

Research Article

Growth Performance and Biomass of Selected Indigenous Tree Species in the Permanent Nursery, Addis Zemen, Northwest Ethiopia

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The production of seedlings from selected indigenous tree species is influenced by the type of potting media and soil ratios. A nursery experiment was conducted in the Libo Kemekem District of Addis Zemen, northwest Ethiopia, to assess the growth performance and biomass of *Olea africana*, *Albizia gummifera*, *Cordia africana*, *Milletia ferruginea*, and *Grewia ferruginea*. Seeds were initially sown in seedbeds and later transplanted into polythene pots of varying sizes (8, 10, and 12 cm in diameter) filled with a mixture of forest soil, farmyard manure, and fine sand in three different ratios (3:3:1, 3:2:1, and 3:1:1). A factorial experiment using a randomized complete block design with three replications was implemented. Growth and biomass data were analyzed using the general linear model in SPSS software (Version 26). Significant variations were observed in root collar diameter and shoot height among potting media, pot sizes, and their interactions at level of 0.05 but not in shoot and root biomass. The most vigorous seedlings of *G. ferruginea*, *C. africana*, *M. ferruginea*, *A. gummifera*, and *Olea europaea* thrived in a 3:3:1 soil ratio with a 12-cm pot size. While shoot and root dry weights showed minimal variation across treatments, *M. ferruginea* excelled in the 3:3:1 mixture and 12-cm size. The findings indicate that the growth performance of indigenous tree seedlings is significantly influenced by the composition of potting media and pot size. The optimal mixture of forest soil, farmyard manure, and fine sand, particularly with a higher proportion of organic matter, enhances seedling vigor. Therefore, selecting the right substrate is crucial for enhancing the growth of indigenous tree species in nursery settings, thereby contributing to the restoration of degraded Afromontane forests.

Keywords: biomass; growth; indigenous trees and nursery

1. Introduction

Deforestation and degradation are global issues, and while the extent of degradation is not precisely measured, it is widely acknowledged to be even greater [1]. In 2024, tropical forests lost 6.7 million hectares due to human-caused fires and agricultural expansion. This loss resulted in 3.1 gigatonnes of greenhouse gas emissions, equivalent to India's annual fossil fuel emissions [2]. Forest loss and degradation has already led to the extinction of species, altered

hydrological regimes, and damaged the livelihoods of millions of people in the world [3]. Degraded forests are characterized by a loss of forest structure, productivity, native species diversity, and ecological goods and services they provide [4]. Deforestation and forest degradation are causing a significant reduction in the provisioning of valuable ecosystem goods and services from forests in developing countries [5].

Ethiopia is one of the countries that severely affected by natural forest degradation due to the population growth,

poverty and unsustainable wood consumption, agricultural expansion, inadequate natural regeneration, and forest management practices [6–8]. The structures and species composition of the natural vegetation types are diverse due to the presence of wider physiognomic and climatic landscapes in the country [9]. Although, the vegetation of Ethiopia has key production, protection, and conservation functions, there is very limited information on how to manage these forests in a sustainable way and to show their importance for climate change mitigation and adaptation [4].

Developing forest rehabilitation techniques is crucial to reverse the degradation problem and minimize further destruction of forests in the country [10]. For the past 5 decades, the government of Ethiopia has attempted to reforest degraded lands. In addition, hundreds of aid projects have been implemented in different parts of the country to reverse deforestation and land degradation with fast growing exotic and indigenous tree species [10, 11]. Some of the efforts have been given promising results [10, 12]. However, the success stories were below the expectation, and the problem is still immense [13]. This might be related with the lack of appropriate knowledge on species site matching, restoration techniques, tree planting methods, management, and tending operations. Besides, insufficient knowledge of the silvics of the majority indigenous tree species in the country [13].

Therefore, sustainable management of forest resources is critical for ecological balance and economic development, particularly in Northwestern Ethiopia, where deforestation and land degradation pose significant challenges [14, 15]. Indigenous tree species play a vital role in restoring degraded landscapes, enhancing biodiversity, and providing essential ecosystem services [16]. In Northwest Ethiopia, particularly in the Addis Zemen area, the cultivation of indigenous tree species in nurseries has gained attention as a strategy for promoting restoration and biodiversity conservation of the forest. The plans of reforestation are needed to plant seedlings as a key part to address restoration and climate change effect. The assumption is that a well-balanced seedling is prepared to survive out planting. Therefore, the production of selected indigenous tree species seedlings, using potting media with different soil ratios, is very important for the restoration of degraded forest areas. This study aimed to evaluate the different selective indigenous tree species growth performance and biomass based on pot size and soil mixture at tree nursery.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in Addis Zemen nursery site in Libo Kemekem District, South Gondar Administrative Zone of the Amhara National Regional State. It is located between 12° 08'–12° 0' N and 37° 44'–37° 47' E (Figure 1). Altitudinal variation ranges from 1800 to 2200 m above sea level. The study area is generally characterized by moderate climate, known as 'Woina Dega.' The rainfall is characterized by a unimodal distribution with the major rains falling between the months of June and

August. The dry season extends from December to March. Annual rainfall ranges between 900 and 1200 mm with an annual temperature between 11 and 27°C.

