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Adaptation and Growth Performance Evaluation of Selected Agroforestry Tree Species at Fedis and Metta Districts of East Hararghe Zone, Ethiopia

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Abstract- *Multipurpose tree and shrub species are essential for meeting the diverse needs of mixed crop-livestock production systems. This study evaluated the adaptation and growth performance of four agroforestry tree species—Moringa tenophylla, Acacia albida, Acacia saligna, and Casuarina equisetifolia—in the Fedis and Meta districts of Ethiopia. The experiment employed a randomized complete block design (RCBD) with three replications. Key growth parameters measured included diameter, plant height, and survival rate. The results indicated a highly significant ($p<0.05$) variation in survival rates among the tree species. In Fedis, A. saligna, M. stenophthalma, A. albida, and C. equistifolia achieved high survival rates, while M. stenophthalma had a low survival rate at the Meta site. For plant height, root collar diameter, and diameter at breast height, A. saligna and C. equisetifolia exhibited the greatest height growth, followed by M. stenophylla, whereas A. albida showed lower height growth at the Fedis site. At the Meta site, A. saligna and C. equisetifolia again demonstrated superior height growth, followed by A. albida, while M. stenophthalma showed poor height growth. Overall, A. saligna, A. albida, and C. equistifolia outperformed M. stenophthalma in growth performance. These findings indicate that the better-performing species should be prioritized for further demonstration and evaluation in the study area and similar agroecological zones. Adoption and planting of these species as agroforestry practices are recommended for multifunctional purposes in the region.*

Keywords: ***Survival rate, Agroforestry, Multipurpose trees, Climate change, Growth***

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INTRODUCTION

The Eastern Ethiopian highlands are characterized by diverse vegetation and extensive forest cover, comprising a wide range of woody species (Muleta, 2017). However, these forests are declining due to excessive exploitation of both woody and non-woody resources. Accelerated deforestation, primarily driven by increased demand for fuelwood and agricultural expansion, has placed considerable pressure on native woodland species (Danlami, 2018). Without effective intervention, these trends are expected to lead to reduced agricultural productivity, energy shortages, and environmental degradation. Frequent and severe droughts threaten the lives of millions of people in Ethiopia (Mani *et al*., 2024). During the 1970s and 1980s, such droughts occurred approximately once per decade. Unsustainable use of natural resources has resulted in shortages of animal feed and biomass energy. Biomass currently accounts for 88.7% of total energy consumption in Ethiopia, primarily from woody biomass derived from forests, woodlands, shrublands, planted trees, and agroforests. Agroforestry systems offer significant potential to supply fodder, poles, farm equipment, fuelwood, and other agricultural benefits (Muleta, 2017). Multipurpose tree and shrub species (MPTS) are essential for meeting these diverse needs within mixed crop-livestock production systems (BISHT *et al.*, 2025). These species support farming systems by providing manure, mulch, soil conservation, forage, fuelwood, farm implements, shade, and shelter (Ibeawuchi *et al*., 2015). Farmers in East Hararghe practice on-farm and home garden agroforestry, which provides economic, social, and environmental benefits (Musa et al., 2022). Intensifying these traditional practices by incorporating fast-growing multipurpose tree species (MPTS) can help meet the demands of a growing population. Before introducing new species to a specific agroecological zone, comprehensive field trials are necessary to ensure appropriate species-site matching (Kumar et al., 2018). Species screening trials, typically lasting one to three years, evaluate survival and early growth. While numerous screening experiments have been conducted across various regions of Ethiopia (Dubale et al., 2023), limited information is available on suitable multipurpose tree and shrub species for agroforestry in the Fedis and Metta districts. Therefore, identifying adaptable and promising species for these areas is essential. This study evaluated the adaptation and growth performance of four multipurpose tree species to identify early-performing exotic and indigenous species suitable for Fedis, Metta, and similar agroecological zones.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted in the Fedis and Metta Districts of the East Hararghe Zone, Oromia. Fedis district is one of the twenty in the zone. It is located 550 km east of Addis Ababa and about 24 km from Harar town to the south. The district's geographical location is 9°14'0" N and 42°19'62" E.

