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Effect of Nursery Shading Intensity, Potting Mixture and Pot Size on the Performance of *Pericopsis angolensis* (Baker) Meeuwen Seedlings

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Abstract
Nursery practices are integral to the successful germination, growth, and survival of tree species. However, limited attention has been given to the establishment, management, and performance of seedlings of many indigenous tree species in nursery settings. This study investigated the performance of Pericopsis angolensis seedlings under varying nursery conditions, including shading intensities (SI) (0%, 50%, and 75%), pot sizes (PS) (10 cm, 15 cm, and 20 cm), and potting mixtures (PM) (PM0 [sand: cow manure: forest topsoil (1:2:4)], PM1 [sand: cow manure: forest topsoil (1:2:3)], PM2 [sand: cow manure: forest topsoil (1:4:3)], PM3 [forest topsoil only], and PM4 [PM0 with an additional 5 gm of NPK]). A Completely Randomized Block Design (CRBD) with a 3 x 3 x 3 factorial arrangement was employed. The results revealed that SI had a significant influence on various growth parameters, including root-collar diameter (RCD), shoot height (SH), and leaf count (LC). Specifically, the highest SI (75%) was found to be the primary factor influencing these parameters. Moreover, the study demonstrated that both PS and PM composition significantly influenced leaf development. Larger PSs were associated with increased LC. Notably, seedling biomass was highly affected by SI and PS, with larger pots resulting in greater seedling productivity. It is suggested that shade circumstances be carefully m anaged, with a focus on maintaining 50% SI for the best results, to maximize the growth of Pericopsis angolensis seedlings. This can be accomplished by choosing planting areas with naturally occurring shade or by using shade structures. In addition, this study emphasizes the potential advantages of employing larger PSs composed of forest topsoil to increase seedling productivity, and thus biomass production.

Keywords: Growth Parameters, *Pericopsis angolensis*, Miombo Woodlands, Nursery practices

Introduction

Nursery practices play a critical role in the performance and growth of seedlings because they provide optimal conditions for seed germination and seedling development [1, 2]. Proper nursery management practices can prevent overcrowding and competition for resources, which lead to stronger and more vigorous tree seedlings [3]. Many studies have reported on the importance of proper nursery practices on seedling health and field performance [4-7]. Thus, with the increased effects of climate change in the forest community, the establishment of a proper environment for the effective performance of the indigenous tree species in the field is of paramount importance.

Shading intensity (SI) is an important aspect of nursery practices as it controls the amount of light that reaches seedlings, which can be beneficial in preventing sun damage and reducing water loss [8]. However, excessive shading can also inhibit photosynthesis and reduce and seedling survival [9]. The importance of adopting the appropriate potting mixture (PM) cannot be overstressed since the physical and chemical properties of the PM can significantly affect the growth of *Pericopsis angolensis* [10]. Another important factor in seedling development is the choice of pot size (PS); increasing PS tends to have a positive relationship with seedling growth parameters [11]. However, Weraduwage reported a significant interaction effect between PS and PM ratio, with growth parameters being smaller in smaller pots in Miombo plants [12].

Pericopsis angolensis also known as 'Mbanga' in Kiswahili language is a deciduous shrub or tree native to tropical forests of

Africa, including Tanzania, where it is found in Miombo woodlands and is used for construction and furniture making, as well as traditional medicine to treat fever, diarrhoea, and skin diseases [13-15]. Therefore, whereas the conservation and domestication of native species is important for the restoration of the deforested land, the use of *Pericopsis angolensis* is constrained by poor survival and growth rate in the nursery and early establishment in the field [14, 15].

Generally, there is scarce information on the seedling growth performance of different indigenous tree species especially of *Pericopsis angolensis* during establishment in the nursery [16]. Vyamana et al. conducted an experiment on growing *Pericopsis angolensis* under different nursery practices, but only assessed few growth parameters such as survival and growth, seedling diameter, and seedling height. Therefore, this study assessed the performance of the *Pericopsis angolensis* seedlings under different nursery treatments of SI, PS and PM [14]. It is expected that the information obtained will inform further research and operationalization process by adopting efficient procedures and practices to ensure high survival and performance of *Pericopsis angolensis* during establishment.