2.2. Methods of Data Collection. The following tree species were identified for growth performance and biomass determination: These were *Olea europaea* (Weyra), *Albizia gummifera* (Sesa), *Cordia africana* (Wanz), *Milletia ferruginea* (Birbira), and *Grewia ferruginea* (Lenquata). The purpose of choosing these tree species was to restore degraded forest areas. The tree species were selected based on their socioeconomical and environmental importance, adaptability, growth, and pioneer characteristics. For seedling growth parameters, a nursery experiment was performed. Seeds were collected from the nearby forest, and appropriate presowing treatments were applied. Seeds were sown on seedbeds and then transplanted into different sized polythene plastic pots filled with a mixture of forest soil, farm yard manure, and fine sand using 3 different ratios. Factorial experiments with RCBD with three replications were used. The following treatments, i.e., pot size (8, 10, and 12 cm), lay flat diameter and 15 cm height of each pot. Potting mixture ratio (3:3:1, 3:2:1; & 3:1:1) were tested, i.e., forest soil, farm yard manure, and fine sand, respectively. A total of 25 seedlings per tree were used for each treatment. The seedlings were grown under partial shade (50% full sunlight) constructed from locally available materials. Watering was done twice a day at the beginning, thereafter as often as needed to maintain an ideal condition of the soil moisture. Randomly uprooting five seedlings of tree species were taken at the end of the year. The studied species were determined using the ratio of wet weight to dry weight under each treatment.

The data were collected for 1 year. Root collar diameter (RCD) and height were collected for each seedling 3 times. Shoot height was measured from the surface of the container to the highest tip of seedlings using a centimeter measuring tape. RCD was measured on the girth of the seedlings immediately after the surface of the container using a caliper. Biomass data were collected and recorded once at the end of the year. After measurement of SH and RCD, the seedlings were uprooted, and then the parts were separated into shoot and root components. After hand washing, shoot and root parts, including fine roots, were oven-dried at 80°C for 72 h to determine root dry weight (RDW) and shoot dry weight (SDW). The weight was measured using a sensitive digital weight balance.

2.3. Data Analysis. All the data were statistically analyzed using statistical software (SPSS Version 26). ANOVA was performed following the GLM procedure to detect significant mean growth and biomass differences among seedlings planted in different potting media and different pot sizes. The data were checked for normality and homogeneity of error variance. When significant treatment effects were detected across potting media, means were compared by Tukey's (HSD) test. Mean differences were considered significant when $p \leq 0.05$.

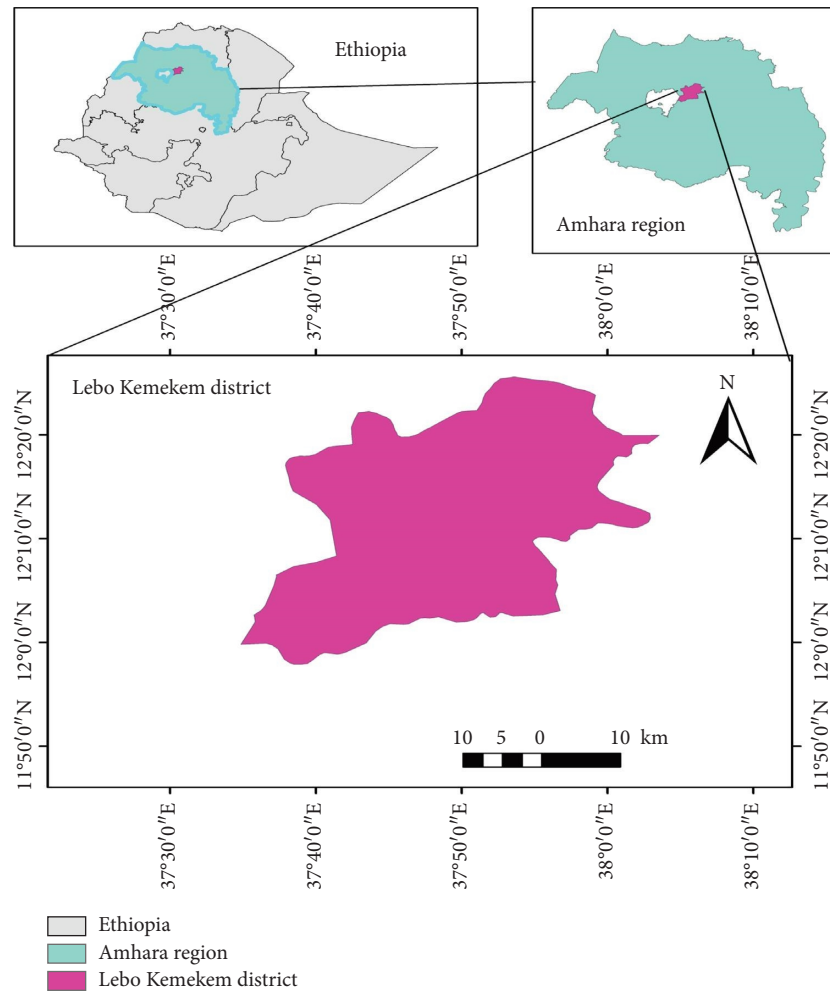


FIGURE 1: Map showing the study area in Lebo Kemekem District, Amhara region, Ethiopia.

