Leaf yield and Nutritive value of *Moringa stenopetala* and *Moringa oleifera* Accessions: Its potential role in food security in constrained dry farming agroforestry system

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INTRODUCTION
Agroforestry from different perspective

There are different definitions of agroforestry. ICRAF agroforestry "refers to a dynamic, ecologically based, natural resource management system that, through the integration of trees in farms and agricultural landscape, diversifies and sustains the production for increased social, economic and environmental benefits for land users at all level" (ICRAF, 1996).

According to Simute et al. description in Danforth and Noren (1994), the two missionaries defined - "Agroforestry as an ancient farming system established by God when He created the Garden of Eden (Genesis 1 and 2). In Eden, they further described God had every kind of plant and animal in association with trees for the benefit of people's survival and pleasure".

In Ethiopia farmers' natural garden are found in the southern parts of the country namely in Gedeo, Sidama areas of the southern high potential parts of Ethiopia where coffee-enset, trees and fruit trees with other herbs and annual crops as well as livestock are produced in combination. The current Forestry College was based at place called Wondo and the name Genet was later annexed, which has eluded from its paradise garden and tree mix, signifying Heaven.

In marginal dry parts of Ethiopia Moringa tree intercrop of the Konso people and the surrounding people of the South Ethiopia is on farm tree (homegarden) farm that supports nearly high population density.

In hoe culture in Konso where perennial plants like *M. stenopetala* are part of the cultivation system, over 500 people/km^2 can be self sufficient when 50 people/ km^2 in the same agroecology under ox farming are permanently under food aid despite one step ahead in development stage. Such tragedy is one of the root causes of the problem that caused and is causing famine in a potential country and is converting the green mountain to a rocky mountain.

The root causes are:

- Producing shallow rooted monocropping like teff and sorghum without using rotational cropping practices.
- Unchanged ox plough farming for centuries on steep slopes

- Large number of animal under free grazing practices

Multi-storey Moringa tree inter-cropping system in the southern dry land farming

Homegarden and multi-storey system in the dry land farming is the best exemplary agroforestry system in Ethiopia. Soil nutrients mined at different soil strata level and above ground air and sun energy is trapped optimally compared to mono cropping. Such vertical intensification will increase production in a given area and minimize product loss through diversification.

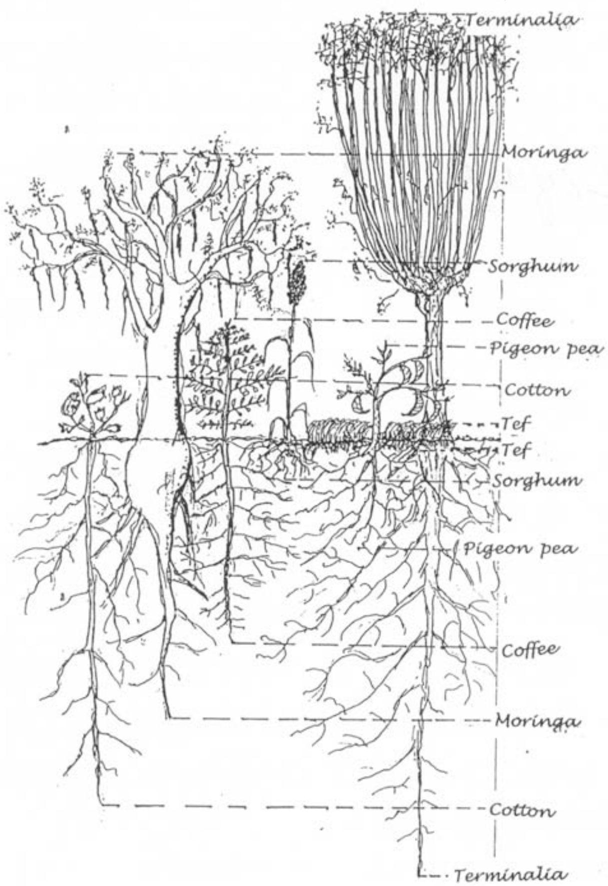


Figure 1: Multi-storey formation of mixed cropping of Konso farming system

Moringa distribution in Ethiopia

Moringa stenopetala, family *Moringaceae* is a native tree in arid and semi-arid regions in the southern Rift Valley of Ethiopia .The local farmers use the species as one of the major arable tree inter-crop in multi-storey system especially by the Konso people in Gamo Gofa. *Moringa stenopetala* has a wide range of adaptation from arid to humid climates with a prospect to be grown in a wide range of land use classes. The potential growing area fall in a rainfall range from 300-1400 mm per year with soil reaction of 6-7, Mayer (1990). It does not require fertile soils, in Sudan it performs well on marginal and poor soils (Jahn, 1986) as reported in Mayer (1990).

The sites in Ethiopia are mostly characterized by marginal soils in arid and semi arid areas. In konso, for example, the distribution of rainfall is bi-modal; the mean monthly distribution of two decades (1970-89) is less than 500mm/year. The average mean annual temperature ranges from 25-30^{0}C National Atlas of Ethiopia (1988). In general, it is quite a harsh agro-ecology for tree growth. The lower area of natural habitat is even drier. However, in the case of *Moringa* once it is established it will not show any sign of moisture stress.

Moringa stenopetala grows in the lowlands of West of the Rift Valley lakes from arid to semi-humid areas in the altitudinal ranged from 390m to about 2200m a.s.l. The coverage includes South Ethiopia, North Kenya and East Somalia from 1^{0}N –7^{0}N and 35^{0}E-42^{0}E in isofloric term. For the distribution of *Moringa species* see figure 2 as originally presented by Knapp (1973) and reported in Mayer (1990). Recently over 14 species of *Moringa* has been identified at species level.

