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Determining the causal factors affecting the survival of young plantations in Udayapur, Nepal

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Abstract. *Ayer S, Bhandari Y, Gautam A, Gautam J. 2023. Determining the causal factors affecting the survival of young plantations in Udayapur, Nepal. Asian J For 7: 82-88.* The plantation is a form of land management and rehabilitation to reverse land degradation, and the survival rate of seedlings is a critical factor for a successful plantation. This study aimed to investigate the survival rate of seedlings in ten plantation sites in Udayapur District, Nepal and identify the major causes of seedling mortality and stunted growth. Planting was done in April/May of 2020 and the total count of the seedlings was done in January/February 2021. Square plots of 5m x 5m each were used for inventory using systematic random sampling with 0.1% sampling intensity. Direct field observation and interviews with officials, *heralu*, and community forest users were conducted to identify reasons behind seedling mortality and stunted growth. The results showed that the overall survival rate of seedlings in the study site was 36.02%. However, site-wise survival rates varied significantly, with Paluwatar CF having the highest survival rate of 87.73% and Sunkoshi CF having the lowest survival rate of 10.76%. Species-wise survival rates also varied, with *Syzygium cumini* having the highest survival rate of 80% and *Cassia siamea* having the lowest survival rate of 5.55%. The major causes of seedling mortality were found to be soil composition and quality (38%), drought (27%), and plant diseases (12%). In addition, carelessness during handling, transportation, and after plantation (21%) were identified as the major causes of stunted growth. This study provides valuable insights into the factors affecting seedling survival and growth in a plantation site, which can be used to guide future plantation efforts. However, further research is needed to understand the complex interactions between different factors better and develop effective strategies for improving seedling survival and growth.

Keywords: Growth, mortality, plantation, seedlings, survival

INTRODUCTION

At the global, local, and regional levels, forests produce various ecosystem services, including providing food, lumber and medicinal plants, freshwater regulation, erosion control, carbon sequestration, ecotourism and so on (MEA 2005; Morgan et al. 2022; Nur et al. 2022). However, growing human population, conversion of forest areas to farmland, and progressive deterioration due to unsustainable agricultural practices have all contributed to worldwide land degradation (Singh et al. 2020; Morgan et al. 2022). Around 60% of the world's land surface is subjected to the degradation process (Pimentel 2006). In recent years, the restoration of degraded areas through plantations has been at the forefront of forest resource management (Abrha et al. 2020). Even though several studies have revealed low levels of biodiversity in plantations (Matthews et al. 2002; Barlow et al. 2007; Makino et al. 2007), other research suggests that plantations can play a significant role in biodiversity conservation, wood production, soil and water conservation, carbon sequestration (Rudel et al. 2005), restoration of forest species (Brockerhoff et al. 2008), provides critical habitat for endangered species (Pejchar et al. 2005; Arrieta and Suárez 2006) and also acts as wildlife corridors (Lindenmayer and Hobbs 2004). Therefore, various sectors like government, private individuals and communities plant seedlings to restore degraded landscapes through afforestation and reforestation programs and mitigate climate change's adverse effects (World Vision 2020).

Land degradation due to deforestation and forest degradation are serious environmental problems affecting Nepal's economy and natural ecosystem, mostly in Terai and Chure Region (Chaudhary et al. 2016; Chalise et al. 2019). More than 28% (3.262 million ha) of land area of Nepal is considered to be degraded (MoEST 2008). Population growth, illegal harvesting, unsustainable harvesting, encroachment, overgrazing, and infrastructure development are some major drivers of deforestation and forest degradation in Nepal, resulting in unpredicted erosion, landslide, lowland flooding and sedimentation (Jha et al. 2013; Chaudhary et al. 2016). Therefore, afforestation and reforestation programs have been prioritized in Nepal's Terai and Chure Region (DFRS 2015). Large-scale plantations in the hilly regions of Nepal were initiated in the early 1980s (Gilmour et al. 1990) to restore the forest. Terai Community Forestry Program has done extensive plantation in Terai Regions using local plant species Sissoo (*Dalbergia sissoo*) and other fast-growing exotic species such as Teak (*Tectona grandis*), Eucalyptus (*Eucalyptus camaldulensis*), Poplar (*Populus deltoides*) etc in the late eighty's (MoFSC 2015). However, poor survival rate is usually recorded due to different factors such as immature seedlings, harsh conditions of plantation sites and improper species-site selection (Paudel and Acharya 2018). Therefore, identifying these factors through survival count is important so that actions can be directed for either enrichment or replacement plantation based on the survival status (World Vision 2020).