3. Result and Discussion

3.1. Interaction Effect of Pot Size and Growing Media on Five Selected Indigenous Tree Species. The current study showed significant differences in seedling shoot height, RCD, and the ratio of shoot height to RCD due to variations in pot size and soil mixtures, as well as significant interaction effects between these factors (Table 1). However, no significant differences were observed in shoot and root dry weights or the root-to-shoot dry weight ratios, indicating that while pot size and soil mixture influence certain growth parameters, they do not affect biomass accumulation. The ratio of shoot height to RCD indicative of seedling sturdiness was remarkably influenced by the experimental conditions. A higher RCD relative to shoot height indicates stronger seedlings. The analysis confirmed significant interaction effects among the dependent variables (RCD, shoot height, and sturdiness ratio) across species, particularly at the 0.05 significance level (Table 1). The ratio of shoot height to RCD is called sturdiness that a tree seedling is measured by the ratio of its height to its stem diameter. The tree seedling with a greater RCD relative to its shoot height is sturdier or strong.

TABLE 1: Observed significance level of F (p value) for the performance of five tree seedlings at the end of the study period.

Variables	Pot size (P)	Soil mixture (M)	P × M interaction
RCD	0.001	0.004	0.001
Shoot height	0.001	NS	0.001
Shoot DM	NS	NS	NS
Root DM	NS	NS	NS
RDW to SDW	NS	NS	NS
SH to RCD	0.001	0.001	0.001

Note: NS = not significant ($p > 0.05$).

Abbreviations: DM = dry matter, RCD = root collar diameter, RDW = root dry weight, SDW = shoot dry weight, and SH = shoot height.

The current study confirmed a significant interaction effect among the RCD, shoot height, and the ratio of shoot height to the RCD in both species at the 0.05 level (Table 1). In larger pot sizes, 12 cm of all studied species higher seedling shoot height and RCD were recorded at the mixing ratio of 3:3:1 (Table 2). However, in smaller pot sizes, a mixing ratio of 3:1:1 and 3:2:1 gave the highest growth parameters in most of the studied species, respectively (Table 2).

TABLE 2: The effect soil mixture on growth performance of five indigenous tree species at the end of the study period.

