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Survival Status of Young Plants in Paluwatar Plantation Site of Udayapur District, Nepal

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KEYWORDS

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ABSTRACT

Forests provide multitude of benefits, including carbon sequestration, biodiversity conservation, timber production, and recreational opportunities. However, these valuable ecosystems are facing severe threats due to deforestation and land degradation. To counter this, plantation has emerged as a key strategy to restore degraded lands and ensure a continuous supply of ecosystem services. Yet, the success of these plantation sites remains uncertain due to a lack of systematic assessment of their survival status. Therefore, this study focuses on evaluating the survival status of young plantations on degraded riverbanks in Udayapur District, Nepal. Through systematic sampling at 0.5% intensity, 30 plots, each spanning 25 m², were established for regeneration inventory. Soil samples were collected using soil augers to a depth of 30cm for nutrient analysis. Nitrogen (N), Phosphorus (P), and Potassium (K) levels were determined using soil testing kits, while organic matter (OM) content was assessed using the Loss-on-Ignition (LOI) method. The results revealed an encouraging overall seedling survival rate of 95% at the research site. Notably, *Dalbergia sissoo* (Sissoo) and *Tectona grandis* (Teak) exhibited the highest survival rates at 100%, whereas *Phyllanthus emblica* (Amala) and *Delonix regia* (Gulmohar) showed lower survival rates at 40%. The site demonstrated low levels of N, P, and K, alongside high organic matter content. Unexpected high survival rate (95%) despite presence of a low level of nutrients raises intriguing questions about the adaptive mechanisms of the planted tree species. Further replication of similar studies as well as investigation of factors playing crucial role in seedling survival and growth beyond soil nutrient status is recommended.

INTRODUCTION

Forests are complex and diverse ecosystems that offer numerous ecological, economic, and social benefits, ranging from carbon sequestration and biodiversity conservation to timber production and recreational

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opportunities (MEA, 2005; Morgan et al., 2022). However, forests worldwide are facing various challenges and threats that jeopardize their sustainability and the benefits they provide. Deforestation, habitat fragmentation, climate change, and unsustainable logging practices are among the pressing issues that have led to forest degradation and loss (Singh et al., 2020; Morgan et al., 2022). Deforestation, driven by factors such as agriculture expansion, logging, and urbanization, leads to habitat loss, biodiversity decline, and carbon emissions (Veldkamp et al., 2020). Habitat fragmentation disrupts ecological connectivity and can result in the loss of specialized species (Mullu, 2016). Climate change poses additional threats, altering temperature and precipitation patterns, increasing the frequency and intensity of natural disasters, and affecting the distribution and behavior of plant and animal species (Muluneh, 2021). Unsustainable logging practices further exacerbate forest degradation, leading to soil erosion, loss of wildlife habitat, and negative impacts on local communities (Veldkamp et al., 2020). To address these challenges and restore forest ecosystems, plantations have gained prominence as alternatives to natural forest regeneration (Matthews et al., 2002; Makino et al., 2007).

Deforestation and forest degradation have become significant environmental issues in Nepal, particularly in the Terai and Chure regions (Chaudhary et al., 2016; Chalise et al., 2019). Around 28% (3.262 million ha) of Nepal's land area is considered degraded (MoEST, 2008), primarily due to factors such as population growth, illegal and unsustainable harvesting, encroachment, overgrazing, and infrastructure development (Jha et al., 2013; Chaudhary et al., 2016). These activities have led to erosion, landslides, flooding, and sedimentation. To address these challenges, afforestation and reforestation programs have been prioritized, particularly in the Terai and Chure regions (DFRS, 2015). In the early 1980s, large-scale plantations were initiated in the hilly regions of Nepal to restore forests (Gilmour et al., 1990). The Terai Community Forestry Program has also carried out extensive plantations in the Terai region, using local plant species such as Sissoo (*Dalbergia sissoo*) and fast-growing exotic species like Teak (*Tectona grandis*), Eucalyptus (*Eucalyptus camaldulensis*), and Poplar (*Populus deltoides*) (MoFSC, 2015). However, these plantations often experience poor survival rates due to various factors, including the use of immature seedlings, unsuitable plantation site conditions, and improper selection of tree species for specific sites (Paudel and Acharya, 2018). Therefore, it is essential to evaluate the survival status of plantation sites to effectively monitor progress. These assessments enable the implementation of specific measures, such as enrichment or replacement strategies, based on the survival status of the existing plantations (World Vision, 2020).