Seedling's survival count means checking the existence of planted seedlings in the field, whether they are alive, dead or missed (World Vision 2020). The seedlings survival count guideline by World Vision (2020) states that if the survival rate is above 80%, the planted seedlings are performing well and only require protection and other management actions for fast growth and better quality, while if the survival rate is below 80%, replanting is required. Mortality and stunted growth of seedlings in plantation sites are common problems that can greatly affect the success of reforestation efforts (Fargione et al. 2021). The loss of seedlings can be costly and time-consuming, requiring additional resources and effort to replant and maintain the site (Le et al. 2012). Furthermore, stunted growth can lead to decreased productivity, reducing the overall yield of the plantation (Bhadouria et al. 2016). Therefore, it is important to identify the factors that contribute to these issues and develop effective strategies to prevent or mitigate them. Every year, millions of seedlings have been planted in Nepal, and a huge budget is spent on seedling development and plantation (Paudel and Acharya 2018). For the fiscal year 2016/17, the Government of Nepal allocated around NRs. 170 million (1.29 million USD) to the Departments of Forests to produce around 23 million seedlings (DoF 2016). Nevertheless, in many cases, the seedling status is not assessed, so the need for replanting is not realized, resulting in the failure of plantation programs (Paudel and Acharya 2018).

Very few studies (e.g., Paudel and Acharya 2018; Khanal et al. 2021) have been done to assess survival status of plantations. Furthermore, assessment and comparison of survival status of seedlings among various plantation sites are still lacking. This paper thus aims to assess survival status and causes of mortality and stunted growth of seedlings in various plantation sites in Katari Municipality of Udayapur District. The information gathered from this study will provide valuable insights for the forestry sector to understand the causes of mortality better and develop strategies to improve planting success in the future. Furthermore, by identifying the challenges faced in plantation sites and suggesting ways to overcome them, this study may contribute to sustainable forestry development in Udayapur District.

MATERIALS AND METHODS

Study area

The study areas lies in Katari and Tapli municipality (26° 57′ 0″ N, 86° 22′ 12″ E) of Udayapur District in eastern Nepal Figure 1).

