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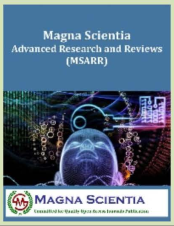

(RESEARCH ARTICLE)

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Growth and fruiting of selected provenances of *Moringa oleifera* Lam. in South Eastern region of Kenya

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Abstract

There is increasing narrowing of the genetic base of exotic species introduced in many parts of the world. This is causing a restricted genetic diversity and consequential loss of biotic and abiotic tolerance of these species. Hence, there is need to establish the genetic stability of such species for future genetic broadening. One such plant is *Moringa oleifera* Lam. which belongs to the family moringaceae; a monogeneric family of shrubs and trees consisting of 13 species and is native to India. *M. oleifera* is the most economically useful species in the genus and is widely cultivated and naturalized in tropical and subtropical areas and in over 60 countries worldwide. In Kenya, *M. oleifera* is widely cultivated in coast and some parts of Eastern Kenya. A provenance trial was set up at South Eastern Kenya University (SEKU), located at Kwa Vonza location, lower Yatta Sub-County, Kitui County. The aim of the provenance trial was i) to determine whether the collected Moringa exhibited different growth and fruiting habits and ii) if so, select the best performing provenances for large-scale propagation of the species in Kenya. The trial involved fifteen provenances selected from a wide geographical region in Eastern and Coastal regions of Kenya. Each provenance consisted of 200 seedlings at a spacing of 2m by 2m and was replicated three times. The experiment was laid in a randomized complete block design (RCBD). Growth data (diameter and height), fruiting and fruit maturation were measured for a period of 12 months. Monthly growth data were used to generate horizontal and vertical growth curves. Duncan Multiple Range Test (DMRT) and test of homogeneity of variances were used to detect existence of statistically significant differences in the fifteen provenances. The results indicated statistically significant differences ($p<0.05$) between the provenances with the Mwakiki provenance being the most significantly different and the Mackinnon one being the least. Intra-seasonal fruiting and fruit maturation peaked in the months of November and December. Pearson and Spearman correlation analysis showed very strong positive correlations between growth and yield traits. The results also showed that the Mwakiki provenance had a stable performance in the three traits studied and is recommended for adoption especially where fruit production is the preferred end product. Molecular analysis of all the species should also be done to determine the genetic base status and correlate them with this phenotypic analysis.

Keywords: *M. oleifera*; Provenance; Fruiting and Fruit Maturation; Vertical and Horizontal Growth

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1. Introduction

Moringa oleifera Lam. belongs to the family moringaceae, a monogeneric family of shrubs and trees consisting of 13 species [1, 2]. *M. oleifera* is the most economically useful species in the genus and is widely cultivated in tropical and subtropical and naturalized in over 60 countries worldwide [3, 4]. The species is well adapted to survive in different ecological conditions and grows best in well-drained sandy or loamy soil with a neutral to slightly acidic pH at an altitude up to 2000 m a.s.l (Nouman *et al.* 2014; Salem, 2016). Further, according to Manh *et al.* (2005), the species can grow well and produce high biomass in acid sulfate soil. Maundu & Tengnas (2005) documented that the species grows best under conditions characterized by direct sunlight, mean annual temperature of 12.6 ^{0}c to 40 ^{0}c and mean annual rainfall of at least 500mm. The species tolerates harsh environmental and climatic conditions and does not rely on moisture from immediate rainfall as it stores water within the roots and other succulent tissues for utilization during periods of water scarcity [5]. *M. oleifera* is a promising species in agroforestry systems [6].

M. oleifera is largely propagated by seeds and cuttings [7] with seeds being the most preferred part of the plant [8, 9]. The species is multi-purpose and is used for its medicinal values, fodder, food, water purification, biopesticides, biofuels, growth regulator, soil improvement amongst a host of other uses [10]. According to [11], *M. oleifera* is easily cultivated in variable range of climatic and geographical conditions. Its leaves and green pods serve as valuable sources of protein supplement for human and ruminants in the tropics during the dry season [12, 13]. The recent attention into biodiesel production has put Moringa as an alternative source of fuel production [11].

Despite the fact that *M. oleifera* has been widely grown in many African countries, its original native homeland still remains unknown [14, 3]. Due to lack of such information, scientists have raised concerns over likelihood of using propagation materials of narrow genetic base with restricted genetic diversity [15]. To address the challenge, provenance trials have been carried out in different countries [16, 17, 18] with the aim of selecting best performing provenances for cultivation. As a precursor to establishment of large-scale *M. oleifera* plantations in the South Eastern region of Kenya, seeds were collected from different parts of eastern and coastal regions of Kenya. A provenance trial was carried out in South Eastern Kenya University (SEKU). The objectives of the study was to determine whether the collected *M. oleifera* provenances exhibited different growth and fruiting habits and if so, identify the best performing provenance based on growth and fruit traits.

2. Material and methods

2.1. Study Site

The *M. oleifera* provenance trial was carried out in South Eastern Kenya University (SEKU) located 15 km off Kwa Vonza Market, along the Kitui-Machakos main road, Yatta/Kwa Vonza location, Lower Yatta Sub-County, Kitui County. The site lies at latitudes and longitudes of 037.75546^{0} E 01.31358^{0}S respectively. The site elevation is 1173m a.s.l (Figure 1).

