Evaluation on Growth Performance of Moringa Stenopetala Provenance at Daro Lebu and Hawi Gudina Districts, West Hararghe Zone, Oromia, East Ethiopia

Shimelis Dekeba Alemayehu Diriba Mosisa Mezgebu Wasihun Gizaw
Mechara Agricultural Research Center, Mechara, Ethiopia Corresponding Author‘s
Email: shimedekeba@gmail.com, alemayhudiriba@gmail.com

Abstract
*Six Moringa stenopetala provenances (*Abay Filklik, Arbaminch, Gofa, Wolayita, Konso and Babile) *were examined for survival and growth parameters at Daro Lebu district* at Mechara and Hawi Gudina district at Hawi Gudina site July 2019. This study was undertaken with *randomized complete block design with four replications. At age of three year; survival rate, tree* height, diameter at breast height (DBH) over bark, root collar diameter, canopy diameter (*RCD)* and fresh leaf biomass were assessed. The result indicated that at Mechara site, there were significantly ($P < 0.001$) among provenances; in their survival, height, root collar diameter, and fresh leaf biomass, but DBH and canopy diameter did not show statistical difference. At Hawi Gudina, there was significant difference only in fresh leaf biomass between provenances. Survival at Mechara site ranged from 50% for (M.gofa and M.wolayita) to 83.33% for M.babile ; while at Hawi Gudina site survival ranged from 91.67% for M.abay Filiklik to 100% for (M.konso, M.arbaminch and M.wolayita) provenances. At Mechara site, M.abay Filiklik demonstrated superior mean height (2.53 m) followed by M.babile (2.09 m) and M.wolayita (1.2 m) is the shortest provenance. At Hawi Gudina site, M.arbami demonstrated superior mean height (2.32m) followed by M.konso (2.3 m) and M.babile(1.57 m) were the shortest provenance. M.gofa demonstrated superior *RCD* (99.17 *mm*) followed by M.babile (98 mm), while M.wolayita (61.09 mm) shown the lowest performance at Mechara site. While, at Hawi Gudina site site, M.arbaminch demonstrated superior RCD (138.67mm) followed by M.konso (135.42 mm); while M.babile (107.09 mm) shown the lowest performance. At Mechara site, M.babile demonstrated superior fresh leaf biomass (1.61 kg) followed by M.gofa (1.59), while M.wolayita (0.48 kg) shown the lowest performance. At Hawi Gudina site, M.gofa demonstrated superior fresh leaf biomass (3.11 kg) followed by Wolayita (2.91 kg), while M.babile (1.34 kg) shown the lowest performance. Owing to superior growth performances attained, M.babile, M.gofa and M.konso be recommended for Mechara and similar agro-ecology, while M.arbaminch, M.gofa and M.konso for Hawi Gudina and similar agro-ecology.
Keywords: Moringa provenance, survival rate, growth, Leaf fresh biomass, Mechara, Hawi Gudina
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1. INTRODUCTION

Moringa stenopetala belongs to family Moringaceae that is represented only by a single genus Moringa. The genus Moringa is represented by 14 different species to which M.stenopetala belongs (Yisehak et al., 2011). M. stenopetala grows in the wild in elevations between 1,000 and 1,800 (Mark, 1998) but from personal observations the species grows as high as 2200 m.a.s.l and as low as 300 m (herbarium sources) in Ethiopia.

Moringa is drought resistant and can be grown in a wide variety of poor soils, even barren ground, with soil pH between 4.5 and 9.0. The species is easy to reproduce and its growth is very fast that have raised growing international interest due to its social, economic and environmental importance which can benefit humans and animals nutritionally, economically and as an energy source. Moringa is an important food source in many countries. Moringa stenopetala leaves are the staple food of the Konso people in Ethiopia (*Ezekiel et al., 2014)*.