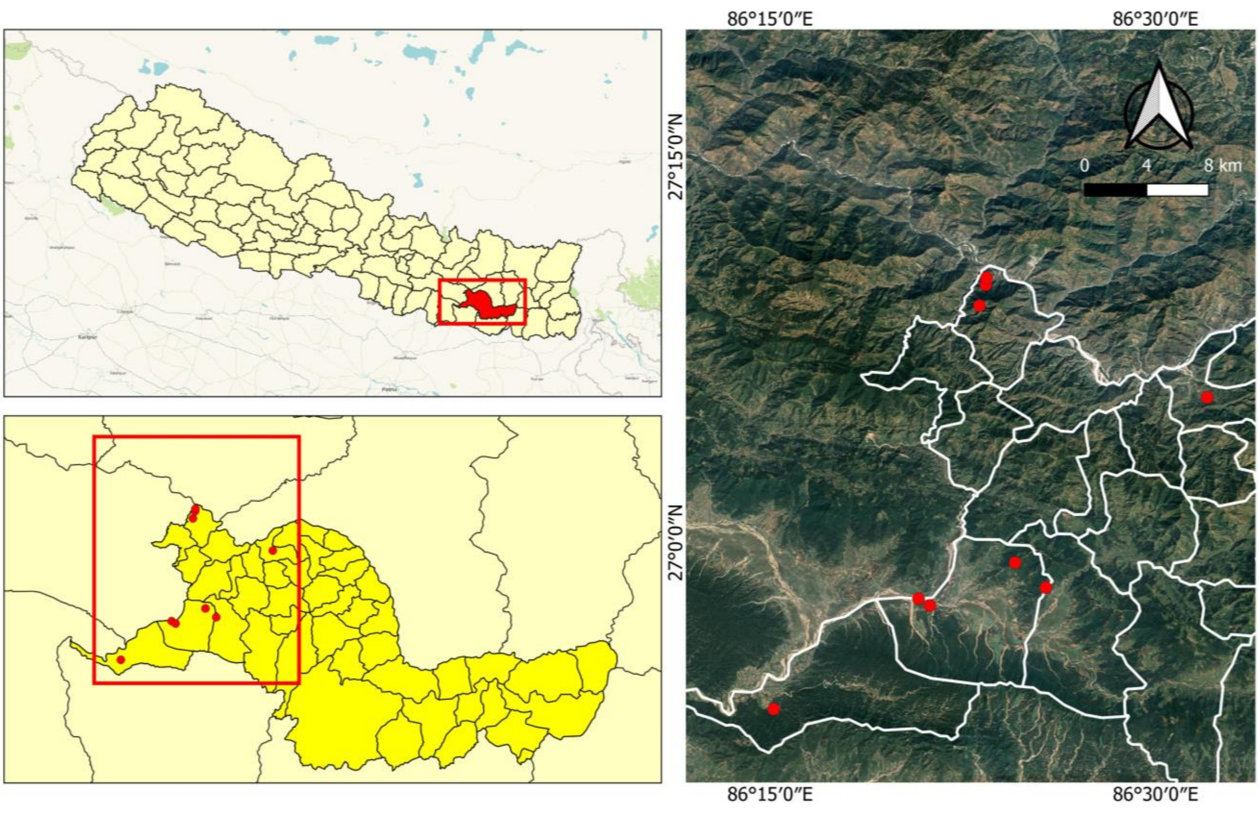

Figure 1. Map of study area and location of the sampled plantations in Udayapur District, Nepal

Table 1. Details about plantation sites in Udayapur District, Nepal examined in this study

Name of plantation site	Elevation (m asl.)	Location	Area (ha)	No. of sample plots	Species planted
Kalikhadi CFUG	210	Katari-5	4	5	Teak, Khair, Masala, Khamari, Siso, Amala
Lekhani (Bare land)	390	Katari-14	30	12	Teak, Khair, Masala, Salla
Kalikhola CFUG	220	Katari-1	4.5	5	Teak, Khair, Mahogony, Amala
Paluwatar CFUG	180	Katari-3	15	6	Teak, Khair, Masala, Khamari, Siso, Amala, Gulmohar, Jamun, Khanyu
Baliya khahare Tawakhola	180	Katari-3	5	5	Khair, Siso, Amala
Sisaghari CFUG	200	Katari-5	10	5	Katahar, Khair, Masala, Khamari, Amala, Salla, Casia simea
Solubhir CFUG	325	Katari-14	59.3	23	Teak, Khair, Masala, Khamari, Siso, Amala, Ambak, Mahogony, Kimbu, Thingure Salla, Laligurans, Ipil Ipil
Solubhir Bhangbhari CFUG	320	Katari-14	14.24	6	Masala, Khamari, Mahogony, Siso, Ipil ipil, Khair
Sunkoshi CFUG	350	Katari-14	14	6	Masala, Ambak, Khamari, Khair, Salla, Mahagony, Amala
Tapli CFUG	390	Tapli-5	15	6	Ambak, Masala, Siso, Mahogony, Khair

Note: Amala: *Phyllanthus emblica,* Casia simea: *Cassia siamea,* Ambak: *Psidium guajava,* Gulmohar: *Delonix regia,* Ipil ipil: *Leucaena leucocephala,* Jamun: *Syzygium cumini,* Katahar: *Artocarpus heterophyllu*s, Khair: *Senegalia catechu,* Khamari: *Gmelina arborea,* Khanyu: *Ficus semicordata*, Kimbu: *Morus alba*, Laligurans: *Rhododendron arboreum,* Mahogony: *Swietenia mahagoni,* Masala: *Eucalyptus camaldulensis*, Salla: *Pinus roxburghii,* Siso: *Dalbergia sissoo*, Teak: *Tectona grandis*, Thingure Salla: *Tsuga dumosa*