2.1.1. Climate

The experimental site falls under agroecological zone IV characterized by semi-arid conditions and erratic rainfall regimes. The rainfall pattern is bimodal with the short rainy season occurring between November and December and the long one between April and May. Mean annual rainfall ranges between 500-1050 mm with annual mean temperatures ranging between 16^{0} C to 34^{0} C [19].

2.1.2. Soils and Geology

The soil texture at the study site is mainly sandy to loamy sand, which is prone to soil erosion and are generally poorly drained [20]. The geology of study site consists of high grade metamorphic granitoid granulites which are composed of quartz and feldspars (over 90%) and mafic hornblende and pyroxenes which is about 10% or less [21].

2.2. Selection of *M. oleifera* Provenances

M. oleifera was first introduced to the Kenyan coastal region from India in the turn of 19th century [2]. The provenances were selected from original introduction sites located at the Kenyan coast and some parts of Eastern Kenya. The location and elevation of the fifteen provenances are shown in Table 1 and figure 2.

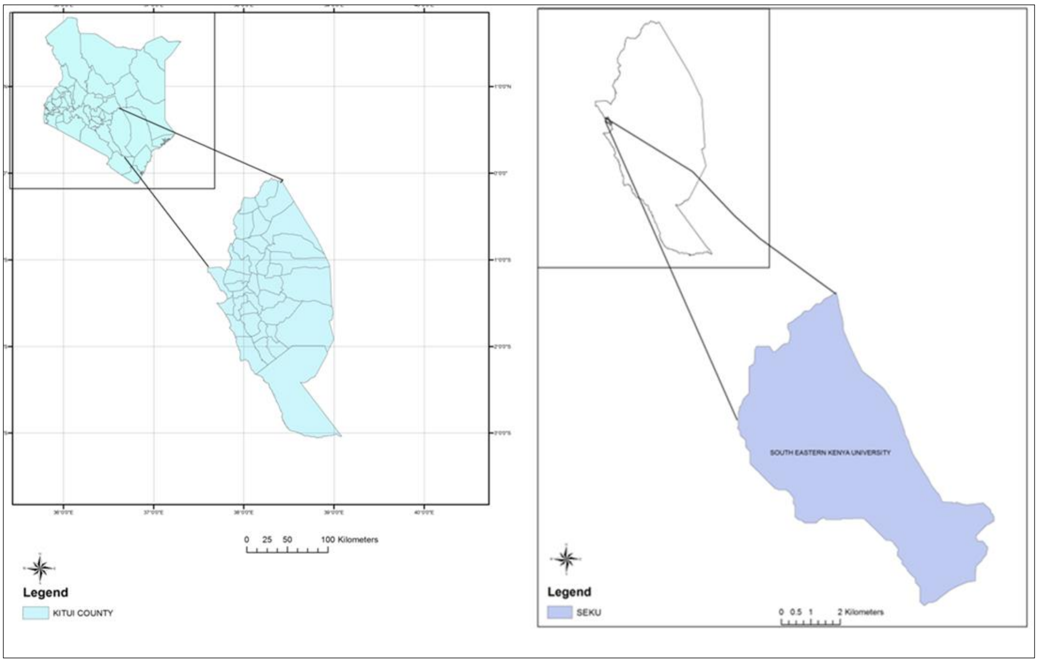

Figure 1 Location of research site in SEKU, Kitui County, Kenya **[22]**

Table 1 The elevation and location of the 15 provenances of *M. oleifera* used in the study

S/No.	Provenance location	Elevation (m)	Latitude	Longitude
1.	Maungu	530	047° 26' 95"	96° 06' 570"
2.	Kilifi	27	059° 44' 79"	95° 98' 335"
3.	Saburu	283	052° 95' 49"	95° 80' 457"
4.	Mwakiki	710	044° 20' 76"	96° 28' 881"
5.	Diana Ukunda	27	056° 37' 71"	95° 30' 786"
6.	Pwani University	16	059° 45' 79"	96° 00' 249"
7.	Vipingo	19	059° 13' 83"	95° 81' 938"
8.	Mbololo	687	044° 36' 46"	96° 28' 838"
9.	Waa Kwale	20	056° 68' 96"	95° 38' 948"
10.	Gede	5	060° 39' 55"	96° 28' 791"
11.	Mackinnon	364	050° 50' 71"	95° 87' 498"
12.	Likoni	15	057° 23' 26"	95° 48' 075"
13.	Miasengi	447	049° 37' 28"	95° 94' 039"
14.	Kibwezi Town	867	038° 71' 81"	97° 37' 178"
15.	Shika Adabu	26	057° 05' 38"	95° 44' 872"