Assessing seedling survival and monitoring the success of plantations is crucial for sustainable forestry operations (Berhe, 2017). It provides valuable insights and information that guide future management decisions. Survival assessments allow us to evaluate the performance of plantations and determine the success of tree establishment efforts (World Vision, 2020). By systematically monitoring the survival rates of seedlings over time, we can identify patterns and trends, understand the factors influencing survival, and make informed decisions for future plantings (Ayer et al., 2023). This information helps us assess the effectiveness of different planting techniques, species selection, and site preparation methods, enabling us to refine and improve our plantation practices. In addition to seedling survival assessments, evaluating soil conditions is equally important for successful plantation establishment (Ayer et al., 2023). Assessing soil properties, such as fertility, texture, and moisture content, provides valuable information about the soil's capacity to support seedling growth and survival (Khanal et al., 2021; Mousavijad et al., 2022). By understanding the soil characteristics, forest managers can implement appropriate soil management practices, such as fertilization, irrigation, or erosion control measures, to create optimal conditions for seedling establishment and growth (Pitigala and Gunatilake, 2002; Idowu, 2019). By continuously monitoring and assessing seedling survival and soil health, we can improve plantation success rates, enhance ecosystem resilience, and achieve long-term sustainability in forestry practices (Curran, 2005; Idowu, 2019).

Despite the importance of successful forest regeneration and the substantial investments made by the government in plantation efforts, limited comprehensive research has been carried out on seedling survival status in Nepal (Paudel and Acharya, 2018; Khanal et al., 2021; Ayer et al., 2023). Therefore, this study aims to address the existing research gap by assessing the survival status of different species of seedlings planted. Additionally, it seeks to analyze the variation in survival rates and growth of species by examining the status of selected soil properties in the target site. By addressing these research objectives, this study aims to contribute to the existing knowledge on seedling survival and plantation success and propose recommendations and solutions to improve the success of future plantation initiatives in the Udayapur district. Furthermore, findings of this research will provide valuable insights for forestry practitioners, policymakers, and local stakeholders in formulating strategies and implementing more effective plantation practices in the future.

MATERIALS AND METHODS

Study area

The study area is situated in Katari Municipality (26° 57′ 0″ N, 86° 22′ 12″ E) of Udaypur district in eastern Nepal (Figure 1). Covering a total area of 15 hectares, this plantation site is located along the banks of a river at an elevation of 180 meters above sea level. The study area has a tropical and subtropical climate, with an annual minimum temperature of approximately 16.8°C and an annual maximum temperature of around 28.1°C. Similarly, it receives an average annual rainfall of about 1349.2 mm (DoHM, 2017).

Prior to the plantation initiative undertaken in 2021, the study area was characterized as a degraded river bank. In 2021, a comprehensive plantation was carried out in the study area to restore the degraded river bank. A total of 24,000 seedlings were planted across the 15-hectare site to revive the ecosystem. Following the recommendations of Division Forest Officials, a planting density of approximately 1600 seedlings per hectare was employed. These seedlings were spaced at intervals of 2.5 meters by 2.5 meters, as part of a strategic approach to ensure effective growth and management of the tree species. The tree species planted in the plantation site are presented in Table 1.

Table 1: Overview of tree species planted in Paluwatar plantation site

SN	Local Name	Scientific Name	No of Planted Seedling
1	Khair	*Acacia catechu*	9000
2	Sisam	*Dalbergia sissoo*	9000
3	Amala	*Phyllanthus emblica*	500
4	Gulmohar	*Delonix regia*	500
5	Jamun	*Syzygium cumini*	1000
6	Teak	*Tectona grandis*	1000
7	Masala	*Eucalyptus camaldulensis*	2000
8	Khanyu	*Ficus semichordata*	600
9	Khamari	*Gmelina arborea*	400
		Total	24000