Materials and Methods

Experimental Site

The study was conducted from December 2021 to May 2022 at the Tanzania Forest Services Agency (TFS) Tree Seed Production Station (TSPS) nursery, in Kihonda - Mbuyuni, Morogoro municipality, Tanzania. The station is 3 km from Msamvu bus stand on the road to Dodoma region. TSPS is located 511 m a.s.l. at latitude and longitude 6° 49' 12'' and 37° 38' 36'' respectively. The station has minimum and maximum temperatures of 16°C and 33°C respectively and annually the area receives rainfall ranging between 821 mm - 1505 mm [17].

Experimental Design and Treatments

A 3 x 3 x 3 factorial arrangement fitted into a Completely Randomized Block Design (CRBD) was employed in this study. The three factors investigated were SI, PS and PM. SI was regulated at three different levels (intensities) by shade nets, resulting in 0% (SI0), 50% (SI1), and 75% (SI2) relative SI [18]. PS was varied by using three different heights: 10 cm (PS1), 15 cm (PS2), and 20 cm (PS3). Each experimental container (made of polyethene tube) had a standardized lay-flat diameter of 10.16 cm [14]. The PMs were based on volumetric ratios as outlined by Vyamana et al. where [14]:

- PM0: sand: cow manure: forest top soil (1:2:4);
- PM1: sand: cow manure: forest top soil (1:2:3);
- PM2: sand: cow manure: forest top soil (1:4:3);
- PM3: forest top soil only; and
- PM4: PM0 with an additional 0.5 gm of NPK.

Three major plots were established, representing a different SI (SI0, SI1, and SI2). Each major plot was further sub-divided into five sub-plots, each corresponding to a specific PM (PM0, PM1, PM2, PM3, and PM4). Finally, within each sub-plot, the three different PSs were tested (PS1, PS2, and PS3) producing 30 pots per treatment combination. Additionally, each PS was replicated ten times, resulting in a total of 150 pots for each SI and a grand total of 450 pots for the entire experiment, allowing for a comprehensive assessment of the combined effects of the treatment factors on *P. angolensis* seedling performance.

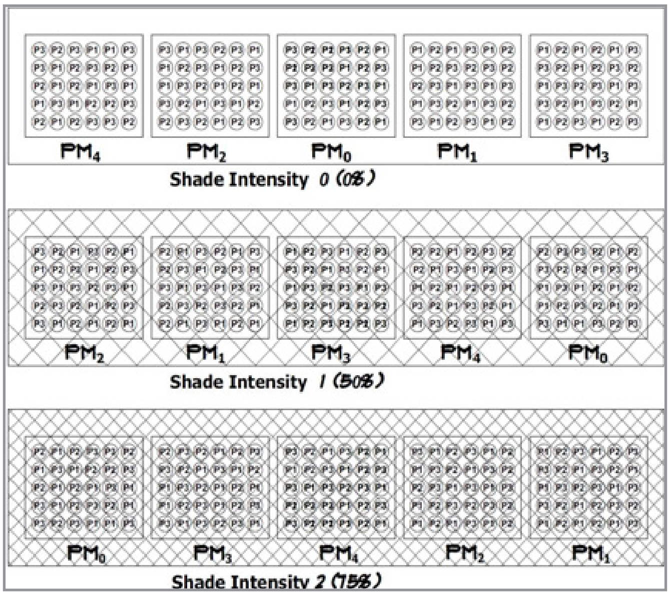

Figure 1: Arrangement of Shade Intensity, potting Mixtures and Pots in the Nursery

Data Collection

Growth Parameters

The assessment of growth parameters namely root collar diameter (RCD), shoot height (SH) and leaf count (LC) as non-destructive parameters were recorded after every 2 weeks for 4.5 months; while root length (RL) and total dry biomass (TDB) were recorded at the end of the experiment. The first data collection was taken on the 30th day after seed sowing date. SH was taken from the plant emerging point in a container at the level of soil surface to the highest apical meristem and RCD was measured at the level of soil surface/line. The recognizable leaf was counted from each plant/seedling. Seedling survival was recorded by counting the surviving seedlings at the end of the experiment.

Seedling Quality Parameter

Seedling quality in terms of the sturdiness quotient (SQ) was also evaluated. This is a measure of the vigour and robustness of a seedling. It was calculated by dividing SH by RCD, which is the point on the stem where the root system begins. The SQ provides a quick and simple method of evaluating seedling quality, as it considers both above-ground growth and root development.