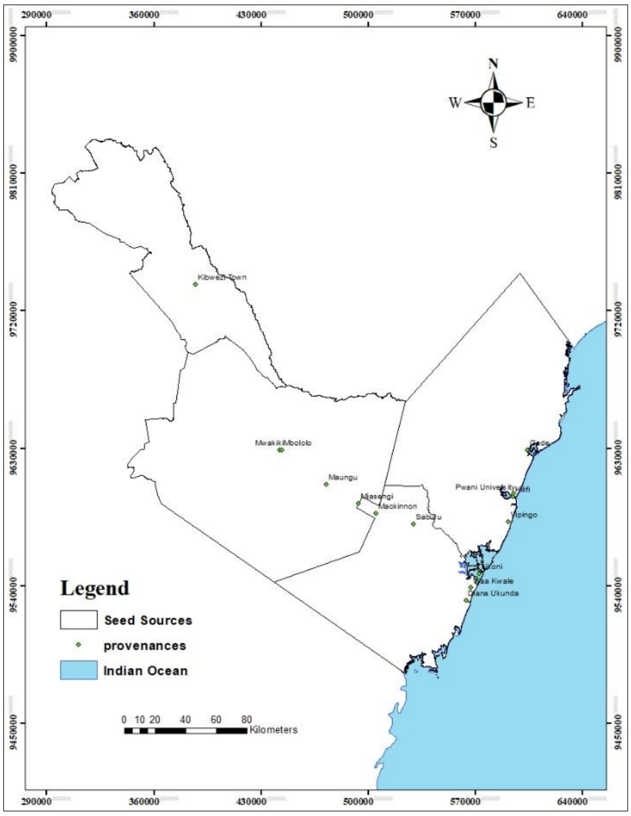

Figure 2 Location of seed collection areas (provenances)

2.3. Field Experimental Design

The provenance trial was set up in a 10 acre piece of land. Staking was carried out and pits of 0.3m by 0.3m prepared. For each provenance, 200 seedlings were transplanted using a spacing of 2m by 2m and the same was replicated three times. The experiment was laid in a randomized complete block design (RCBD). The subplots within the main plot were separated by 4m. A buffer zone measuring 10m wide was created around the core field plot.

2.4. Data collection

2.4.1. Growth parameters

One month after transplanting, 20 plants for each provenance were selected randomly at the centre core of each subplot and tagged. Boundary plants were avoided. Root collar diameter (RCD)/diameter at breast height (DBH) and height were monitored and recorded on monthly basis for 12 months. A veneer caliper and a ruler were used to measure diameter and height respectively. As the plants grew, the veneer caliper and the ruler were replaced with a diameter tape and calibrated height measuring rod respectively. At the initial measurements, RCD was measured at 30cm above the ground.

2.4.2. Fruiting and fruit maturation

The tagged plants were monitored for fruiting and fruit maturation during the October-December fruiting season. Direct counts of the total number of fruits per tree and the total number of mature/harvested fruits were carried out twice a month during the fruiting season.

2.5. Data analysis

Diameter and height data for the fifteen provenances were used to generate horizontal and vertical growth curves respectively. In addition, the diameter and height data were subjected to Duncan Multiple Range Test (DMRT) to detect existence of significant differences. Both diameter and height data were also subjected to Pearson correlation analysis to isolate existence of significant relationships between the two growth traits. Intraseasonal fruiting and fruit maturation were subjected to test of homogeneity of variances to detect existence of significant differences across the fifteen provenances. Spearman correlation analysis was used to establish existence of relationships between growth parameters (diameter and height) and fruiting. Similarly, intraseasonal fruiting was subjected to Spearman correlation analysis to detect existence of significant relationship between fruiting and time during the fruiting season. Charts were used to depict mean fruiting and fruit maturation per tree for the fifteen provenances.

3. Results

3.1. Diameter of *M. oleifera* provenances

Shika Adabu provenance had the highest mean DBH of 6.79cm followed by Mwakiki with a mean of 6.65cm and Maungu with 6.17cm (Figure 3). Mackinnon provenance had the least mean DBH of 3.95cm followed by Gede and Likoni provenances with mean DBH of 4.23cm and 4.5cm respectively (Figure 3). When the data was subjected to Duncan Multiple Range Test (DMRT), there were significant statistical differences ($p<0.5$) among the fifteen provenances.

