	Narra, mahogany, rambutan, coffee, nangka
SUFA	Nangka, coffee, cacao, narra, guyabano
ECO-FARMERS	Narra, bagtikan, white lauan, tindalo, dao
UFAB	Dao, white lauan, tindalo, yakal, narra

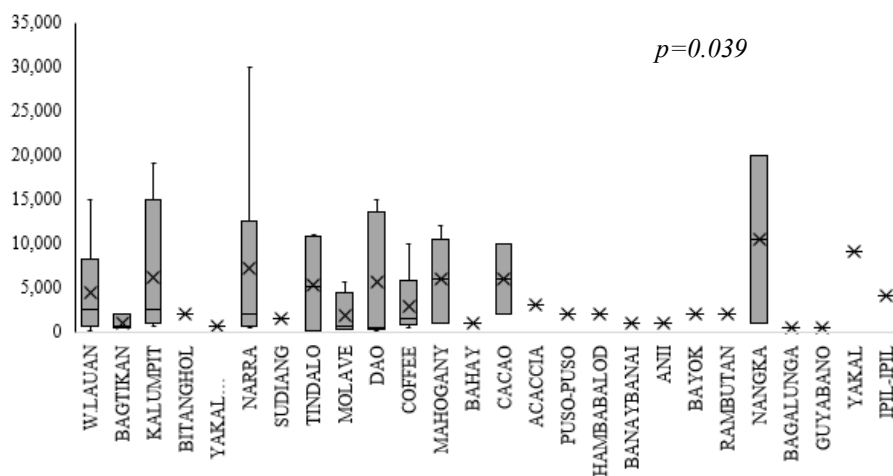


Figure 3. Boxplot showing the variation in seedling numbers of different tree species surveyed across 10 nurseries. One-way ANOVA revealed significant differences in seedling counts among species ($p = 0.039$). Post hoc comparisons were not conducted, but the overall p-value suggests variation in seedling count distribution among species

For planting materials, nurseries primarily sourced either seeds or wildlings. Wildlings were predominantly used for native species such as white lauan and *bagtikan* (*Parashorea malaanonan* (Blanco) Merr.), while seeds were commonly used for exotic and fruit species. Most nurseries operated for income generation through seedling sales, which supported ongoing operations and provided a livelihood for nursery operators. Figure 3 further highlights these disparities, with species like *nangka*, *dao*, and mahogany showing broad distributions and high medians, in contrast to many native species that appear as sparse outliers or with negligible seedling representation. In contrast, many indigenous or native species had low median values, limited interquartile ranges, or appeared only as outliers, reflecting minimal or inconsistent propagation across sites.

Species preferred and reasons

Most nursery operators expressed a strong preference for cultivating native tree species. This preference is influenced mainly by the National Greening Program (NGP), which encourages using indigenous species due to their ecological benefits and superior timber quality. Among the native species, narra and white lauan were the most commonly grown across the surveyed nurseries. In contrast, mahogany stood out as the most frequently produced exotic species. Fruit trees were not widely cultivated, although coffee was the most commonly raised among them. This pattern suggests that nursery operators tend to focus on species that are more accessible and viable within their available resources and local conditions.

Tree seedling evenness and diversity

The diversity and distribution of tree and fruit seedling species across the ten surveyed nurseries were assessed using the Shannon Diversity Index (Table 3). Among all nurseries, the Sibugay Upland Farmers Association (SUFA) recorded the highest diversity score at 1.90, indicating the widest variety of seedling species in its nursery. Regarding species evenness, which measures how evenly individual seedlings are distributed among the

different species, UFAB stood out with a high evenness score of 0.95. This suggests a well-balanced distribution across the seven tree species cultivated in their nursery. On the other hand, PNCA and AGSAM 1 showed lower evenness scores of 0.63, where nursery production was heavily skewed toward a few dominant species, particularly narra and white lauan.

Similarity of tree seedlings grown in nurseries

The similarity of seedling species cultivated across the ten selected nurseries was assessed using the Sorensen Similarity Index. Among the nursery pairs, the Patag Nature Conservation Association (PRA) and ECO-FARMERS displayed the highest similarity score of 0.66, indicating a substantial overlap in the seedlings they raised. On the other end of the spectrum, the CSVFA–PRA and CSVFA–UFAB registered the lowest similarity scores at 0.13, reflecting a notable difference in the species they cultivated (Table 4). These contrasting scores indicate significant variation in nursery practices and species selection among the surveyed groups.

