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Research Article

Comparative Analysis of Impact of Soil Mixture and Fertilization on Growth and Seedling Quality of Selected Agroforestry Tree Species

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The study was conducted to determine the most suitable soil amendment for germination and early seedling growth of selected indigenous multipurpose agroforestry tree species, viz., *Cordia africana*, *Fiadherbia albida*, *Millettia ferruginea*, and *Moringa stenopetala* at Haramaya University, Ethiopia. Seedlings were raised in polythene tubes having 10 cm diameter and 15 cm height and the experimental plots were laid out with eight treatments (i.e., potting soil mixture of, A = agricultural soil, M = manure, S = sand, D = DAP, and U = Urea) and three replications. The morphological attributes of seedlings such as shoot and root height, root collar diameter, leaf area were measured to assess tree seedlings vigor and robustness. Analysis of variance indicated that the shoot height of *C. africana*, *F. albida*, and *M. ferruginea* were significantly different ($P < 0.05$) whereas shoot height of *M. stenopetala* was highly significant ($P < 0.01$). Actual leaf area (cm^2) of *F. albida* and *M. stenopetala* were significantly different ($P < 0.05$) and estimated leaf area (cm^2) of the four species were highly significant at ($P < 0.01$). Treatment 8 (3A: 2M: 1S) for *C. africana*, treatment 5 (3A: 2M: 1S: 23U) for *F. albida* and treatment 2 (2A: 2M: 2S: 25D) for both *M. stenopetala* and *M. ferruginea* exhibited the lowest sturdiness quotient, which indicates that they are good-quality seedling for plantation. The shoot-to-height ratio indicated positive correlation with most seedling growth parameters whereas root collar diameter and sturdiness quotient showed negative correlation for all species. Treatment 3 (3A: 2M: 1S: 75D) is recommended as the best pot soil mix and fertilization compared to all other treatments, though it needs further study.

1. Introduction

There is increasing pressure on forest resources from competing sectors for food and energy production, settlement, and other purposes. The green growth approach is proposed to harmonize competing paradigms [1, 2]. Nowadays, forest conservation and development dominates the global sustainability discourses on the management of the world's forests [3]. However, such discourses also pay less attention to the different situations in developed and developing countries [4].

As in many countries in the tropics forest destruction, land degradation, and loss of biodiversity are significant environmental problems in Ethiopia [5, 6]. In the highlands of Ethiopia, the indigenous tree species have been mainly replaced by a few exotic species, notably Eucalyptus. Certainly, those exotics are essential for the livelihood of the rural populations today, but they cannot provide such a wide variety of products and services as do indigenous trees [7]. Even if the forest sector in Ethiopia plays a vital role in mitigating and adapting climate change, it is constrained by inferior quality of planting material and species-site matching and a lack of access to quality seedlings [8–10].

Nursery-related problems are manyfold but not limited to low genetic quality of available germplasm, lack of support facilities such as seed orchards and an efficient seed supply pathway, lack of skills in the nursery sector, lack of markets, and lack of profitability. Smallholders also lack knowledge about the importance of using high-quality seedlings, a major factor limiting the market demand for higher-priced high-quality seedlings [11, 12]. Growth medium has been reported to be the most critical factor determining seedling quality in the nursery [13]. The quality of seedlings is significantly influenced by the growth medium [14]. To raise quality seedlings, nursery techniques should begin with knowing the appropriate soil composition for each tree species. Poor seedling propagation rates can be attributed to inadequate knowledge of their requirements including appropriate growth media that can enhance their growth at the nursery [15]. Soil amendment has been reported [16, 17] as a factor for improving soil structure. In the study area, tree seedling production is constrained by poor-quality nursery soil mix emanating from lack of forest soil and competing interest for manure from different vegetables, coffee (*Coffee arabica*), and Khat (*Catha edulis*) producers [18]. The current study area, Haramaya University's tree nursery uses a soil mixture of three-ratio-to-two-ratio-to-one (agricultural soil, manure, and sand, respectively) as a medium of tree seedling growth. The study hypothesized that the seedling growth rate is influenced by the tree nursery soil amendments. Therefore, this study strived to experiment the better tree nursery soil amendment for four selected indigenous agroforestry tree species of Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted at the Haramaya University (Figure 1) forest nursery site, eastern Hararghe zone, Oromia Regional State, Ethiopia. The Haramaya University is located 510 km east of Addis Ababa, the capital city of Ethiopia. Its altitude ranges from 1890 to 2043 m a.s.l. and geographically; it is located at 9°24′15″_9°25′45″N and 42°1′45″_42°2′30″E. The mean annual precipitation is 801 mm and is characterized by bimodal structure. The dry period extends from October to January inclusive. The wet season starts in February. The monthly rainfall is more than 100 mm from April to September, except in June (65 mm). The wettest month is August with 144 mm. The daily temperature ranges from about 10°C to 25°C.