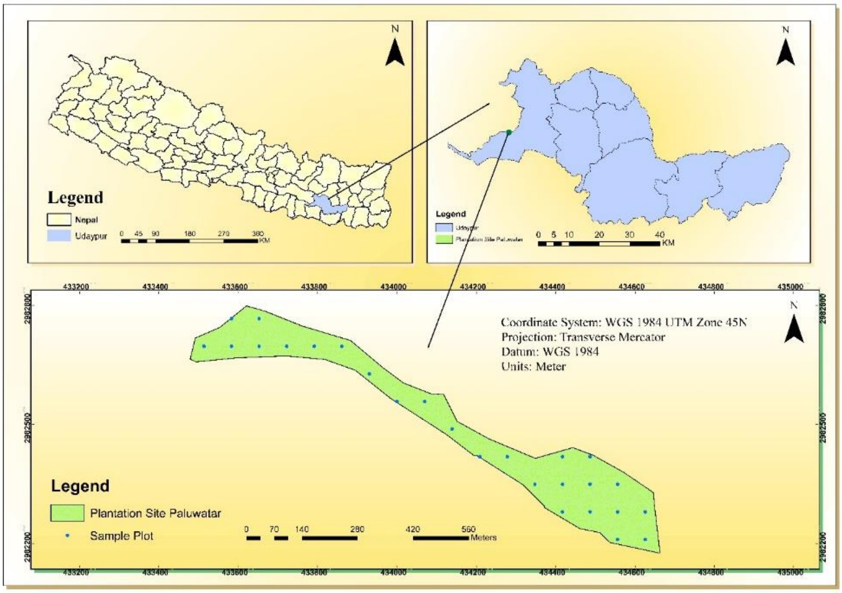

Figure 1: Location map of study area

Data collection

In January/February 2022, the regeneration count was carried out in collaboration with community forest user groups. Regeneration count was done using systematic sampling having 0.5 % sampling intensity. A total of 30 square plots having 25m² each were established. Within each plot, regeneration was counted, height was measured using linear tape and collar diameter (10 cm from ground level) was measured with the help of diameter tape.

Similarly, a total of 30 composite soil samples from 30 cm depth were collected using soil auger. To ensure representative sampling, composite samples were created by gathering soil from the four corners of each sample plot. These samples were thoroughly mixed together, resulting in one composite sample per lot. Subsequently, all composite soil samples were carefully sealed in ziplock bags for secure transport to the laboratory located at the Faculty of Forestry in Hetauda. Colorimetric method was used to determine Nitrogen, Phosphorus and Potassium levels using soil testing kits. Commercial soil testing kits commonly employ a colorimetric method to determine macronutrient and pH levels (Yamin et al., 2020). In this process, a measured amount of soil is placed into a sample container, and an extractant is introduced. After a designated reaction time, the user compares the resulting color to a provided color card. This color card is calibrated to represent different categorical levels of nutrients and pH (Yamin et al., 2020). Additionally, the content of Organic Matter (OM) was evaluated through the Loss-on-Ignition (LOI) method (Robertson, 2011).

Data analysis

The data collected from the seedling inventory were analyzed using Microsoft Excel 2013, version 15.0. Total number of seedlings survived and total number of seedlings initially planted were used for calculating survival percentage of the site as well as particular species (Ayer et al., 2023).

Plantation site Survival rate (%) = (total plants survived in the plantation site/total plants planted in the plantation site) x 100%.

Species wise survival rate (%) = (total seedling of species A survived in the plantation site/total seedling of species A planted in the plantation site) x 100%.

In this study, the assessment of soil NPK (Nitrogen, Phosphorus, and Potassium) status employed a comprehensive methodology that combined qualitative ranking and a nutrient index approach (Ravikumar, 2013). The initial step involved assigning categorical values to each category of N, P, and K levels: a value of 1 for "low," 2 for "medium," and 3 for "high." The calculation was performed using the following formula:

Nutrient Status Index = (1 * Number of samples with low NPK) + (2 * Number of samples with medium NPK) + (3 * Number of samples with high NPK) / Total number of samples.

Index value below 1.67 were classified as having a "low" nutrient status, those falling between 1.67 and 2.33 were categorized as "medium," and samples with an index value exceeding 2.33 were designated as having a "high" nutrient status. Similarly, soil organic matter content (OM) was calculated by Loss-on-Ignition (LOI) at 120º C method (Robertson, 2011) using formulae, OM % = {Pre ignition weight of soil (g) – Post ignition weight of soil (g) / Pre ignition weight} *100.

