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# NUMERICAL ANALYSES OF LEAF AND FRUIT EXTERNAL MORPHOLOGY IN *Moringa oleifera* LAM

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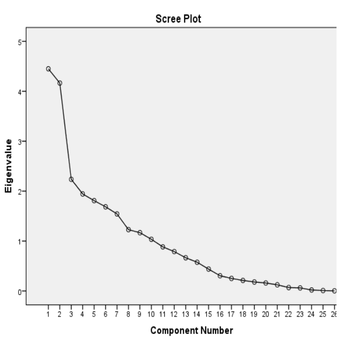
## Graphical abstract




## Abstract

The wide range of uses of *Moringa oleifera* in recent time has witnessed increasing demand of its foliar and seed products in nutritional, medical and ecological applications. The upsurge of demand for these products needs to be balanced with new varieties of improved performance to meet the supply chain. To achieve this, morphological diversity assessment is prerequisite for future crop improvement programme. Therefore, numerical analyses of the external morphology of leaf and fruit of thirty accessions of *Moringa oleifera* were assessed. The study was carried out on both qualitative and quantitative characters to assess the diversity at morphological level to establish the phenetic relationships and the delimitation of accessions. Relationship studies showed considerable correlation between the leaf and fruits characters that produced clear and reproducible threats and were selected for diversity study. Numerical analysis of the qualitative and quantitative characters clustered the accessions into five groups – operational taxonomic units (OTUs) 1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30 were clustered in group one; OTUs 6 and 8 were clustered in group two and three respectively; OTUs 15 and 16 in group four and OUT 23 in group five cluster membership. Principal Component Analysis was carried out to augment the Cluster Analysis which showed large morphological diversity existing in accessions of *Moringa oleifera* hence, infraspecific classification is hereby proposed. These analysis particularly traits related to leaf and fruits yield can also be utilised for crop improvement programme.

*Keywords:* Accessions, cluster analysis, dendrogram, phenetics, taxonomy



## 1.0 INTRODUCTION

The use of computers by taxonomists has established an interesting modern trend called Numerical taxonomy or Taximetrics which had been used to understand relationships between different taxa in plant kingdom such as *Moringa* and *Adansonia* [1]. Mathematical and statistical evaluation of taxonomic information and computation of this data have provided taxonomists with new approaches to understand classification ([2], [3] and [4]. Numerical taxonomy has the power to integrate the data from variety of sources, being mathematical and quantitative; it provides a more exact basis for classification and permits classifications to be built on wide range of characters.

*Moringa oleifera* commonly called Ben-oil tree, drumstick tree, horse-radish tree, cobbage tree clarifier tree [5]. Moringa tree (English), okwe oyibo (Igbo), zogallandi, zogale (Hausa), ewe-igbale (Yoruba). [6] and [7] reported that the tree species is grown mainly in semiarid, tropical, and subtropical areas. While it grows best in dry, sandy soil and it tolerates poor soil in coastal areas. It is a fast-growing, drought-resistant tree that is native to the southern foothills of Himalayas in North-Western India. It is a multi-purpose plant with a tremendous variety of potential uses, and recently attracted the attention of several authors such as [8], [9] and [10]. [11] considered the potentials of *M. oleifera* tree products in different ways that improve man and his environmental well-being. These uses include in alley – farming, animal forage, vegetable, biogas production, dye, honey clarifier, ornamental, pulp, water purification, edible oil, fiber, fertilizer, cosmetics, ointment, erosion control, textile printing, insecticide, fungicide, lubricants, tanning leather, fences, wind barrier, cane juice clarifier, condiment, plant growth enhancer [7].

In medicine, [12] and [13] reported that it aids in the treatment of several diseases. In developing countries like Nigeria, *Moringa* has potential to improve nutrition, boost food security, foster rural development and support sustainable land care [14]. In Nigeria with wide range of uses of *Moringa* products, most research efforts are focused mainly on its medicinal value [15], anatomical identification of plant fragment [16] and [10], anti-viral activity of the seeds [17] and water treatment [18]. Morphological and anatomical characters of the plant have been used by many authors in plant identification [19], [20], [21], [22] and [23]. According to [10], taxonomic identification has been the basis on which plant breeding efforts are founded such that diagnostic characters are assigned to specific or varietal parentage.

In the light of the above, the present study was conducted to examine and analyse the leaf and fruit morphological features of some accessions of *M. oleifera* with a view to identify possible varieties in the species. This information could form basis or foundation for the improvement of this multi-purpose plant for enhanced productivity.

## 2.0 EXPERIMENTAL

### 2.1 Collection of Plant Materials

The leaves and fruit pods of *Moringa oleifera* were obtained from mature plant stands at the *Moringa oleifera* Plantation of the University of Ilorin, Ilorin, Kwara State, Nigeria; between December, 2012 and July, 2014. Photographs of all the specimens collected were taken with digital camera for study.