Table 3. Diversity and percent evenness of seedlings raised in each nursery

Nursery	Diversity (Shannon)	% Evenness
CSVFA	1.77	0.85
PNCG	1.44	0.74
PRA	1.47	0.71
PAGGFA	1.39	0.67
PNCA	1.13	0.63
AGSAM 1	1.38	0.63
AGSAM 2	1.15	0.70
SUFA	1.90	0.79
ECOFARMERS	1.18	0.73
UFAB	1.86	0.95

Note: Numerical indicators: 0-0.5: less diverse; 0.5-1: diverse; 1-2: highly diverse. 0-0.5: low evenness; 0.5-0.99: moderate evenness; 1: high evenness

Table 4. Sorensen Index of Similarity of seedlings grown in different nurseries in Leyte, Philippines

	CSVFA	PNCG	PRA	PAGGFA	PNCA	AGSAM 1	AGSAM 2	SUFA	ECOFARMERS	UFAB
CSVFA		0.27	0.13	0.25	0	0	0	0.32	0.31	0.13
PNCG	0.27		0.53	0.53	0.46	0.25	0.17	0.44	0.66	0.42
PRA	0.13	0.53		0.63	0.43	0.25	0.31	0.42	0.31	0.26
PAGGFA	0.25	0.53	0.63		0.29	0.24	0.15	0.42	0.15	0.27
PNCA	0	0.46	0.43	0.29		0.27	0.36	0.35	0.18	0.15
AGSAM 1	0	0.25	0.25	0.24	0.27		0.14	0.3	0.14	0.13
AGSAM 2	0	0.17	0.31	0.15	0.36	0.14		0.25	0.2	0.15
SUFA	0.32	0.44	0.42	0.42	0.35	0.3	0.25		0.25	0.22
ECOFARMERS	0.31	0.66	0.31	0.15	0.18	0.14	0.2	0.25		0.5
UFAB	0.13	0.42	0.26	0.27	0.15	0.13	0.15	0.22	0.5	

Note: Numerical indicator: 0-0.5: Less similarity, 0.5-1: Moderate similarity, 1: Similar

Seedling quality

The quality of seedlings produced by the ten surveyed nurseries was evaluated based on visual and physical characteristics, including stem structure, leaf color and size, and root system integrity. While most seedlings appeared healthy at first glance, with straight stems and dark green, regularly sized leaves, further inspection revealed underlying issues affecting their suitability for reforestation. The assessment showed that eight of ten nurseries produced seedlings with a high percentage of imbalanced root-to-shoot ratios, indicating poor physiological quality. Additionally, many seedlings exhibited root defects such as J-rooting, coiled, and curled root systems, particularly those propagated from improperly potted wildlings. These structural issues compromise the seedlings' chances of surviving once transplanted. Interestingly, all nursery operators believed they were producing good-quality planting materials, despite the objective assessment pointing to quality concerns (Table 5).

The assessment of seedling sturdiness across the ten nurseries showed that most of the sampled seedlings had a sturdiness quotient above 6, a value considered suboptimal for field survival (Table 6). Only AGSAM 1 had approximately 40% of seedlings with a sturdiness below 6, suggesting better seedling vigor than the other nurseries. In addition to poor sturdiness scores, most seedlings exhibited an imbalanced root-to-shoot ratio. Furthermore, eight out of ten nurseries produced a high percentage of seedlings with root deformities, such as J-rooting, curling, and coiling, particularly those derived from wildlings. Despite these physical quality issues, 100% of the nursery operators believed they produced quality seedlings. Many also claimed to collect seeds and wildlings from healthy mother trees, though the condition of the seedlings observed does not support this assertion.

Constraints to nursery production

The survey of nursery operators across the ten selected sites revealed several recurring constraints that significantly affect the production and sales of planting stocks. The most frequently cited challenge was the lack of access to reliable and quality planting materials, directly influencing the quantity and variety of seedlings produced. Many nursery operators reported difficulty collecting seeds from mother trees in natural forests, where terrain and distance create logistical barriers. This problem is compounded by the uncertainty around fruiting seasons and proper seed collection timing, making seed gathering labour-intensive and unpredictable. Due to these challenges, most nursery operators rely heavily on wildlings as their primary source of planting stock. However, this reliance often results in lower seedling quality and reduced species diversity, limiting the nurseries' capacity to meet broader reforestation goals and market demands.