The study area encompasses a broad range of elevations (300-3000 m asl). Due to the unique geographical features and various climatic conditions (from lower tropical to temperate), the area is endowed with excellent habitats for diverse flora and fauna. Different topography, geology, and altitude have established three distinct physiographic zones i.e., Inner Terai, Churia, and Mahabharat range. The forest types include tropical evergreen forests to Alder forests. More than 80% area is in high-temperature zone. The rest of the areas have temperate climates. Most of this region is extremely sloped in the northern part of Chure/Siwalik. The vegetation in the study area includes *Shorea robusta, Terminalia chebula, Adina cordifolia, Acacia catechu, Terminalia bellirica, Bombax ceiba, D. sissoo, Schima wallichii, Castanopsis indica, Pinus roxburghii, Alnus nepalensis, Rhododendron arboreum, Lyonia ovalifolia, Myrica esculenta*, etc. (Lamichhane and Karna 2009). The study area has tropical and subtropical climate with an annual minimum temperature of 16.8°C, and annual maximum temperature of 28.1°C and annual rainfall is about 1349.2 mm (DoHM 2017).

The plantation sites examined in this study were situated only at an elevation range of 180-390 m asl (Figure 1). These sites were selected based on accessibility and the availability of data. While the selected sites may not represent the entire plantation area of the study region, they do provide valuable insights into the factors affecting seedling survival in the low to mid-elevation range. Details of plantation sites are presented in Table 1.

Data collection

From the District Forest Office's records, it was possible to identify the plantations that were carried out in 9 community forests and 1 bare land of national forest site in 2020 (Table 1). Pits of standard size of 30x30x30 cm were prepared in April/May of 2020, and plantation was completed in June/July of that year. The District Forest Office, Udayapur (Triveni) provided one-year old seedlings that were planted. About 1600 seedlings were planted per hectare with spacing of 2.5m x 2.5m according to Division Forest Officials.

The assessment of the survival of the planted seedlings was addressed with concern of community forest members. In January/February 2021, a total seedling count was performed with the help of the community forest user groups. For this research work, the community forestry inventory guideline 2061 (DoF 2016) was followed. To evaluate the regeneration status, systematic random sampling with a 0.1% sample size was used because the site exclusively consisted of planted seedlings. The sample plot and map were created using Arc Map 10.8. The sample plots were located by Garmin GPSMAP 60CSx with accuracy of 3 meters. In each plantation site, minimum of five square sample plots of 5m x 5m were established, and an inventory was completed.

To gather information on possible reason behind mortality and stunted growth of seedlings, we conducted discussions with officials and interactions with local users and *heralu* (plantation site guards). We also spoke with officials responsible for plantation management to gain insights into their experiences and observations on seedling mortality. Additionally, we held discussions with local users who had practical knowledge of the area to gain further insights on the potential causes of mortality. We selected these causes based on their frequency of occurrence and potential impact on seedling survival for data analysis.

Some additional causes of mortality identified in the field observations were not represented in figures in the result section as they were not mentioned by the majority of respondents in the survey. However, we included the additional causes identified through field observations in the Result and Discussion sections to provide a more comprehensive understanding of the factors affecting seedling survival in the study area.

Data analysis

The data were pooled and analyzed with Ms-Excel 2013 Version 15.0. The total seedlings planted was estimated by multiplying the total plantation area of CFs with 1600 seedlings. Survival percentage was calculated by simple formulae, calculating the total plant survived in the 5x5m area and calculating the total number of plants planted in the same area (Khanal et al. 2021). Similarly, total survived seedlings in each plantation site was calculated by multiplying survival rate with total planted seedlings in each plantation site.

Survival rate (%) = (total plants survived in the sampled plots/total plants planted in the sampled plots) x 100%.

Total survived seedlings in each plantation site = survival rate × total planted seedlings in each plantation site

RESULTS AND DISCUSSION

Site-wise survival rate of plantation

According to DFO officials, a total of 253,664 seedlings were planted in 10 CFs of the study area. Among the total planted seedlings, only 36.02% (n = 91,375) were found to survived in the area during our study. It should be noted that this survival rate is based on the sample that we studied, not the entire population of planted seedlings. The highest number of seedlings were planted in Solubhir CF (n = 94,880). However, Paluwatar CF has highest survival rate (87.73%), while Sunkoshi CF has lowest survival rate (10.76%) (Table 2).