RESULTS

Plantation survival status

Overall survival status of plantation was found to be 95%. Species-wise, *D. sissoo* (Sissoo), *T. grandis* (Teak), *F. semicordata* (Khanyu) and *E. camaldulensis* (Masala) demonstrated an impressive 100% survival rate, with all planted seedlings thriving. Additionally, *A. catechu* (Khair) and *S. cumini* (Jamun) also achieved satisfactory survival rates of 98% and 80% respectively. However, *G. arborea* (Khamari), *P. emblica* (Amala) and *D. regia* (Gulmohar) showed poor result attaining a survival rate of 50%, 40% and 40% only (Figure 2).

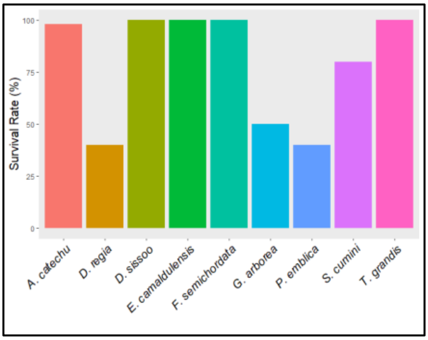

Figure 2: Survival status of tree species in plantation site

Status of soil properties

The nutrient index values for nitrogen, phosphorus, and potassium were found to be 1.07, 1.40, and 1.46, respectively (Figure 3). The pH value was determined to be 7.33 ± 0.14 (Figure 4). The organic matter content was measured to be 11.05 ± 2.21% (Figure 4).

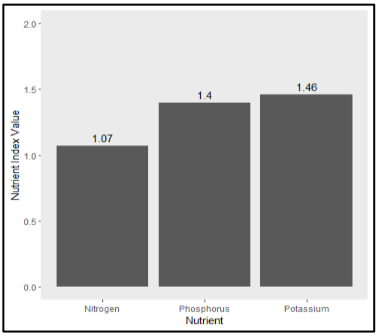

Figure 3: Nutrient Index (Nitrogen, Phosphorus, Potassium)

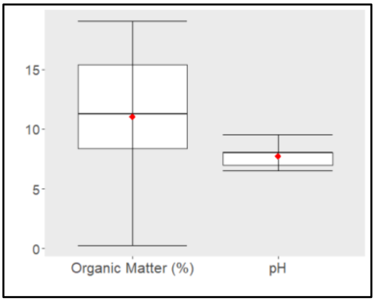

Figure 4: Boxplot of the pH and organic matter measurements (Red dot denotes mean value)

Growth of seedlings

Among the species studied, *D. sissoo* displayed the highest mean height at 250 cm, while *D. regia* and *G. arborea* had the lowest mean height of 50 cm (Figure 5). *A. catechu* had the largest mean collar diameter of 11.54 cm, while *G. arborea* had the smallest mean collar diameter of 3 cm (Figure 6). *D. sissoo* exhibited the highest mean height-to-diameter ratio of 32.94. On the other hand, *D. regia* had the lowest mean ratio of 12.50 (Figure 7).