Statistical Analysis

Three-factor analysis of variance (ANOVA) was employed to test the effects of SI, PS and PM treatments on the changes in RCD, SH, LC, RL, TDB and SQ of the seedlings. A total of 30 seedlings per plot were used in the data analysis. Tukey's HD multiple comparisons test was used separate treatment means that were significantly different. All statistical analyses and visualizations were performed using R-software and Excel software respectively. All probabilities were tested at p = 0.05 significance level.

Results

Treatment Effects on *P. angolensis* Survival Rate

The investigation into the effects of the experimental treatments on seedling survival rate revealed distinct patterns. SI emerged as a critical determinant, where seedlings under SI0 exhibited 0% survival rate, in contrast to SI1 and SI2, where all of the seedlings survived (100%) (Figure 3.2) during the experimental period.

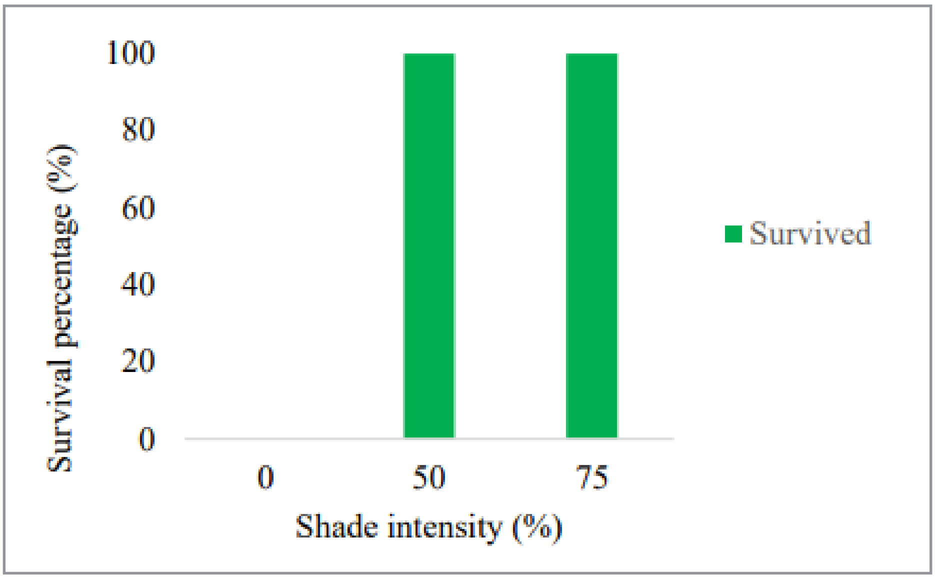

Figure 2: Effect of shade intensity on seedlings survival rate

Treatment Effects on *P. angolensis* Seedling Growth Parameters

The analysis of how different treatments impacted the growth of *Pericopsis angolensis* seedlings provided valuable insights. SI had a strong influence on RCD, with a statistically significant effect. SH was significantly affected by SI, PM, PS, and their interactions. Similarly, LC was significantly influenced by SI, PS, PM, and the interactions between them, with SI having the strongest impact. RL was affected by all factors and their interactions. TDB was impacted by most treatments except the interactions between SI and PS, and between PS and PM (Table 3.1, Figures 3.3- 3.7). Notably, PS had the most significant influence on the growth parameters of *Pericopsis angolensis* seedlings, highlighting its importance.

Table 1: ANOVA Results of Treatment Effects on *P. angolensis* Seedling Growth Parameters

Growth parameter	Source of variation	Mean Sq	F-value	p-value
Root collar diameter (RCD)	SI	139.754	308.333	<0.001
	PM	0.470	1.038	0.3857
	PS	0.005	0.011	0.9889
	SI:PM	0.228	0.503	0.8544
	SI:PS	0.095	0.211	0.9323
	PM:PS	0.060	0.134	0.9977
	SI:PM:PS	0.192	0.424	0.9771
Shoot height (SH)	SI	221.502	449.096	<0.001
	PM	3.833	7.772	<0.001
	PS	2.642	5.358	0.0048
	SI:PM	5.543	11.238	<0.001