2.2. Experimental Design and Procedure. Seedlings were raised in polythene tubes having 10 cm diameter and 15 cm height. The experimental plots were laid with eight (8) treatments and three (3) replications in complete randomized design (CRD). Polythene tubes were filled with different soil mixes (agricultural soil (A), sand soil (S) and manure (M), and two types of inorganic fertilizer (DAP or di-ammonium phosphate and urea) were used at varying rates. The use of organic manure to meet the nutrient requirement of crop would be an inevitable practice since organic manures generally improve the soil physical, chemical, and biological properties along with conserving capacity of the moisture holding capacity of soil and this, resulting in enhanced crop productivity along with maintain the quality of crop produce [19]. Di-ammonium Phosphate comes as a granule contains 18-46-0 (18% N, 46% phosphorus pent oxide (P_2O_5), and no potassium oxide (K_2O). Its Molecular formula is (NH_4) $2HPO_4$, and the molecular weight is 132.056 g·mol^{-1}. DAP fertilizer is an excellent source of P and nitrogen (N) for plant nutrition. It is highly soluble and thus dissolves quickly in soil to release plant-available phosphate and ammonium [20]. The combination of soil mixes were as follows:

T1 = 3 part of agriculture soil; 1 part of manure; 2 part of sand, and 50 kg·ha^{-1} DAP (3A: 1M: 2S:50D)

T2 = 2 part of agriculture soil; 2 part of manure; 2 part of sand, and 25 kg·ha^{-1} DAP (2A: 2M: 2S: 25D)

T3 = 3 part of agriculture soil; 2 part of manure; 1 part of sand, and 75 kg·ha^{-1} DAP (3A: 2M: 1S: 75D)

T4 = 1 part of agriculture soil; 2 part of manure; 3 part of sand, and 46 kg·ha^{-1} urea (1A: 2M: 3S: 46U)

T5 = 3 part of agriculture soil; 2 part of manure; 1 part of sand, and 23 kg·ha^{-1} urea (3A: 2M: 1S: 23U)

T6 = 2 part of agriculture soil; 2 part of manure; 2 part of sand; and 23 kg·ha^{-1} urea (2A:2M: 2S: 23U)

T7 = 3 part of agriculture soil; 1 part of manure; 2 part of sand, and 46 kg·ha^{-1} urea (3A: 1M: 2S: 46U)

T8 = 3 part of agriculture soil, 2 part of manure and 1 part of sand (control) (3A: 2M: 1S)

2.3. Soil Sample Preparation, Laboratory Analysis and Pot Filling

2.3.1. Soil Sample Preparation and Laboratory Analysis. Agricultural soil was taken from the Haramaya University (HU) farm site and Cattles' manure was taken from Haramaya University nursery site and sand soil from nearest area. The physicochemical properties of soil were tested at HU soil chemistry laboratory following the standard procedures. The soil samples were first air dried, crushed and sieved with 2-mm mesh for chemical properties assessment except for soil organic carbon, which was subjected to pass through 0.5 mesh. Soil texture was determined by the Bouyoucos hydrometer method [21] Soil H was determined in water suspension at a rate of 1 : 2.5 (soil: water ratio) by pH meter [22]. Total nitrogen (TN) was determined using the micro-Kjeldahl digestion, distillation, and titration process as described by [23]. The available soil phosphorus was determined using the Olsen method [24] and exchangeable potassium by flame photometry [25]. The potassium dichromate method was used for the analysis of soil organic matter content and EC in soil was analyzed using conductivity meter [23] Percent of organic matter was calculated by the following formula: [26, 27].

$$\%OM = \%OC * 1.724. \tag{1}$$

2.3.2. Pot Filling and Seed Sowing. Soil and inorganic fertilizer were mixed with different ratios (agricultural soil, manure, sand, and inorganic fertilizers) and wetted by water.

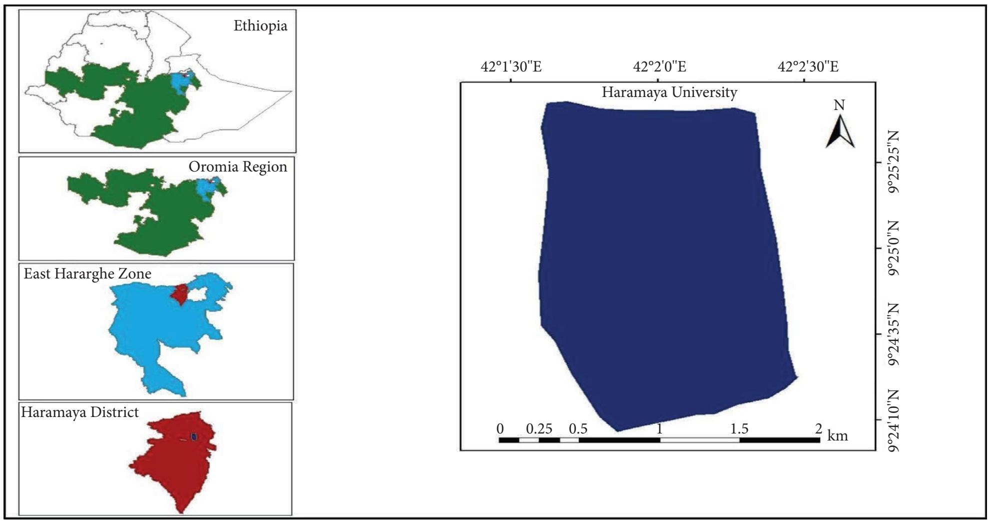

Figure 1: Map of Haramaya University.