Scientific name	Pot size	Soil mix	RCD	SH	SH/RCD (sturdiness)
<i>Albizia gummifera</i>	8	3:3:1	5.720 (1.032) ^b	29.600 (6.251) ^a	4.936 (0.433) ^b
		3:2:1	5.608 (1.032) ^a	40.160 (6.251) ^a	6.990 (0.433) ^a
		3:1:1	5.624 (1.032) ^a	37.960 (6.251) ^a	6.608 (0.433) ^a
	10	3:3:1	3.608 (1.032) ^b	16.040 (6.251) ^a	4.488 (0.433) ^b
		3:2:1	5.596 (1.032) ^a	33.080 (6.251) ^a	6.400 (0.433) ^a
		3:1:1	5.680 (1.032) ^a	40.080 (6.251) ^a	7.613 (0.433) ^a
	12	3:3:1	6.080 (1.032) ^b	36.800 (6.251) ^a	6.031 (0.433) ^b
		3:2:1	5.824 (1.032) ^a	30.040 (6.251) ^a	5.430 (0.433) ^a
		3:1:1	6.060 (1.032) ^a	31.120 (6.251) ^a	4.945 (0.433) ^a
<i>p</i> value		0.004	0.127	0.001	
<i>Cordia africana</i>	8	3:3:1	21.480 (1.032) ^b	92.800 (6.251) ^a	4.034 (0.433) ^b
		3:2:1	24.320 (1.032) ^a	96.280 (6.251) ^a	4.066 (0.433) ^a
		3:1:1	22.600 (1.032) ^a	115.080 (6.251) ^a	4.618 (0.433) ^a
	10	3:3:1	14.360 (1.032) ^b	75.840 (6.251) ^a	4.856 (0.433) ^b
		3:2:1	18.560 (1.032) ^a	86.720 (6.251) ^a	4.795 (0.433) ^a
		3:1:1	20.240 (1.032) ^a	101.600 (6.251) ^a	5.071 (0.433) ^a
	12	3:3:1	32.960 (1.032) ^b	174.120 (6.251) ^a	5.278 (0.433) ^b
		3:2:1	22.520 (1.032) ^a	118.800 (6.251) ^a	5.118 (0.433) ^a
		3:1:1	20.600 (1.032) ^a	106.640 (6.251) ^a	4.940 (0.433) ^a
<i>p</i> value		0.004	0.127	0.001	
<i>Grewia ferruginea</i>	8	3:3:1	13.848 (1.032) ^b	48.240 (6.251) ^a	3.589 (0.433) ^b
		3:2:1	12.360 (1.032) ^a	78.720 (6.251) ^a	7.078 (0.433) ^a
		3:1:1	14.000 (1.032) ^a	73.480 (6.251) ^a	5.443 (0.433) ^a
	10	3:3:1	16.107 (1.032) ^b	101.091 (6.251) ^a	6.671 (0.433) ^b
		3:2:1	14.784 (1.032) ^a	86.200 (6.251) ^a	5.970 (0.433) ^a
		3:1:1	15.320 (1.032) ^a	98.800 (6.251) ^a	6.840 (0.433) ^a
	12	3:3:1	16.560 (1.032) ^b	105.720 (6.251) ^a	6.411 (0.433) ^b
		3:2:1	15.360 (1.032) ^a	89.800 (6.251) ^a	5.940 (0.433) ^a
		3:1:1	15.520 (1.032) ^a	99.280 (6.251) ^a	6.791 (0.433) ^a
<i>p</i> value		0.004	0.127	0.001	
<i>Millettia ferruginea</i>	8	3:3:1	16.920 (1.032) ^b	48.080 (6.251) ^a	3.082 (0.433) ^b
		3:2:1	12.560 (1.032) ^a	72.000 (6.251) ^a	6.701 (0.433) ^a
		3:1:1	12.900 (1.032) ^a	73.640 (6.251) ^a	6.184 (0.433) ^a
	10	3:3:1	15.060 (1.032) ^b	97.880 (6.251) ^a	6.642 (0.433) ^b
		3:2:1	13.000 (1.032) ^a	72.480 (6.251) ^a	6.036 (0.433) ^a
		3:1:1	13.260 (1.032) ^a	84.840 (6.251) ^a	6.937 (0.433) ^a
	12	3:3:1	17.720 (1.032) ^b	102.960 (6.251) ^a	5.886 (0.433) ^b
		3:2:1	14.241 (1.032) ^a	74.066 (6.251) ^a	5.435 (0.433) ^a
		3:1:1	13.760 (1.032) ^a	86.200 (6.251) ^a	6.525 (0.433) ^a
<i>p</i> value		0.004	0.127	0.001	
<i>Olea europaea</i>	8	3:3:1	11.480 (1.032) ^b	56.960 (6.251) ^a	5.226 (0.433) ^b
		3:2:1	8.720 (1.032) ^a	71.480 (6.251) ^a	8.209 (0.433) ^a
		3:1:1	10.800 (1.032) ^a	70.120 (6.251) ^a	6.548 (0.433) ^a
	10	3:3:1	6.520 (1.032) ^b	42.960 (6.251) ^a	7.132 (0.433) ^b
		3:2:1	9.600 (1.032) ^a	72.560 (6.251) ^a	7.930 (0.433) ^a
		3:1:1	8.240 (1.032) ^a	66.560 (6.251) ^a	8.492 (0.433) ^a
	12	3:3:1	12.320 (1.032) ^b	80.280 (6.251) ^a	6.623 (0.433) ^b
		3:2:1	10.360 (1.032) ^a	65.400 (6.251) ^a	6.604 (0.433) ^a
		3:1:1	11.280 (1.032) ^a	70.440 (6.251) ^a	6.670 (0.433) ^a
<i>p</i> value		0.004	0.127	0.001	

Note: For a given species, values in parenthesis are standard errors, and values with different letters in a column differed significantly ($p < 0.05$). Abbreviations: RCD = root collar diameter and SH = shoot height.

Similar studies conducted that there were a significant interaction effect between pot sizes, and the species (*A. nilotica* and *Z. spina-christi*) raised in larger pots had greater performances than those in smaller pot sizes (*A. tortilis* and *D. glabra*) in both height and RCD [17]. Besides, the interaction effect between soil mixture and

species (*Z. spina-christi*) was significant, resulting in greater height and RCD than in the other tree species [17]. Likewise, the tree species showed a differential response in the nursery study on *Eucalyptus camaldulensis*, *Acacia mearnsii*, and *Leucaena pallida* in different soil mixtures [7].

3.2. The Effect of Pot Size on the Growth Performance.

This study result showed that the species *C. africana*, *G. ferruginea*, *M. ferruginea*, and *Olea africana* of RCD and shoot height were higher in a large pot size (12 cm) with 3:3:1 soil mixture. On the other hand, *A. gummifera* RCD was larger in a larger pot size (12 cm), but its shoot height was higher in a smaller pot size (8 cm) (Table 2). There was a significant difference in RCD and shoot height between pot sizes as well as the interaction at the 0.05 level (Tables 1 and 2). These growth parameters were significantly higher in a larger pot size (12 cm) than in smaller pots (8 and 10 cm) (Tables 1 and 2). The species seedling shoot height to the RCD ratio was higher in smaller pot sizes (8 and 10 cm). That means there was no significant difference between pot size 8 and 10 cm, but it is significantly different from pot size 12 cm at the 0.05 level (Tables 1 and 2).