Table 5. Mean dry weight, root-shoot ratio, of five seedling samples collected in each nursery

Nursery	Roots (g)	Shoots (g)	Root/Shoot ratio
CSBFA	1.57	1.36	1.29
PNCG	2.20	1.95	1.10
PRA	2.20	1.95	1.10
PAGGFA	0.57	0.45	1.32
PNCA	0.92	0.91	2.00
AGSAM S	5.12	3.50	1.60
AGSAM M	3.42	3.22	1.80
SUFA	2.52	3.85	0.73
ECOFARMERS	2.26	2.36	1.03
UFAB	4.11	3.92	0.88

Note: Numerical indicator: 0-1: Excellent; 1-2 or above: Poor

Table 6. Result of physical quality assessment of seedlings in each nursery. Values given represent the proportion of seedlings that passed/failed the criteria (n = 5)

Nursery	Proportion of seedlings with SQ >6 (%)	Proportion of seedlings with defective root formation (%)
CSVFA	13.6(80)	60
PNCG	11.6(100)	100
PRA	11(100)	60
PAGGFA	13.4(100)	80
PNCA	9.4(100)	80
AGSAM 1	9.8(60)	100
AGSAM 2	9.4(100)	80
SUFA	6.8(80)	80
ECOFARMERS	11.2(100)	40
UFAB	13.8(100)	20

Note: Numerical indicator: 0-6: Excellent; 6 or above: Poor



Figure 4. Seedlings produced by AGSAM PO in Mahayahay, Salvacion, Leyte, Philippines

Discussion

The variation in seedling production across nurseries seems closely linked to their contractual agreements with the Department of Environment and Natural Resources (DENR) (Figure 4). Nurseries with larger DENR contracts benefited from better financial and logistical support, allowing them to scale production and maintain more consistent seedling outputs. Gregorio et al. (2007) emphasize that providing nurseries with adequate financial support can significantly improve the quality of seedlings, streamline the process of accreditation, and foster more competitive and sustainable markets for planting materials and timber, highlighting the essential role of funding in strengthening forestry value chains, especially in developing regions. In contrast, smaller groups like CSVFA and ECO-FARMERS had fewer resources, which constrained their ability to scale operations or invest in quality improvements. Githae et al. (2015) point out that when funding falls short, even well-designed training programs struggle to achieve their goals, as they often lack the essential tools, materials, and infrastructure needed to make a meaningful and lasting impact on the communities they serve.

Temporary nurseries, especially those managed by newly formed organizations, often reflect deeper issues of limited funding and technical support. Singh (2024) highlights that these organizations frequently face difficulties securing financial resources due to underdeveloped financial ecosystems. Traditional banking mechanisms often fall short, offering limited credit access and imposing high interest rates that further constrain nursery operations and long-term viability. The absence of key infrastructure, like greenhouses and proper hardening facilities, can negatively affect seedling quality and survival, especially when exposed to harsh environmental conditions. As Kumar et al. (2022) point out, regulating the microclimate through greenhouse structures helps support healthier growth and better yields, highlighting how even simple improvements in nursery conditions can make a meaningful difference in seedling performance. Transporting seedlings across long distances poses significant logistical and biological challenges, threatening their viability. Long travel times can cause physical damage or stress to the seedlings, reducing their chances of survival once planted. Stjernberg (1997) notes that seedlings often experience mechanical shocks during transport—such as jostling, drying, or compression—which can reduce their vigor and significantly increase mortality rates in the field. This highlights the need to consider nursery management and logistical planning in reforestation efforts. Finally, the variation in seedling prices, especially the lower rates for surplus or overaged stock, points to a mismatch between production and planting schedules. Improving coordination could help reduce waste and increase efficiency. As Erickson and Halford (2020) emphasize, practical, science-based planning, such as assessing site disturbances, developing reference models, and aligning species selection with specific goals, timelines, and available resources—is essential to ensure timely seedling availability and reduce

mismatches in production and planting schedules. Nevertheless, it is encouraging to see some nurseries expanding their reach through partnerships with NGOs outside the province, which may offer new opportunities for sustainability and growth.