M. stenopetala is often referred to as the East African Moringa tree because it is native only to southern Ethiopia and northern Kenya (Mark, 1998). Though it grows in many other parts of the tropics, it is not as widely known as its close relative, M. oleifera of India but often considered generally more desirable than *M. oleifera* (Yisehak et al., 2011). According to Edwards et al., 2000, *M. stenopetala* is a tree 6-12 m tall; trunk: more or less 60 cm in diameter at breast height; crown: strongly branched sometimes with several branches; thick at base; bark: white to pale gray or silvery, smooth; wood: soft; leaves: up to 55 cm long; inflorescence: pubescent, dense many flowered panicles 60 cm long. Optimum light for germination of all Moringa species is half shade. Seeds could be planted about 2 cm deep in soil that is moist but not too wet. Sprouting occurs normally in 1-2 weeks. It can be allowed to grow for shade (6-15 m), or kept low (about 1-1.5 m) for easier harvesting (Yisehak *et al.,* 2011).

The cultivation of Moringa stenopetala in Ethiopia occurs mainly in the zones and special districts such as South Omo, Gamo Gofa, Kaffa, Sheka, Bench Maji, Wolaita, Dawaro, Bale, Borena, Sidama, Burji, Amaro, Konso and Derashe (Edwards et al., 2000). Perennial types of Moringa are best with many production constraints, such as a relatively long period to bear fruit, non-availability of planting materials, requirement for long rainy period in regions where water is scarce and vulnerability to pests and diseases (Price, 1985; Endeshaw, 2003; Moges, 2004). Various indigenous fodder trees and shrubs rich in condensed tannins including *M.stenopetala* is considered as nutritionally potential feed supplements under small holders farming system in the tropics (Yisehak et al., 2010).

In Ethiopia, it is grown as a backyard crop in the southern parts of the Rift Valley and adjoining lowlands for its edible leaves, flowers and tender pods. The leaf of Moringa is very popular vegetable in Southern Nations and Nationalities and Peoples Regional State of Ethiopia and valued for its special flavor. It is grown as backyard tree to make it accessible for daily use in more than six million households of Southern Ethiopia (Endeshaw, 2003). Moringa has attracted enormous attention of ethno botanists and plant genetic resource conservationists due to its widespread use in agriculture and medicine.

Among the wide range of uses it provides are human food, fuel wood, livestock forage, medicine, dye, water purification, soil and water conservation, quality of cooking oil, green manure and the tree is used as source of income for Moringa growers (Demeulenaere, 2001; Palada and Jiru et al., 2006; ECHO, 2009; Morey, 2010;Melesse et al., 2011).

M. stenopetala is particularly important as human food because the leaves, which have high nutritional value (Abuye et al., 2003), appear towards the end of the dry season when few other sources of green vegetables are available. The leaves contain high amounts of essential amino acids and vitamins A and C (Abuye et al., 2003). Although Moringa is fast growing, drought tolerant and easily adapted to poor soil and arid conditions, it has not received significant research attention to select and develop potential ecotypes that might be valuable both as horticultural and medicinal crops (Tenaye et al., 2009). Now a days, some rural households in Hararghe area use Moringa for veterinary and other utility.

A needs for the *M. stenopetala* is increasing by livelihood as a result of its utility however, it's not access in case of limited amount of species and lack of identification more adaptation provenance supported with research at study area. Despite its more significant contributions to livelihood, *M. stenopetala* has not been given due research on provenance at study area to establish and expanded its species. At the study area, there are gabs between amount of Moringa contribution and needs of livelihood because of not given attention to expanded amount of *M. stenopetala* with its usage.

The knowledge about genetic improvement, proper management and utilization of this valuable multipurpose tree species is limited. One of the means to overcome the problems is to evaluate different provenances of this species with a view of identifying the provenances that maximize productivity. Hence, the present study is initiated with an objective to evaluate different Moring stenopetala provenance and select the best adapted provenance in Western Hararghe Zone.

