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Adaptation and Growth Performance Evaluation of Selected Multipurpose Trees and Shrubs at Yabello District, Borana Zone, Southern Oromia, Ethiopia

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Abstract

A study was conducted on three multipurpose agroforestry tree species: *Moringa oleifera*, *Olea europea*, and *Calliandra calothyrsus* at Yabello Agriculture Research Center to evaluate their adaptability and growth performance. The experiment was arranged in RCBD with three replications. The growth parameters; survival rate, plant height, diameter at breast height, and root collar diameters were measured and recorded each year. The results revealed that the variations among tree species in survival rate were highly significant ($p<0.001$) after four years of age. This could be due to environmental factors and the genetic potential of the species, which generally govern the growth of a given species. Among the species tested, *Moringa oleifera* and *Olea europea* showed the highest performance in terms of survival rate. *Olea europea* and *Moringa oleifera* showed the highest survival rates, with 83.33%, and 77.78% respectively. On the other hand, *Calliandra calothyrsus* showed the lowest survival rate (22.22%). Thus, the long dry season, which extended for the last four years in the study area, clearly explains the poor survival and growth response of the species. Hence, it can be inferred that the conditions in Yabello match the environmental requirements of *Moringa oleifera* and *Olea europea*. Therefore, the species offers much promise for future use in agroforestry practices in the area. Thus, the study advocates for the proper allocation of adapted species in Yabello conditions and related agroecology for agroforestry practices, forest plantations, and economic benefits for stakeholders.

Keywords

Agroforestry, Diameter at Breast Height, Height Growth, Survival Rate, Multipurpose

1. Introduction

Dryland regions of Ethiopia are currently facing challenges like land degradation, recurrent drought, and shortage of human and livestock feeds due to different factors. Thus, one of the important causes is the removal of forest and vegetative cover as a result of the increased human population, leading to high demand for forest products and land for expanding agricultural activities [1]. In spite of the importance of the forest ecosystem to the livelihoods of the people in the area, the forest is dwindling from time to time due to the high exploitation of woody and non-woody products. Rapid deforestation caused by an escalating demand for fuel wood expansion for agriculture has brought ever-increasing pressure on native woodland species [2]. If no remedial action is taken, this will have a severe impact on agricultural productivity, leading to energy poverty and environmental degradation. Frequent and severe droughts often present a serious threat to millions of lives [3]. Shortages of animal feed and biomass energy are also such an unsustainable use of natural resources.

Therefore, the agroforestry system has much potential for supplying food, fodder, poles, farm equipment, fuel wood, and agricultural improvements for the farm family on a sustained basis [3, 4]. Thus, agroforestry practices, interventions, reforestation, and current Ethiopian government watershed-based natural resource management require the raising of different trees suitable to the area. However, many reforestation projects fail due to inappropriate species choice, a consequence of inadequate knowledge about the potential of species and their growth and survival rates under different site conditions, which is basic for plantation success [5]. The growth characteristics and phenology of many plants are influenced by environmental factors such as temperature, moisture, and soil type [6]. In arid and semi-arid ecosystems, precipitation and nutrient availability are the main constraints on the growth and productivity of plants [7]. Especially, in drylands, water availability is a primary factor controlling plant growth processes and productivity [8].

Multipurpose trees and shrubs provide a wide range of benefits to local communities in arid and semi-arid regions, including food, fodder, fuelwood, timber, and non-timber products [9]. However, identifying suitable species adapted to specific agroclimatic conditions is crucial for successful establishment and production. The Borana pastoral community heavily depends on indigenous bush and shrub species for dry-season grazing. Still, land degradation and recurrent drought have led to a loss of plant biodiversity and rangeland productivity [10]. Introducing fast-growing and drought-tolerant multipurpose trees could provide alternative sources of livestock feed and restore degraded communal lands. Species screening trials are important to identify promising species for wider dissemination and planting in the target environment [11]. Hence, this will be effective if the right species are planted in the right place, as their adaptability potential is strongly dependent on the local climatic conditions and soil characteristics [12, 13]. This has pointed out that, prior to planting any tree or shrub species in a given agroecology, there is always the need to conduct a field trial on the suitability of the species for a particular site, focusing on their adaptability and growth performance. In many parts of Ethiopia, studies on the adaptability and growth performance of tree and shrub species have been conducted [12, 14]. Thus, the performance of some multipurpose tree species namely Faidherbia albida, Melia azedarach, Moringa stenopetala, and Sesbania sesban were evaluated in four soil and moisture conservation structures (soil level bund, half-moon, trench, and normal pit) in Dugda dawa district of similar agroecology with Yabello district [15]. However, information available on the performance of multipurpose agroforestry tree and shrub species in the Yabello district of Borana zone is very limited.