Polythene tubes were filled by hand, and in the middle of the polythene tube, a hole was first pressed into the soil by a picking stick to bury the seed and facilitate germination. Certified seeds were obtained from the Ethiopian Forest Research Institute. After sowing seeds in each polythene tube, watering was undertaken twice a day for the first two weeks. Then after, watering was done at the field capacity level as necessary.

2.4. Seedlings Data Collection. A total of 480 seedlings were grown to increase the precision of the experiment. This means five pots were used for a single treatment and one species because there might be germination failure. As stated in the experimental design the data were taken from three (3) replication for each treatments and each species. In general, the data were taken from 24 seedlings for one species and 96 seedlings for the four (4) species. The morphological features used to determine seedling quality were: shoot height (cm), root length (cm), number of leaves per plant, estimated leaf area (cm^2) and actual leaf area (cm^2), root collar diameter (mm), and shoot and root dry weight (g). Estimated leaf area (cm^2) was determined by multiplying the midrib length by leaf width. Easily measured leaf parameters such as length and width, and their combinations have been used for nondestructive leaf area estimation, though the accuracy of the predictions is dependent on the variation of the leaf shape due to differential genotypes [28]. The actual leaf area (cm^2) was determined by using a CID Bio-Science portable laser leaf area meter. The leaf area index (LAI) was calculated by dividing the actual leaf area by the polythene tube area. The leaf area correction factor (CF) was calculated by the following equation:

$$CF = \frac{ALA}{ELA} \tag{2}$$

where ELA is the Estimated Leaf Area, CF is the Leaf Area Correction Factor and ALA is the Actual Leaf Area. Sturdiness quotient (SQ) was calculated as follows:

$$SQ = \frac{\text{Shoot height (cm)}}{\text{RootCollardiameter (mm)}}. \tag{3}$$

The lower the sturdiness quotient value; the higher the seedling quality. A sturdiness quotient of less than 6 has been suggested as a desired characteristic of high-quality seedlings in tropical systems [29] broadly suggesting that lower values are preferable. Studies have also found sturdiness quotient to correlate with seedling survival and initial growth following outplanting [30]. The total measurement was continued up to a maximum of 110 days for all species and measurement was done in 15-day intervals. The dried weight was determined after the samples were dried in an oven at 68°C for 48 h [12]. At the end of the experiment and after removing the soil, shoot height and root length (cm) were measured using a ruler, and root collar diameter (mm) was measured by Vernier caliper whereas shoot and root dry weights (g) were measured by sensitive electronic balance.

2.5. Data Analysis and Interpretation. The data were analyzed using R statistical software team core version 4.0.3 and mean comparison, which was done using LSD test (least significant difference) at a probability of 0.05%, and Pearson correlation test was also used to determine relation among different treatments. Finally, results interpreted and presented in graph and table formats.

3. Results and Discussion

3.1. Soil Physicochemical Properties

3.1.1. Soil Physicochemical Properties. Soil laboratory results indicated the presence of high soil nutrients in soil samples with a mixture of manure whereas lower soil nutrients were rerecorded for agricultural and sand soil. The lower percent of N and available P could be related to the lower concentration of soil OM, which could result from low plant residue and a lower rate of decomposition [31, 32]. As depicted in Table 1, exchangeable potassium is lower in the sand than other soil mixtures, resulting in the absence of organic matter. Treatments with organic matter or manure mixture witnessed slightly basic characteristics, whereas agricultural soil had slightly acidic characteristics. This indicates that adding organic matter to soil can minimize soil acidity besides improving soil fertility [33]. Except for sandy soil where it was lower, the soil organic matter for other soil mixtures was greater than 3%, indicating good soil aggregate stability [34]. According to [35], if the percentage of soil organic carbon percent falls below 1, the compaction and friability characteristics of soils become more limiting for plant growth and tillage operations. The soil textural classes (USDA, 2008) were sandy loam and loam sand which indicated the presence of manure in the soil mixture. The texture is important with more clayey soils but less influenced by soil organic matter [32].

3.2. Morphological Characteristics of Seedlings. Analysis of variance (ANOVA) indicated significant difference of shoot height of *Cordia africana* among treatments at ($P \leq 0.05$). However, no significant difference was observed between T4, T5, and T7. As depicted in Table 2, T3 and T2 scored the highest shoot height at 110 days after sowing compared to the other treatments [36, 37]. Besides, treatments 3, 4, and 7 had higher collar diameters than the other treatments. As shown in (Table 2), the seedling height of *Fiadherbia albida* was significantly different ($P \leq 0.05$) while the root length was not. However, no significant difference in shoot height ($P \leq 0.05$) was encountered among T3, T5, T6, and T7. On the other hand, T1 had the least shoot height and root collar diameter [30, 38, 39]. The shoot height of *Moringa stenopetala* was highly significant at ($P \leq 0.01$) but the root length was significant at ($P \leq 0.05$). Treatments 7 and T5 achieved the highest shoot height and root collar diameter at 110 days after sowing compared to the other treatments. Similarly, a significant difference was observed in the shoot height of *Millettia ferruginea* at $P \leq 0.05$. However, no significant difference was observed in the root length at ($P \leq 0.05$). Treatments 2 and T3 achieved the highest shoot (cm) and root collar diameter (mm) at 110 days of sowing compared to the other treatments. The sturdiness quotients of all treatments ranged from 3.92 to 5.30, which indicates the vigor of seedlings though there were slight differences within treatments [12].