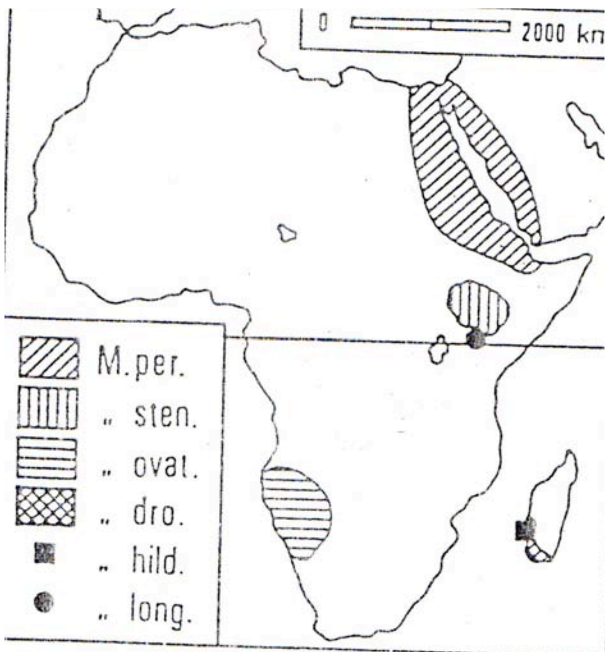


Figure 2 Distribution of some Moringaceae: *Moringa Pregrina. M. stenopetala, M.ovalifoliolata, M.drouhardii, M.hildebrandii, M.longituba.* Source : Mayer (1990)

It is a strategic plant in being a unique food tree in drought prone areas and is also political in linking countries in the horn with its high social and economic value. It has been recently distributed to Wello, Shoa, Harargie and Sidamo for demonstration purpose by the Soil and Water Conservation of the Ministry of Agriculture .The Forestry Research Center has also tried an alley cropping in Fontenina (Wello), Dhera (Arsi) and a windbreak trial at Ziwai, Awassa College of Agriculture and International Livestock Center for Africa (ILCA) planted the tree in Ziwai (Dechasa, 1995). They all performed well at establishment phase in these semi-arid areas under rain fed conditions.

Konso is a dry land which is known for its best model traditional stone terrace and agroforestry traditional practice.

Figure 3 The onfarm trees and the stone terraces in Konso area

Material and Methods

Method of Leaf sampling

In this nutritive value analysis fourteen accession of *Moringa stenopetala* leaves and two (one species and one improved variety) of *Moringa oleifera* were analyzed and compared. Nutrient analysis in this section focuses on the feed aspect. Thus material from the leaf (leaf blade with the rachis) is not pure leaf but leaflet. It is intentionally done due to the fact that animal feed on the leaflet not pure leaf blade as clearly illustrated in the methodology for both species. The food nutritive and palatability study followed the same method of sampling due to limitation of leaf sample size required in the laboratory which is a minimum of one kilogram fresh weight. This has been continuously consulted with the lab and the nutritionist.

All together for nutritive and palatability study 8 out of 40 accessions of *Moringa stenopetala* and 2 accessions (1species and 1variety) out of 4 of *Moringa oleifera* were selected from the pollarded when they were 3 years old. These accessions were growing near Arba Minch town which is 1100 m a.s.l. From the whole 43 accessions, 18 of them were taken for the necessary analysis to be conducted in the study both for nutritive and palatability. Each accession was replicated four times. The regrowth was sampled for foliage yield. The final leaf let and twigs were sampled and dried for the nutritive content and other relevant parameters analysis. The nutritive content assessment was then done in the International Livestock Research Institute located in Addis Ababa following standard procedures. Upon insufficient amount of both yield for leaf biomass and time during leaf harvest at the first pollarding leaf biomass is rescheduled to be measured from coppice leaf when they reach harvestable age. The result of the analysis is the combined result of the leaf which is the rachis and the leaf blade as illustrated below.