This research provides important empirical data on how introduced multipurpose trees perform in the semi-arid Borana rangelands. The results will guide recommendations for local farmers on which fast-growing and drought-hardy species are suitable for planting in the Yabello District and similar agroecological zones. Moreover, promoting adapted multipurpose trees can support climate change resilience and sustainable livelihoods for Borana pastoralists through diversified income sources and environmental rehabilitation. Therefore, this study was initiated to evaluate the adaptability and growth performance of selected multipurpose tree species to Yabello conditions and sites of similar agroecology.

2. Materials and methods

2.1 Description of the study area and site selection

The study was conducted in the Yabello district of Borana range land, southern Oromia (Figure 1). Yabello district is situated in the Borana zone of Oromia National Regional State, 570 km south of Addis Ababa. The study area lies between 4^0 38' 30'' N to 4^0 57' 0'' N and 38^0 2' 0'' E to 38^0 16' 30'' E. Yabello district has a bi-modal rainfall pattern, with the main rainy season (Ganna) between March and May and the peak in April [16]. The short rainy season (Hagayya) extends from September to November, with a peak in October. The mean annual rainfall of the area ranges from 352 mm in the southern part to 605 mm in the northern part of the zone. The mean annual rainfall is 587.2 mm. The mean annual temperature varies from 15 to 24˚C and shows little variation across the seasons [16].

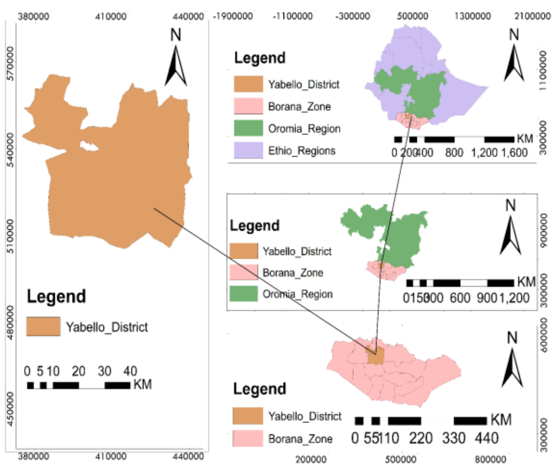

Figure 1. Description of the study area.

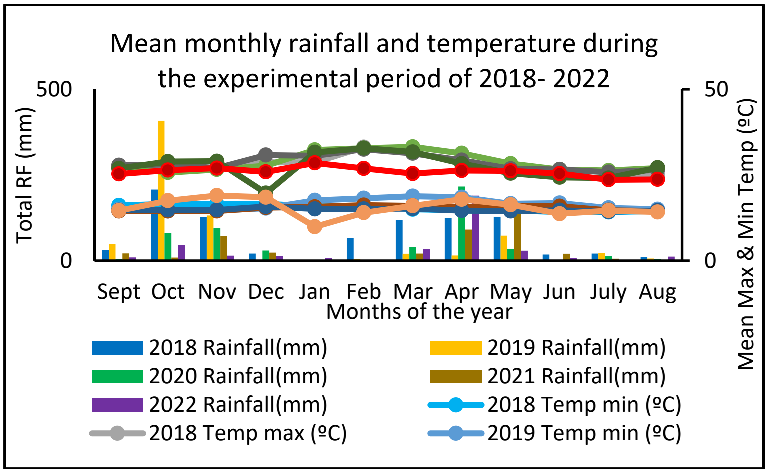

Figure 2. Mean monthly rainfall and temperature during the experimental period of 2018- 2022 (Hawassa meteorological agency).

2.2 Methods

2.2.1 Study sites and species selection

The study was conducted in the Yabello district of the Borana zone. The sites have been selected purposively, and the experiment was conducted at the Yabello on-station site.