The current study has shown R: S ratio ranging from 0.28 to 0.52, 0.31–0.48, and 0.21–0.61 with mean value of 0.4 for *C. africana*, *F. albida, and M. ferruginea* respectively. On the other hand, the R: S ratio *M. stenopetala* was 0.37–0.86 with a mean value of 0.62 [40].

3.3. Mean Shoot Height at Different Durations of Measurement. The shoot height of treatments with mixture of manure and inorganic fertilizers were significantly different at ($P \leq 0.05$) (Table 3). Treatment 2 for *C. africana and M. stenopetala,* T4 for *F. albida* and T7 for *M. ferruginea* has shown highly significant differences compared to the other treatments indicating that species responded differently to different soil mixtures. The result is corroborated with the findings of where they reported a positive repose of plant height to the combined application of organic and inorganic fertilizers, which might be due to the presence of macro and micronutrients in the organic matter [41, 42]. Plant height increased with the application of organic and inorganic fertilizers due to increased absorption of available nutrients [43]. While inorganic fertilizers render nutrients, which are readily accessible in soil solution and thereby making them instantaneously available, organic fertilizers provide nutrients through microbial activities [41, 44]. Another study [45] demonstrated better growth parameter of seedlings on application of mixed organic and inorganic fertilizers.

3.4. Actual and Estimated Leaf Area. The result showed the actual leaf area of *C. africana* was significantly different at ($P \leq 0.05$) with a mean leaf area correction factor (LACF) of 0.59. It was also noted that T5, T3, and T7 scored the highest actual leaf area (cm^2) in descending order. The actual leaf area of *F. albida* was highly significant at ($P \leq 0.01$). T4 treatment scored the highest estimated and actual leaf area (cm^2). On the other hand, T1 and T8 have showed the lowest actual leaf area (cm^2). Mean Leaf Area Correction Factor (LACF) for *F. albida* was found 0.63 (Table 4). Similar to *F. albida*, the actual leaf area of *M. stenopetala* was highly significant at ($P \leq 0.01$). Of all the treatments, T5 and T2 scored the highest actual leaf area (cm^2); whereas T3 and T6 scored the lowest actual leaf area (cm^2). The leaf area correction factor (LACF) for *M. stenopetala* was 0.73. As depicted in Table 4, the actual leaf area of *M. ferruginea* was significantly different at ($P \leq 0.05$). As indicated in the same table, T3 and T4 had the highest actual leaf area (cm^2) compared to the other treatments. On the contrary, T8 had the lowest leaf area, which indicates some nutrient deficiencies in the soil mix and the need for amendment with inorganic fertilizers [34]. The productivity potential of the plant is determined by the leaf area [17, 28, 34]. An increase in absorbed photosynthetically active radiation increases gross primary productivity (GPP), as GPP is proportional to absorbed photosynthetically active radiation. Accordingly, GPP increases with increasing LAI [46].

The following figures were taken at different durations of seedling growth and data collection. They indicates the seedlings of *C. africana* (Figure 2), *C. africana* seedlings ready for measurements of the intended parameters (Figure 3), seedlings of *M. stenopetala* (Figure 4), seedlings of *M. ferruginea* (Figure 5), root of *M. stenopetala* ready for collar diameter and root length measurement (Figure 6), *A. albida* seedlings ready for measurements of the intended parameters (Figure 7), sample seedlings of *A. albida* ready for the measurements of the dry matter (Figure 8), and pots arrangement and early seedlings growth (Figure 9).

Table 1: Physicochemical properties of the soil mixtures.

Trt	pH	EC (ds/m)	% TN	Av. P (mg/g)	% OC	C: N	% OM	Ex. K (meq/100 g)	Sand (%)	Silt (%)	Clay (%)	Texture class
	Parameters								Soil texture			
1	7.36	0.53	0.252	22.31	2.92	11.58	5.02	3.58	81	8	11	Sandy loam
2	7.38	0.45	0.196	12.14	2.27	11.58	3.90	2.48	81	7	12	Loam sand
3	7.39	0.67	0.182	16.05	2.11	11.59	3.63	4.23	81	8	11	Sandy loam
4	7.13	0.55	0.224	19.79	2.60	11.60	4.47	3.38	76	10	14	Sandy loam
5	7.41	0.72	0.188	17.23	2.13	11.32	3.66	4.07	80	8	12	Sandy loam
6	7.27	0.48	0.191	12.09	2.32	12.14	3.99	2.44	79	7	14	Loam sand
7	7.32	0.51	0.257	22.43	2.88	11.20	4.95	3.56	82	7	11	Sandy loam
8	7.37	0.69	0.179	16.35	2.16	12.27	3.72	4.52	82	8	10	Sandy loam
Manure	7.16	3.00	0.95	27.92	3.87	4.07	6.66	4.88	79	13	8	Loam sand
Sand	8.22	0.08	0.014	1.34	0.16	11.42	0.28	0.08	95	2	3	Sandy
Agr. soil	6.63	0.11	0.168	8.75	3.06	18.21	5.26	2.98	71	12	17	Sandy loam

Trt: treatments; pH: power of hydrogen; EC: electrical conductivity; %TN: percent of total nitrogen; P: phosphorus; OC: organic carbon; C: N: carbon nitrogen ratio; OM: organic matter; Exc. K: exchangeable potassium.