LITERATURE REVIEW

Favorable Condition for *Moringa stenopetala* growth

M. stenopetala can be grown at elevations from 390 - 2,200 meters. It grows best in areas where annual temperatures are within the range of 25 - 35°c, but, can tolerate 15 - 48°c. Plants can tolerate light frosts; even heavier frosts do not always kill the plant since it is able to sprout from the base. It prefers a mean annual rainfall in the range 500 - 1,500mm, but tolerates 200 - 2,800mm.Grows best in a sunny position, but tolerates light shade. It prefers a well-drained soil with a high groundwater table, but it can also withstand dry conditions well, and consequently it is found in both wetlands and dry areas. It prefers a pH in the range of 6 - 8, tolerating 5- 9. Plants are very drought tolerant; remaining green and continuing to grow even during exceptionally long dry season (Fern, 2018).

Importance of *Moringa stenopetala*

Alley cropping/Intercropping

With their rapid growth, long taproot, few lateral roots, minimal shade and large amount of biomass yield of high protein content. Moringa trees are one of the best MPT candidates for use in alley cropping systems. Traditionally, the species is grown in mixed multi-story stands with food crops. For instance, around Arba Minch, farmers plant in their home gardens mostly 5 and sometimes up to 15 Moringa trees per 0.1 ha. Farmers practice permanent multistoried cultivation with *M. stenopetala* at the uppermost level, papaya, coffee and bananas in the upper-middle level; cassava, maize and sugar cane in the lower-middle level and cotton and pepper in the lowest level (Yisehak *et al.,* 2011).

Socio-economic values

The economic status of an individual in low lands of southern Ethiopia is closely associated with the number of *Moringa stenopetala* (Haleko) trees they have in their backyard. For example, when a young man proposes marriage in the former administrative region of Gamo Goffa of the South Ethiopia, the girl's (bride) family enquires whether or not the wouldbe husband has Haleko trees in his farm (Endeshaw, 2003).

Demeulenaere (2001) observed in some parts of southern Ethiopia, especially among the Konso people, that the abundance of Moringa species in the garden or on farmland was an indication of the social status of the owner among the society. The one with many Moringa trees in the garden or on farmland had a higher social status and was also considered as a prosperous person. Among the various uses of *M. stenopetala* are animal feed, fertilizer, honey production, life fencing, medicinal (traditional) and pollution control (Yisehak *et al.,* 2011).

Season and planting method:

Moringa is propagated either by stem (limb) cuttings or by seed. In perennial types, limb cuttings 100-150 cm in length with a diameter of 14-16 cm are planted *in situ* during the rainy season. Elite trees are cut down, leaving a stump with a 90 cm head from which 2 to 3 branches are allowed to grow. From these shoots, cuttings 100 cm long and 4 to 5 cm in diameter are selected and used as planting material (Bezabeh, 1993; Teketay, 1995).

The branch cuttings are planted in pits of 60x60x60 cm at a spacing of 5x5 m, during the months from June to August. The monsoon rains during the period facilitate easy rooting and further growth. While planting, one-third of the cutting should be kept inside the pit. Under moderate clay situations, watering should be done just too optimum levels to avoid root rot. The seeds of annual Moringa may be directly dibbled in the pit to ensure accelerated and faster growth of the seedlings. The best suited season for sowing the seeds is March to August under Southern Ethiopian conditions. The time of sowing has to be strictly adhered to because the flowering phase should not coincide with the rainy seasons, which results in heavy flower shedding. A plant spacing of 2.5x2.5 m between rows and plants should be adopted, giving a plant population of 1600 plants ha^{-1}. The seed germinates 10 to 12 days after sowing. The seed requirement per hectare is 625 g. When planted in single row along with irrigation channels, a spacing of 2 m is sufficient. Treatment of Moringa seeds with Azospirillum cultures at the rate of 100 g per 625 g of seeds before sowing resulted in early germination and increased seedling vigor, growth and yield. The most common method of propagating *M. stenopetala* is by direct sowing without pre-treatment of seed. But standard nursery raised seedlings are also commonly used. Removing the spongy seed coat improves germination. In a nursery it needs 7-10 days to germinate. Use of wide polythene is advised as the bulgy root requires large enough space (12 cm diameter flat). In about 3 months the seedlings will be ready for planting out. Some farmers occasionally propagate the species by using branch-sized cuttings (Yisehak *et al.,* 2011).