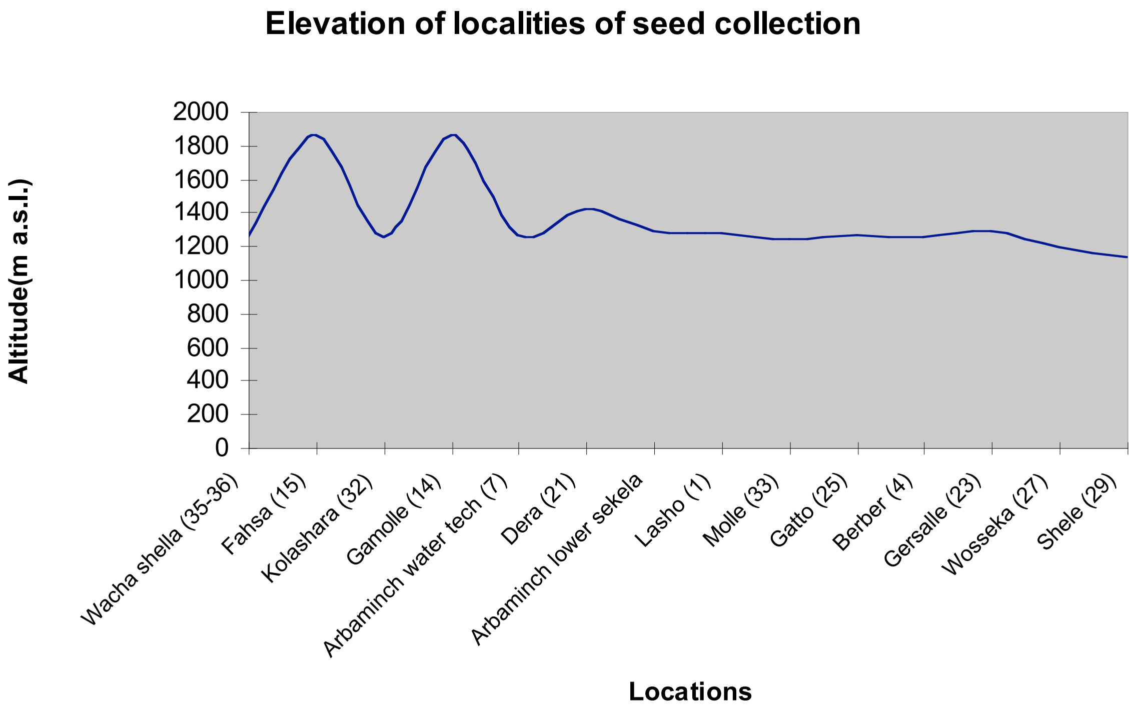
According to the second plan the branch-let samples were taken from all coppices of the six plants and bulked in each replication. The leaves were ripped and weighted. The branch let (without leaf which we call it leaf-twigs) were also weighted and recorded. For human consumption the leaf blade is ripped and cooked. For animal feed the entire leaflet which is supplied and consumed by farm animals. Thus the nutritive value analysis should be made using the entire leaflet that is collected from the field. In palatability nutrient analysis the leaf blade need to be separated and analyzed in principle. Since the minimum sample size of fresh leaf weight is one kilogram enough samples was not available specially upon sharing of each sample into two, namely feed and food nutritive samples. Thus upon consultation with the professionals from the field to the ILRI and Addis Ababa University using the leaflet for food analysis was opted.

The detail lab analysis method and the protocol have been annexed at the end of the main document.

Results and discussions.

Source of variation in nutrient can be genetics and environment. The genetic variability has been studied by an attachment Masters program using Gene marker. The nutrient analysis focuses on Geographical variation. Location in elevation is the most important factor compared to latitude and longitude. The result showed that it had no significant influence in the nutrient cont of the species from mere observation.

Latitude has more variation in terms of location and influence. Thus it is considered as one of the parameters. Yet no clue has been found in terms of indication. Thus further study needs to be carried out on other nutrient, vitamins under special and controlled conditions. The following graph shows location in elevation latitude and longitude. None of them showed correlation with the nutrient content, except significance on Ash and Organic mater. Such conclusion seems unreliable in the faces where lignin is high and organic mater is low due to insect attack. But one could also argue that insect attack is at random for the local species. Since we are also comparing both, much cannot be said at this level.



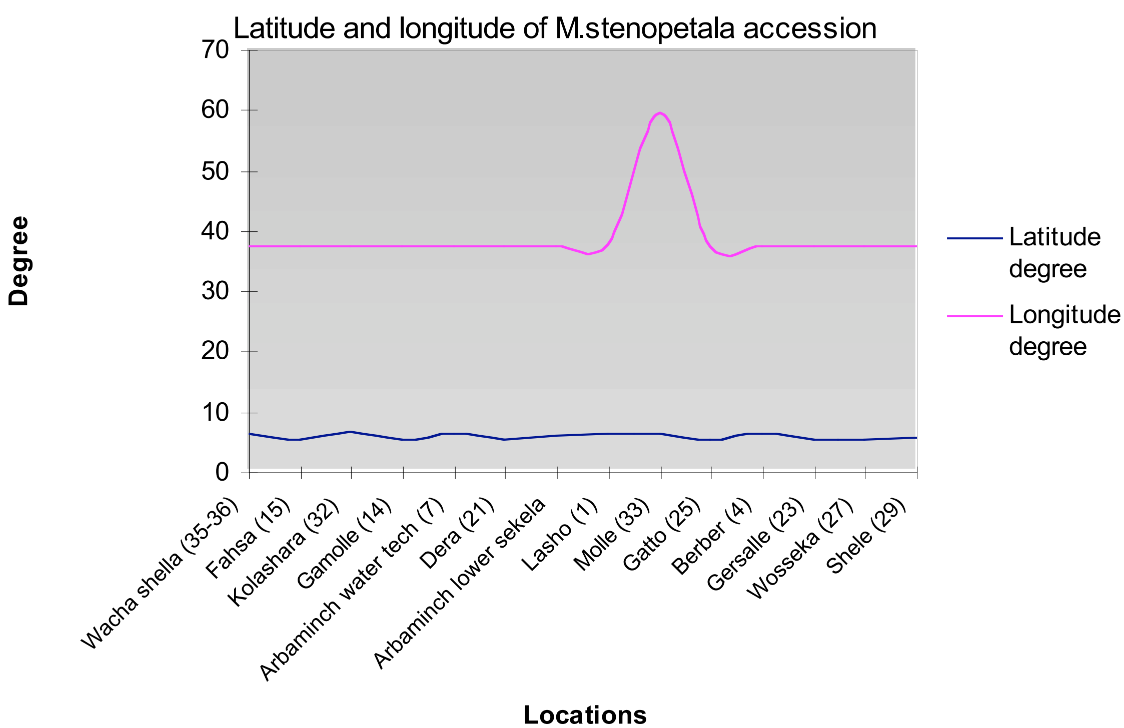


Figure 4 Elevation and seed collection latitudes and longitudes of the localities of the seed collection areas