The dominance of native species in these nurseries reflects a growing commitment to sustainable and ecologically sound forestry practices, particularly in alignment with the objectives of the National Greening Program, which, as noted by Gregorio et al. (2017), aims to enhance nursery management by prioritizing the use of native tree species to promote ecosystem restoration. By prioritizing locally sourced planting materials, these nurseries contribute to biodiversity conservation and the resilience of reforested areas, based on the idea that local genotypes are adapted to site conditions (Waters 2008; Krauss et al. 2010). However, evidence is mixed; some studies show local sources perform better, while others find non-local seeds can be equally or more successful, depending on species and site factors (Carter et al. 2013; Bucharova et al. 2017). Seed sourcing should therefore consider both genetics and site suitability for effective restoration. The widespread use of native seeds and wildlings offers a low-cost and ecologically sound option for community nurseries. The limited cultivation of fruit trees and exotic species highlights persistent challenges within the nursery system. Although fruit trees can offer long-term economic benefits in agroforestry systems, many small-scale nursery operators hesitate to grow them. This is mainly because fruit tree seedlings often cost more to produce and have lower survival rates than other species. The limited local demand and weak seedling markets make it hard for nurseries to profit, so many avoid the risk.

On top of that, most small nursery owners lack access to reliable market information, basic business training, and support from research or extension services, all of which are critical for running a successful fruit tree nursery (Russell and Franzel 2004). Similarly, while exotic species like mahogany and gmelina are still grown, their reduced presence indicates a shift away from species historically associated with monoculture plantations, in line with growing ecological concerns and policy efforts favoring native species in reforestation (Schneider and Pohnan 2012). Patterns in planting material sourcing reflect nurseries' key ecological and operational strategies. Using wildlings for native trees demonstrates a reliance on natural regeneration, which, while ecologically beneficial, requires careful management to avoid depleting wild populations (Morris and Davies 2025).

Meanwhile, seed-based propagation for exotics and fruit trees underscores the need for improved access to high-quality seed sources. According to Kumar et al. (2024), the successful establishment of tree species largely depends on the quality of planting materials. However, many seeds exhibit dormancy caused by both physiological and environmental factors. These issues hinder germination, resulting in reduced growth and survival rates. Nursery operations play a critical economic role in rural areas by offering stable, small-scale income opportunities, especially for women and marginalized groups. Seedling

sales provide essential income for many families, directly linking livelihood and environmental stewardship. Community nurseries help make this possible by giving local people access to natural resources like seeds and planting materials. These nurseries create jobs, boost local incomes, and support broader goals such as sustainable development and diversifying livelihood options within the community (Wubayehu 2020). Supporting these community-based nurseries through technical and financial assistance could enhance reforestation outcomes and rural development.

The preference for native species among nursery operators highlights a growing awareness of the ecological value and long-term benefits of indigenous trees. This shift is backed by growing scientific evidence. In Indonesia, reforesting with native dipterocarps has been shown to improve soil structure and water absorption, which are vital for healthy and productive landscapes (Rachmat et al. 2021). In Australia, planting a mix of native species created better habitats for local wildlife than monoculture plantations, helping to bring back biodiversity in degraded areas (Cunningham et al. 2015). Native trees are also naturally adapted to their environment, making them more resilient to challenges like drought. For instance, in Brazil's Atlantic Forest, native species bounced back strongly after dry conditions, showing their potential to withstand climate-related stress (Yaakobi et al. 2023). The National Greening Program has played a key role in shaping this trend by promoting sustainable reforestation practices that prioritize biodiversity and resilience. Despite their ecological importance, native species present serious propagation challenges due to biological, logistical, and institutional constraints. One of the most pressing issues is the limited availability of healthy mother trees, which restricts the ability of nurseries to produce a diverse range of indigenous planting materials. Unlike exotic species, which are often well-domesticated and have established seed sources, many native species still rely on wild collections (Rantala-Sykes and Campbell 2019). Unfortunately, decades of logging and forest degradation have reduced the populations of mature, seed-producing native trees. This scarcity complicates seed collection and affects the consistency and quality of native seedling production.

Many nurseries' low number of fruit trees points to deeper challenges, such as high seed costs, complex propagation requirements, and limited market access. These barriers often prevent small nursery operators from investing in fruit trees, even though they hold strong potential for improving livelihoods. While fruit trees like coffee offer potential livelihood opportunities, their cultivation is often constrained by seed cost, lower survival rates, and a lack of technical support. Many fruit nursery growers also face limited access to training, funding, and infrastructure, which hinders their capacity to produce and market quality seedlings. As Farooq et al. (2023) emphasize, government support through targeted subsidies, capacity building, and enabling policies is essential to overcome these barriers and unlock the full potential of fruit tree cultivation. Nursery operators prioritize species that are easier to propagate and have a steady demand, such

as mahogany for timber and narra for reforestation. While the inclination toward native species is encouraging, it underscores the need for stronger support systems. These include improved access to mother trees (Tripathi 2023), training in propagation techniques (Leakey et al. 2006), and more consistent market incentives for native and fruit-bearing species (Jamnadass et al. 2011).

