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Growth Performance Evaluation of Multipurpose Tree Species under Dire Dawa Administration and Harari People Regional State Condition, Eastern Ethiopia

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Abstract

Tree growth is a function of the genetic potential of the species and environmental conditions. Hence, before introducing any species to a given agro ecology there is always a need for a well conducted field trial for matching species to a particular site. A study was conducted to evaluate adaptation and growth performance of five agro forestry tree species at Dire Dawa Administration; Adada2 and Harari Region; Erer dodota for three years (June 2016 - June 2019). Five agroforestry tree species (*Sesbania sesban, Moringa oliefera, Gravilea robusta, Azadarichta indica and Leuceana leucocephala*) were compared in randomized complete block design with three replications. Data on growth parameters, diameter, plant height and survival rate were measured and recorded at interval of three months. Results revealed that there were highly significant ($p<0.05$) variations among tree species in height growth, root collar diameter development, diameter at breast height and survival rate at both study areas. This could be due to environmental factor and/or genetic potential of the species, which generally govern the growth of a given species. Among the species tasted, *Moringa oliefera* showed the highest performance followed by *Azadarichta indica*, *Sesbania sesban* and *Leuceana leucocephala* in terms of height growth, root collar diameter and diameter at breast height at both Dire Dawa Administration ad Harari Region. After three years of establishment, *Moringa oliefera, Azadarichta indica, Sesbania sesban* and *Leuceana leucocephala* showed the highest mean survival rate at both study areas. Hence it can be inferred that the conditions of Dire Dawa Administration and Harari Region matched with the environmental requirement of those tree species. On the other hand, species of Gravilea robusta showed lowest performance at both study areas. Thus, the long dry season, which extended from eight to ten months in the study area, clearly explains the poor survival and growth response in some of the species. Generally, these findings may help forest and agroforestry managers to properly allocate species into the site that grow and adapt well. Further testing of provenances of the best performing species is recommended to select the most adaptable ones for such areas for future agroforestry practices at wider scale; on which success of agroforestry practices and forest plantations depend.

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Keywords

Agroforestry, diameter at breast height, height growth, root collar diameter.

Introduction

Land degradation in Ethiopia is a major problem due to a number of factors. One of the important causes is the removal of forest and vegetative cover as a result of increased human population leading to high demand for forest products and land for expanding the agricultural activities (Demel *et al.,* 2001). Consequently; these areas

are now characterized by loss of soil fertility and soil erosion problems. Eastern Ethiopia particularly, East Hararghe high land is well known by vegetation cover and most of the surrounding area is covered by forests comprised of a rich mixture of woody species (Abebe *et al.,* 2000). In spite of the importance of forest ecosystem to the livelihoods of the people in the area, the forest is dwindling from time to time due to high exploitation of woody and non-woody products. Rapid deforestation caused by an escalating demand for fuel wood expansion for agriculture has brought an ever-increasing pressure on native woodland species (Mebrate *et al.,* 2004).

If no remedial action is taken, this will cause severe impact on agricultural productivity leading to energy poverty and environmental degradation. Frequent and severe droughts often present a serious threat for millions of lives (Brockerhoff, 2008), which have occurred once in a decade in the 1970s and 1980s. Shortages of animal feed and biomass energy are also such an unsustainable use of natural resources Currently, biomass energy constitutes 88.7% of all energy consumed in Ethiopia which is mainly derived from the woody biomass resources (forests, woodlands, shrub lands, planted trees, agro forests). Agro forestry system has much potential for supplying fodder, poles, farm equipment, fuel wood and agricultural improvements (Abebe, 2000).