Table 1 Mean± S.error of the mean values of contents of different accessions of *M. stenopetala*

Accessions	Dry Matter (%)	Ash (%)	Organic matter (%)	Nitrogen (%)	Crude protein (%)	True IVOMD (%)
Wacha shella	89.49±0.29	13.80±0.44	86.20±0.44	3.56±0.12	22.24±0.73	84.72±0.76
Kolashara	90.05±0.47	12.43±0.40	87.57±0.40	3.41±0.23	21.32±1.43	87.21±1.76
Gamolle	90.47±0.93	11.20±0.29	88.80±0.29	3.66±0.15	22.84±0.95	88.83±1.16
Arbaminch water tech.	89.82±0.22	12.84±0.34	87.17±0.34	3.51±0.34	21.92±2.15	84.30±1.30
Dera	90.59±0.97	12.86±1.26	87.14±1.26	3.41±0.19	21.29±1.20	84.87±1.61
Arbaminch lower sikela	89.72±0.27	12.10±0.20	87.90±0.20	3.66±0.14	22.85±0.89	89.47±2.22
Lasho	89.89±0.43	12.08±0.55	87.92±0.55	3.70±0.17	23.12±1.09	90.99±0.89
Molle	90.29±0.12	12.89±0.51	87.11±0.51	3.51±0.32	21.91±1.98	88.27±1.79
Gatto	89.34±0.61	12.23±0.63	87.78±0.63	3.79±0.25	23.64±1.54	90.07±1.42
PkmIndia	90.56±0.48	13.47±0.59	86.53±0.59	3.48±0.22	21.78±1.35	84.31±1.72
Aselle	90.53±0.31	14.10±0.40	85.90±0.40	3.39±0.23	21.19±1.45	83.38±2.36
Berber	89.93±0.27	12.92±0.24	87.08±0.24	3.73±0.35	23.29±2.17	85.16±2.32
Gersalle	89.92±0.43	13.80±0.47	86.21±0.47	3.52±0.16	22.00±1.03	85.35±0.68
Exbaringo oleifera	90.25±0.24	13.59±0.60	86.41±0.60	3.46±0.06	21.65±0.38	82.55±1.21
Wosseka	90.32±0.63	12.49±0.41	87.52±0.41	3.49±0.23	21.82±1.45	82.04±1.92
Shele	89.94±0.24	12.99±0.04	87.01±0.04	3.46±0.06	21.60±0.41	85.19±2.10
Dokatu	89.98±0.20	13.59±0.43	86.42±0.43	3.27±0.26	20.45±1.62	89.08±2.51
P - value	***ns***	***0.035***	***0.035***	***ns***	***ns***	***0.006***

It was possible to find out that the dry matter content did not show any significant difference among the different accessions of *M. stenopetala*. The ash content (%) and the organic matter content have shown a significant difference among accessions (*p=0.035 at α=0.05)*. The true IVOMD (indicator of digestibility) has shown a highly significant difference among accessions (*p=0.035 at α=0.05)*. But no statistic difference was observed for nitrogen content (%) and crude protein content (%) among the assessed accessions (table 1).

Table 2 The correlation matrix of the components of the leaf with altitudes of the collection sites

		DM %	Ash %	OM%	N%	Crude protein %	True IVOMD %	Altitude
DM %	Correlation	1						
	Sig. (2-tailed)	.						
Ash %	Correlation	0.121	1					

	Sig. (2-tailed)	0.391	.					
OM%	Correlation	-0.121	-1.000	1				
	Sig. (2-tailed)	0.391	0.000	.				
N%	Correlation	0.021	-0.194	0.194	1			
	Sig. (2-tailed)	0.880	0.168	0.168	.			
Crude protein %	Correlation	0.022	-0.193	0.193	1.000	1		
	Sig. (2-tailed)	0.876	0.169	0.169	0.000	.		
True IVOMD %	Correlation	-0.133	-0.452	0.452	0.368	0.367	1	
	Sig. (2-tailed)	0.349	0.001	0.001	0.007	0.007	.	
Altitude	Correlation	0.166	-0.351	0.351	0.057	0.055	0.192	1
	Sig. (2-tailed)	0.239	0.011	0.011	0.687	0.696	0.174	.

The analysis has indicated that the *Gamolle, Dera, Molle, Aselle, Exbaringo olifera* and *Wosseka* accessions have shown a high dry matter (%). This indicates that these accessions have higher density of plant matter as compared to the other accessions. The smallest dry matter (%) content was recorded for *Wacha shella, Arba minch water tech, Arba Minch Lower Sikela, Gatto* and *Lasho*. The extreme small dry matter (%) content belongs to *Wacha shella* and *Gatto* accessions (fig 5).