2.2.2 Multipurpose trees and shrubs species selection

Multipurpose tree species selected for the study were *Olea europea, Moringa oleifera, and Calliandra calothyrsus.* The species selection was based on the assumption that these tree species are compatible and have the potential to grow well in the study area, which is degraded and moisture-stressed, and used for fodder purposes, facilitating land rehabilitation and improving soil fertility. Seeds of the selected species were obtained from the Bako Agriculture Research Center (BARC) and Forestry Research Center (FRC).

(1) *Moringa oleifera*

Moringa oleifera is native to India and Arabia. The species is currently distributed to different parts of the pantropical. Ecologically, the species grows in the lowland tropics, ranging from 0 to 750 m a s l, 760-2250 mm annual rainfall on well-drained, deep soils (pH 5-7 preferred) [17]. The main uses of the species were food (pods when young, leaves, roots, flowers); fuelwood; fodder (leaves); honey production; medicine (bark, roots, leaves); water purification (seeds); soap (seeds); and industrial lubricant [17].

(2) *Calliandra calothyrsus*

A multipurpose species is grown primarily for forage as a supplement to low-quality roughages for ruminant livestock. *Calliandra calothyrsus* can be used to rehabilitate erosion-prone areas and recover land exhausted by agriculture, where it easily dominates undesired weeds. Roots can fix atmospheric nitrogen because of the symbiosis with Rhizobium bacteria (to which root nodules bear witness) and the symbiosis with root fungus. High leaf biomass production and high yields of protein leaf material on less fertile soils make it very suitable as green manure, and it is used in alley-cropping systems. *Calliandra calothyrsus* is compatible with crops, with both deep roots and extensive fibrous roots [18, 19]. Calliandra occurs naturally in some parts of the tropics at altitudes ranging from sea level to 1900 m, where the average annual rainfall is above 1000 mm. It can withstand dry seasons of 2-4 months with less than 50 mm of rainfall per month [18].

(3) *Olea europea*

Widely distributed in dry forests and forest margins, often with *Juniperus procera,* in East Africa and Ethiopia [20]. It reaches southern Africa, as well as India and China, ranging from tall trees to stunted shrubs. It does best in good forest soil but is hardy and drought-resistant once established, even in poor soils. It does best in Moist and Wet Weyna Dega and lower Dega agroclimatic zones. It is used for firewood, charcoal, poles, posts, timber (furniture, carving, floors, paneling), medicine (stem, bark, leaves), bee forage, milk flavoring (smoking wood), toothbrushes (twigs), and walking sticks.

2.3 Experimental design and field planting

2.3.1 Seedling raising and caring

Seeds of the selected species were obtained from the Bako Agriculture Research Center (BARC) and the Forestry Research Center (FRC). After acquiring the seeds, necessary seed dormancy-breaking techniques (mechanical, chemical, and heat scarification) were used before sowing the seeds according to the species and raised in Yabello Pastoral and Dryland Agriculture Research Centre nursery sites in the place where the maximum possible cares were taken. The seedlings in the nursery were watered every day, early in the morning and evening.

2.3.2 Field planting and management

Before field establishment and planting, necessary land preparation, the construction of soil and water conservation, and planting holes were done. Following this, the selected tree species were planted on the field plots in a randomized complete block design with three replications. The experimental field was blocked along the slope to reduce soil variation per site and replicated three times. The selected multipurpose tree species were randomly allocated to the plots for each block to reduce the error of planting the same species on the same line with different slopes within different blocks. To control the edge effects, other trees and shrubs naturally found in and around the experimental field were removed. Plantation plots were neither irrigated nor fertilized however, they were planted in recommended soil and water conservation structures (soil micro basins). A plot size of 10 m x 6 m was used, and the spacing between blocks and plots was 3 m and 2 m, respectively. The spacing between plants was 2.5 m x 2.5 m, consisting of 12 plants over a single plot. In each plot, 12 trees were planted, and the six inner seedlings were taken as a sample for data collection. To reduce the error of initial size variation in seedlings, seedlings with the same sizes (height and RCD) of these species were planted. After planting, the site was protected from grazing and human interference for the duration of the study. The experimental plots were kept free of weeds. After field planting, survival, and growth parameters were taken every year after the main rainy seasons. Survival, height (from ground level to the tip of the plant), diameter at breast height (DBH), and root collar diameter (RCD) were recorded every year from April 2019 G. C up to June 2023 G. C.