Multipurpose tree and shrubs species (MPTS) play a considerable role in addressing such multifaceted demands in the mixed crop-livestock production system (Betre *et al.,* 2000). They have the ability to fit into the farming system to be used as a source of manure, mulch, soil conservation, forage, fuel wood, farm implements and other like shade and shelter (Kahsay *et al.,* 2001).However, each/shrubs species has its own biotic and abiotic factors in which it performs to its maximum potential. It has specific edaphic and climatic requirements (Abebe *et al.,* 2000). Some possible research needs include soil-plant interactions, soil fertility and N-fixation studies on wide range of species, crop tree yield studies and optimum tree density, socioeconomic studies, and species selection and screening including seed tests, establishment, and management. In Babile district, farmers practice on farm and home garden for economic, social and environmental benefits (Getahun *et al.,* 2014). These traditional agroforestry practices could be intensified by using fast growing multipurpose tree species (MPTS) to satisfy the demands of the growing population. Thus, before introducing any species to a given agro ecology, there is always a need for a well conducted field trial for matching of the species/provenance to a particular site (Mebrate *et al.,* 2004). The first trial should be a species screening trial that will test the survival and early growth of the species in one to three years. Deciding what species to plant in any agroforestry system to meet the intended objectives require a well- conducted field trial to match a species to a particular site.

Many species screening experiments have been conducted in different parts of country (Betre Alemu *et al.,* 2000). However information is scarce at Dire Dawa Administration and Harari Region to recommend promising multipurpose tree and shrubs species for use in agro forestry practices. Hence, there is a need to investigate adaptable and promising tree and shrubs species in the areas. Therefore this trail was designed to evaluate the adaptation and growth performance of five agroforestry tree species to Dire Dawa Administration; Adada2 and Harari Region: Erer Dodota conditions and sites of similar agro-ecology.

Materials and Methods

Description of the study area

The experiment was conducted in Dire Dawa Administration, Biyyo Awalle Cluster in Adada2 on farmer land and Harari People Regional State, Erer Waldea District in Erer Dodota on Farmers Training Center (FTC). The study area geographically lies at an altitude of 1300-1800 m. a. s l which is lowland. The area was characterized by very short rainy season of 3 to 4 months (single quarter of the year), with all its intermittent condition and erratic distribution which may affect the growth and performance of trees. The soil is clay loam in texture and medium in organic matter content and high in exchangeable potassium.

Generally, the pH of the soil (7.94) is in the optimum range for growth of most plants. The experiment was also conducted at Dire Dawa Administration; Biyyo Awalle cluster; Adada2 Peasant Association (PA) which is located at $41^0$51'E longitude, $9^0$31'N latitude and an altitude of 1160 m a. s. l. It is situated in the semi-arid tropical belts of eastern Ethiopia at the middle of the eastern Hararghe mountain chain. The area experiences a bimodal type of rainfall with the mean annual precipitation of 556.5 mm. The mean annual maximum and minimum temperatures vary from 28.3^0C to 34.9^0C and 15.1^0C to 22.7^0C, respectively. Soil type of the experimental site is clay loam. The area is classified under semi-arid climate (Adnew, 2005).

Seeds source

Seeds of five agroforestry tree species were obtained from Central Ethiopian Environment and Forestry Research Center.

Treatments and experimental design

Seedlings of tree species *(Sesbania sesban, Gravilea robusta, Azadarichta indica, Leuceana leucocephala and Moringa oliefera*) were raised directly into polythene tubes at Adada2 and Erer nursery sites with the recommendation of nursery activities. Seedlings with the same age of these tree species were planted in the field in June, 2016 at both experiment sites using a randomized complete block design with three replications. Each replication had five experimental plots, representing five tree species of nine seedlings each. The spacing between blocks and plots were 2.5 m and 2 m; respectively and the space between trees in a plot was 2 m. After planting, the sites were protected from grazing and human interferences. Plantation plots were neither irrigated nor fertilized. Survival rate, plant height (from ground level to the tip of the plant), diameter at breast height (DBH) and root collar diameter (RCD) were recorded every three months from June 2016 - June, 2019.

Data Collection

In order to fit the given objectives, data were collected on growth and adaptation parameters such as Plant height, root collar diameter, diameter at breast height and survival rate for the three years at interval of three months. Root collar diameter were collected only up to the tree reaches 1.3 meters in height and diameter at breast height were collected after tree reaches 1.3 m whereas plant height and survival rate were up to the end of the period of the activity. Height growth was determined by using measuring tape and root collar diameter and diameter at breast height by digital caliper.