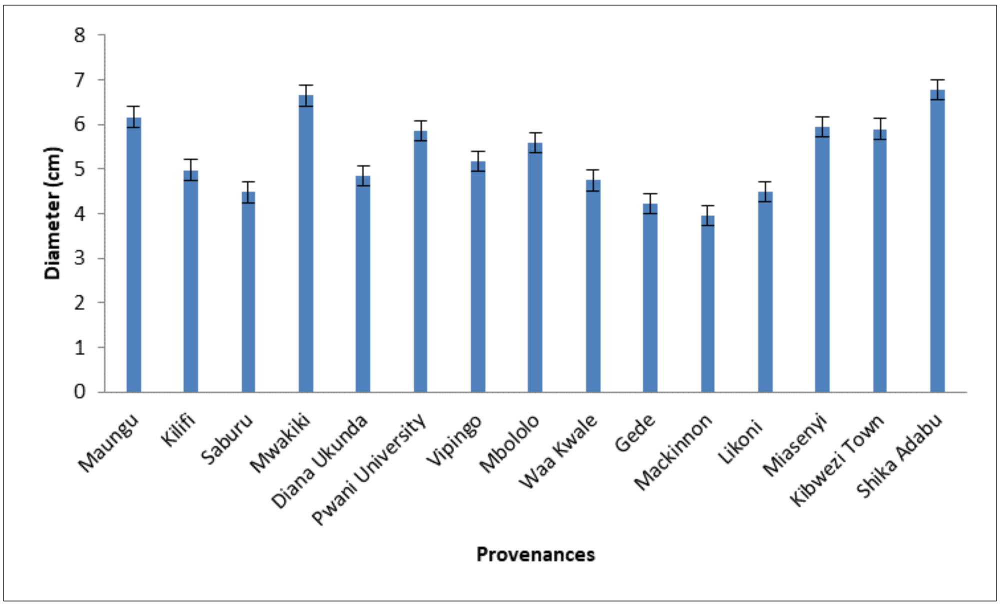

Figure 3 Diameter of fifteen provenances of *M. oleifera*

3.2. Height of *M. oleifera* provenances

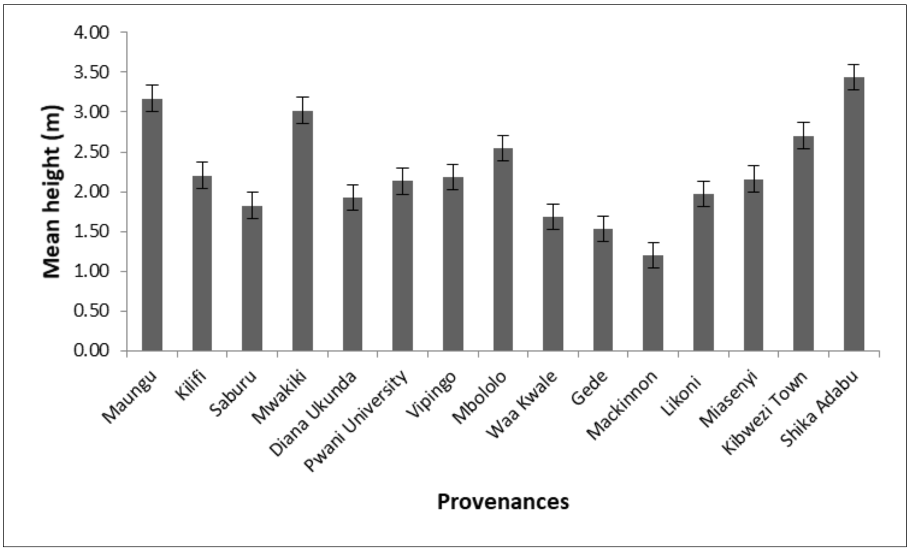

Figure 4 Height of fifteen provenances of *M. oleifera*

The fifteen provenances of *M. oleifera* showed statistically significant differences in height ($p<0.05$). The provenances performance in height followed an almost similar trend as observed in diameter with Shika Adabu provenance having the highest mean height (3.44m) followed by Maungu provenance with 3.17m and Mwakiki recording 3.02m (Figure 4). Mackinnon provenance had the lowest mean height of 1.2m while Gede and Waa had 1.53m and 1.68m respectively. The height for all provenances had not leveled off by the end of the monitoring period. All the fifteen provenances showed a strong positive correlation (Pearson, $r_s = 0.918$, $p<0.01$) between DBH and Height.

3.3. Intra-seasonal fruiting and fruit maturation of *M. oleifera* provenances

Test of homogeniety of variances showed that Mwakiki provenance was the most statistically significant at $p=0.011$ in terms of fruit production. Similarly, Miasenyi and Kilifi provenances had significant differences ($p<0.05$) in fruit production. Fruiting had a positive correlation (Spearman, $r_s = 0.856$, $p<0.01$) with DBH. A similar positive correlation (Spearman, $r_s = 0.795$, $p<0.01$) was also observed between fruiting and height of the provenances. Mwakiki provenance had the highest mean fruits production at 153.25 fruits per plant followed by Maungu and Shika Adabu at 104 and 80 fruits per plant respectively (Figure 5). Mackinnon provenance recorded the lowest mean fruits production at 6 fruits per plant followed by Gede and Waa each at 12.5 fruits per plant (Figure 3.3).