The high diversity index observed in SUFA reflects an intentional effort to cultivate a broader range of species, which may be linked to a more holistic or diversified reforestation strategy. Diversifying species in nurseries improves ecological resilience, supports varied planting needs across ecosystems, and enhances seedling survival, contributing to more effective restoration outcomes (Clark et al. 2023). Diverse species compositions enhance ecosystem functionality and long-term stability by increasing resistance to biotic and abiotic stressors. The high evenness score of UFAB indicates a well-balanced approach to seedling production, where no single species dominates. Evenness is a key component of biodiversity and is often used to assess ecosystem health, as it reflects the ability of species to coexist without one outcompeting the others (Roberts 2019). Such balance may enhance the ecological value of planting efforts by supporting species-rich reforested areas that mimic natural forests more closely. This even distribution also reduces risks associated with monoculture planting, such as vulnerability to species-specific pests or diseases.

In contrast, the lower evenness scores in PNCA and AGSAM 1 suggest a reliance on a few preferred species, particularly narra and white lauan. Although narra and white lauan are ecologically important, an overreliance on a limited number of species may reduce structural diversity and ecosystem resilience, factors critical to long-term reforestation success (Biță-Nicolae and Dhyan 2025). These findings highlight the importance of promoting diversity and evenness in nursery operations. Supporting nurseries accessing a wider variety of seeds and providing technical guidance can help achieve more balanced and ecologically sound seedling production.

The high similarity score between PRA and ECO-FARMERS suggests that these nurseries likely source their planting materials from similar locations or operate under shared guidelines, possibly influenced by proximity, technical support, or participation in the same government programs. This alignment in species selection is often shaped by standardized planting requirements under programs like the National Greening Program, which promote specific native and commercially viable species based on reforestation targets and market demand. In contrast, the low similarity scores observed between CSVFA and the other two nurseries highlight the diversity of nursery practices and preferences across communities. These differences could stem from varying site conditions, organizational priorities, or availability of planting materials. For instance, CSVFA may focus on a distinct set of species suited to their local environment or aligned with unique project requirements, which may diverge from the species commonly cultivated by PRA and UFAB. This variation in seedling composition underscores the

importance of tailoring nursery production to local contexts while considering broader ecological objectives. Understanding species similarity and divergence among nurseries can help guide resource sharing, seed distribution planning, and technical assistance efforts, especially in programs like the National Greening Program that aim to coordinate large-scale reforestation activities across diverse landscapes.

The mismatch between nursery operators' perceptions and the actual physical quality of seedlings reveals a critical gap in technical knowledge and quality control practices. While many seedlings looked visually healthy, characteristics such as overgrowth and root deformities can severely affect survival rates in reforestation efforts (Figure 2). Studies have shown that species with thick fine roots and deeper root systems tend to perform better, highlighting the important role of root traits in successful establishment during tropical dry forest restoration (Werden et al. 2022). Overgrown seedlings, in particular, may have already passed their optimal transplanting window, making them more vulnerable to stress and transplant shock. However, this concern is debated. Andivia et al. (2021) found that larger seedlings often show higher survival rates, suggesting that size alone may not limit successful establishment. Root defects like J-rooting and coiling are commonly associated with improper potting practices, especially when handling wildlings (Jat and Jat 2023). These defects hinder root development and anchorage, ultimately reducing the seedling's ability to absorb nutrients and water once planted in the field. This widespread problem underscores the urgent need for targeted training programs in nursery management, suggesting short-term capacity-building efforts to reduce deformities and improve seedling field performance. The fact that nursery operators believed they were producing quality seedlings, despite evidence to the contrary, highlights a need for standardized quality assessment protocols and regular training. By aligning perceptions with technical standards, nursery operators can improve the quality of their planting materials, ensuring better survival rates and more successful reforestation outcomes under programs like the National Greening Program.