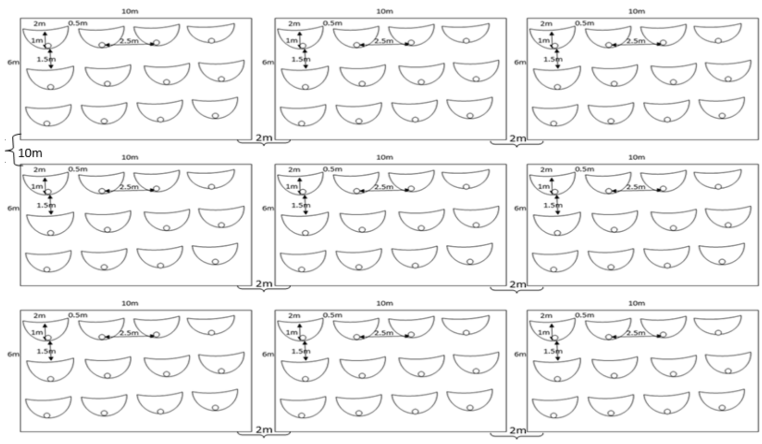

Figure 3. Plantation's layout of multipurpose trees and shrubs.

2.4 Data collection

In this case, data were collected for survival rates and growth parameters such as plant height, root collar diameter, and diameter at breast height for four years. Diameter at breast height (DBH) was collected only after the tree reached 1.3 m in height. Height growth was determined by measuring tape, root collar diameter, and diameter at breast height with a digital caliper.

2.5 Data analysis

The analysis of variance was computed using the SAS statistical software package to test the significant difference among tree species. The least significant difference (LSD) test was employed to separate statistically different means using the software package at the 0.05 level of probability.

3. Results and discussions

3.1 Survival rate of tree species

The survival rate of the multipurpose tree and shrub species selected for this study revealed that there was no significant difference observed (P>0.05) for survival rate in the first year of the experiment (Table 1). However, there was a significant difference (P<0.001) observed in survival rate in the second, third, and fourth years of the experiment. After four years of establishment, *Moringa oleifera* and *Olea europea* attain the highest mean values of survival percentages 77.78% and 83.33% respectively. This suggests that the condition of the study area matches well with the environmental requirements of these species. The finding was similar to the study, which reported that in the fourth year, a higher survival rate (60.12%) was observed for *Moringa oleifera* in the Babille district [21]. Another study also stated that *Moringa oleifera* showed good survival rates, with mean values of 100% at Bako conditions [22]. The findings verified a study by [23] that stated that the moringa species are among the more drought-resistant plants. This implies that *Moringa oleifera* and *Olea europea* were found to be highly resistant to the moisture stress of the study area.

On the other hand, *Calliandra calothyrsus* had the lowest survival rates (91.67%, 63.89%, 36.11%, and 22.22%) over the entire experimental period. The result was also similar to the study, which reported that *Calliandra calothyrsus* had the lowest survival rates (83.89%, 52.78%, and 11.11%) over a three-year experimental period at Dello-Menna District [24]. The lower survival rates of *Calliandra calothyrsus are attributed* to their suitability for fodder production. As a result of this fact, the seedlings of this species were adversely attacked by wild animals during the experimental period. Moreover, the long dry season, which extended for the last four seasons in the study area, clearly explains the low survival rate of the seedlings. Thus, during the assessment period, the mortality of the seedlings was subjectively attributable to abiotic factors such as drought and moisture stress and biotic problems like wild animals. Consequently, the environmental condition of Yabello may not be suitable for *Calliandra calothyrsus*. Generally, the trend of survival rate for all tree species (*Moringa oleifera, Olea europea,* and *Calliandra calothyrsus*) showed a declining trend for the survival rate for the entire assessment study period.

Table 1. Survival rate of tree species within different year intervals

Tree species	Mean survival rate across the year (%)			
	year I	year II	year III	year IV
Olea europea	100	94.45a	86.11a	83.33a
Moringa oleifera	100	88.89a	86.11a	77.78a
Calliandra calothyrsus	91.67	63.89b	36.11b	22.22b
LSD (0.05)	NS	9.62	16.65	12.40
CV (%)	4.95	5.84	12.00	10.16
Mean	97.22	82.41	69.44	61.11
P value	0.1251	0.0005	0.0005	0.0001

Notes. LSD = Least Significant Difference, CV = Coefficient of Variation.
NB: Means in columns with the same letters are not significantly different.