Species-wise survival rate of plantation

A total of 18 species of plants were used for plantation in 10 different locations. Among which, *Senegalia catechu* was planted in the highest number (n = 46,200), followed by *E. camaldulensis* (n = 34,100), and so on, while *Ficus semicordata* was planted in lowest quantity (n = 600). The survival rate was highest for *Syzygium cumini* (80%) and lowest for *Cassia siamea* (5.55%) (Table 3). The highest number of species were planted in Solubhir CF (n = 13).

Causes of stunted growth of planted seedlings

We noted that the carelessness during handling, transportation, and after plantation were the major causes of stunted growth of seedlings (response by 21% of the respondent). While, 18% of respondents had no idea about the causes (Figure 3). In the field, authors also observed that carelessness during species selection, lack of care of planted seedlings, no weeding, drought, and soil composition as the causes for stunted growth.

Causes of seedlings mortality

The result showed that majority of the respondent (38%) mentioned soil composition and quality as the main cause of seedlings mortality in the site, followed by drought (27%), plant diseases (12%), and so on (Figure 2). Moreover, in the field we observed the inappropriate pit size and wrong species selection, which might be the possible causes of mortality.

Discussion

The purpose of this study was to assess the survival rate and causes of mortality of seedlings planted in different sites and species in Udayapur District, Nepal. A total of 253,664 seedlings were planted, and the survival and mortality rate was evaluated after a certain period of time. The results of this study indicate that the overall survival rate of seedlings planted in the study area was only 36.02% (n = 91,375) which was quite lower than the findings of Paudel and Acharya (2018) and Khanal et al. (2021).

Table 2. Site-wise survival rate of the seedlings planted in ten sites in Udayapur District, Nepal

Name of plantation site	Total planted seedlings	Survival rate (%)	Total survived seedlings
Kalikhadi CF	6400	52.78	3378
Lekhani Bare Land	48,000	25.52	12,250
Kalikhola CF	4800	75.02	3601
Paluwatar CF	24,000	87.73	21,056
Baliya Tawakhola CF	8000	74.15	5932
Sisaghari CF	16,000	27.08	4332
Solubhir CF	94,880	32.80	31,119
Solubhir Bhangbhari CF	22,784	25.30	5766
Sunkoshi CF	22,400	10.76	2410
Tapli CF	6400	23.93	1531
Total	253,664	36.02	91,375

Table 3. Species-wise survival rate of the planted seedling across ten sites in Udayapur District, Nepal

Species name	Planted	Survived	Survival rate (%)	Mortality rate (%)
Artocarpus heterophyllus	2000	222	11.10	88.90
Cassia siamea	2000	111	5.55	94.45
Dalbergia sissoo	23,200	12,044	51.91	48.09
Delonix regia	500	200	40.00	60.00
Eucalyptus camaldulensis	34,100	9918	29.08	70.92
Ficus semicordata	600	456	76.00	24.00
Gmelina arborea	16,300	4290	26.32	73.68
Leucaena leucocephala	11,000	4207	38.24	61.76
Morus alba	7000	484	6.91	93.09
Phyllanthus emblica	16,200	3882	22.60	77.40
Pinus roxburghii	26,200	13,831	52.79	47.21
Psidium guajava	12,200	1904	15.60	84.40
Rhododendron arboreum	7000	4599	65.70	34.30
Senegalia catechu	46,200	20,958	41.03	58.97
Swietenia macrophylla	19,164	7314	38.16	61.84
Syzygium cumini	1000	800	80.00	20.00
Tectona grandis	22,000	3133	14.24	85.76
Tsuga dumosa	7000	3022	43.17	56.83
Total	253,664	91,375	36.02	63.98