The findings highlight a significant disconnect between the nursery operators' perceptions of quality and the actual physical condition of the seedlings they produce. A sturdiness quotient above 6 generally indicates that a seedling is too tall relative to its root collar diameter, making it more prone to breakage and poor survival after outplanting. Except AGSAM 1, most nurseries exhibited elevated sturdiness quotient values, a red flag for poor post-transplant survival and mechanical vulnerability in field conditions. Root deformities such as J-rooting and curling severely compromise seedling establishment. Improper potting methods, such as using shallow or oversized containers and poorly executed wildling extraction, are key drivers of root defects, problems well-documented to hinder root elongation, anchorage, and nutrient uptake. The widespread occurrence of such defects suggests a need for more standardized and science-based nursery practices. Moreover, despite clear evidence of structural flaws, the

operators' firm belief in the quality of their seedlings reveals a knowledge gap. This misalignment underscores the necessity for training and awareness-raising programs focused on seedling quality standards, proper propagation methods, and correct sourcing from verified healthy mother trees. Ultimately, improving the technical capacity of nursery operators will play a crucial role in enhancing the effectiveness of reforestation programs. Ensuring that quality planting materials are produced is not just a matter of perception but of measurable, science-based criteria that support long-term forest restoration success.

The findings highlight how logistical and environmental challenges can significantly constrain nursery production in rural or forest-adjacent areas. The inaccessibility of high-quality mother trees, particularly those found in natural forests, reduces the availability of genetically diverse and viable seeds. This shortage can undermine conservation efforts for at-risk populations, often resulting in reforested landscapes lacking species richness and genetic diversity (Pooler et al. 2024). Consequently, many nursery operators turn to wildlings—seedlings harvested from forest floors—that are often physiologically stressed, prone to root deformities, and exhibit poor transplant survival (Jin et al. 2024). These limitations not only compromise seedling vigor but also diminish the ecological success of reforestation efforts due to their unpredictable performance in field conditions.

Furthermore, the lack of technical knowledge around identifying fruiting periods and seed maturity leads to poor timing of seed collection, which compromises seed viability and germination rates. This uncertainty also restricts the variety of species that can be cultivated, contributing to limited biodiversity in nursery stocks. The downstream effects are considerable: low seedling quality, reduced sales, and limited options for species selection, all of which hinder the long-term success of reforestation initiatives such as the National Greening Program. These constraints underscore the need for targeted interventions, such as establishing community seed sources, offering seed collection and propagation training, and providing technical support to improve nursery practices. Addressing these issues will improve the viability of nursery operations and enhance the quality and ecological relevance of seedlings produced for landscape restoration.

In conclusion, this study examined the species composition, physical quality, and operational realities of ten community-based nurseries in Leyte, Philippines—a region at the forefront of national reforestation efforts. Findings revealed stark differences in nursery scale, infrastructure, and species grown. While most nurseries embraced native species in alignment with the National Greening Program (NGP), propagation was concentrated on just a handful of species like *P. indicus* (narra), *S. contorta* (white lauan), and *D. dao* (*dao*), limiting the ecological diversity intended by restoration programs. Species richness and evenness varied widely, with only a few nurseries showing balanced and functionally diverse species profiles. Seedling quality presented an even more urgent concern. Across sites, many planting stocks exhibited structural deformities, J-rooting, coiled roots, and

disproportionate root-to-shoot ratios, undermining field survival. These defects were persistent in wildling-derived seedlings. However, nursery operators expressed confidence in their stock, a striking disconnect between perceived and actual seedling quality. This perceptual gap is not merely academic; it risks derailing reforestation outcomes at scale. Such findings signal deeper systemic flaws: limited access to quality planting materials, poor technical capacity, and logistical constraints were common, reflecting the fragility of smallholder nursery systems.

These findings directly address its objectives, such as assessing the diversity, physical quality, and operational challenges in nursery systems critical to Philippine reforestation. In doing so, the study offers an empirical lens on the grassroots realities behind national forest restoration campaigns, exposing the weak links that threaten long-term ecological success. The implications are far-reaching. Seedling quality is not just a technical metric; it determines whether reforested landscapes will thrive or fail. Inadequate planting stock leads to poor survival rates, biodiversity loss, and wasted investments in public reforestation. Conversely, building better nursery systems, with strong seed sourcing protocols, sustained technical support, and functional quality assurance, can accelerate forest recovery, enrich biodiversity, and empower upland communities economically and ecologically.

This study was limited to ten nurseries in a single province and relied on physical and visual seedling assessments. It did not include survival tracking post-planting or genetic analyses of planting materials. While the localized focus allowed for depth, caution is advised in extrapolating findings nationally. Future research should follow the seedlings into the field, tracking survival and growth across varied sites. Genetic provenance studies, socioeconomic evaluations of nursery operations, and impact assessments of DENR's policy frameworks would deepen understanding. A broader regional sample would also help map national nursery performance, informing reforms that can ensure reforestation not only plants trees, but also grows forests.

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