3.2 Plant height

The result revealed that the mean height of each species over the years of the study period was shown (Table 2). Hence, the plant heights of *Olea europea, Moringa oleifera*, and *Calliandra calothyrsus were* 1.48 m, 3.24 m, and 2.01 m respectively. The study was in line with the findings of [25] reported that the height of *Moringa oleifera* was 2.917m in Babille district, east Hararghe. Likewise, the study from [22] also reported that the height of *Moringa oleifera* was 3.97 m in Bako conditions. Another finding also stated that the height of *Calliandra calothyrsus* is 0.371 m in the Dello-Menna District of Bale Zone [24].

Similarly, it also stated that apart from indicating productivity, height may also be seen as a measure of the adaptability of trees to the environment, as tall trees are usually better adapted to the site than short trees [26]. Moringa species could also play a great role in the rehabilitation process, especially during periods of drought or in areas where nutrient resources are not available. Several similar studies also showed that the fast growth of seedlings is an important indicator in terms of determining the situation of growth response, especially in the first growing period, and it is commonly assumed that the early fast growth rates of tropical trees reflect the productivity status of the species [27]. This might be attributed to the environmental requirements of the species and/or their genetic superiority.

Table 2. Tree height of tree species within different year intervals

Tree species	Mean plant height across the year (m)			
	year I	year II	year III	year IV
Olea europea	0.75	1.05	1.26	1.48
Moringa oleifera	1.14	1.60	2.21	3.24
Calliandra calothyrsus	0.75	1.13	1.54	2.01

3.3 Diameter at breast height (DBH)

As shown in Table 3, all the planted seedlings did not reach 1.3 m in height during the first two years of the study, and the diameter at breast height was recorded for the third and fourth years of the experiment. Following this, the diameter at breast height of *Olea europea*, *Moringa oleifera*, and *Calliandra calothyrsus* in the final year of the study period were 1.94 cm, 3.72 cm, and 2.12 cm respectively. The result was similar to the findings of [25] reported that the DBH of *Moringa oleifera* was 2.85 cm in Babille district, east Hararghe, and DBH of *Moringa oleifera* was 4.92 cm in Bako conditions [22].

Table 3. Diameter at breast height (cm) of tree species within different year intervals

Tree species	Mean diameter at breast height across year (cm)	
	year III	**year IV**
Olea europea	1.52	1.94
Moringa oleifera	2.30	3.72
Calliandra calothyrsus	1.55	2.12

3.4 Root collar diameter

The root collar diameter of the species was increased with the increase of the study years (Table 4). Accordingly, the root collar diameter of *Olea europea, Moringa oleifera, and Calliandra calothyrsus* tree species was 2.67 cm, 4.84 cm, and 2.15 cm respectively. The result was similar to the findings of [25] reported that the RCD of *Moringa oleifera* was 4 cm in Babille district, east Hararghe. Another study from [22] reported that the RCD of *Moringa oleifera* was 4.75 cm in Bako conditions. Similar studies from [24] also stated that the RCD of *Calliandra calothyrsus* was 2.96 cm in the Dello-Menna District of Bale Zone.

Table 4. Root collar diameter (cm) of tree species within different year intervals

Tree species	Mean root collar diameter across the year (cm)			
	year I	**year II**	**year III**	**year IV**
Olea europea	1.02	1.44	2.19	2.67
Moringa oleifera	1.80	3.22	3.59	4.84
Calliandra calothyrsus	1.05	1.62	1.98	2.15

Figure 4. Trees on the field (Source: picture by the first author: Sisay Taye).

4. Conclusions and recommendations

The experiment was conducted for four consecutive years to evaluate the adaptation and growth performance of three multipurpose agroforestry tree species at Yabello Agriculture Research Center, on-station, for 2019-2023 G. C. The results indicated that there was a significant effect among tree species on survival rate. The result revealed that the survival rate of *Olea europea* was the highest, followed by *Moringa oleifera* while *Calliandra calothyrsus* showed a poor survival rate. Thus, poor survival rate and growth performance might be explained as responses to site conditions, drought, and wild animal attacks.

Generally, results on growth performance showed that *Moringa oleifera* and *Olea europea* had better performance than *Calliandra calothyrsus*. Therefore, planting these better-performing multipurpose tree species and increasing their promotion as agroforestry practices were recommended as important for forage (fodder), soil conservation, shading, and general multifunction purposes in the area.

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