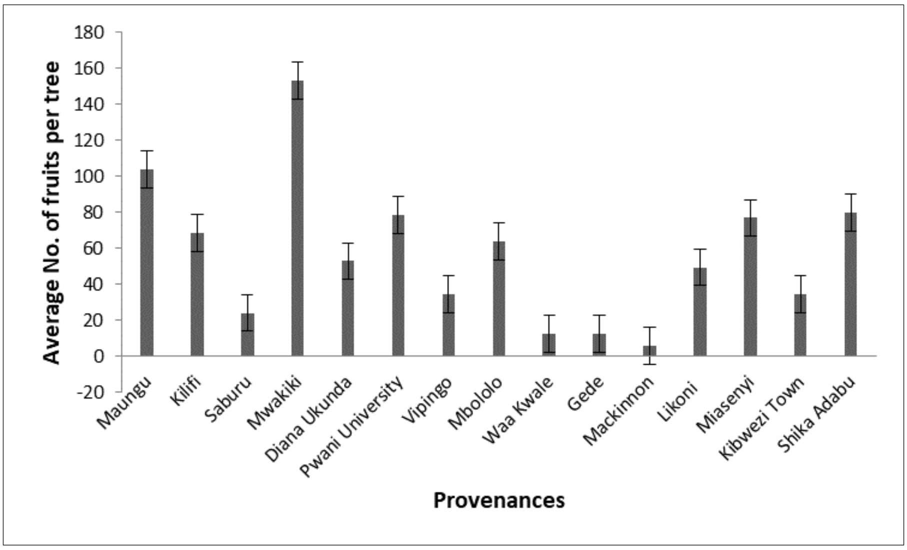

Figure 5 Fruit production for the fifteen provenances of *M. oleifera*

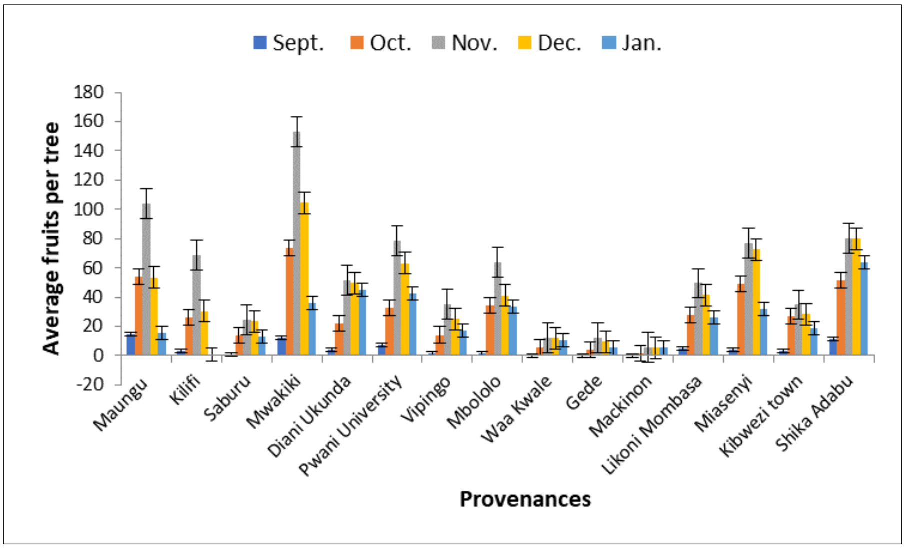

Figure 6 Intraseasonal fruiting of fifteen provenances of *M. oleifera*

Intraseasonal fruiting indicated that fruiting started in the month of September and peaked in November. While all the other provenances showed a decline in fruiting after the peak. Saburu, Diani, Miasenyi and Shika Adabu provenances maintained peak fruiting in the months of November and December (Figure 6). Though fruiting started in the month of September when the study site was dry, a strong sychronization of peak fruiting and peak rains in the months of November and December was observed. When intraseasonal fruiting was correlated with time, a very strong positive correlation (Spearman, $r_s = 0.928$, $p<0.01$) was found at the onset of the fruiting season in September but a relatively lower positive correlation (Spearman, $r_s = 0.663$, $p<0.01$) at the end of the fruiting season in January.

Though fruiting started in the month of September, fruit maturation for most of the provenances started in October. Fruit maturation peaked in the month of December for all the provenances except Diani, Waa and Shika Adabu where fruiting peaked in January (Figure 7). When harvested fruits from the fifteen provenances were subjected to analysis of variance, statistically significant differences ($p<0.05$) were found in Pwani, Mwakiki and Miasenyi provenances.