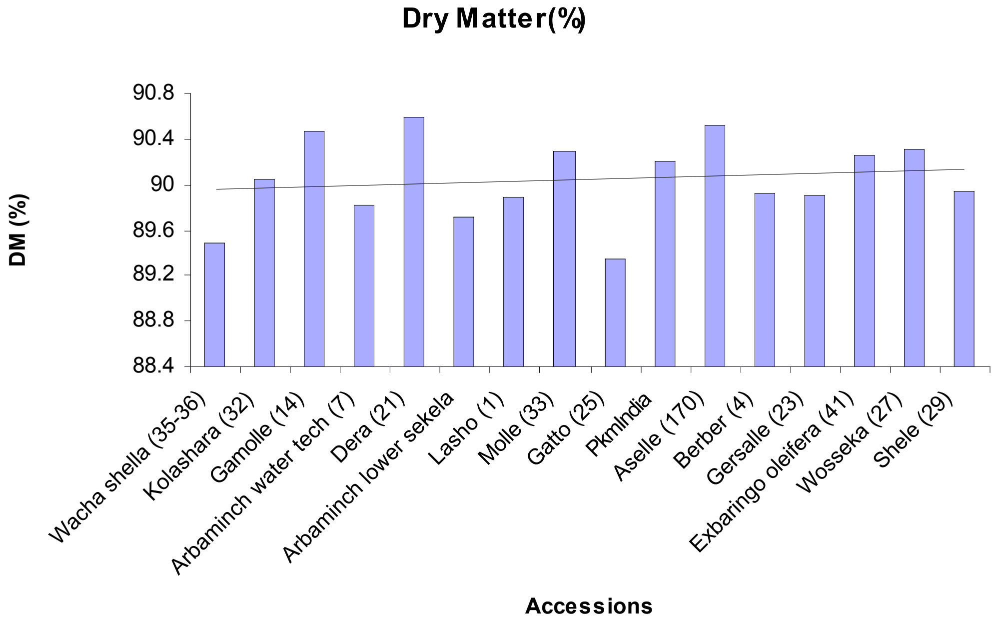


Figure 5 Dry matter (%) of the different *M. stenopetala* accessions

The ash content was found to be higher for the *Wacha shella, Aselle, Gerselle, Ekbaringo Oleifera* and the accession from *Arba Minch water technology compound* (fig 6). The accession from *Aselle* has also recorded highest amount of dry matter (%). The accessions from *Gamolle, Arba Minch lower Sikela* and *Lasho* have had the smallest ash content comparatively. The accession from the *Arba minch Lower Sikela* and the *Lasho* accessions also had very low dry matter content. Thus in both dry matter and ash content these two accessions are not preferable.

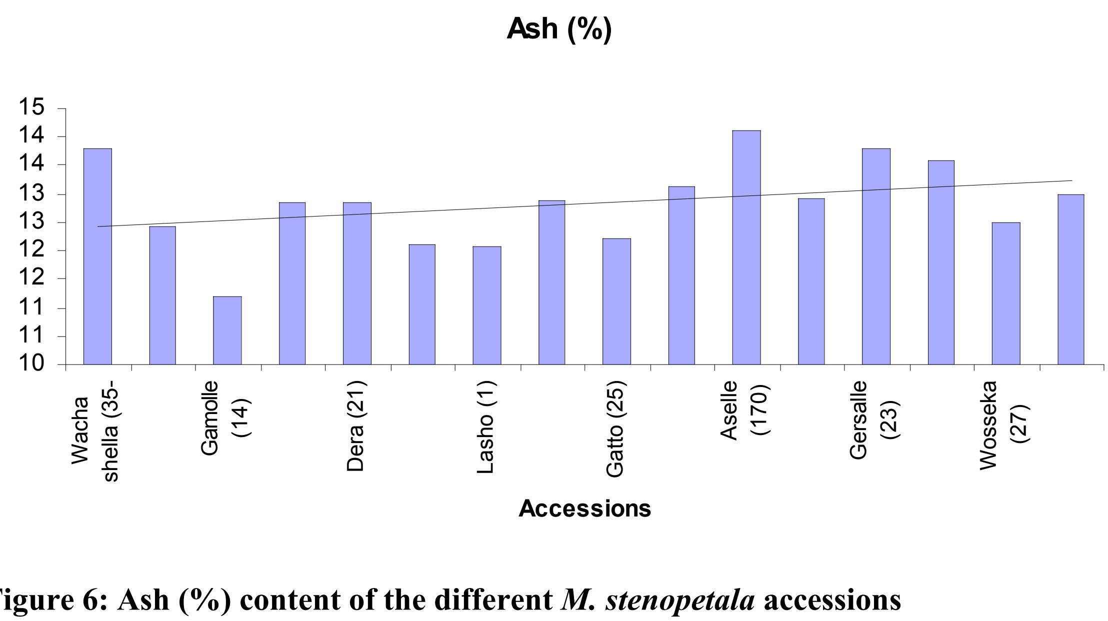


Figure 6: Ash (%) content of the different *M. stenopetala* accessions

Gamolle, Gatto, Lasho, Arba Minch lower Sikela and *Wasseka* area had the highest organic matter content as compared to all the others. In contrary, *Aselle* and *Wacha Shella* recorded the lowest OM content (fig 7).