Data Analysis

Analysis of variance was computed using Genstat software (18^{th} edition) package to test the significant difference among tree species. Least significant different (LSD) test was employed to separate statistically different means using the software package at 0.05 level of probability.

Results and Discussion

Survival rate

Among tree species, differences were highly significant ($p<0.05$) for survival rate as well (Table 2 and 3). After three years of establishment, *Moringa olifera* demonstrate the highest survival rate at both experiment sites. Yitebitu, 2004 also reported that *Moringa* species are quite drought resistant species which is similar to the observation of the present study. This can be attributed to the moisture stress experienced, which as Kozlowski *et al.,* (1991) also stated can affect the growth, survival and distribution of forest trees. *Azadarichta indica, Sesbania sesban, Leuceana leucocephala* demonstrated the good survival rate at both Dire Dawa, Adada2 and Harari, Erer Dodota; respectively. Hence, it can be inferred that the condition of Dire Dawa and Harari matched well with the environment requirement of these species. *Gravilea robusta* on the other hand, showed lowest survival rate at both study areas. The long dry season, which extended from seven to nine months in the study areas, clearly explains the low survival of the *Gravilea robusta* seedlings during the experimental period. In the present study, the mortality was subjectively attributable to abiotic factors such as drought and moisture stress during the initial growth from October to June, although biotic problems like termites were also experienced during the assessment period at both study area. Thus, the environmental condition of Dire Dawa and Harari not suitable for *Gravilea robusta.* Soil and below ground competition are also other factors that influence the growth and survival rate (Casper and Jackson, 1997). On the other hand, *Moringa oliefera, Azadarichta indica, Sesbania sesban* and *Leuceana leucocephala* were found to be highly resistance to moisture stress in the both Dire Dawa Administration, Adada2 and Harari Region, Erer Dodota. Highly significant variations was among the tree species in survival rate ($p<0.05$) was recorded at all three years of age after transplanting.

Table.1 Details of tree species used in the adaptation trial

Tree species	Family name	Seeds source
Sesbania sesban	Leguminosae	CEFRC
Leuceana leucocephala	Leguminosae	CEFRC
Moringa oliefera	Moringaceae	CEFRC
Azadarichta indica	Meliaceae	CEFRC
Gravilea robusta	Proteaceae	CEFRC

CEEFRC: Central Ethiopian Environment and Forestry Research Center

Table.2 Mean survival rate (%) of agroforestry tree species planted in Biyyo Awalle; Adada2, over three years (2016/17- 2018/19)

Tree species	Stages age of seedling after transplanting		
	Year (2016/17)	Year (2017/18)	Year (2018/19)
Sesbania sesban	86.67[a]	85.00[a]	76.67[a]
Azadarichta indica	89.00[a]	88.33[a]	83.33[a]
Leuceana leucocephala	89.67[a]	80.00[a]	76.67[a]
Moringa oliefera	95.00[a]	90.00[a]	85.00[a]
Gravilea robusta	65.00[b]	42.33[b]	37.00[b]
LSD(0.05)	9.86	12.00	12.67
CV (%)	6.2	8.3	9.4
Mean	85.1	77.1	71.7
P value	<.001	<.001	<.001

N.B. Means in columns with the same letters are not significantly difference using LSD
CV=Coefficient of Variation, LSD= Least Significant Difference

Table.3 Mean survival rate (%) of agroforestry tree species planted in Erer Dodota; Harari Region over three years (2016/17 - 2018/19)

Tree species	Stages age of seedling after transplanting		
	Year (2016/17)	Year (2017/18)	Year (2018/19)
Sesbania sesban	85.67[a]	81.00[a]	72.33[a]
Azadarichta indica	86.67[a]	86.33[a]	79.33[a]
Leuceana leucocephala	88.33[a]	78.33[a]	72.00[a]
Moringa oliefera	92.67[a]	89.00[a]	81.33[a]
Gravilea robusta	64.00[b]	41.33[b]	34.33[b]
LSD(0.05)	9.97	12.80	11.09
CV (%)	6.3	9.0	8.7
Mean	83.5	75.2	67.9
P value	<.001	<.001	<.001