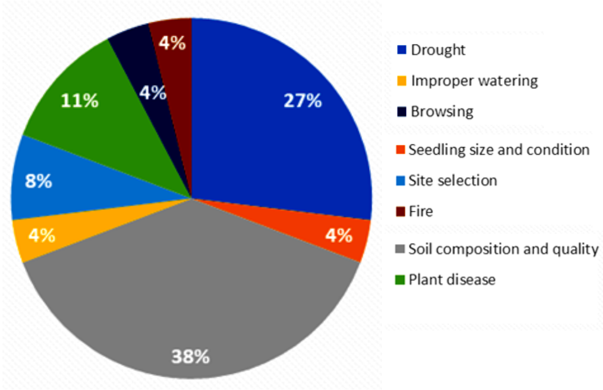

Figure 2. Causes of mortality of the planted seedling across ten sites in Udayapur District, Nepal

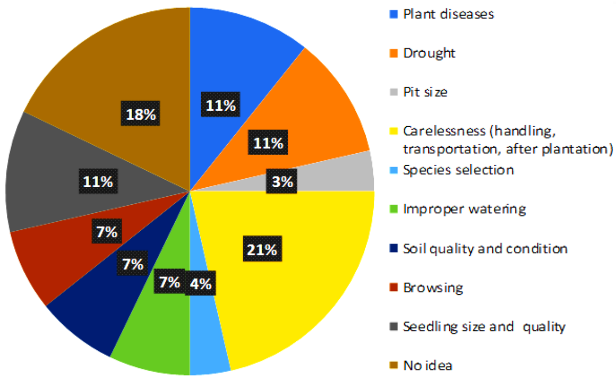

Figure 3. Causes of stunted growth of the planted seedling across ten sites in Udayapur District, Nepal

The differences in study locations and tree species planted may have contributed to the variation in survival rates. The study by Paudel and Acharya (2018) was conducted in Parbat District and assessed survival rate of 11 tree species which were different than species planted in our study area. Similarly, study by Khanal et al. (2021) was conducted in Tanahun district and focused on *Cinnamomum* plantation. Analyzing the survival rates of each plantation site in our study, it was found that some sites have survival rates above the desired ratio of 80%, while others fall below it. For instance, Paluwatar CF had a survival rate of 87.73%, indicating that replacement planting may not be necessary in that area. However, Sunkoshi CF had a survival rate of only 10.76%, indicating a need for replacement planting in that site. Thus, proper land use involving the replacement of dead or unviable seedlings with new healthy seedlings is necessary to improve the stock and maintain healthy plantations (World Vision 2020).

Site-specific conditions play a significant role in seedling survival rates (Duan and Abduwali 2021). In our study, site-wise survival rate varied significantly, with Paluwatar CF having the highest survival rate of 87.73% and Sunkoshi CF having the lowest survival rate of 10.76%. Inappropriate species selection according to site conditions and lack of care of planted seedlings may have influenced the survival rates of these plantation sites. Similarly, a study by Abrha et al. (2020) reported average seedling survival rate of 50% due to poor management of seedlings after planting. In addition, previous studies (Wang et al. 2017; Kambo and Danby 2018; Duan and Abduwali 2021) had reported that local site conditions can have a significant impact on seedling survival. Therefore, we emphasize the importance of considering factors such as soil quality and composition, water availability, temperature, topography, and exposure to wind when planning future plantation works to improve the survival rates of seedlings.

Species-wise survival rate also varied, with *S. cumini* having the highest survival rate of 80% and *C. siamea* having the lowest survival rate of 5.55%. While different species have different growth requirements that can impact survival rates (Duan and Abduwali 2021), it is also possible that seedlings of these species were planted in sites with inappropriate soil conditions or other unsuitable environmental factors. The selection of appropriate tree species that can tolerate or thrive under the prevailing climatic conditions is critical for plantation success (Rudolf et al., 2020; Masaba and Etemesi 2021). For example, some species may require specific temperatures, precipitation levels, or soil pH levels to grow and survive (Parlucha et al. 2017). Therefore, it is important to carefully consider the species-specific requirements when choosing species for planting, as it can significantly affect seedling survival and growth.