	SI:PS	12.836	26.026	<0.001
	PM:PS	5.571	11.093	<0.001
	SI:PM:PS	4.472	9.060	<0.001
Leaf count (LC)	SI	708.883	130.266	<0.001
	PM	240.101	44.121	<0.001
	PS	45.292	8.323	<0.001
	SI:PM	16.920	3.109	0.0017
	SI:PS	20.599	3.785	0.0044
	PM:PS	29.820	5.479	<0.001
	SI:PM:PS	10.270	1.880	0.0173
Root length (RL)	SI	164.280	20.573	<0.001
	PM	99.388	12.446	<0.001
	PS	1351.263	169.221	<0.001
	SI:PM	42.721	5.350	<0.001
	SI:PS	63.210	7.915	<0.001
	PM:PS	26.475	3.315	0.0012
	SI:PM:PS	29.514	3.690	0.0004
Total dry biomass (TDB)	SI	1.684	19.616	<0.001
	PM	1.011	11.781	<0.001
	PS	2.560	29.822	<0.001
	SI:PM	0.689	8.035	<0.001
	SI:PS	0.102	1.195	0.304
	PM:PS	0.062	0.200	0.674
	SI:PM:PS	0.242	2.820	0.005

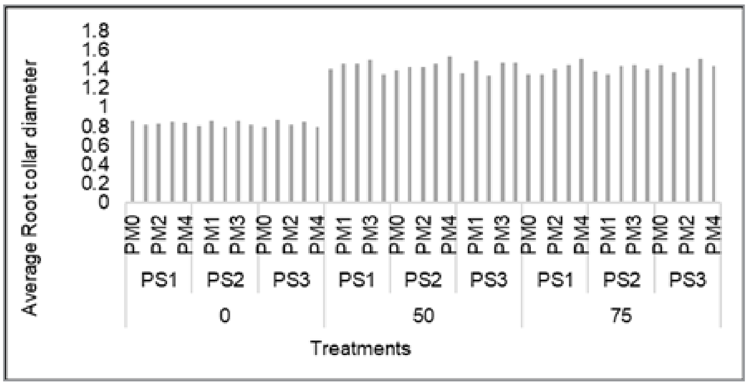

Figure 3: Influence of Treatment Factors on Average Root Collar Diameter

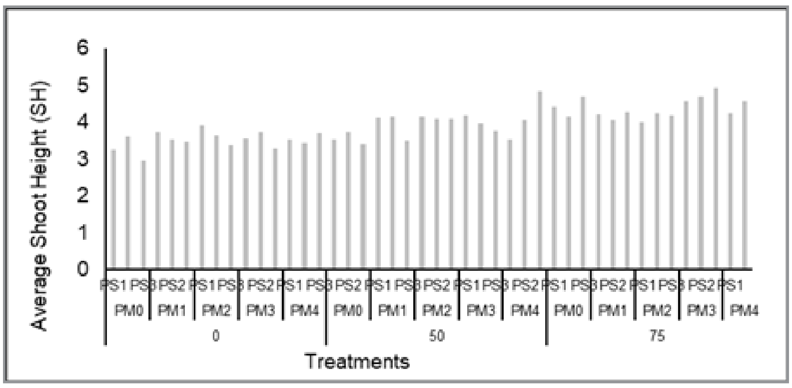

Figure 4: Influence of Treatment Factors on Average Shoot Height

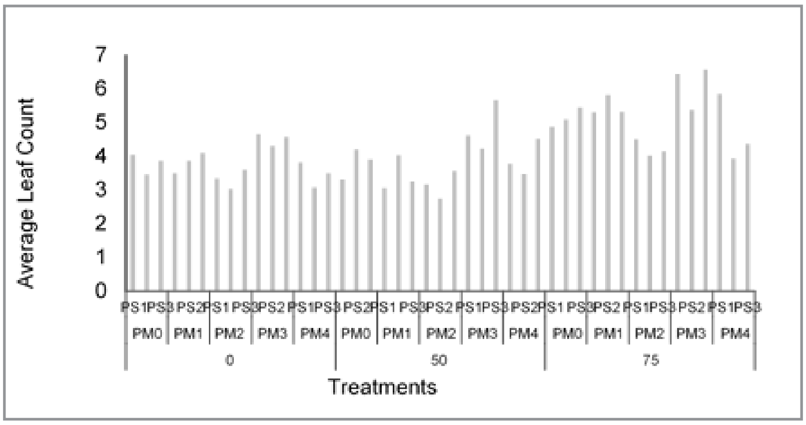