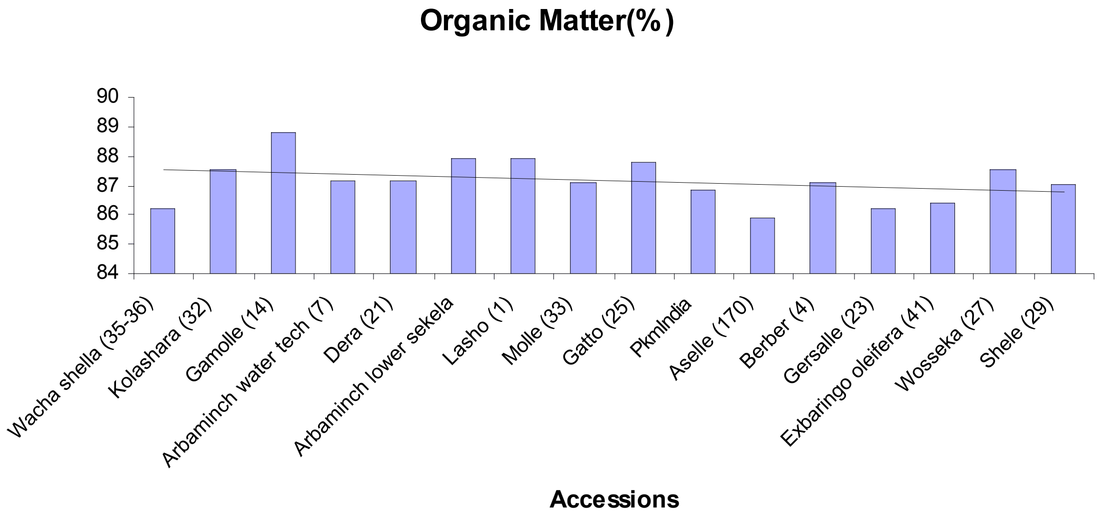


Figure 7: Organic matter (%) content of the different *M. stenopetala* accessions

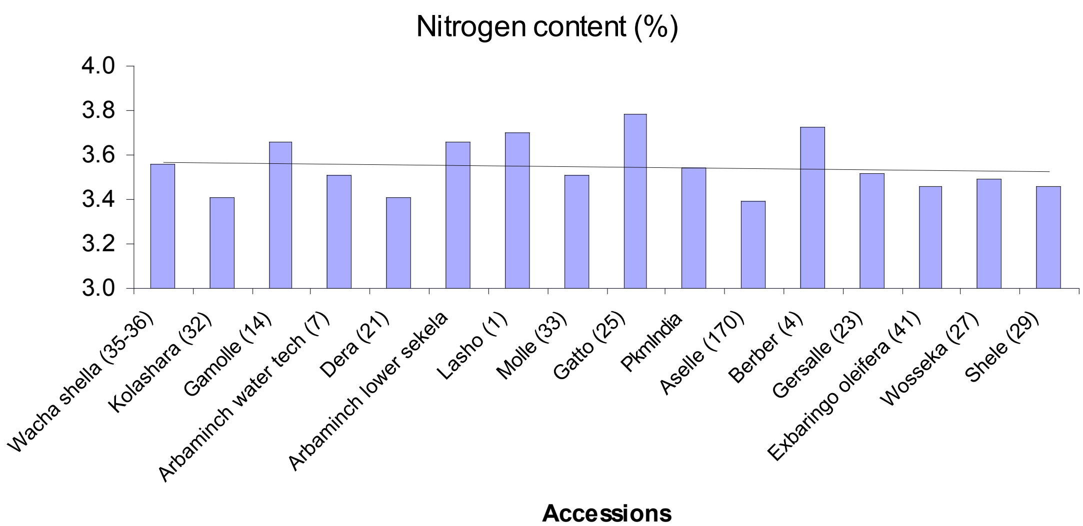


Figure 8: Nitrogen content (%) content of the different *M. stenopetala* accessions

The N content has a similar result with slight variations. The *Gamolle, Gatto, Berber, Lasho and Arba Minch lower Sikela* accessions had the highest N content while *Kolashara, Dera* and *Aselle* had the lowest values comparatively (fig 8). The presence of higher N could be of an added advantage for the accession because their preference both for human and animal consumption.

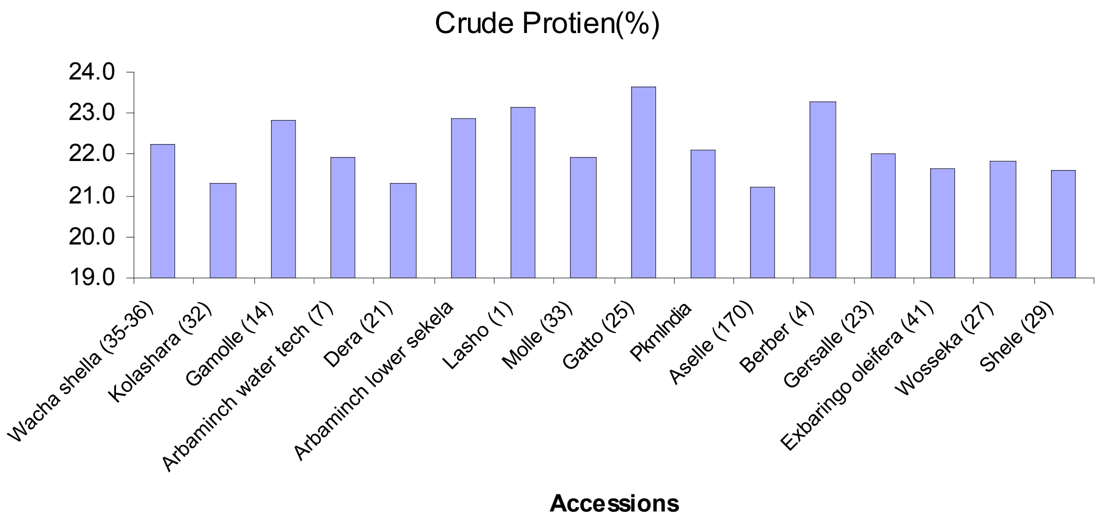


Figure 9: Crude protein (%) content of the different *M. stenopetala* accessions

The crude protein content is found to be highest for the accession from *Gatto*. Following *Gatto, Berber, Lasho, Arba Minch Lower sikela,* and *Gamolle* exist in the order of their crude protein content (fig 9). It has to be noted that one of the criterion to select the accessions could be based on the composition of the crude protein. Therefore from this study it is possible to find out that *Gatto* followed by *Berber* and *Lasho* make up the best accessions for consumption by humans.