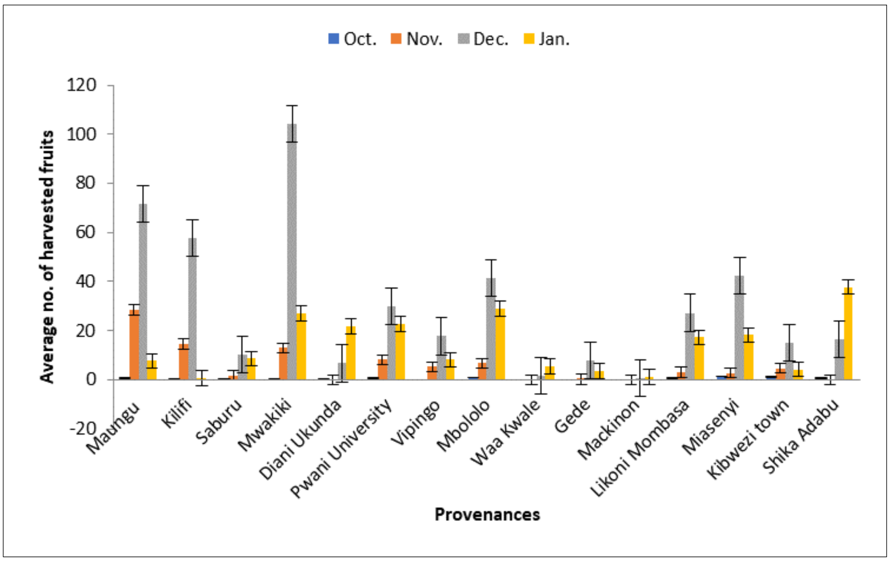

Figure 7 Intraseasonal fruit harvesting of fifteen provenances of *M. oleifera*

4. Discussion

4.1. Diameter of *M. oleifera* provenances

In this study, we observed diameter ranges of 3.95cm - 6.79cm. Similar DBH performances were observed in two provenances of *M. oleifera* grown in Zimbabwe [17]. Further, the DBH ranges obtained in this study are closely comparable with those obtained by [18] which ranged between 2.86cm-8.58cm. The statistically significant differences in DBH of *M. oleifera* provenances observed in this study have also been reported elsewhere by [23]. The observed differences in DBH growth performance across the fifteen provenances is likely to have been contributed by seed transfer distances as well as changes in elevation. For instance, Mwakiki and Maungu provenances are nearer to the experimental site compared to Gede and Likoni provenances and had mean DBH of 6.65cm and 6.17cm respectively compared to Gede and Likoni provenances which had mean DBH of 4.23cm and 4.5cm respectively. Further, Mwakiki and Maungu provenances home sites had elevations of 730m a.s.l and 510m a.s.l respectively compared to Gede and Likoni provenances with very low elevations of 5m a.s.l and 15m a.s.l respectively. Probably, the differences in seed transfer distances combined with differences in provenances home-site elevations contributed to differences in adaptability at the experimental site and hence the observed differences in DBH. Our findings are supported by [24] who documented provenances home-site advantages and the effects of long distance seed transfers. [25] in a study on the performance of provenances attributed the variations in growth to climatic changes caused by seed transfer distances. Elsewhere, in a study on performance of different provenances of *M. oleifera*, [18] attributed the differences in DBH development to variations in adaptability among provenances, good climatic condition, that is, availability of rainfall and genetic superiority.

4.2. Height of *M. oleifera* provenances

The results of height growth showed that Shika Adabu had the highest mean height of 3.44m followed by Maungu and Mwakiki provenances with 3.17m and 3.02m respectively while Gede provenance had a mean height of 1.58m. This showed that height growth followed an almost similar trend followed by DBH growth where best performing provenances in terms of DBH performed equally well in height growth and vice versa. The observed similar trend in DBH and height growth can be attributed to allometric growth pattern common in many terrestrial plants. Further, it is highly likely that the factors that influenced DBH growth such as seed transfer distances and elevation equally affected the height growth. For instance, the experimental site has an elevation of 1173m a.s.l while the fifteen provenances had their native elevations ranging between 5m-867m a.s.l. Technically, in the experimental site, all the provenances were growing outside their native altitude range thus forcing them to adapt to the new elevations. Probably, the furthest moved Gede provenance with an elevation of 5m a.s.l was greatly disadvantaged by the changes in elevation at the experimental site. However, it is important to note that *M. oleifera* grows in wide range of altitude such as between 0 – 1000m a.s.l [3] and upto 2000m a.s.l [26]. Changes in elevation lead to pronounced changes in temperature and consequently the rainfall regime. While the climatic condition at the experimental site is generally dry, the climate at the coastal Kenya, where most of the provenances were obtained, is moist. Elsewhere, in a study on performance of *M. oleifera* provenances in Zimbabwe, [18] attributed the observed variations to provenance adaptability as well as rainfall differences. The influence of local climatic and environmental conditions on performance of provenances has also been documented by [27, 28].

The minimum and maximum mean heights of the provenances of 1.2m and 3.44m respectively obtained in this work are relatively lower than mean height documented by [18] which ranged between 2.66m-8.16m. The differences in mean heights for the two studies can be attributed to differences in monitoring period in which this study monitored the provenances for 12 months while Edward's monitoring lasted for 30 months. The differences in mean height between the two studies clearly explain why the height growth curves had not leveled off in this research work at the end of the test period. It is likely that if the provenances in the current research were monitored until the curves levels-off, a higher mean height would have been achieved. Positive correlation across growth traits observed in this work has been reported elsewhere. For instance, in a study on seed characteristics and biomass production of *M. oleifera* provenances grown in Ouagadougou, Burkina Faso, [16] found significant positive Pearson product-moment correlation coefficients (r) among the studied traits. Similar positive height-diameter relationship has been supported by [29, 30].

4.3. Intraseasonal fruiting and fruit maturation of *M. oleifera* provenances

The findings of this work indicated that intraseasonal fruiting was highest in Mwakiki provenance. Mwakiki and Maungu provenances ranked second and fourth in terms of nearness to the experimental site and produced 153.25 and 140 fruits per plant respectively. Fruit production for the two provenances was higher than that of the furthest moved Gede and Waa provenances where each produced 12.5 fruits per plant. Similarly, Mwakiki and Maungu provenances home sites had relatively higher elevations of 710m a.s.l and 530m a.s.l respectively compared to low home sites elevations of 5m a.s.l and 20m a.s.l for Gede and Waa provenances respectively. Based on these trends, it is highly likely that seed transfer differences played a critical role in fruit production with the furthest moved provenances being disadvantaged by long seed transfer distances that probably led to pronounced changes in environmental and climatic conditions. Additionally, the furthest moved provenances had major changes in elevation and latitude which are of major concern due to their influence in temperature regimes. The findings of this research work raises similar questions with [24] on how far a plant material can be moved from home site and remain ecologically productive. Further, our findings complement [31, 24] assertions that local provenances are the best.