Generally, the result revealed that seedlings of the most studied species growth in large pots showed a more rapidly and sound shoot height and RCD increment than raised in other smaller pot sizes. Thus, the tree species grown in larger pot sizes has a fundamental effect on seedling height and RCD growth. Similar studies are conducted by Segaw [18] on *Cajanus Cajan* and *Sesbania sesban* and by Abera *et al.* [17] on the species *A. tortilis*, *Z. spina-christi*, and *A. nilotica* in dryland areas of Ethiopia. Furthermore, Dumroese *et al.* [19] reported that the seedling growth has positive increments on large pot sizes than smaller pot sizes.

The present results verify that seedlings grown in bigger pots would have healthier development in a shorter time than those raised in pots of smaller sizes. Because of the ease of use of more growing space, greater trees seedling performance was observed in large pots. Thus, allowing the premature growth of a long taproot to break out drought for the success of transplantation in semiarid or arid conditions. The overall trend suggests that larger pots facilitate better growth due to increased root space, which may enhance nutrient and water uptake. This is crucial for successful transplantation, especially in semiarid regions where drought resilience is vital.

3.3. The Effect of Soil Mixture on the Growth Performance.

The study revealed significant differences in RCD among the three soil mixtures, although shoot height did not exhibit similar variation. The interaction between soil mixture and species was significant at the 0.05 level (Table 1). Particularly, species such as *C. africana*, *G. ferruginea*, *M. ferruginea*, and *O. africana* showed superior RCD and shoot height in the soil mixture of 3:3:1, significantly outperforming the other mixtures (Table 2). Conversely, *A. gummifera* displayed larger RCD and shoot height in the 3:1:1 mixture. While no significant differences in shoot height were observed among the species, the RCD showed marked improvement with the 3:3:1 mixture, suggesting that this specific composition fosters better root development. In contrast, *A. gummifera* thrived in both 3:2:1 and 3:1:1 mixture, indicating that this species may have unique nutritional requirements or tolerances compared to the others.

Thus, the findings suggest that increasing the proportion of farmyard manure in the soil mixture positively influences the growth of most studied species. This aligns with previous research indicating that organic amendments enhance plant growth by improving soil structure and nutrient availability [20]. These results showed a critical role of nursery growing media in producing high-quality seedlings. Similarly, a potting mixture with a higher proportion of farmyard manure was found to be more effective for *E. camaldulensis* (3 parts local soil, 1 part sand, and 2 parts farmyard manure) compared to *Acacia* species [21]. In contrast, another study indicated that the soil mixture did not significantly affect the growth of seedlings for *A. tortilis*, *Z. spina-christi*, and *A. nilotica* in dryland areas of Ethiopia [17].

Overall, the soil mixture can significantly influence the vigor and water status of tree seedlings by enhancing ventilation, water retention, and nutrient availability in the root plug [22]. This difference may be attributed to the specific environmental conditions or soil characteristics in those regions. In general, this study underlines that soil mixture composition significantly impacts the growth performance of indigenous tree seedlings. Optimal mixtures can enhance both the vigor and water retention capacity of seedlings, ultimately contributing to their establishment success in various environments.

3.4. Effect of Soil Mixture on the Biomass of Five Indigenous Tree Species.

The current study verified how different soil mixtures affect the biomass of five native tree species. The analysis indicated that soil mixtures had no significant effect on both RDW and SDW across all species at the 0.05 significance level (Tables 1 and 3). Particularly, *G. ferruginea* and *M. ferruginea* had the highest mean SDW in the soil mixture of 3:3:1 at a pot size of 12 cm, while *O. europaea* and *A. gummifera* showed superior performance in the soil mixture of 3:1:1 (Table 3). Conversely, *C. africana* exhibited its highest mean SDW in the 3:2:1 mixture. Although no statistically significant differences were found in SDW across soil mixtures, mean differences were evident, suggesting the potential for variations in growth performance. On behalf of RDW, *M. ferruginea* demonstrated higher values in the 3:3:1 mixture, whereas *O. europaea* and *G. ferruginea* had greater RDWs in the 3:1:1 mixture. Furthermore, *A. gummifera* and *C. africana* had higher RDWs in the 3:2:1 mixture compared to the others. These findings align with previous research by Bonfant *et al.* [23], emphasizing the importance of soil composition in plant growth.

The results emphasize the necessity of evaluating growth performance and biomass accumulation of indigenous species to ascertain their viability for large-scale planting, as noted by Brancalion *et al.* [24]. Factors such as soil quality, climate, and management practices are critical in influencing growth rates and overall biomass production [23]. Hence, assessing these parameters is essential for selecting appropriate species that can thrive in local conditions and contribute to sustainable land use. Though the present study found no significant effects of soil mixtures on biomass, the observed mean differences suggest that specific soil compositions may benefit particular species.