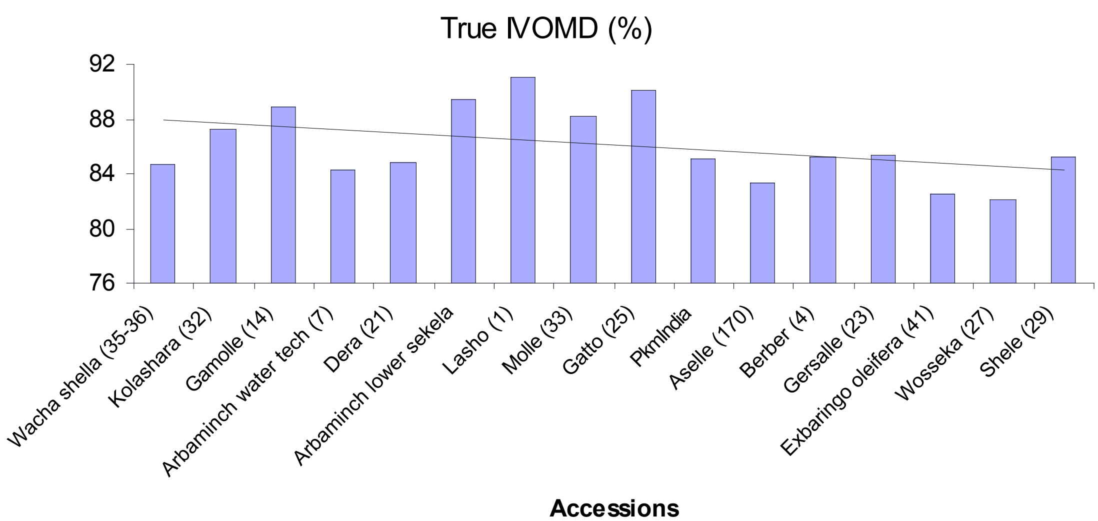


Figure 10: True IVOMD (%) content of the different *M. stenopetala* accessions

The True In vitro Organic Matter Digestibility IVOMD (%) assessment indicates whether a given plant material is easily digestible or not. Simply it depicts the proportion of the plant material which is easily digestible by the human and livestock. The current assessment has indicated that the *Lasho>Gatto>Arba Minch Lower Sikela* make the top best digestible *Moringa* accessions.

The different parameters assessed above can be summarized as follows:

Dry matter (%) – *Gamolle > Dera > Molle > Aselle> Exbaringo olifera >Wosseka* ((Lowest values) *Gatto < Wacha shella < Arba Minch Lower Sikela < Lasho*)

Ash (%) – *Shella > Aselle > Gerselle > Ekbaringo Oleifera > Arba Minch water technology compound* ((lowest ash (%) (*Gamolle < Gatto=Lasho= Arba Minch Lower Sikela*))

Organic Matter (%) – *Gamolle > Gatto=Lasho =Arba Minch Lower Sikela > Kollashara*

Nitrogen (%) – *Gatto > Berber > Lasho> Arba Minch Lower Sikela > Gamolle*

Crude protein (%) - Gatto> *Berber > Lasho > Arba Minch Lower sikela > Gamolle*

True IVOMD (%) – *Lasho > Gatto > Arba Minch Lower Sikela > Gamolle > Molle*

From the summary above it is possible to see that *Gatto* is the best accession as a whole. It has high N (%) and Crude protein (%). It has also a comparatively superior True IVOMD (%). Moreover, it has a better organic matter (%). It contains lower amount of ash (%) which could be of an added advantage for the accession. The second ranking accessions is the *Lasho* followed by *Arba Minch Lower sikela* accession (all selected based on similar criteria as that of the Gatto).

Comparison of *M. stenopetala* and *M. oleifera* in growth and development

At the initial planting stage *M. oleifera* had shown five folds in growth and development. The leaf production cycle is short and the plant being not very perennial like that of the indigenous *M. stenopetala* has short gestation period. It is smaller in size at full matured tree size and can be planted in closer spacing for higher yield. The traditional farmers planting of *M. oleifera* is scattered tree on farm. In a natural stand like any trees in dry agro-ecology it is found as an open wood land. Thus spacing determination technology is a practice that is cut and pasted from nature with modest modification to suit crop mixing.