This work observed peak fruiting in the month of November for all the provenances as well as syschronization of the fruiting episode with the peak rains in the October-December rain season. The observed synchronization of peak fruiting to peak rains is a clear evidence of a natural sychrony by the provenances to ensure fruit survival. Fruiting is a resource demanding activity and syschronizing it with peak rains ensure fruit survival due to availability of resources particularly water. Our findings are supported by [32] who found out that synchrony is an adaptation strategy developed against water scarcity. Elsewhere, [33], in an experiment on *M. oleifera*, noted that fruit set decreased with the decrease in irrigation treatment. According to [34], peak fruiting in India occurs in the months of September and October which is slightly earlier than what was noted in this research work. However, it is worth noting that the monsoon season in India lasts from June to September. This work noted that some provenances such as Saburu, Diani, Miasenyi and Shika Adabu had a prolonged peak fruiting and late fruit maturation. Though the study could not authoritatively explain the causes, the prolonged peak fruiting and delayed fruit maturation can consequently delay fruit harvesting. The onset of fruiting in September as observed in this work is a clear indication that flowering in *M. oleifera* occurs during the dry season. Our findings are consistent with [35] who documented that dry period favours flowering and fruit set in *M. oleifera* and heavy rainfall leads to flower drop, which ultimately leads to poor pod set.

Though fruit maturation and harvesting in this experiment occurred between October-January, [34] reported fruit harvesting between September and November. Peaking of fruit maturation in the month of December as noted in this work is an indication of when mass harvesting of the fruits should be done.

5. Conclusion

The study concluded that Mwakiki provenance had a generally good and stable performance in DBH, height and fruiting indicating a probable influence of seed transfer distances and elevation on the performance. Further, though Shika Adabu provenance performed best in DBH and height growth, its low fruit production make it less preferred for adoption especially where fruit production is the preferred end product.

Recommendations

It is strongly recommended that Mwakiki provenance is adopted due to its stable performance in all the three traits under study and its adaptability to the local conditions. Further, the nearer to the planting site, the better the provenance performance. However, the genetic base status of the provenances needs to be determined and correlated with the morphological and climatic data obtained above. The broadening of the genetic base can be done by sourcing germplasm from native plant species in India.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The author and co-authors have no conflict of interest in this work.

References

[1] Ramachandran C, Peter K, Gopalakrishnan P. (1980). Drumstick (Moringa oleifera): A Multipurpose Indian Vegetable. Economic Botany, 34 (3), 276-283

[2] Muluvi G, Sprent J, Soranzo N, Provan J, Odee D, Folkard J, McNicol J, Powell W. (1999). Amplified fragment length polymorphism (AFLP) analysis of genetic variation in Moringa oleifera Lam. Molecular Ecology, 8(3), 463-470.

[3] Maundu P and Tengnas B. (2005). Useful trees and shrubs for Kenya. World Agroforestry Centre. ISBN: 9966-896-70-8

[4] Castillo-Lopez R, Leon-Félix J, Angulo-Escalante M, Gutiérrez-Dorando R, Muy-Rangel M, Heredia J. (2017). Nutritional and phenolic characterization of M. oleifera leaves grown in Sinaloa, Mexico. Pak. J. Bot, 49, 161–168

[5] Mabapa M, Ayisi K, Mariga I. (2018). Seasonal effect on M. oleifera gaseous exchange and water use efficiency under diverse planting densities. Journal of Applied Botany and Food Quality, 91, 219-225 DOI:10.5073/JABFQ.2018.091.029

[6] Boumenjel A, Papadopoulos A, Ammari Y. (2020). Growth response of M. oleifera (Lam) to water stress and to arid bioclimatic conditions. Agroforest Syst. 2020; Springer, Nature.

[7] Ben N, Ajayi S, Imaobong N. (2016). Comparative Study of Propagation Methods on the Early Growth Rate of Moringa oleifera. International Journal of Research, 3 (09).

[8] Kiragu J, Mathenge P, Kireger E. (2015). Growth Performance of M. oleifera Planting Materials Derived from Cuttings and Seeds. International Journal of Plant Science and Ecology, 1(4), 142-148

[9] Leone A, Spada A, Battezzati A, Schiraldi A, Aristil J, Bertoli S. (2015). Cultivation, Genetic, Ethnopharmacology, Phytochemistry and Pharmacology of M. oleifera Leaves: An Overview. Int. J. Mol. Sci., 16, 12791-12835.

[10] Yaseen A and Hájos M. (2020). Study on moringa tree (M. oleifera Lam.) leaf extract inorganic vegetable production: A review. Res. on Crops, 21 (2), 402-414. DOI: 10.31830/2348-7542.2020.06

[11] Boukandoul S, Casal S, Zaidi F. (2018). The Potential of Some Moringa Species for Seed Oil Production. Agriculture, 8 (150).

[12] Melesse A, Steingass H, Boguhn J, Schollenberger M, Rodehutscord M. (2012). Effects of elevation and season on nutrient composition of leaves and green pods of Moringa stenopetala and M. oleifera . Agroforest Syst., 86, 505–518.

[13] Manh L, Dung N, Ngoi T. (2005). Introduction and evaluation of M. oleifera for biomass production and as feed for goats in the Mekong delta. LRRD, 17(9).