Table 2: Shoot height, root length, collar diameter, and dry matter measurement.

Species name	S/N.	Treatments	Ht	SDW	RL	RDW	RCD	R: S	SQ
C. africana	1	3A: 1M: 2S: 50D	17.00bc	2.31a	17.00a	0.83a	4.78d	0.36	3.56
	2	2A: 2M: 2S: 25D	20.66ab	1.84ab	18.00a	1.07a	6.34c	0.58	3.26
	3	3A: 2M: 1S: 75D	22.00a	4.09ab	19.00a	1.56a	7.86a	0.38	2.79
	4	1A: 2M: 3S: 46U	18.66abc	3.96ab	22.00a	1.73a	7.49ab	0.44	2.49
	5	3A: 2M: 1S: 23U	19.00abc	1.02bc	18.00a	0.54a	6.79c	0.52	2.80
	6	2A: 2M: 2S: 23U	16.66bc	2.47bc	20.00a	1.19a	6.58c	0.48	2.53
	7	3A: 1M: 2S: 46U	19.66abc	3.71bc	18.66a	0.98a	7.11b	0.26	2.77
	8	3A: 2M: 1S	15.33c	3.56c	19.00a	1.13a	6.64c	0.32	2.31
	CV%	14.60	17.70						
	LSD (0.05)	4.76	5.88						
F. albida	1	3A: 1M: 2S:50D	25.33c	1.78a	18.67a	0.61a	4.51e	0.34	5.62
	2	2A: 2M: 2S: 25D	32.66bc	2.11ab	20.17a	0.79a	5.78d	0.37	5.65
	3	3A: 2M: 1S: 75D	35.33ab	2.05ab	18.00a	0.63a	5.93d	0.31	5.96
	4	1A: 2M: 3S: 46U	43.66a	2.96ab	21.00a	0.92a	7.32a	0.31	5.96
	5	3A: 2M: 1S: 23U	37.33ab	1.54bc	18.33a	0.74a	6.82b	0.48	5.47
	6	2A: 2M: 2S: 23U	38.66ab	2.19bc	22.83a	0.81a	6.54bc	0.37	5.91
	7	3A: 1M: 2S: 46U	39.66ab	2.28bc	21.33a	1.02a	7.21a	0.45	5.50
	8	3A: 2M: 1S	33.66bc	1.57c	19.33a	0.58a	5.67d	0.37	5.94
	CV%	13.41	16.00						
	LSD (0.05)	8.41	5.20						
M. stenopetala	1	3A: 1M: 2S: 50D	21.00cd	0.84a	14.00ab	0.43a	5.17c	0.51	4.06
	2	2A: 2M: 2S: 25D	20.66cde	0.53ab	9.33c	0.38ab	5.12c	0.72	4.04
	3	3A: 2M: 1S: 75D	17.33e	0.62ab	17.00a	0.41ab	6.22b	0.66	2.79
	4	1A: 2M: 3S: 46U	26.00ab	0.76ab	14.33ab	0.34ab	6.58ab	0.45	3.95
	5	3A: 2M: 1S: 23U	24.00bc	0.64bc	11.33bc	0.55bc	7.37a	0.86	3.26
	6	2A: 2M: 2S: 23U	18.33de	0.71bc	12.00bc	0.26bc	4.98c	0.37	3.68
	7	3A: 1M: 2S: 46U	27.66a	0.75c	18.00a	0.28bc	7.15a	0.37	3.87
	8	3A: 2M: 1S	21.00cd	0.52c	12.00bc	0.19c	5.10c	0.37	4.12
	CV%	8.80	4.51						
	LSD (0.05)	3.39	19.10						

Table 2: Continued.

Species name	S/N.	Treatments	Ht	SDW	RL	RDW	RCD	R: S	SQ
M. ferruginea	1	3A: 1M: 2S: 50D	21.00c	3.08a	18.66a	0.89a	4.88c	0.29	4.30
	2	2A: 2M: 2S: 25D	29.66a	3.93a	18.33a	1.08a	7.46a	0.27	3.98
	3	3A: 2M: 1S: 75D	28.66ab	2.86ab	23.33a	0.97a	5.41c	0.34	5.30
	4	1A: 2M: 3S: 46U	26.33abc	2.17ab	22.00a	0.82a	6.37b	0.38	4.13
	5	3A: 2M: 1S: 23U	23.33bc	1.69bc	19.00a	1.03a	5.20c	0.61	4.49
	6	2A: 2M: 2S: 23U	23.00bc	2.04bc	19.66a	0.76a	4.99c	0.37	4.61
	7	3A: 1M: 2S: 46U	25.33abc	3.12bc	19.33a	0.64a	5.10c	0.21	4.97
	8	3A: 2M: 1S	23.66bc	2.31c	19.00a	0.90a	4.46d	0.39	5.30
	CV%	13.61	5.20						
	LSD (0.05)	5.98	14.90						

Means within column followed by the same letter are not significantly different from each other at the prescribed level; LSD = least significant difference; CV = Coefficient of variation. Ht = mean shoot height (cm); RL = root length (cm); R: S = root to shoot ratio and RCD = root collar diameter (mm), SDW = shoot dry weight (g), RDW = root dry weight (g) and R: S = root to shoot ratio.