Figure 1: Map of study areas

The area's altitude ranges from 1200 to 2100 m a.s.l. The district receives a mean annual rainfall of 650 to 850 mm; the average temperature is 25°C to 30°C. The district has two basic agro-climatic conditions: midland (39%) and lowland (61%). It contains 19 rural PAs and two rural towns. Total population is 149,664, with 76,182 males (50.9%) and 73,482 females (49.09%) (Derribew, 2013). The average family size is estimated at 6 per rural household and 4 per urban household. The average landholding per farm family is 0.73 hectares. The district's total area is 110,502 hectares. Agriculture is characterized by small-scale, mixed subsistence farming, with livestock production integral to it. Meta district is one of the twenty districts in the East Hararghe zone. It is located 532 km east of Addis Ababa and about 84 km north of Harar town. The district's geographic coordinates are 9°14'60" N and 41°24'59" E. The altitude ranges from 1400 to 2850 m a.s.l. Mean annual rainfall ranges from 350 to 900 mm. The average temperature is 17°C to 27°C. The district has three agro-climatic zones: highland (28%), midland (44%), and lowland (28%). It includes 22 rural PAs. Meta has a total population of 252,185 (127,311 males; 124,874 females) (Zemedu, 2014). The average family size is 7 in rural households and 3 in urban households. Average landholding is 0.74 hectares per farm family. Agriculture is small-scale, subsistence-based mixed farming, and livestock production is integral.

Treatments and Experimental Design

The activity was conducted in the Fedis and Metta Districts, the Boko Research Station, and Metta TVET College. Seeds of Casuarina equisetifolia, Moringa stenopetala, Acacia albida, and Albizia gummifera were purchased from the Central Ethiopian Environment and Forestry Research Center (EEFRC) and Ethiopian Biodiversity Institute (EBI). Seedlings were raised in polythene tubes at the Fedis nursery near the study area. Standard nursery practices were followed. In June 2019, seedlings were planted at the experimental sites using a randomized complete block design (RCBD) with three replications. Each replication included four plots—one per tree species—each with nine seedlings. Blocks, plots, and seedlings were spaced 2 m apart.

Method of Data Collection: Data were collected on growth and adaptation parameters, including survival rate, plant height, root collar diameter, and diameter at breast height, over a four-year period at three-month intervals. Tree height and survival rate were recorded at three-month intervals throughout the study. Root collar diameter was measured until trees reached 1.3 meters in height, after which the diameter at breast height was measured. Plant height was determined using a measuring tape, while root collar diameter and diameter at breast height were measured with a digital caliper.

Method of Data Analysis: Analysis of variance was performed using SAS software to test for significant differences among tree species. The least significant difference (LSD) test was employed to separate statistically different means using the software package at a 0.05 level of probability.

RESULTS AND DISCUSSION

Survival rate at Fedis and Metta Districts across a year : Analysis of variance indicated a highly significant variation in survival rate among the tree species ($P<0.05$). At Bokko station, *A. albida, A. saligna, C. equistifolia, and M. stenophatala demonstrated strong performance. At the Metta site, A. albida, A. saligna, and C. equistifolia exhibited higher survival rates compared to M. stenophthalma. U*nder Fedis conditions, survival rates were approximately 84.01% for A. albida, 88.33% for A. saligna, 80.33% for *C. equistifolia, and 86.8% for M. stenophthalma, indicating favorable adaptation. In Metta, A. albida, A. saligna, and C. equistifolia achieved survival rates of 83.35%, 92.09%, and 84.01%, respectively, while M. stenophthalma had the lowest survival rate at 35.93%. These results suggest that the environmental conditions of Fedis and Metta are well-suited to the better-performing species. Previous studies have also identified Moringaolifera, A. saligna,* and *A. albida* as drought-resistant species (Moges & Tsegaye, 2004). The poor performance of M. stenophatala at Metta is likely due to unsuitable environmental factors. A general decline in survival rate was observed for all species over the assessment period.