Origin of *Moringa stenopetala*

M. stenopetala is often referred to as the East African Moringa tree because it is native only to southern Ethiopia and northern Kenya (Mark, 1998). Though it grows in many other parts of the tropics, it is not as widely known as its close relative, *Moringa oleifera* of India but often considered generally more desirable than it.

MATERIALS AND METHODS

Trial site, seed sources and experimental design

Climatic Description of the Study Area

The trial was conducted at Mechara Agricultural Research Center (on station). The center is located at 431 Km west of Addis Ababa capital city of Ethiopia at 1780 m a.s.l and Hawi Gudina sub station that found south of Daro Lebu woreda at 70 km away from Mechara Daro Lebu woreda town. The elevation of Hawi Gudina is 1453 m.a.s.l. Rainfall pattern in the both location is bi-modal; Mechara Agricultural Research Center receive on average during *belg* rainy season (February 26, March 90, April 157 and May 128mm) and *kiremt* rainy season (June 101, July 144, August 158 and September 127mm) and also Hawi Gudina receive on average during *belg* rainy season (February 32, March 31, April 145 and May 328mm) and *kiremt* rainy season (June 26, July 168, August 46 and September 98mm figure1). Average annual rainfall amount is 1120 mm Mechara Agricultural Research Center and 992mm at Hawi Gudina (Figure2). Mean annual temperature is 21°C with mean annual minimum temperature of 15°C and maximum 28°C Mechara Agricultural Research Center while, at Hawi Gudina mean annual temperature is 23°C with mean annual minimum temperature of 16°C and maximum 20°C (Wasihun, 2021 unpublished).

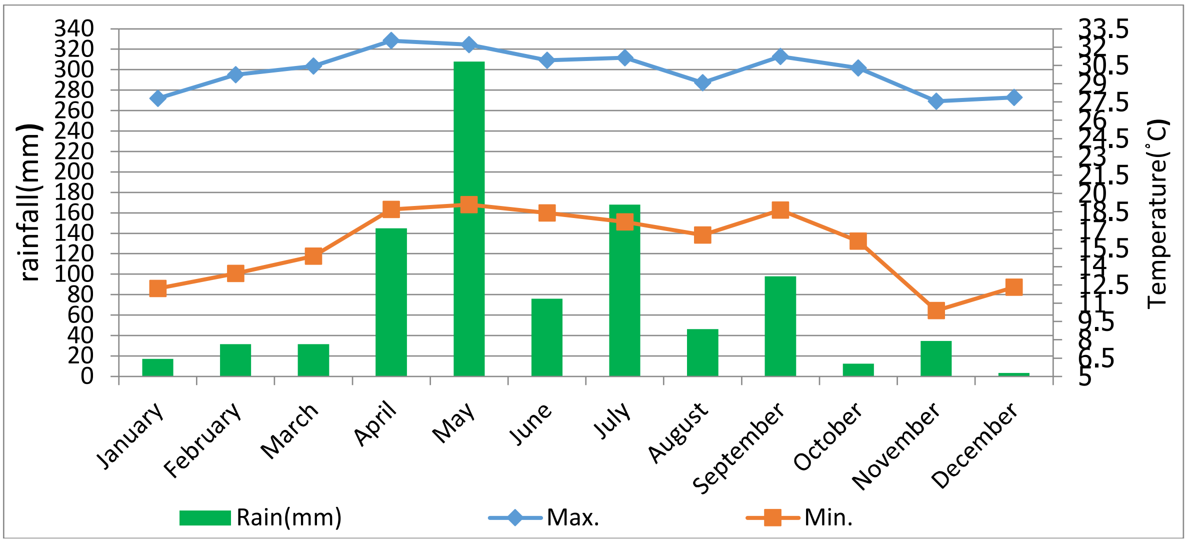

Figure 1. Mean monthly rainfall amount, Mean minimum temperature and Mean Maximum Temperature at Hawi Gudina