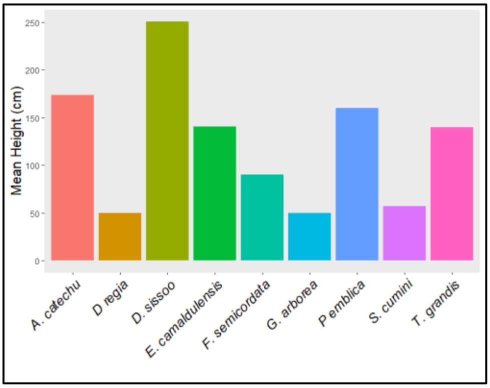

Figure 5: Barplots showing mean height (cm) of planted tree species

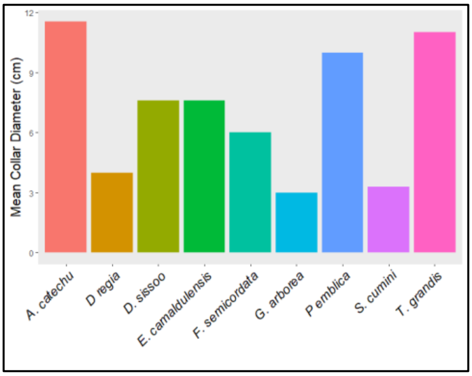

Figure 6: Barplots showing mean collar diameter (cm) of planted tree species

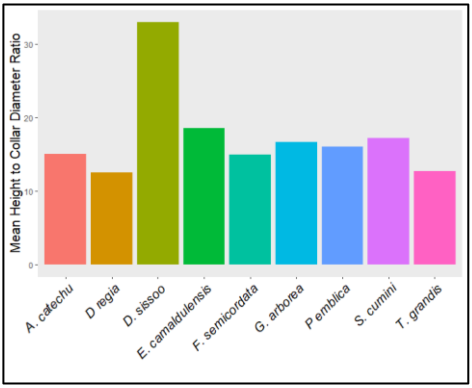

Figure 7: Barplots showing mean height to collar diameter ratio of planted tree species

DISCUSSION

Plantation survival status

The present study was conducted to assess the survival rates of different tree species planted in the degraded riverbank. The need for this study arises from the substantial investments made in plantation projects each year, but often without comprehensive assessments of the survival status of the planted seedlings. Our study found an overall survival rate of 95% for the planted tree species (Table 1), which was significantly higher than the survival rates reported in previous studies conducted by Paudel and Acharya (2018) and Khanal et al. (2021). This could be due to differences in study locations and the specific tree species planted (Ayer et al., 2023). Study by Paudel and Acharya (2018) in Parbat District centered on the survival rates of 11 tree species, which differed from those planted in our study area. Likewise, a study by Khanal et al. (2021) in Tanahun District focused specifically on *Cinnamomum tamala* plantation presenting a distinct context.

Our study found varying degrees of success in the survival of the planted tree seedlings across different species. Species such as Sissoo (*D. sissoo*) and Teak (*T. grandis*) demonstrated excellent adaptability to the local environmental conditions, resulting in a

100% survival rate. These species are known for their resilience and ability to thrive in a wide range of environmental conditions (Singh and Bhati, 2005). Therefore, they could be recommended for extensive plantation projects in similar regions. On the other hand, the species Amala (*P. emblica*) and Gulmohar (*D. regia*) showed lower survival rates of only 40%. This may suggest that these species might require more specialized care and specific environmental conditions to establish successfully. Despite the high overall survival rate of 95%, our findings emphasize the need for continuous monitoring and maintenance of the planted seedlings.

Status of soil properties

The results of the soil analysis reveal that plantation site exhibits low levels of essential nutrients nitrogen, phosphorus, and potassium (Figure 3). These nutrients are critical for supporting plant growth and development, and their deficiency can limit the productivity of crops or vegetation in the area (White and Brown, 2010). The low nutrient levels observed in the soil analysis can be attributed to the site's previous condition as a river bank. River banks are dynamic environments exposed to constant water flow, which can cause erosion and sediment deposition (Chakraborty and Saha, 2022). Over time, the natural process of erosion may have removed nutrient-rich topsoil, leading to reduced nutrient content in the remaining soil (Sahoo et al., 2015). Additionally, fluctuating water levels in river banks can result in higher leaching rates, where nutrients are washed away from the soil and carried downstream or deposited in other areas (Chimwanza et al., 2006). The intermittent flooding events may have also contributed to nutrient loss through leaching (Salazar et al., 2014). As a result of these processes, the soil at the study site might have experienced nutrient depletion, leading to the observed low levels of essential nutrients such as nitrogen, phosphorus, and potassium. However, our study found high organic matter content in plantation site (Figure 4). This might be due to transportation of organic-rich sediment to the degraded riverbank. The slightly alkaline pH range observed in this study (Figure 4) may also be influenced by the underlying sediment composition and the presence of alkaline minerals typically found in river bank soils (Xue et al., 2017). These findings raise concerns about soil fertility and its potential implications on plant health and ecosystem productivity. The observed low nutrient levels could adversely impact plant growth, leading to nutrient deficiencies and reduced vigor in the vegetation (Kumari et al., 2018). Therefore, our study emphasizes the importance of proactive soil management in the plantation sites.