Table (1). The mean survival rate (%) of the species over the years/months of the study period

Tree species	Year I(12 month)	Year I(12 month)	Year II(24 month)	Year II(24 month)	Year III(36 month)	Year III(36 month)	Year IV(48 month)	Year IV(48 month)	Average mean	Average mean
Tree species	Fadis	Meta	Fadis	Meta	Fadis	Meta	Fadis	Meta	Fadis	Meta
A. albida	**89.30b**	**89.50b**	**83.55b**	**83.30b**	82.53b	**82.54b**	**80.67b**	78.07b	**84.01b**	**83.35b**
A. saligna	**94.38a**	**100.0a**	**89.33b**	90.16a	**85.60b**	**89.60b**	**84.00b**	**88.60b**	**88.33a**	**92.09a**
C. equistifolia	**85.51b**	**86.13b**	**81.07b**	**85.87b**	**80.37b**	**84.32b**	**78.37b**	**80.12b**	**80.33b**	**84.11b**
M.stenophatala	**92.38a**	**42.33c**	**85.99b**	**38.33c**	**85.60b**	**34.33c**	**83.33b**	**27.77c**	**86.83a**	**35.93c**
CV (%)	1.20	2.30	1.70	3.00	2.40	2.40	8.18	15.90	7.16	9.18
LSD(0.05)	2.11	3.54	2.80	4.40	3.75	3.40	20.93	11.20	19.73	22.73

N/B: Means in columns with the same letters are not significantly different, LSD= Least significant difference. Results from the study show that, except for the site significant difference ($p<0.05$), the survival rate of M. stenophthalma was not significantly different (Table 1). During the study period, *A. albida, A. saligna, and C. equistifolia attained* the highest mean values, ranging from 80.33% to 92.01%. This indicated that the condition of the study area matched well with the environmental requirements of these species. In contrast, *M. stenophthalma had* the lowest survival rates over the entire experimental period under the Metta condition.

Tree Height, Root Collar Diameter, and Diameter at Breast Height at Fedis and Metta districts

Tree height, root collar diameter, and diameter at breast height were measured to assess the adaptation and growth performance of the selected tree species. These parameters were evaluated independently at both locations to determine variations among the species. Accordingly, the height growth of *F. albida* (1.42m),*A. saligna* (3.24m),*C. equistifolia* (3.22m) and *M. stenophylla* (2.69m) were measured, root collar diameter growth of *A. albida* (2.78cm), *A. saligna*(4.01), *C. equistifolia* (3.89cm), and *M. stenophylla* (3.65cm) were measured, and diameter at breast heightgrowth of *F. albida* (1.21cm),*A. Saligna* (3.22cm), *C. equistifolia* (3.42cm), and *M. stenophthalma* (2.22cm) were measured in the Fedis district. Height growth of *A. albida* (1.11),*A. Saligna* (3.76m), *C. equistifolia* (3.26m), and *M. stenophylla* (1.01m) were measured, and root collar diameter growth of *F. albida* (2.53cm), *A. saligna* (4.10cm), *C. equistifolia* (4.05cm), and *M. stenophylla* (1.66cm) were measured, and diameter at breast heightgrowth of *A. albida* (1.12cm),*A. Saligna* (3.31cm), *C. equistifolia* (3.07cm), and *M. stenophatala* (0.32cm) were measured at the Metta district. Raebild*et al.* (2003) stated that tree growth and productivity, as well as height, may also be seen as measures of the adaptability of trees to the environment, as tall trees are usually better adapted to the site than short trees (Table 2). Accordingly, *A. albida (*1.42m) is the shortest tree in the Fedis district. The tree species with the greatest root collar diameter were those, that grew tallest. Similarly, species with lower height growth had lower root collar diameter growth (Raebildt et *al.,* 2003).

Table (2). Average mean growth performance of tree species in plant height (m), root collar diameter (cm), and diameter at breast height (cm) across the experimental period

Types of Trees	Others growth parameters	Others growth parameters	Others growth parameters	Others growth parameters	Others growth parameters	Others growth parameters
Types of Trees	Fedis district	Fedis district	Fedis district	Meta district	Meta district	Meta district
Types of Trees	Height(m)	RCD(cm)	DBH(cm)	Height(m)	RCD(cm)	DBH(cm)
A. albida	**1.42c**	**2.78c**	**1.21c**	**1.12b**	**2.53b**	**1.11b**
A .saligna	**3.24a**	**4.01a**	**3.22a**	**3.76a**	**4.10a**	**3.31a**

C. equistifolia	**3.22a**	**3.89b**	**3.42a**	**3.26a**	**4.05a**	**3.07a**
M. stenophatala	**2.69b**	**3.65b**	**2.22b**	**1.01b**	**1.66c**	**0.32c**
CV (%)	5.53	8.42	24.35	6.37	7.37	22.40
LSD(0.05)	2.40	2.83	3.75	1.36	4.40	3.40