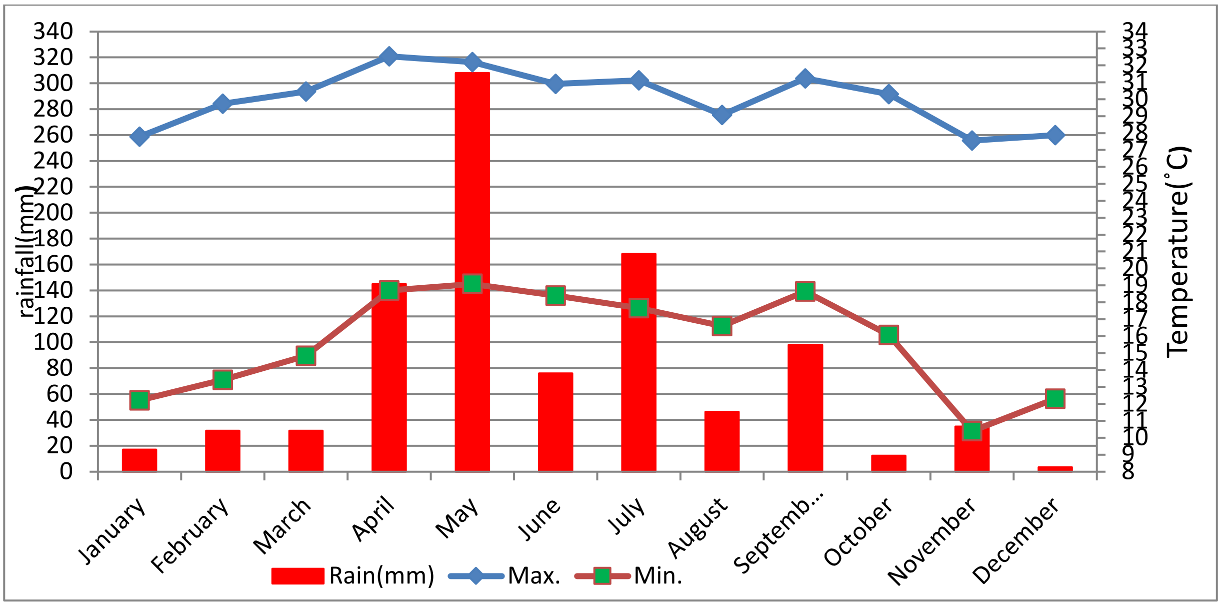

Figure 2. Mean monthly rainfall amount, Mean minimum temperature and Mean Maximum Temperature at Mechara