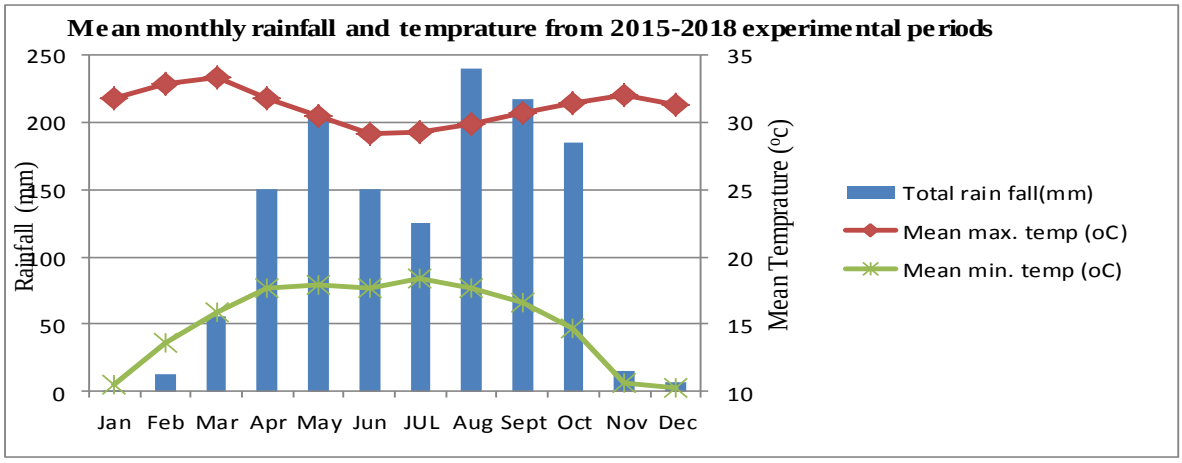
N.B. Means in columns with the same letters are not significantly difference using LSD
CV=Coefficient of Variation, LSD= Least Significant Difference

Table.4 The mean of Plant height, survival rate, diameter at breast height and root collar diameter of agroforestry tree species for three years (2016/17 – 2018/19) at Dire Dawa Administration; Adada2.

Tree species	Survival rate (%)	Plant height(m)	Root collar diameter (cm)	Diameter at breast height (cm)
Sesbania sesban	83.00[a]	3.383[c]	7.750[b]	4.867[a]
Azadarichta indica	87.00[a]	4.167[a]	10.647[a]	5.133[a]
Leuceana leucocephala	82.33[a]	3.467[bc]	8.067[b]	4.467[a]
Moringa oliefera	90.33[a]	3.900[ab]	9.933[a]	4.583[a]
Gravilea robusta	48.00[b]	1.503[d]	4.913[c]	3.247[b]
LSD(0.05)	8.51	0.4806	1.182	0.769
CV (%)	5.8	7.8	7.6	9.2
Mean	78.1	3.284	8.26	4.46
P value	<.001	<.001	<.001	0.004

N.B.: Means with the same letters are not significantly different using LSD
CV=Coefficient of Variation; LSD= Least Significant Difference

Fig.1 Mean monthly rainfall and temperature during experimental period at Harari Region and Dire Dawa Administration respectively based on meteorological data nearest to the study areas.