Note: RCD- Root Collar Diameter, DBH- Diameter at Breast height

Description of the Selected Tree Species

Faidherbiaalbida

Faidherbiaalbida is a member of the family Fabaceae, which is one of the largest thorn trees, reaching 30 m in height, with spreading branches and a rounded crown. The basal thickening is a characteristic distinguishing this species from the acacias with long thorns. Agro-ecological zones of Faidherbia albida are dry and moist kolla and dry weynadega. Faidherbia albida grows at an altitude of 270-2700 m, a mean annual temperature of 18-300C, a mean annual rainfall of 250-1200 mm, and soil type of coarse-textured, well-drained alluvial soils. It tolerates seasonal waterlogging and salinity but cannot withstand heavy clayey soils. During the dry season, people eat the seeds of Faidherbia albida. Products of Faidherbia albida include firewood, timber, farm tools, household tools, medicine, and fodder, and most species are scattered in crop land, homesteads, boundary/live fences, and for soil conservation. Ecological Services from tree species include dead fence, shade, erosion control, improved soil fertility through nitrogen fixation, and windbreak. The origin of *Faidherbiaalbida*is native (Ereso , 2019).

Acacia saligna

Acacia saligna is a member of the family Fabaceae, a dense, multi-stemmed, thornless, spreading shrub or a single-stemmed, small tree up to 9 m in height. The bark is smooth and grey to red-brown on the branches, becoming dark grey and fissured with age. Agro ecological zone of *Acacia saligna,* dry and moist kolla, and dry weynadega.*Acacia saligna* grows at altitudes of 0-500 m, with mean annual temperatures of 23-360 °C, mean annual rainfall of 250-600 mm, and soil types of light-to-medium loams and well-drained soils. Income from Acacia saligna includes firewood, timber for construction, fodder, and gums/resins*. The niche* of *Acacia saligna* is scattered on crop land, in homesteads, boundary/live fence, Woodlot, Soil conservation, and riparian areas. Ecological Services: live fence, shade, erosion control, soil fertility improvement through nitrogen-fixing, and wind break. *Acacia saligna* is an exotic species. The trees are susceptible to white scale insects, which attack leaves and stems (Gebretsion et *al*., 2019).

Casuarina equisetifolia

Casuarina equisetifolia is a member of the Casuarinaceae family, an evergreen, dioecious or monoecious tree 6- 35 (60) m tall, with a finely branched crown. Crown shape is initially conical but tends to flatten with age. Trunk straight, cylindrical, usually branchless for up to 10 m, up to 100 cm in diameter. The climate in its natural range is semi-arid to sub-humid (dry, moist, and wet kolla and wenyadega). Altitude: 0-1400m, mean annual temperature 10-350 °C, mean annual rainfall 200-3 500 mm, soils are invariably well-drained and rather coarse textured, principally sands and sand loams. C. equisetifolia wood is hard to very hard and strong for timber use. Since it is salt-tolerant and grows in sand, C. equisetifolia is used to control erosion along coastlines, estuaries, riverbanks, and waterways. Its general tolerance to strong winds has encouraged its use in protective planting. C. equisetifolia to fix atmospheric nitrogen. With high productivity and properties that enhance soil fertility, C. equisetifolia shows promise as an agroforestry species for arid and semi-arid areas. *Acacia saligna* is an exotic species. C. equisetifolia is only rarely attacked by diseases and pests, unless grown under unfavorable conditions (Bakewell-Stone, 2023).

Moringastenopetala

Moringastenopetala is a member of the Moringaceae family, is 6-12 m tall, has a diameter of 60cm (DBH), and has smooth bark. Ecologically, *Moringastenopetala* grows naturally in a*rid, semi-arid, and semi-humid areas* and is often found in well-drained soils at altitudes of 400-2100 m, with a mean annual temperature 24-300C. The species is quite drought-resistant. It has been found in areas of an annual rainfall ranging from 500 to 1400mm. Cold temperatures are a limiting factor for the cultivation of the species in Ethiopia because it does not tolerate frost. The species has no specific soil requirements, except that it does not grow on waterlogged or swampy soils. The soil pH ranges from acidic to alkaline, but is mostly neutral. The leaves and fruits are eaten as vegetables (food) and are rich in proteins, calcium, and iron, phosphorus, as well as vitamins A and C. Products: fruits, Other foods, firewood, timber for construction, medicine. The use of leaves and pods for animal fodder is currently of

minor importance compared to their use for human consumption. Yet, due to their high protein content, this is a promising potential use. Growing rapidly, these trees have softwood that is not particularly suitable for fuel. The species is grown in mixed multi-storey stands with food crops. *Moringastenopetala* is more resistant to insect pests than other species of its family. Most farmers in its natural range report that they have never seen diseases or pests on this tree (Bania et *al*., 2023).