The surveyed respondents identified soil composition and quality (38%), drought (27%), and plant diseases (12%) as the major causes of seedling mortality. In a study by Eshetie et al. (2020), 78.49 % of respondents found that planting seedling in infertile soil as abiotic factor affecting seedling survival. Similarly, research studies such as Chen et al. (2010) and Record et al. (2016) have shown that soil nutrients are a crucial factor in tree seedling survival. Specifically, soil properties such as total phosphorus and total nitrogen concentrations have been found to positively affect seedling survival rates (Wang et al., 2012). In addition to these nutrients, other soil properties such as soil organic carbon and soil moisture have also been identified as important factors for seedling survival, as indicated by studies such as Pu et al. (2017). Therefore, soil quality can impact the availability of essential nutrients and water for seedlings, which can have a direct impact on their survival and growth rates. Seedling growth can also be negatively affected by drought stress, which can cause a decrease in shoot length, leaf size, leaf area, and dry leaf weight (Pettigrew 2004). Furthermore, increased plant water stress has been associated with a decline in photosynthesis and chlorophyll contents (Chastain et al. 2016). In addition, drought stress can indirectly lead to seedling mortality by exacerbating other stresses such as salinity, pathogen attack, and heat (Ahluwalia et al. 2021). Similarly, several plant pathogens, including fungi, bacteria, and viruses, can infect seedlings and cause various symptoms, such as wilting, discoloration, and necrosis (Nazarov et al. 2020).

These symptoms can weaken or kill the seedlings, depending on the severity of the infection and the plant's resistance to the pathogen. Additionally, it can also exacerbate the effects of other stresses, such as drought or nutrient deficiencies, and further contribute to seedling mortality (Seleiman et al. 2021). Field observations by authors further indicated that pit size and wrong species selection according to site condition were also possible causes. This suggest that multiple factors can contribute to seedling mortality in the study area. While the respondents' perception may not entirely match the field observation, both perspectives provide valuable insights into the factors that contribute to seedling mortality. Our finding however was contrasted with findings of Paudel and Acharya (2018) where small size and unhealthy seedlings and careless in transportation and handling of seedlings caused 52% mortality. This could be due to differences in the seedling quality, growing conditions, or other factors specific to their study area (Masaba and Etemesi 2021).

In our study, high percentage of respondents (21%) identified carelessness during handling, transportation, and after plantation as the cause of stunted growth of seedlings. This might be due to physical damage to seedlings such as broken stems, damaged roots, or bent leaves caused by carelessness. These physical injuries can impede the seedling's ability to absorb water and nutrients from the soil, leading to stunted growth (Kennelly et al. 2012). In addition, mishandling during transportation and planting can result in improper planting depth or inadequate soil contact, both of which can limit root growth and cause stunted growth (Elefritz et al. 1998). Furthermore, improper handling of seedlings can expose them to stressors like extreme temperatures or sunlight by damaging their leaves, stems, or roots, which can also impact their growth and survival (Van Der Zanden 2008). This highlights the need for increased attention to these stages of the plantation process. It also emphasizes the importance of providing adequate training and education to those involved in plantation activities, so that seedlings can be handled and planted correctly. The field observations further indicate that other factors such as species selection, drought, soil composition, and no weeding can also play a role in stunted growth of planted seedling.

In conclusion, this study aimed to assess the survival rate and causes of mortality of seedlings in a different plantation sites of study area. The results showed that the site-wise survival rate varied significantly, with Paluwatar CF (87.73%) having the highest survival rate and Sunkoshi CF (10.76%) having the lowest. The species-wise survival rate also varied, with *S. cumini* (80%) having the highest survival rate and *C. siamea* (5.5%) having the lowest. The study also identified soil composition and quality as the main cause of seedlings mortality and carelessness during handling, transportation, and after plantation as the major cause of stunted growth. These results highlight the importance of considering local site conditions and carefully selecting species when planning future plantation works, as well as ensuring proper care of seedlings after planting to promote growth and survival. In light of these findings, it is recommended to implement best practices for seedling handling, transportation, and after plantation care to improve the survival rate and growth of seedlings in future plantation efforts. Our study provides valuable insights into the factors affecting seedling survival in low to mid-elevation plantation sites in the study region. However, it is important to note that the findings of this study may not be applicable to the entire plantation area of the study region due to the limited elevation range of the examined sites. Further research is needed to investigate the factors affecting seedling survival in higher elevation plantation sites. Similarly, further research on various biotic and abiotic factors that influences survival and mortality rate of seedlings in plantation sites is recommended to better understand the complex interactions between different factors and to develop effective strategies for improving seedling survival and growth.

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