TABLE 3: The effect of soil mixture on dry weight of five indigenous tree seedlings at the end of the study period.

Scientific name	Pot size	Soil ratio	RDW	SDW	RDW to SDW ratio
<i>Grewia ferruginea</i>	8	3:3:1	20 (11.291) ^a	51 (42.871) ^a	0.39 (0.263) ^a
		3:2:1	23 (11.291) ^a	77 (42.871) ^a	0.30 (0.263) ^a
		3:1:1	43 (11.291) ^a	138 (42.871) ^a	0.31 (0.263) ^a
	10	3:3:1	34 (11.291) ^a	103 (42.871) ^a	0.33 (0.263) ^a
		3:2:1	28 (11.291) ^a	73 (42.871) ^a	0.38 (0.263) ^a
		3:1:1	39 (11.291) ^a	66 (42.871) ^a	0.59 (0.263) ^a
	12	3:3:1	61 (11.291) ^a	142 (42.871) ^a	0.43 (0.263) ^a
		3:2:1	33 (11.291) ^a	100 (42.871) ^a	0.33 (0.263) ^a
		3:1:1	42 (11.291) ^a	89 (42.871) ^a	0.47 (0.263) ^a
<i>p</i> value		0.714	0.820	0.588	
<i>Albizia gummifera</i>	8	3:3:1	13 (11.291) ^a	29 (42.871) ^a	0.45 (0.263) ^a
		3:2:1	16 (11.291) ^a	20 (42.871) ^a	0.80 (0.263) ^a
		3:1:1	10 (11.291) ^a	18 (42.871) ^a	0.56 (0.263) ^a
	10	3:3:1	7 (11.291) ^a	10 (42.871) ^a	0.70 (0.263) ^a
		3:2:1	10 (11.291) ^a	15 (42.871) ^a	0.67 (0.263) ^a
		3:1:1	9 (11.291) ^a	17 (42.871) ^a	0.53 (0.263) ^a
	12	3:3:1	9 (11.291) ^a	15 (42.871) ^a	0.60 (0.263) ^a
		3:2:1	12 (11.291) ^a	16 (42.871) ^a	0.75 (0.263) ^a
		3:1:1	14 (11.291) ^a	22 (42.871) ^a	0.64 (0.263) ^a
<i>p</i> value		0.714	0.820	0.588	
<i>Millettia ferruginea</i>	8	3:3:1	77 (11.291) ^a	137 (42.871) ^a	0.56 (0.263) ^a
		3:2:1	29 (11.291) ^a	52 (42.871) ^a	0.56 (0.263) ^a
		3:1:1	22 (11.291) ^a	52 (42.871) ^a	0.42 (0.263) ^a
	10	3:3:1	57 (11.291) ^a	206 (42.871) ^a	0.28 (0.263) ^a
		3:2:1	37 (11.291) ^a	84 (42.871) ^a	0.44 (0.263) ^a
		3:1:1	42 (11.291) ^a	102 (42.871) ^a	0.41 (0.263) ^a
	12	3:3:1	80 (11.291) ^a	244 (42.871) ^a	0.33 (0.263) ^a
		3:2:1	43 (11.291) ^a	100 (42.871) ^a	0.43 (0.263) ^a
		3:1:1	56 (11.291) ^a	125 (42.871) ^a	0.45 (0.263) ^a
<i>p</i> value		0.714	0.820	0.588	
<i>Cordia africana</i>	8	3:3:1	112 (11.291) ^a	352 (42.871) ^a	0.32 (0.263) ^a
		3:2:1	147 (11.291) ^a	430 (42.871) ^a	0.34 (0.263) ^a
		3:1:1	100 (11.291) ^a	288 (42.871) ^a	0.35 (0.263) ^a
	10	3:3:1	73 (11.291) ^a	91 (42.871) ^a	0.80 (0.263) ^a
		3:2:1	59 (11.291) ^a	106 (42.871) ^a	0.56 (0.263) ^a
		3:1:1	50 (11.291) ^a	162 (42.871) ^a	0.31 (0.263) ^a
	12	3:3:1	34 (11.291) ^a	39 (42.871) ^a	0.87 (0.263) ^a
		3:2:1	84 (11.291) ^a	141 (42.871) ^a	0.60 (0.263) ^a
		3:1:1	47 (11.291) ^a	77 (42.871) ^a	0.61 (0.263) ^a
<i>p</i> value		0.714	0.820	0.588	
<i>Olea europaea</i>	8	3:3:1	29 (11.291) ^a	81 (42.871) ^a	0.36 (0.263) ^a
		3:2:1	35 (11.291) ^a	83 (42.871) ^a	0.42 (0.263) ^a
		3:1:1	51 (11.291) ^a	158 (42.871) ^a	0.32 (0.263) ^a
	10	3:3:1	38 (11.291) ^a	95 (42.871) ^a	0.40 (0.263) ^a
		3:2:1	19 (11.291) ^a	52 (42.871) ^a	0.37 (0.263) ^a
		3:1:1	29 (11.291) ^a	98 (42.871) ^a	0.30 (0.263) ^a
	12	3:3:1	39 (11.291) ^a	124 (42.871) ^a	0.31 (0.263) ^a
		3:2:1	41 (11.291) ^a	131 (42.871) ^a	0.31 (0.263) ^a
		3:1:1	44 (11.291) ^a	137 (42.871) ^a	0.32 (0.263) ^a
<i>p</i> value		0.714	0.820	0.588	

Note: For a given species, values in parenthesis are standard errors, and values with different letters in a column differed significantly ($p < 0.05$). Abbreviations: RDW = root dry weight and SDW = shoot dry weight.