[14] Panga J. (2002). Effect of processing on nutritional quality of M. oleifera leaves and pods. MSc. Dissertation, SUA, Tanzania. pp. 81

[15] Rufai S, Hanafi M, Rafii M, Ahmad M, Arolu I, Ferdous J. (2013). "Genetic Dissection of New Genotypes of Drumstick Tree (Moringa oleifera Lam.) Using Random Amplified Polymorphic DNA Marker", BioMed Research International, vol. 2013, Article ID 604598, 6 pages

[16] Cangré M, Dao M, Walsh D. (2017). Correlation between seed characteristics and biomass production of M. oleifera provenances grown in Ouagadougou, Burkina Faso. African Journal of Plant Science, 11(11), 385-393. DOI: 10.5897/AJPS2017.1579

[17] Gadzirayi C, Mudyiwa S, Mupangwa J, Gotosa J. (2013). Cultivation Practices and Utilization of M. oleifera Provenances by Small Holder Farmers: Case of Zimbabwe. Asian Journal of Agricultural Extension, Economics & Sociology, 2(2), 152-162.

[18] Edward E, Chamshama S, Ngaga Y, Mndolwa M. (2014). Survival, growth and biomass production of M. oleifera provenances at Gairo inland plateau and Ruvu Coastal Region in Tanzania. African Journal of Plant Science, 8(1), 54-64.

[19] Pauw P, Mutiso S, Mutiso G, Manzi K, Lasage R, Aerts J. (2008). An Assessment of the Social and Economic Effects of the Kitui Sand Dams: Community based Adaptation to Climate Change.

[20] Borst L and Haas de S. (2006). Hydrology of sand storage dams. A case study in the Kiindu Catchment, Kitui District, Kenya, M.Sc. Thesis, Vrije Universiteit Amsterdam. 27p.

[21] Winkler F and Sen K. (1973). Nomenclature of granulites and other high grade metamorphic rocks. N. Jb. Mineral. Mh. 393-402. Stuttgart

[22] Mutiso F, Kimiti J, Muchugi A, Gachuiri A, Jamnadass R, Xu J. (2017). Introduction from the Wild and Growth Characterization of Three Provenances of Calotropis procera (Ait) in a Domesticated State in Drylands of South Eastern Kenya. Journal of Natural Sciences Research, 7(24), 102-112. ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)

[23] Goss M. (2012). A study of the initial establishment of multi - purpose moringa (M. oleifera Lam) at various plant densities, their effect on biomass accumulation and leaf yield when grown as vegetable. Afr. J. Plant Sci., 6(3), 25-129.

[24] Lisa G, Denhof C, Lelia K, Stuber S, Steven B. (2018). Seed sourcing for longleaf pine ground cover restoration: using plant performance to assess seed transfer zones and home-site advantage: Seed sourcing implications for restoration. Restoration Ecology, 10.1111/rec.12673.

[25] Lu P, Parker H, Cherry M, Colombo S, Parker W, Man R, Roubal N. (2014). Survival and growth patterns of white spruce (Picea glauca [Moench] Voss) rangewide provenances and their implications for climate change adaptation. Ecol Evol, 4(12), 2360–2374.

[26] Nouman W, Basra S, Siddiqui M, Yasmeen A, Gull T, Alcayde M. (2014). Potential of Moringa oleifera L. as livestock fodder crop: A review. Turk. J. Agric. For., 38, 1–14.

[27] Kundu S. (2000). Evaluation of provenance variation on early growth and survival of Neem (Azadirachta indica) in bangladeshi and India. Journal of Tropical Forest Science, 12(3), 509-523

[28] Pengxin L, William P, Marilyn C, Steve C, William P, Rongzhou M, Ngaire R. (2014). Survival and growth patterns of white spruce (Picea glauca [Moench] Voss) rangewide provenances and their implications for climate change adaptation. Ecology and Evolution, 4. 10.1002/ece3.1100.

[29] Mahmut D. (2004). The Relationships between Diameter at Breast Height, Tree Height and Crown Diameter in Calabrian Pines (Pinus brutia Ten.) of Baskonus Mountain, Kahramanmaras, Turkey. Journal of Biological Sciences, 4. 10.3923/jbs.2004.437.440.

[30] Rais A, Kuilen J, Pretzsch H. (2014). Growth reaction patterns of tree height, diameter, and volume of Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) under acute drought stress in Southern Germany. European Journal of Forest Research, 133 (6), 1043

[31] Kristina H, Erik V, Hans L, Siegfried K. (2016). Genetic delineation of local provenance defines seed collection zones along a climate gradient. AoB Plants, 8: plv149. 10.1093/aobpla/plv149.

[32] Fandohan A, Salako V, Assogbadjo A, Diallo B, Van Damme P, Sinsin B. (2015). Effect of climatic conditions on flowering and fruiting of Tamarindus indica (Fabaceae). Journal of Horticulture and Forestry, 7(8), 186-192

[33] Muuhl Q, Toit E, Steyn J, Apostolides Z. (2013). Bud development, flowering and fruit set of Moringa oleifera Lam. (Horseradish Tree) as affected by various irrigation levels. Journal of Agriculture and Rural development in the Tropics and Subtropics, 114(2), 79-87.

[34] Rajbhar Y, Rajbhar G, Rawat P, Shukla S, Kumar M. (2018). Grow Moringa (M. oleifera), the miracle tree on the earth. Horticult Int J., 2(4), 166-172.

[35] Sharmila C, Pugalendhi L, Pushpanathan K. (2018). Off Season Production of Annual Moringa (Moringa oliefera Lam.) cv.PKM 1 through Canopy Management and Chemical Manipulation Practices. Journal of Pharmacognosy and Phytochemistry, SP1, 2218-2224.