Growth of seedlings

D. sissoo had the highest mean height followed by *A. catechu* (Figure 5). *A. catechu* had the highest mean collar diameter (Figure 6). Similarly, *D. sissoo* had highest mean height to collar diameter ratio (Figure 7). These findings highlight their distinctive growth strategies and adaptations to the environment of study area. This might be due to the fact that *D. sissoo* and *A. catechu* are riverine species and their preference for riverbank environments and their ability to thrive in harsh conditions could have played a significant role in its taller mean height compared to the other species (Mishra et al., 2002; Srivastava and Bharti, 2023). For instance, riverbanks undergo fluctuations in water levels due to varying seasons and rainfall. *D. sissoo* and *A. catechu* probably possess sophisticated water management mechanisms that not only guarantee their survival during water scarcity but also enhance their capacity to flourish in challenging circumstances, aided by their resistance to flooding (Kafle, 2006; Yigit et al., 2016). Moreover, the nutrient dynamics of degraded riverbanks can be erratic due to erosion and disturbance. These species have developed strategies that contribute to nutrient-efficient growth, including deep and extensive root systems that enable them to access nutrients from deeper soil layers (Shaltout et al., 2010). Numerous studies have highlighted their remarkable survival success in these environments, further underscoring their capacity to overcome the adversities associated with degradation (Maikhuri et al., 2000; Giri et al., 2001; Mandal et al., 2018; Ayer et al., 2023). However, tree growth on degraded riverbanks is likely influenced by a combination of factors including adaptive traits, competitive advantage, resilience to stress, efficient resource utilization, microclimate, soil condition, hydrological status and so on (Westermann et al., 2008; Hubble et al., 2010; Talema et al., 2017; Mondal and Tripathy, 2020). Conducting additional field studies and tailored experiments in the similar study area could be crucial for obtaining tangible evidence that supports these hypotheses and uncovers the precise mechanisms underlying these growth patterns.

Interestingly our study found quite high survival rate (95%) despite presence of a low level of nutrients which raises intriguing questions about the adaptive mechanisms of the planted tree species. Species such as *A. catechu* and *D. sissoo* can thrive in such conditions which could have raised overall survival rate of the site and other species might have adapted to the conditions (Edrisi et al., 2019; de Dato & Gil-Pelegrín, 2021). Conventionally, low nutrient availability is associated with reduced plant growth and survival (Leghari et al., 2016; Marschner & Rengel, 2023). However, our findings suggest a potential resilience or adaptation of the selected species to nutrient limitations. It is plausible that these species have evolved physiological strategies, such as efficient nutrient uptake mechanisms or mutualistic relationships with soil microbes, enabling them to thrive in such suboptimal conditions (Munir et al., 2022). Similarly, a study by Collins et al. (2022) also documented elevated survival rates in a low-nutrient setting, emphasizing the pivotal role of environmental factors beyond nutrient availability. This shared trend of heightened survival in seemingly suboptimal conditions prompts a reevaluation of the factors influencing seedling resilience. This apparent contradiction underscores the need for a deeper understanding of the complex interactions between tree species and their environment, highlighting the resilience of certain species in the face of nutrient constraints.

CONCLUSION

This study was undertaken to evaluate the survival status of the planted tree species and nutrient status in degraded riverbank of Udayapur district. The results suggest that the site can be classified as a successful plantation, given its high survival rates (95%). Species wise *D. sissoo* (Sissoo), *T. grandis* (Teak), *F. semichordata* (Khanyu), *G. arborea* (Khamari), *E. camaldulensis* (Masala) demonstrated an impressive 100% survival rate; however, *P. emblica* (Amala) and *D. regia* (Gulmohar) exhibited comparatively lower survival rates (40%). The soil at the site has low levels of nitrogen, phosphorus, potassium, indicating a potential scarcity of essential soil nutrients. However, site exhibited elevated levels of organic matter content. Unexpected high survival rate (95%), despite presence of a low level of nutrients, raises intriguing questions about the adaptive mechanisms of the planted tree species. *D. regia* and *P. emblica* had the greatest growth in terms of both mean height and collar diameter compared to the other tree species in the study. Our study underscores the significance of selecting tree species that are well-suited to the specific site conditions. Furthermore, our study proposes two important considerations. Firstly, there is a clear need for further investigation to comprehensively understand the factors playing crucial role in seedling survival and growth beyond soil nutrient status. By delving deeper into this connection, we can uncover more nuanced insights that may have broader implications for effective reforestation practices. Secondly, we recommend the replication of similar studies in various plantation sites to assess the success of plantation programs. By replicating these studies at different locations and under various conditions, we can gather a broader perspective on the effectiveness and outcomes of reforestation efforts.

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