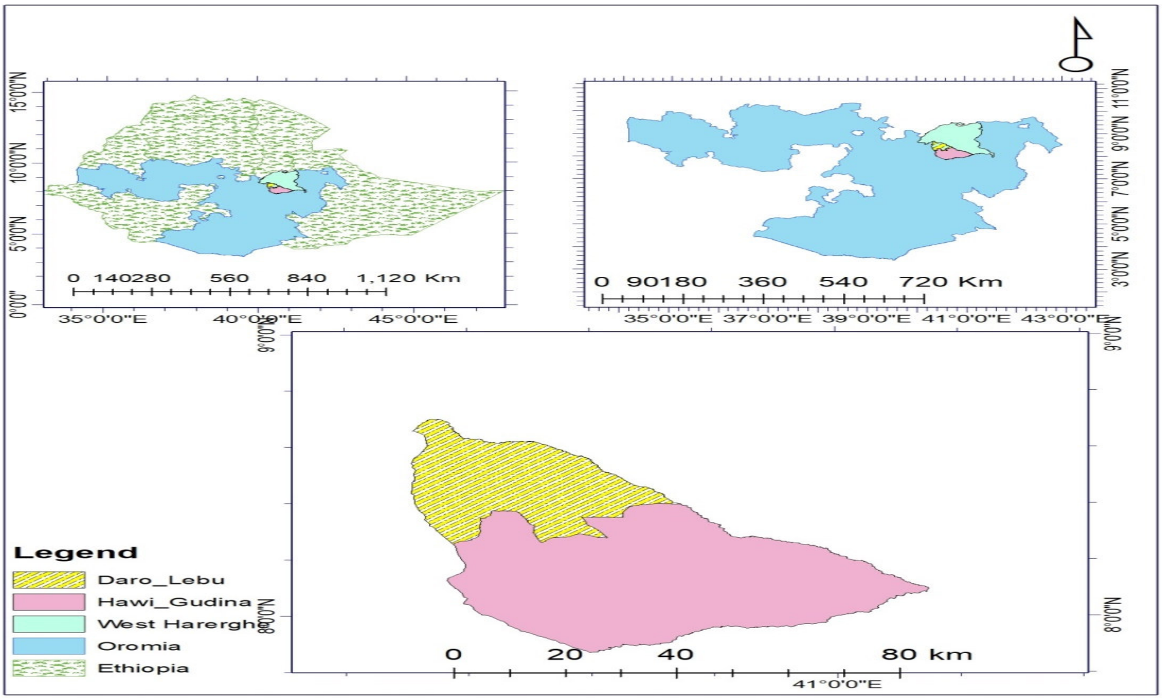

Figure 3. Map of the study area

Seed source (provenance) and procedure of treatment

Six (6) M. *stenopetela* provenances were studied in both site which were brought from, Abay Filklik, Arbaminch, Gamo Gofa, Wolayita, Konso and the local (Babile). Potted seedlings of the provenances were raised with polythene tube at Mechara nursery using standard cultural techniques (Forest Division, 1982). The trial sites were manually cleared and land tilled followed by and pitting (pit size: 30 x 30 cm).before seedling planting. Planting was done in July 2019 at Mechara and Hawi Gudina sites respectively. Weeding was done three times during the rainy season and once during the dry season.

Experimental design

Randomized Complete Block Design (RCBD) was used for the six provenances of *M. stenopetala* (treatment species) with four replications. The sizes of the plots was 4m*2m = ($8m^2$) and per plot six (6) trees were planted with 2m*2m spacing. The spacing between plots and blocks were 3m. Sixteen (16) plots at one trial site were prepared while 96 trees were planted at total areas of 25m*17m = (425m2) on each trial site.

Data collection

Assessment was carried out at 3rd year after planting for variables such as; survival, root collar diameter 30 cm above ground (RCD), height (H), canopy diameter, diameter at breast height (DBH) and leaf biomass. Leaf biomass production was measured at final assessment. Height was measured using calibrated height measuring pole and canopy were measured using tape meter while RCD and DBH were measured using caliper.

Data analysis

The collected data were analyzed with analysis of variance (ANOVA) following the General Linear Model (GLM) procedure using Statistical Analysis Systems (SAS Inst. Inc., 1991). The important variation, mean separation using, LSD of result indicator were conducted at 5 % point of significance level.

RESULTS AND DISCUSSION

Survival rate

Survival rate was significantly different between provenances ($p < 0.05$) at Mechara site; while at Hawi Gudina site there was no significant difference (Table 1 and 2). Survival at Mechara site ranged from 50% for M.Gofa and M.wolayita to 83.33% for M.babile; while at Hawi Gudina site survival ranged from 91.67% for M.abay Filiklik to 100% for M.konso, M.arbaminch and M.wolayita. All provenances in both sites except the two at Mechara site had survival above 66%. The insignificant differences among provenances at Hawi Gudina site may imply all provenances have performed similarly.