Table 3: Mean shoot height (Ht) at different durations of measurements.

Species name	S/N.	Treatments	Ht (cm) at 50 days	Ht (cm) at 65 days	Ht (cm) at 80 days	Ht (cm) at 95 days	Ht (cm) at 110 days
C. africana	1	3A: 1M: 2S: 50D	4.66d	7.00c	10.66cd	13.66bc	17.00bc
	2	2A: 2M: 2S: 25D	5.33cd	8.33bc	12.00bc	16.00ab	20.66ab
	3	3A: 2M: 1S: 75D	7.66a	11.66a	15.66a	18.66a	22.00a
	4	1A: 2M: 3S: 46U	5.33cd	8.33bc	11.00cd	14.66bc	18.66abc
	5	3A: 2M: 1S: 23U	7.00abc	9.00bc	9.00cd	16.00ab	19.00abc
	6	2A: 2M: 2S: 23U	5.66bcd	7.66bc	9.66cd	14.00bc	16.66bc
	7	3A: 1M: 2S: 46U	7.33ab	9.66ab	15.00ab	16.66ab	19.66abc
	8	3A: 2M: 1S	4.66d	6.66c	8.66d	12.33c	15.33c
F. albida	1	3A: 1M: 2S: 50D	6.00b	8.33d	13.66d	20.00b	25.33c
	2	2A: 2M: 2S: 25D	6.33b	11.33cd	16.66cd	24.33bc	32.66bc
	3	3A: 2M: 1S: 75D	8.00ab	12.16bcd	17.33cd	25.33abc	35.33ab
	4	1A: 2M: 3S: 46U	7.00ab	12.00cd	19.66bcd	34.00a	43.66a
	5	3A: 2M: 1S: 23U	9.66a	17.66a	26.00ab	34.00a	37.33ab
	6	2A: 2M: 2S: 23U	8.83ab	15.33abc	23.00abc	33.00ab	38.66ab
	7	3A: 1M: 2S: 46U	8.83ab	17.00ab	28.00a	33.33a	39.66ab
	8	3A: 2M: 1S	7.16ab	12.66bcd	18.33cd	25.66abc	33.66bc
M. stenopetala	1	3A: 1M: 2S:50D	13.00b	16.00ab	18.66ab	19.33c	21.00c
	2	2A: 2M: 2S: 25D	13.00b	19.33a	22.33a	24.33ab	29.66a
	3	3A: 2M: 1S: 75D	17.33a	19.33a	21.33ab	23.66ab	28.66ab
	4	1A: 2M: 3S: 46U	10.66b	13.33b	19.33ab	25.66a	26.33abc
	5	3A: 2M: 1S: 23U	12.66b	15.00ab	18.00ab	21.33bc	23.33bc
	6	2A: 2M: 2S: 23U	10.33b	13.33b	17.33b	19.00c	23.00bc
	7	3A: 1M: 2S: 46U	10.67b	13.00b	18.00ab	22.66abc	25.33abc
	8	3A: 2M: 1S	10.00b	13.66b	17.33b	21.33bc	23.66bc
M. ferruginea	1	3A: 1M: 2S: 50D	6.00b	12.66c	14.33cd	16.33d	21.00cd
	2	2A: 2M: 2S: 25D	6.33b	13.00bc	16.00bcd	18.66bcd	20.66cde
	3	3A: 2M: 1S: 75D	8.00ab	9.66d	13.33d	16.00d	17.33e
	4	1A: 2M: 3S: 46U	7.00ab	15.66ab	19.00a	21.33ab	26.00ab
	5	3A: 2M: 1S: 23U	9.66a	13.33abc	16.33cd	19.33bc	24.00bc
	6	2A: 2M: 2S: 23U	8.33ab	11.66cd	15.00cd	18.00cd	18.33de
	7	3A: 1M: 2S: 46U	8.33ab	16.00a	18.66ab	24.00a	27.66a
	8	3A: 2M: 1S	7.16ab	13.33abc	15.66cd	18.33cd	21.00cd

Table 4: Estimated and actual leaf area among treatments.