Figure 5: Influence of Treatment Factors on Average Leaf Count

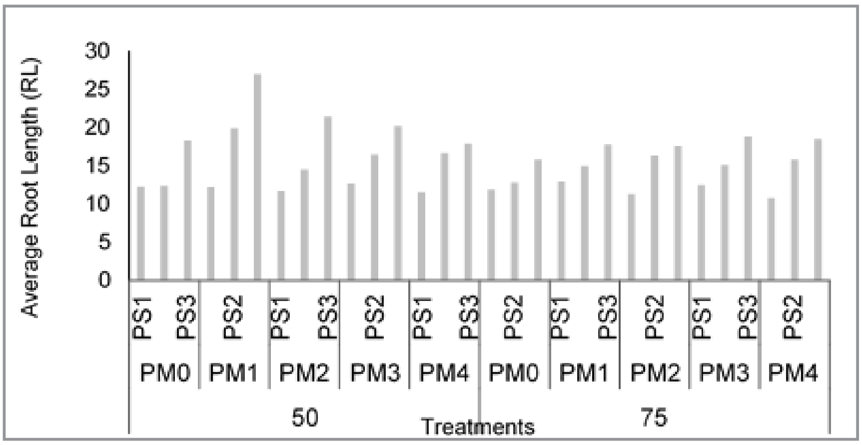

Figure 6: Influence of Treatment Factors on Average Root Length

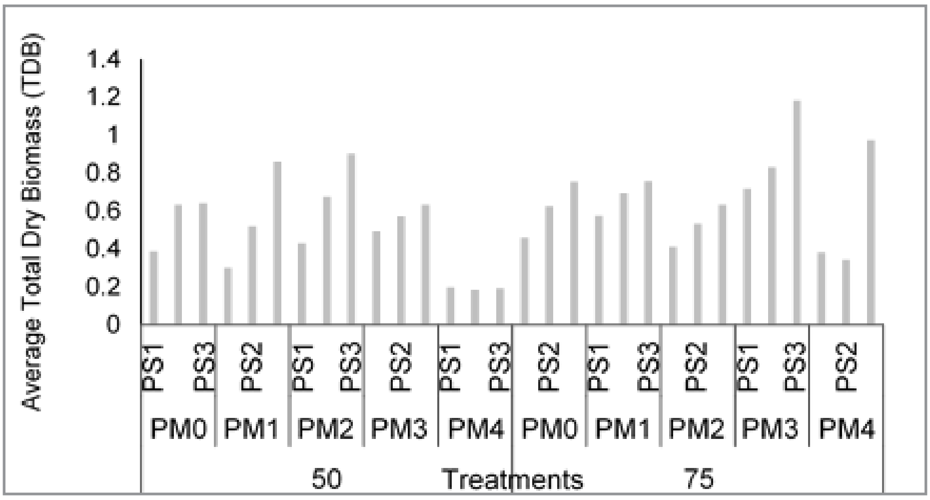

Figure 7: Influence of Treatment Factors on Average Total Dry Biomass

Treatment Effects on Sturdiness Quotient

The analysis of treatment effects on *P. angolensis* seedling quality as indicated by SQ showed significant effects from two factors: SI and PM (Table 3.2). SI showed a highly significant effect on SQ (F = 54.313; P < 0.001), with the lowest SI level (SI0) resulting in relatively higher SQ compared to other levels. Similarly, PM showed a significant influence on SQ (F = 2.630; P < 0.05), with PM0 and PM2 contributing to higher SQ than another PM (Table 3.2). These findings are represented visually in Figures 3.7 and 3.8, showing the noticeable trends in seedling quality with varying SIs and PMs.