Table (3). Characteristics of selected tree species

Description	Tree Species	Tree Species	Tree Species	Tree Species
Description	*Acacia albida*	*Acacia saligna*	*Casuarina equisetifolia*	*Moringasteopetala*
Family	Fabaceae	Fabaceae	Casuarinaceae	Moringaceae
Agroecological Zone	Dry and Moist Kolla and Dry WeynaDega	Dry and Moist Kolla and Dry WeynaDega	Dry, moist, and wet Kolla and WenyaDega	Arid, semi-arid and semi-humid areas
Rainfall	250-1200 mm	250-600 mm	200-3 500 mm	500-1400mm
Temperature	18-300C	23-360C	10-350C	24-300C
Altitude	270-2700 m	0-500 m	0-1400 m	400-2100m
Height	30 m in height	up to 9 m in height	6- 35 (60) m tall	6-12 m tall
Products	Firewood, Timber, Farm tools, Household tools, Medicine, Fodder	Income, Firewood, Timber for construction, Fodder, Gums/Resins	Fodder	Fruits, Other Foods, Firewood, Timber for construction, Medicine
Niche	Scattered on crop land, in homestead, boundary/live fence, Soil conservation	Scattered on crop land, in homestead, boundary/live fence, Woodlot, Soil conservation, Riparian areas	Scattered in homestead	Scattered in homestead, Contours/Soil conservation
Ecological Services	Dead fence, Shade, Erosion control, Soil fertility improvement through Nitrogen-fixing, Wind break	live fence, Shade, Erosion control, Soil fertility improvement through Nitrogen-fixing, Wind break	Live fence, Shade, its use in protective planting	Ornamental, Shade. It is a valued ornamental in its natural range.
Growth rate	Fast growing	Fast growing	Fast growing	Fast growing
Soil	Coarse-textured well-drained alluvial soils	light-to-medium loams and well-drained soils	sands and sand loams soils	The species does not have any specific soil requirements, except it does not grow on waterlogged soils.
Origin	Native	Exotic	Exotic	Native

Sources: Bekele-Tesemma, A. (2007).

CONCLUSION AND RECOMMENDATIONS

The results demonstrated significant differences in survival rates among the tree species. Under Fedis conditions, A. saligna, M. stenophatala, A. albida, and C. equistifolia demonstrated strong survival rates. In the Meta district, A. saligna, C. equistifolia, and A. albida outperformed M. stenophthalma, which exhibited poor survival. The low survival and growth performance of *M. stenophthalma may* be attributed to environmental factors such as climate and soil type. For plant height, root collar diameter, and diameter at breast height, A*. saligna and C. equisetifolia were* the

tallest at the Fedis site, followed by *M. stenophylla, while A. Albida had* the shortest height. At the Meta site, A. saligna and C. equistifolia again achieved the greatest height, followed by A. albida, with M. stenophatala being the shortest. Maximum diameters were recorded for A. saligna, followed by C*. equistifolia, M. stenophthalma, and A. albida at Fedis*, and for A. *saligna* and *C. equistifolia,* followed by A. albida and M. stenophthalma at Meta throughout the experimental period.*quistifolia, and M. stenophthalma* demonstrated superior performance and high mean survival rates in the Fedis area, while A. Saligna, A. albida, and C. equistifolia performed best in the Meta district. M. stenophatala exhibited the lowest performance and failed to adapt in Meta. It is recommended to promote and plant the better-performing species as agroforestry practices for soil conservation, shading, forage, fuelwood, and other multifunctional purposes. These species are also suitable for plantation efforts. The authors express gratitude to the Oromia Agricultural Research Institute for financial support. Appreciation is also extended to the Fedis Agricultural Research Center for providing essential research facilities. The contributions of the natural resources research process members are acknowledged for their dedicated efforts in ensuring the project's success. significant efforts in making the project a success.

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