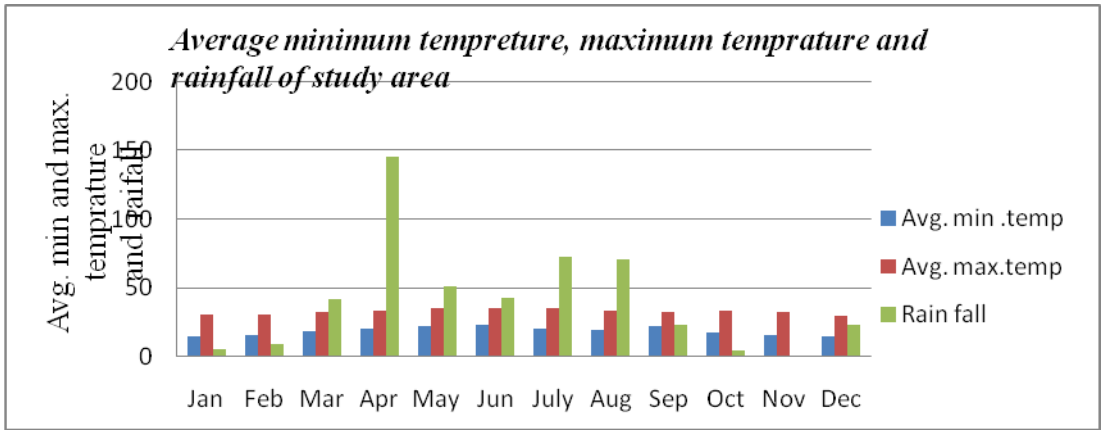
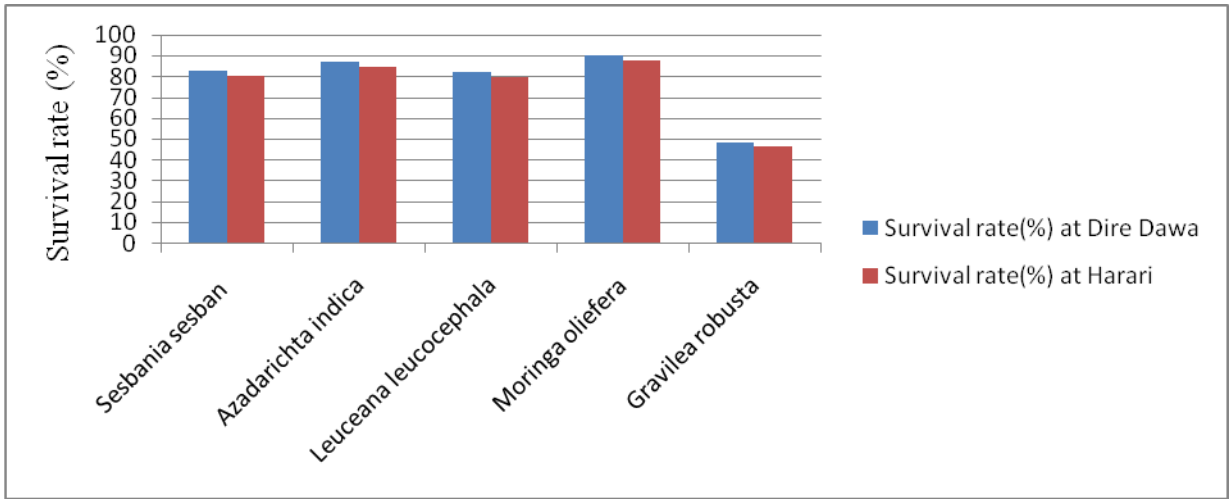


Table.5 The mean of Plant height, survival rate, diameter at breast height and root collar diameter of agroforestry tree species for three years (2016/17 - 2018/19) at Harari Region; Erer Dodota.

Tree species	Survival rate (%)	Plant height (m)	Root collar diameter (cm)	Diameter at breast height (cm)
Sesbania sesban	80.00[b]	3.167[b]	7.450[b]	4.533[a]
Azadarichta indica	84.33[ab]	3.917[a]	10.150[a]	4.883[a]
Leuceana leucocephala	79.67[b]	3.217[b]	7.883[b]	4.267[a]
Moringa oliefera	87.67[a]	3.500[ab]	9.667[a]	4.400[a]
Gravilea robusta	46.33[c]	1.490[c]	4.617[c]	3.083[b]
LSD(0.05)	7.078	0.5283	1.052	0.885
CV (%)	5.0	9.2	7.0	11.1
Mean	75.60	3.058	7.95	4.23
P value	<.001	<.001	<.001	0.013

N.B.: Means with the same letters are not significantly different using LSD
CV=Coefficient of Variation; LSD= Least Significant Difference

Fig.2 Means of survival rate (%) of *Gravilea robusta, Azadarichta indica, Leuceana leucocephala, Moringa oliefera* and *Sesbania sesban* through sequential periods from June 2016 to June 2019 at Dire Dawa Administration and Harari People Regional State.