Table 2: ANOVA Results on *P. angolensis* Seedling Sturdiness Quotient

Seedling quality indicator	Source of variation	Mean Sq	F- value	p- value
Sturdiness quotient	SI	1201.728	54.313	0.000
	PM	58.202	2.630	0.033
	PS	2.141	0.096	0.908
	SI:PM	17.661	0.798	0.604
	SI:PS	20.440	0.923	0.448
	PM:PS	19.541	0.883	0.529
	SI:PM:PS	10.354	0.468	0.962

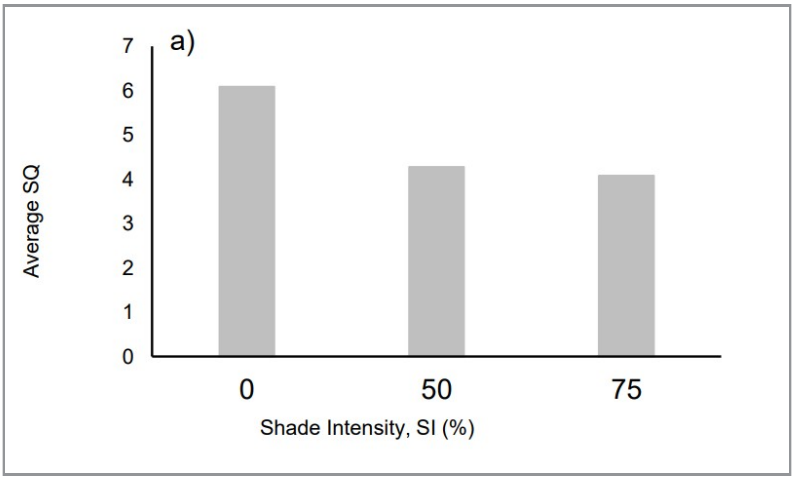

Figure 8: Influence of (a) Shading Intensity on *P. angolensis* Sturdiness Quotient

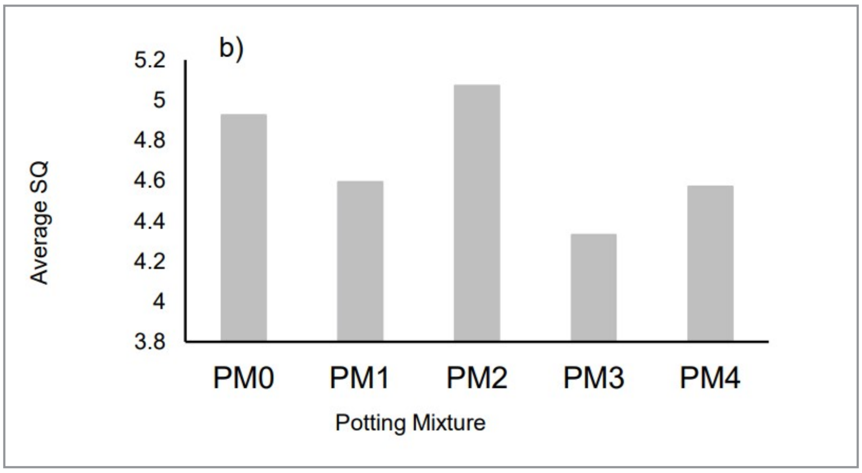

Figure 9: Influence of Potting Mixture on *P. angolensis* Sturdiness Quotient

Discussion

The development of seedlings in a nursery is a crucial aspect of successful tree planting and restoration programmes in tropical countries. In order to ensure the survival and smooth growth of seedlings, it is essential to have proper facilities in place within the nursery setting. Experiments on seedling establishment for various tropical tree species, such as those found in Tanzania, have yielded positive results. However, many nurseries in Tanzania are locally run and may lack proper regulation of important elements, such as shade. Shade can greatly impact field-grown seedlings by reducing plant and soil evaporative demands or by decreasing the risk of photodamage [19-21]. The effect of shading on plants may also depend on the soil moisture content [18, 22]. The facilitation effect of shading is explained to be one of the factors for reduced mortality of seedlings during establishment stage in Mediterranean region [23, 24]. These results agree with findings of to this study as there was high mortality of seedlings under full sun.