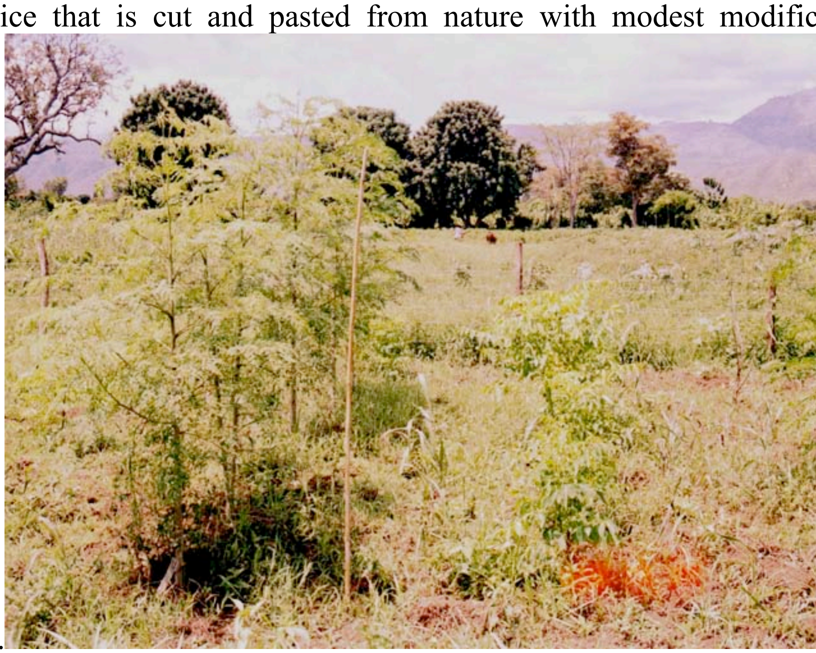


Figure 11: Comparative growth performance of *M. oleifera* with *M. stenopetala*

The leaf and twigs ratio of *M. oleifera* is *2.3:1* while for the local species *M. stenopetala* it is relatively low which is *1.5:1*. This indicates that the exotic is leafier than the local. If we compare the leaf twigs index *M. oleifera* has only *5%* twigs (rachis and the mid rips) while *M. stenopetala* has *7.4%* which is still an indicator of low leaf content.

In the month of March to May there was leaf infestation by an insect. The level of infestation was reported on the insect feeding experiment. *M. oleifera* was less infested compared to *M. stenopetala*.

In general *M. oleifera* is a fast growing species and it can recover quickly and reach optimum leaf biomass production level. From information generated from the coppices there will be a significant contribution for the huge variation observed between the two species. Thus successive leaf harvest task need to be made to determine the actual and precise difference.

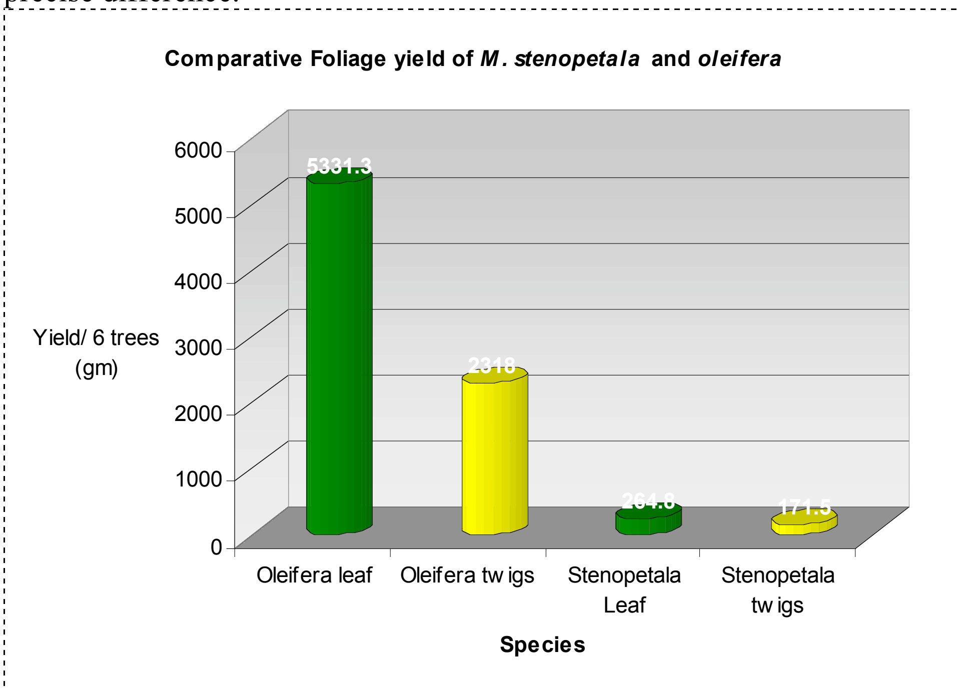


Figure 12: Comparative foliage yield assessment of *M. stenopetala* and *M. oleifera*

In animal feed *Leuceana leucocephala* is among the selected cultivars introduced and recommended for planting. Among the native fodder *Acacia albida* is another important fodder tree of the natural tree intercrop.

According to Hou'erou (1980) chemical composition and nutrient findings, the result is compared with the analysis obtained on the two Moringas from ILRI laboratory as shown in the graph (fig 12). Crude protein for *M. stenopetala* is the highest with a value of 26.91% compared to even the improved *M. oleifera* which is 22.21% which is lower by 17.5%. Ash content is the same. Calcium content is higher for *M. oleifera* which is 2.5 compared to 1.5% which corresponds to 60%. Since the leaf samples for *M. stenopetala* are analyzed with the wood twigs and the samples for *M. oleifera* was predominantly leafy, the gap would have been not greater than 25%. Such variation will be a cross cutting issue for other results. We couldn't take the samples of the leaf blade due to

- Insufficient sample size from the field since leaf was eaten by insect.

- Since the animals eat the leaf together with the rachis it was an appropriate for fodder study but not for food.

It is possible to observe that *M. stenopetala* has a higher crude protein (%) and high K (%) than *M. oleifera, Leucaena leucocephala and A. albida.* However, it had a lower Ca and Mg level when compared with *M. oleifera*. There is no difference in the ash content between the two *Moringa* species. The *M. stenopetala* thus exceeds the other tree species considered for comparison in this case.

Conclusion
Since Moringa consumption is limited to the southern nation and Nationalities, the intention is to popularize and scale up in drier parts of the central, northern and other parts of the country where people showed resistance of consuming due lack of habit of consuming tree cabbage and also the bitter taste the leaves poses. A tannin content study will allow to identify a sweater accession for scaling up

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