Table 1. Means of survival rate, height, Diameter at breast height, Root collar diameter, Canopy diameter and Fresh leaf Biomass increment for *M . stenopetela* provenance trial at age 3 at Mechara site

Provenances	SR (%)	H(m)	DBH(mm)	RCD(mm)	CNP(m)	FLB(kg)
M.abay Filiklik	66.67(13.61)bc	2.53(0.27)a	30.84(2.88)	90.75(13.21)a	0.95(0.2)	0.72(0.03)bc
M.arbaminch	75(9.62)ab	1.57(0)d	18.59(9.2)	85.42(1.39)a	1.25(0.38)	0.79(0.05)bc
M.babile	83.33(0)a	2.09(0.09)b	28.75(2.5)	98(4.74)a	1.03(0.22)	1.61(0.23)a
M.gofa	50(19.25)d	1.78(0.24)cd	27.29(9.92)	99.17(6.31)a	1.38(0.36)	1.59(0.58)a
M.konso	56.25(4.17)cd	1.97(0.25)bc	32.67(9.52)	85.58(14.84)a	1.29(0.31)	0.98(0.43)b
M.wolayita	50(0)d	1.2(0.23)e	29.38(7.08)	61.09(7.04)b	0.77(0.15)	0.48(0.21)c
Mean	63.54	1.86	27.92	86.67	1.11	1.03
PV	0.0006	<.0001	0.227	0.0004	0.051	0.0004
LSD	14.37	0.309	11.839	13.918	0.4162	0.477
CV	15	11.047	28.14	10.66	24.83	30.791

*Values in parenthesis are standard errors. Means with of the same letter within the same column are not significantly different. Significant ($P < 0.05$) ns = Not significant ($P > 0.05$). SR=Survival Rate, H=Height, DBH= Diameter at Breast Height, RCD= Root Collar Diameter, CD=Canopy Diameter and FLB=Fresh Leaf Biomass.

Table 2. Means of survival, height, Diameter at breast height, Root collar diameter, Canopy diameter and Fresh leaf Biomass increment for *M. stenopetela* provenance trial at age 3 at Hawi Gudina site.

Provenances	SR (%)	H(m)	DBH(mm)	RCD(mm)	CNP(m)	FLB(kg)
M.abay Filiklik	91.67(9.62)	2.07(0.28)	52.71(20.87)	105(17.71)	2.15(0.29)	2.03(0.42)bc
M.arbaminch	100(0)	2.32(0.32)	43.92(7.67)	138.67(14.43)	2.04(0.23)	2.72(0.53)ab
M.babile	95.83(8.34)	1.57(0.21)	41.04(8.64)	107.09(24.28)	1.61(0.13)	1.34(0.44)c
M.gofa	95.83(8.34)	2.25(0.18)	39.5(10.06)	126(32.87)	2.14(0.42)	3.11(0.69)a
M.konso	100(0)	2.3(0.45)	39.92(15.47)	135.42(32.25)	1.89(0.4)	2.71(0.17)ab
M.wolayita	100(0)	2.2(0.8)	33.25(26.78)	107.25(29.71)	1.95(0.57)	2.91(1.07)ab
Mean	97.22	2.12	41.72	119.9	1.96	2.47
PV	0.3759	0.22	0.6271	0.2557	0.1576	0.018
LSD	9.55	0.670	23.004	38.07	0.445	1.006
CV	6.52	20.99	36.58	21.07	15.05	27.05

Means of individual provenance with standard error in parenthesis. Means of the same letter within the same column are not significantly different. Significant ($P < 0.05$) ns = Not significant ($P > 0.05$). SR=Survival Rate, H=Height, DBH= Diameter at Breast Height, RCD= Root Collar Diameter, CD=Canopy Diameter and FLB=Fresh Leaf Biomass.

** M.abay Filiklik =Moringa abay filikilik, M.arbaminch=Moringa Arbaminch, M.babile=Moringa Babile, M.gofa=Moringa gofa, M.konso=Moringa konso and M.wolayita=Moringa wolayita**

Height growth

The highest height (2.53m) was scored by the provenance from M.abay Filiklik and the shortest (1.2 m) by the Wolayita provenance for Mechara. At Hawi Gudina the highest one is Arbaminch (2.32 m) and the shortest one is Babile (1.57) provenance respectively. The differences in height growth within a site could be attributed to variations in adaptability among provenances while the between site differences in growth relate with agro climate differences between the two sites. Generally, the provenances showed good performance in height development at Hawi Gudina.