Species name	S/N.	Treatments	NL	ALA (cm^2)	ELA (cm^2)	LACF	LAI
C. africana	1	3A: 1M: 2S:50D	7	305.33b	475.66e	0.64	0.49
	2	2A: 2M: 2S: 25D	8	398.00b	829.33bc	0.48	0.63
	3	3A: 2M: 1S: 75D	9	545.66a	749.66cd	0.72	0.87
	4	1A: 2M: 3S: 46U	8	392.66b	586.33de	0.67	0.60
	5	3A: 2M: 1S: 23U	9	548.00a	1072.66a	0.51	0.87
	6	2A: 2M: 2S: 23U	8	337.66b	545.00e	0.62	0.54
	7	3A: 1M: 2S: 46U	8	530.66a	1009.66ab	0.53	0.87
	8	3A: 2M: 1S	7	355.66b	659.00cde	0.54	0.62
		CV%		17.50	15.07		
		LSD (0.05)		130.76	195.50		
F. albida	1	3A: 1M: 2S: 50D	38	47.33e	81.33	0.58	0.08
	2	2A: 2M: 2S: 25D	81	101.66bcd	131.00cd	0.77	0.16
	3	3A: 2M: 1S: 75D	74	91.66cd	134.33cd	0.68	0.15
	4	1A: 2M: 3S: 46U	104	132.33a	226.00ab	0.59	0.21
	5	3A: 2M: 1S: 23U	88	108.66abc	174.66bc	0.62	0.17
	6	2A: 2M: 2S: 23U	98	128.33ab	235.00a	0.54	0.20
	7	3A: 1M: 2S: 46U	97	121.66ab	191.33ab	0.63	0.19
	8	3A: 2M: 1S	62	78.00d	113.66d	0.68	0.12
		CV%		16.12	18.82		
		LSD (0.05)		28.57	53.04		
M. stenopetala	1	3A: 1M: 2S: 50D	29	169.66cde	227.00bc	0.74	0.26
	2	2A: 2M: 2S: 25D	34	243.00ab	323.00a	0.75	0.35
	3	3A: 2M: 1S: 75D	22	125.00e	179.66c	0.69	0.18
	4	1A: 2M: 3S: 46U	27	198.00abcd	282.00ab	0.70	0.29
	5	3A: 2M: 1S: 23U	31	262.33a	343.33a	0.76	0.31
	6	2A: 2M: 2S: 23U	30	144.66de	181.66c	0.79	0.21
	7	3A: 1M: 2S: 46U	36	238.33abc	307.00b	0.77	0.36
	8	3A: 2M: 1S	32	191.33bcde	278.00b	0.68	0.29
		CV%		20.47	17.68		
		LSD (0.05)		70.47	82.10		
M. ferruginea	1	3A: 1M: 2S: 50D	70	475.33cd	935.00a	0.50	0.76
	2	2A: 2M: 2S: 25D	75	517.66abc	654.00c	0.79	0.81
	3	3A: 2M: 1S: 75D	81	555.33a	776.00b	0.71	0.88
	4	1A: 2M: 3S: 46U	80	543.00ab	953.33a	0.57	0.87
	5	3A: 2M: 1S: 23U	72	491.00bcd	944.33a	0.52	0.78
	6	2A: 2M: 2S: 23U	67	451.66d	680.66bc	0.66	0.73
	7	3A: 1M: 2S: 46U	73	492.00abcd	888.33a	0.55	0.79
	8	3A: 2M: 1S	65	441.66d	647.00c	0.68	0.70
		CV%		7.37	7.55		
		LSD (0.05)		64.00	107.04		

NL = number of leaf, ALA = actual leaf area (cm^2), ELA = estimated leaf area (cm^2), CF = leaf area correction factor, LAI = leaf area index, LSD = least significant difference, CV = coefficient of variation.

Figure 2: *Cordia africana*.

Figure 3: *Cordia africana*.

Figure 4: *Moringa stenopetala*.

Figure 5: *Millettia ferruginea*.

Figure 6: Root of *Moringa stenopetala*.

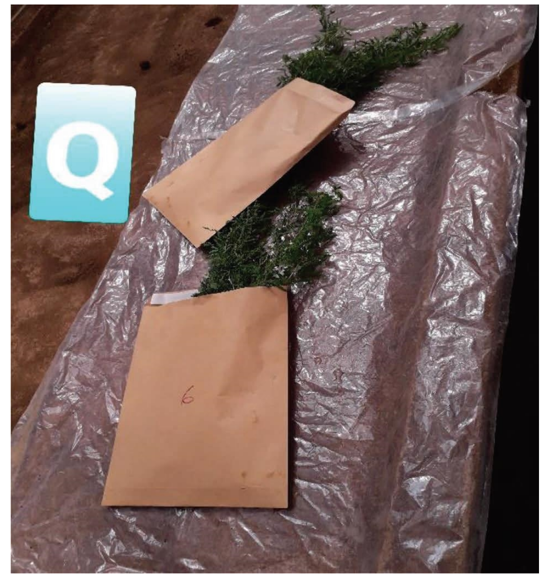

Figure 8: *Acacia albida* (sample).

Figure 7: *Acacia albida*.

Figure 9: Pots arrangement and early germination.

3.5. Interrelation between Seedling Growth Characteristics. Table 5 depicts that, shoot height, number of leaves, and actual leaf area of *C. africana* has shown strong positive correlation whereas, sturdiness quotient, root collar diameter and estimated leaf were positively correlated. For *M. stenopetala* shoot height, number of leaves, actual leaf area, estimated leaf area and root collar diameter indicated strong positive correlation. In contrast, sturdiness quotient, root length, leaf area correction factor and shoot height were positively correlated. In case of *F. albida*, shoot height, number of leaves, actual leaf area, and leaf area correction factor and root collar diameter showed strong positive correlation while root length and leaf area index were positively correlated. On the other hand estimated leaf area, leaf area correction factor and sturdiness indicated negative correlation. For *M. ferruginea,* all the other parameters showed positive correlation with shoot height except sturdiness quotient and leaf area correction factor [47–50]. Root collar diameter and Sturdiness quotient showed negative correlation for all species considered.