3.5. Effect of Pot Sizes on the Biomass of Five Indigenous Tree Species. The current study evaluated the impact of pot sizes on the biomass of five indigenous tree species, revealing that pot size did not significantly affect the RDW and SDW across all species at the 0.05 significance level (Tables 1

and 4). Both *M. ferruginea* and *G. ferruginea* exhibited increased RDW and SDW in the larger pot size (12 cm) with a soil mixture ratio of 3:3:1, aligning with the findings from Yadessa and Bekere [25], who noted higher biomass in larger pots for *L. pallida*. In contrast, *O. europaea*, *A. gummifera*,

TABLE 4: The effect of pot size on dry weight of five indigenous tree seedlings at the end of the study period.

Scientific name	Soil ratio	Pot size	RDW	SDW	RDW to SDW ratio
<i>Grewia ferruginea</i>	3:3:1	8	20 (8.686) ^a	51 (24.782) ^a	0.39 (9.350) ^a
		10	34 (8.686) ^a	103 (24.782) ^a	0.33 (9.350) ^a
		12	61 (8.686) ^a	142 (24.782) ^a	0.43 (9.350) ^a
	3:2:1	8	23 (8.686) ^a	77 (24.782) ^a	0.30 (9.350) ^a
		10	28 (8.686) ^a	73 (24.782) ^a	0.38 (9.350) ^a
		12	33 (8.686) ^a	100 (24.782) ^a	0.33 (9.350) ^a
	3:1:1	8	43 (8.686) ^a	138 (24.782) ^a	0.31 (9.350) ^a
		10	39 (8.686) ^a	66 (24.782) ^a	0.59 (9.350) ^a
		12	42 (8.686) ^a	89 (24.782) ^a	0.47 (9.350) ^a
	<i>p</i> value		0.210	0.212	0.355
<i>Albizia gummifera</i>	3:3:1	8	13 (8.686) ^a	29 (24.782) ^a	0.45 (9.350) ^a
		10	7 (8.686) ^a	10 (24.782) ^a	0.70 (9.350) ^a
		12	9 (8.686) ^a	15 (24.782) ^a	0.60 (9.350) ^a
	3:2:1	8	16 (8.686) ^a	20 (24.782) ^a	0.80 (9.350) ^a
		10	10 (8.686) ^a	15 (24.782) ^a	0.67 (9.350) ^a
		12	12 (8.686) ^a	16 (24.782) ^a	0.75 (9.350) ^a
	3:1:1	8	10 (8.686) ^a	18 (24.782) ^a	0.56 (9.350) ^a
		10	9 (8.686) ^a	17 (24.782) ^a	0.53 (9.350) ^a
		12	14 (8.686) ^a	22 (24.782) ^a	0.64 (9.350) ^a
	<i>p</i> value		0.210	0.212	0.355
<i>Millettia ferruginea</i>	3:3:1	8	77 (8.686) ^a	137 (24.782) ^a	0.56 (9.350) ^a
		10	57 (8.686) ^a	206 (24.782) ^a	0.28 (9.350) ^a
		12	80 (8.686) ^a	244 (24.782) ^a	0.33 (9.350) ^a
	3:2:1	8	29 (8.686) ^a	52 (24.782) ^a	0.56 (9.350) ^a
		10	37 (8.686) ^a	84 (24.782) ^a	0.44 (9.350) ^a
		12	43 (8.686) ^a	100 (24.782) ^a	0.43 (9.350) ^a
	3:1:1	8	22 (8.686) ^a	52 (24.782) ^a	0.42 (9.350) ^a
		10	42 (8.686) ^a	102 (24.782) ^a	0.41 (9.350) ^a
		12	56 (8.686) ^a	125 (24.782) ^a	0.45 (9.350) ^a
	<i>p</i> value		0.210	0.212	0.355
<i>Cordia africana</i>	3:3:1	8	112 (8.686) ^a	352 (24.782) ^a	0.32 (9.350) ^a
		10	73 (8.686) ^a	91 (24.782) ^a	0.80 (9.350) ^a
		12	34 (8.686) ^a	39 (24.782) ^a	0.87 (9.350) ^a
	3:2:1	8	147 (8.686) ^a	430 (24.782) ^a	0.34 (9.350) ^a
		10	59 (8.686) ^a	106 (24.782) ^a	0.56 (9.350) ^a
		12	84 (8.686) ^a	141 (24.782) ^a	0.60 (9.350) ^a
	3:1:1	8	100 (8.686) ^a	288 (24.782) ^a	0.35 (9.350) ^a
		10	50 (8.686) ^a	162 (24.782) ^a	0.31 (9.350) ^a
		12	47 (8.686) ^a	77 (24.782) ^a	0.61 (9.350) ^a
	<i>p</i> value		0.210	0.212	0.355
<i>Olea africana</i>	3:3:1	8	29 (8.686) ^a	81 (24.782) ^a	0.36 (9.350) ^a
		10	38 (8.686) ^a	95 (24.782) ^a	0.40 (9.350) ^a
		12	39 (8.686) ^a	124 (24.782) ^a	0.31 (9.350) ^a
	3:2:1	8	35 (8.686) ^a	83 (24.782) ^a	0.42 (9.350) ^a
		10	19 (8.686) ^a	52 (24.782) ^a	0.37 (9.350) ^a
		12	41 (8.686) ^a	131 (24.782) ^a	0.31 (9.350) ^a
	3:1:1	8	51 (8.686) ^a	158 (24.782) ^a	0.32 (9.350) ^a
		10	29 (8.686) ^a	98 (24.782) ^a	0.30 (9.350) ^a
		12	44 (8.686) ^a	137 (24.782) ^a	0.32 (9.350) ^a
	<i>p</i> value		0.210	0.212	0.355