Height growth

Analysis of variance revealed that variations in height among tree species were highly significant ($p<0.05$) after three years of age at both study areas. Height growth trend (Table 4 and 5) showed that *Azadarichta indica* and *Moringa oliefera* were the tallest trees, followed by *Sesbania sesban, Leuceana leucocephala* but *Gravilea robusta* showed the shortest tree at both Dire Dawa and Harari Region's environmental conditions.

Result on growth performance also showed that *Azadarichta indica* and *Moringa oliefera* were higher than the other species at both study areas. *Sesbania sesban* and *Leuceana leucocephala* also showed good growth performance at both study areas. Similarly, Raebild *et al.,* (2003) 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 usually being better adapted to the site than short trees(Cossalter,1987). *Moringa* species could also play a great importance in the rehabilitation process especially during periods of drought or in areas where nutrient resources are not available. Several similar studies also showed that fast growth of seedling 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 productivity status of the trees (Baris and Ertenkin, 2010).

Diameter Growth

As depicted in Table 4 and 5, there is significant variation among tree species in diameter growth at both study areas. Diameter growth trend (Table 4 and 5) shows that the highest root collar diameter was recorded for *Azadarichta indica* followed by *Moringa oliefera, Sesbania sesban* and *Leuceana leucocephala* but the lowest root collar diameter was recorded for *Gravilea robusta* at Dire Dawa and Harari environment condition. Growth in diameter at breast height also highly significant ($p<0.05$) for the five agroforestry tree species at both study areas. The difference in growth of diameter at breast height (1.3 m) above the ground of tree species *Azadarichta indica, Moringa oliefera, Sesbania sesban* and *Leuceana leucocephala* showed highest diameter at breast height(DBH) within three years data records at both Dire Dawa Administration, Adada2 and Harari Region, Erer Dodota environment condition. On the other hand *Gravilea robusta* showed the lowest diameter at breast height growth at both study areas.

The experiment was conducted for three consecutive years (2016-2019) to evaluate adaptation and growth performance of five agroforestry tree species at Dire Dawa Administration; Adada2 and Harari Region; Erer dodota. The results indicated that there were significant effect among treatments for plant height, survival rate, root collar diameter and diameter at breast height. The result revealed that the survival rate of *Moringa oliefera* was the highest at both experimental sites followed by *Azadarichta indica, Sesbania sesban and Leuceana leucocephala.* While *Gravilea robusta* showed poor survival rate at both study areas. Poor survival rate and growth performance might be attributed to the condition and termite problems of the study areas. *Moringa oliefera, Sesbania sesban, Leuceana leucocephala and Azadarichta indica* were the species attained the highest mean heights, while *Gravilea robusta* had the lowest values at both Harari Region and Dire Dawa Administration. The comparisons between the height and diameter growth average of the species showed that *Azadarichta indica* had the highest mean height followed by *Moringa oliefera, Le*uceana leucocephala and *Sesbania sesban* at both environment condition study areas.

Generally, results on growth performance showed that *Azadarichta indica, Sesbania sesban, Moringa oliefera and Leuceana leucocephala* had better performance than *Gravilea robusta at* both Harari Region and Dire Dawa Administration. Accordingly, those tree species which had better performance were recommended for further demonstration and evaluation in both study areas and similar agro ecologies. Therefore; planting of these better performing tree species and increase their promotion as agro forestry practices were recommended for soil conservation, shading, forage, fuel wood and in general multifunction purposes in the areas. Finally, on farm evaluation of *Sesbania sesban, Leuceana leucocephala* and *Moringa oliefera*, and their contribution to soil fertility improvement and crop yield either in inter-cropping or biomass transfer has to be further investigated to make use of their potential in agro forestry practices.

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