Table 5: Correlation coefficient among seedling growth parameters.

	Ht	NL	ALA	ELA	LACF	RL	RCD	SQ	LAI
C. africana									
Ht									
NL	0.74**								
ALA	0.71**	0.82**							
ELA	0.50*	0.59**	0.84**						
LACF	0.11NS	0.11NS	−0.08NS	−0.60**					
RL	0.05NS	0.12NS	−0.07NS	−0.27*	0.41*				
RCD	0.51*	0.66**	0.65**	0.38*	0.22NS	0.63**			
SQ	0.27*	0.13NS	−0.13NS	−0.04NS	−0.08NS	−0.72**	−0.58		
LAI	0.64**	0.75**	0.98**	0.85**	−0.14NS	−0.12NS	−0.01NS	0.02NS	
F. albida									
Ht									
NL	0.71**								
ALA	0.74**	0.99**							
ELA	−0.31*	0.36*	0.31*						
LACF	0.71**	0.11NS	0.167NS	−0.87**					
RL	0.43*	0.73**	0.71**	0.16NS	0.11NS				
RCD	0.75**	0.59**	0.62**	−0.09NS	0.47*	0.06NS			
SQ	0.04NS	−0.17NS	−0.18NS	−0.274*	0.11NS	0.31*	−0.67**		
LAI	0.69*	0.99**	0.99**	0.37*	0.09NS	0.75**	0.57**	−0.18NS	
M. stenopetala									
Ht									
NL	0.503**								
ALA	0.701**	0.733**							
ELA	0.705**	0.664**	0.979**						
LACF	0.448*	−0.291*	0.013NS	0.018NS					
RL	0.273*	−0.291*	−0.325*	−0.328*	0.114NS				
RCD	0.696**	0.010NS	0.465*	0.461*	0.252*	0.471*			
SQ	0.353*	0.630**	0.304*	0.330*	0.197NS	−0.322*	−0.434*		
LAI	0.751**	0.849**	0.921**	0.914**	0.056NS	−0.200*	0.308*	0.562**	
M. ferruginea									
Ht									
NL	0.941**								
ALA	0.936**	0.997**							
ELA	0.902**	0.931**	0.948**						
LACF	−0.227*	−0.146*	0.182*	−0.480*					
RL	0.531**	0.636**	0.682**	0.741**	−0.373*				
RCD	0.967**	0.948**	0.933**	0.880**	−0.204*	0.496*			
SQ	0.229*	0.064NS	0.099NS	0.157*	−0.070NS	0.162*	−0.023NS		
LAI	0.937**	0.995**	0.997**	0.948**	−0.191*	0.665**	0.930**	0.112*	

Significance codes: 0 0.001 "**" 0.01 "*" 0.05 "." 0.1 "" 1; Ht = shoot height (cm), NL = number of leaf, ALA = actual leaf area (cm^2), ELA = estimated leaf area (cm^2), LACF = leaf area correction factor, RL = root length (cm), RCD = root collar diameter (mm), SQ = sturdiness quotient, LAI = leaf area index.

4. Conclusions

Understanding seedling nutrient requirements and existing correlations between morphological parameters is critical in identifying the best production methods for the production of vigorous seedlings. The current study considered different soil mixes and fertilization and evaluated morphological parameters that insure seedlings' vigor and robustness. Even if, some variations are observed among the plants considered, a soil mixture with both inorganic and organic fertilizers has shown better performance. Finally, treatment 3 (3A: 2M: 1S: 75D) is recommended as the best pot soil mix and fertilization compared to all other treatments, though it needs further study on other indigenous tree species to support plantation efforts.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

(A) The following tables indicate the morphological characteristics of four species (*C. africana*, *F. albida*, *M.*

stenopetala, and *M. ferruginea*) seedlings. (1) Shoot height (Ht) measurement for *C. africana* at different stages of seedling growth. (2) Shoot height (Ht) measurement for *F. albida* at different stages of seedling growth. (3) Shoot height (Ht) measurement for *M. stenopetala* at different stages of seedling growth. (4) Shoot height (Ht) measurement for *M. ferruginea* at different stages of seedling growth. (5) Measurement of morphological characteristics (mean Ht, leaf, root and dry matter and sturdiness quotient) for *Cordia africana*. (6) Measurement of morphological characteristics (mean Ht, leaf, root and dry matter and sturdiness quotient) for *Fiadherbia albida*. (7) Measurement of morphological characteristics (mean Ht, leaf, root and dry matter and sturdiness quotient) for *Millettia ferrugenea*. (8) Measurement of morphological characteristics (mean Ht, leaf, root and dry matter and sturdiness quotient) for *Moringa stenopetala*. (B) Analysis of variance (ANOVA) results. (1) Analysis of variance (ANOVA) for *Cordia africana* parameter after 110 days of measurement. (2) Analysis of variance (ANOVA) for *Fiadherbia albida* parameter after 110 days of measurement. (3) Analysis of variance (ANOVA) for *Moringa stenopetala* parameter after 110 days of measurement. (4) Analysis of variance (ANOVA) for *Millettia ferruginea* parameter after 110 days of measurement. (*Supplementary Materials*)

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