Diameter at breast height

There was no significant difference among the provenances in DBH at both sites. Though there were not significant, the M.konso(32.67) tree provenance had the greatest mean DBH followed by M.abay Filiklik(30.84) (Table 1) at Mechara, while the greatest mean DBH for Hawi Gudina is M.abay Filiklik (52.71) and the least DBH is for M.wolayita (33.25) provenance.

Although there is no significant variation in DBH at Hawi Gudina site all provenances showed good performance in DBH development. All provenances gave comparable diameters when measured at year three.

Root collar diameter

Root collar diameter (RCD) was significantly different between coppice levels ($p < 0.05$) only at Mechara sites, which ranged between M.wolayita 61.09 mm and 99.17 mm for M.gofa provenance (Table 1). Though there is no significant difference in RCD at Hawi Gudina site; the highest RCD were recorded for M.arbaminch (138.67 mm) provenance (Table 2). The differences in RCD development within a site could be attributed to variations in adaptability among provenances, but generally the provenances at Hawi Gudina site showed good performance in RCD development.

Canopy diameter
At both sites provenances did not differ significantly in canopy diameter. Canopy diameter at Mechara site ranged from 0.77 m for M.wolayita to 1.38 m (Table 1) for M.gofa and 1.61 m for M.babile to 2.15 m for M.abay Filiklik (Table 2) provenance respectively.

Fresh leaf Biomass
Fresh leaf biomass was significantly different between provenances ($p < 0.05$) at both sites (Table 1 and 2).Fresh leaf biomass at Mechara site ranged from 0.48 kg for M.wolayita to 1.59 kg for M.gofa and, while for Hawi Gudina site 1.34 kg for M.babile to 3.11 kg for M.wolayita provenance, respectively. Most provenances grown at the Hawi Gudina site showed high production of fresh leaf biomass than those grown at Mechara site. This could be due to agro-ecological variation between these sites. The lowest fresh leaf biomass at Mechara site was recorded from M.wolayita; while at Hawi Gudina site was recorded for M.babile provenances. This poor performance could probably be due to poor genetic adaptations influenced by climatic conditions in this area.

Conclusions and recommendations
In Ethiopia, moringa grown as a backyard crop in the southern parts of the Rift Valley and adjoining lowlands for its edible leaves, flowers and tender pods. The leaf of Moringa is very popular vegetable in Southern Nations and Nationalities and Peoples Regional State of Ethiopia and valued for its special flavor. Knowledge about genetic improvement, proper management and utilization of this valuable multipurpose tree species is limited. One of the means to overcome the problems is to evaluate different provenances of this species with a view of identifying the provenances that maximize productivity. Hence, the present study is initiated with an objective to evaluate different Moring stenopetala provenance and select the best adapted provenance in Western Hararghe Zone

There was significant difference between provenances in their survival, height, root collar diameter, and fresh leaf biomass, but DBH and canopy diameter did not show statistically significant variation at Mechara site.

The current study has showed statistically significant variation among moringa provenances in their survival, height, root collar diameter, and fresh leaf biomass, but DBH and canopy diameter did not show statistically significant variation at Mechara site. At Hawi Gudina, there was significant difference between provenances only in fresh leaf biomass. The study reveals that, at Mechara the most promising provenances are M.babile, M.gofa and M.konso whereas at Hawigudina, M.arbaminch, M.gofa and M.konso. The authors have recommended M.babile, M.gofa and M.konso provenance for Mechara and similar agro-ecology, while M.arbaminch, M.gofa and M.konso provenances for Hawi Gudina and similar agro-ecology for further production.

The research should focus on genetic improvement, nutrient analysis and evaluate the compatibly of these provenances with other crops in agroforestry system.

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