The study reported that shade acted as the mediating factor to regulate the seedling performance in the sense that, the success growth performance was experienced highly when full sun was escaped. Also, the higher seedling RCD (2.18 cm) was observed under 50% and 75% SI. Increase in SI here was associated with the increased RCD in both treatment of PS and PM. Thus, although there was different performance of the tree growth in PS and PM, when categorized into three SI classes, increasing in SI positively improved the diameter values significantly. RCD in 75% shade was lower than those in 50%. These results concur with those reported by Kennedy et al. where RCD of seedlings decreased with increase in SI [25]. Plants usually respond to decreasing light availability by reducing growth [26]. On the other hand, SH in this study increased with increasing in SI. Whereby, SH values of the seedling planted under 75% SI showed consistent SH during the whole study period. These results are also consistent with Kennedy et al. whose results reported SH increase with the increase in SI [25]. The results contrast with Beaudet and Messier (1998) who reported decline of the SH with increasing in SI of *Betula alleghaniensis* and *Fagus grandifolia* species [24]. In conclusion, the influence of the shade on the performance of the seedling development is also linked to the specific tolerance level of the species to shading, either shade tolerant species and shade intolerant species [28].

Shade enhances photosynthesis by reducing the intensity of light, which allows the seedlings to absorb light and convert it into energy. This increased energy production promotes the growth of new leaves and enhances leaf number development. In this study we have observed that the increased SI promoted higher LC than the full sun exposure. The decreased LC on the low SI would be associated with the high moisture stress that also accelerated the leaf dropping as the seedling grows. Theseresults were also observed by Welander and Ottosson, (1998), when assessing the influence of shading on growth and morphology in seedlings of *Quercus robur L*. and *Fagus sylvatica L* [29]. This tendency is linked to the shade acclimated plants where with increasing shade, biomass allocation shifts from root to leaves and shoots [30].

The statistical analysis revealed that out of all the factors tested, only two showed a significant influence on the SQ of the seedlings. These two factors were SI and PM. Results suggest that SI and PM are important factors to consider when aiming to improve the quality of seedlings in terms of SQ. SQ is one of the important scanty information regarding the quality of planting stock that has implication on survival and field performance of our planted tree seedlings [31].

The present study also investigated the effect of SI, PM, and PS on the RL of seedlings. The results showed that all three factors, as well as their interactions, had a significant influence on the RL of the seedlings. These findings are consistent with previous studies that have reported the effects of environmental factors on seedling growth and development. For example, it has been shown that shade can affect root growth by altering the photosynthetic rates of the plant [32]. Small RL was observed in 75% shade compared to 50% shade in this study similar to what was reported by Panetta (1977), where small RL of *Baccharis halimifolia L*. was measured in shaded treatments. Similarly, the type of PM and PS can influence root growth by affecting nutrient availability and water retention. The interaction effect observed in our study suggests that the effects of these factors on seedling RL are not independent, but rather depend on their combined influence. This highlights the complexity of seedling growth and development, and the importance of considering multiple factors when aiming to optimize seedling production.

Findings suggest that PS has a greater impact on seedling dry biomass compared to SI and PM. The significant effect of PS on seedling growth and biomass can be attributed to the fact that larger pots provide more space and nutrients for root development, leading to increased biomass production. This finding is consistent with previous studies that have shown that larger pots can enhance plant growth and biomass by increasing the availability of soil nutrients and water [33]. The significant effects of SI and PM on seedling growth and biomass indicate that these factors also play a role in determining seedling survival and development in the field site. The SI may affect photosynthesis and nutrient uptake in plants, leading to changes in growth and biomass. Similarly, the PM can influence the physical and chemical properties of the soil, affecting nutrient availability and water retention, which in turn can impact seedling growth.

Conclusion

This study clearly demonstrated that nursery conditions significantly impact the growth and survival of *Pericopsis angolensis* seedlings. Our key findings indicate that shading intensities SI1 and SI2 optimize seedling performance, while shade intensity SI0 reduces survival. Larger PS (PS3) also promote increased growth and survival compared to smaller containers. Although PM had a less pronounced effect, tailored compositions can help meet specific management goals and resource constraints. To optimize the growth of *Pericopsis angolensis* seedlings, it is recommended to carefully manage shading conditions, with a particular emphasis on maintaining 50% SI for ideal outcomes. This can be achieved through the use of shade structures or by selecting planting sites with natural shade. However, in order to attain seedlings with good vigor, seedlings raised under the recommended shade intensity maybe partially exposed to no shade for a while and brought back to the respective shade conditions (repeatedly) until they are ready for planting in the field. Furthermore, the study highlights the potential benefits of using larger PSs consisting forest top soil to enhance seedling productivity, with implications for biomass production [36-43].

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Conflict of Interest

No conflict of interest.

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