Note: For a given species, values in parenthesis are standard errors, and values with different letters in a column differed significantly ($p < 0.05$). Abbreviations: RDW = root dry weight and SDW = shoot dry weight.

and *C. africana* were performed better in the smaller pot size (8 cm). Thus, suggesting that certain species may thrive in restricted conditions due to factors such as soil moisture retention or nutrient availability. The p values for RDW, SDW, and RDW to SDW ratio were consistently above 0.210

across all species, indicating no significant differences attributable to the pot size.

This suggests that while pot size may influence growth in certain situations, other environmental or biological factors could play a more critical role in the growth

dynamics of these indigenous species. The results are consistent with previous studies by Bonfant et al. [23] and Yadessa and Bekere [25], who reported similar trends in biomass variation across different pot sizes. The observed mean differences highlight the complexity of plant responses to pot dimensions, emphasizing the need for species-specific considerations in nursery practices. In general, while pot size can influence the growth of some tree species, this study indicates that its effects are not significant. Instead, other factors such as soil composition, watering regimen, and specific species requirements may be more influential in determining biomass outcomes.

4. Conclusion and Recommendation

This study investigated the interaction effects of pot size and soil mixture on the growth performance of five indigenous tree species. The results indicate that both pot size and soil mixture significantly influence key growth parameters, including shoot height, RCD, and the sturdiness ratio of seedlings. Larger pots (12 cm) generally resulted in greater shoot height and RCD for most species, particularly with a soil mixture of 3:3:1. This supports the notion that increased growing space allows for better root development and overall seedling vigor. Conversely, smaller pot sizes (8 cm and 10 cm) enhanced the sturdiness ratio for species such as *A. gummifera*, indicating that while rapid growth is facilitated by larger pots, structural integrity is also crucial for successful establishment. The optimal soil mixture of 3:3:1 significantly promoted growth in species such as *C. africana*, *G. ferruginea*, and *M. ferruginea*. This mixture provided a balance of nutrients and moisture retention, crucial for seedling development. In contrast, *A. gummifera* showed better growth in mixtures with less farmyard manure (3:1:1), highlighting the need for species-specific soil formulation. Despite the significant effects on growth parameters, the study found no notable differences in shoot and RDWs across pot sizes and soil mixtures. This suggests that while growth rates may vary, the overall biomass accumulation may not be as sensitive to these factors in the short term.

- Conduct long-term studies to evaluate the performance of these species post-transplantation, focusing on survival rates and adaptability in different environmental conditions. This will provide valuable insights into the long-term effects of pot size and soil mixture.
- Develop detailed guidelines for nursery managers that specify the optimal pot sizes and soil mixtures for each species. Training sessions should be conducted to ensure that staff understand the implications of these choices on seedling health.
- Engage local communities in the reforestation process by sharing knowledge and best practices derived from this study. Encourage participation in nursery activities to foster a sense of ownership and commitment to biodiversity conservation.

- Encourage adaptive management practices that allow for adjustments in pot sizes and soil mixtures based on ongoing observations and feedback from nursery staff. This flexibility will help refine practices and improve seedling quality over time.

Implementing these recommendations can contribute to more effective afforestation efforts and biodiversity conservation.

Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Abeje Eshete and Aklilu Agidie developed the concepts and planned the methodology. Sintayehu Getie, Zelalem Teshager, and Solomon Guday gathered the data. Tewachew Worku and Melkamu Abere conducted the data analysis and took the lead in drafting the initial version of the manuscript. All authors played a significant role in reviewing the drafts, making edits, and providing final consent for publication.

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