### 2.2 Leaf and Fruit Parameters

Both qualitative and quantitative characters of leaves and fruits were selected and used. Qualitative characters included leaf type, leaflet shape, leaflet apex, leaflet arrangement, leaflet surface, leaflet base, leaflet margin, leaflet venation and leaf attachment. The quantitative features such as the whole leaf length, leaflet length, leaflet width, petiole length, shape of pod, pod length, pod width, pod surface, pod index, seed type, number of seeds in a pod, seed colour, length of stalk as well as type of fruit, fruit streaks and fruit colour were all observed, measured and recorded. Sample size of 30 operational taxonomic units [24] and a total of twenty-six character states were selected. The character states were determined and coded as described by [25].

### 2.3 Statistical Analyses

Quantitative data (mean, standard error and correlation) were analysed using SPSS Package 20 [26]; morphological characters measured i.e. Tables 1 – 3 (qualitative and quantitative) were calculated and the coded data matrix was subjected to Cluster Analysis and Principal Component Analysis using NTSYS software version 2.02 [27].

## 3.0 RESULTS AND DISCUSSION

### 3.1 Results

The leaf quantitative morphological features of the *M. oleifera* OTUs were shown on Table 1. The highest mean terminal leaf length (54.20 mm and 39.57 mm) were recorded by OTU 18 and OTU 10 respectively. The lowest average whole leaf length was 214.0 mm and lowest average terminal leaflet width in OTU 27 was 9.12 mm. The OTU showing the highest number of leaflet per leaf in all the samples studied was OTU 1 with about 144.60 and the least were recorded by OTU 17 which has 18.10 per leaflet. The qualitative characters show two major discontinuous features of leaf stalk colour of either tan or green and leaf stalk surface – glabrous or hairy in all the OTUs studied (Table 2). Other continues features (Figure 1) include ramal phytotaxy, smooth leaf surface, unicostate leaf venation, opposite leaf arrangement, entire leaf margin and petiolated leaf attachment

The fruit pod quantitative features in varieties of *M. oleifera* are presented on Table 3. The highest pod length range 414.5 (495.0) 573.2 mm and fruit stalk length 96.70 (111.41) 119.50 mm were recorded by OTU 26 and 20 respectively. While the highest average pods width was 25.59 mm by OTU 28. The OTU with the highest number of seeds per pod in all the OTUs under consideration is OTU 26 with the mean of 23.40. The pod index is relatively the highest in OTU 15 (5.04) and lowest in OTU 29 (2.66). The seed length in OTU 18 is the highest which ranges from 14.01 – 16.21 mm and the lowest in OTU 13 were 9.12 – 10.98 mm.

**Table 1** *Quantitative Characters of Leaves in varieties of M. oleifera*

| OTUs | Leaf Length (mm) | Leaf Width (mm) | Petiole Length (mm) | Terminal Leaflet Length (mm) | Terminal Leaflet Width (mm) | No. of Leaflets /Leaf |
|---|---|---|---|---|---|---|
| 1 | 234.0±2.33 | 101.0±1.11 | 7.10±0.52 | 33.40±1.57 | 23.40±1.01 | 25.40±1.00 |
| 2 | 316.0±2.06 | 229.0±1.26 | 9.81±0.62 | 32.10±1.22 | 26.68±2.11 | 59.10±1.01 |
| 3 | 436.0±3.23 | 278.0±1.55 | 11.72±0.71 | 20.48±1.03 | 26.68±2.11 | 149.60±4.68 |
| 4 | 361.0±2.12 | 182.0±0.48 | 9.66±0.88 | 27.29±1.44 | 15.17±1.17 | 52.50±2.03 |
| 5 | 283.0±1.48 | 166.0±0.44 | 7.82±0.52 | 20.02±0.92 | 22.72±2.08 | 144.60±4.52 |
| 6 | 318.0±1.67 | 228.0±0.63 | 9.84±0.38 | 30.18±0.90 | 10.15±0.41 | 58.50±3.34 |
| 7 | 284.0±1.94 | 129.0±0.88 | 7.90±0.81 | 40.80±1.43 | 21.22±0.92 | 28.40±1.42 |
| 8 | 291.0±2.14 | 152.0±1.14 | 7.80±0.92 | 24.53±1.24 | 29.48±1.41 | 35.30±3.33 |
| 9 | 350.0±2.66 | 182.0±1.23 | 10.81±0.77 | 20.48±1.50 | 20.42±1.28 | 142.10±4.52 |
| 10 | 214.0±1.72 | 153.0±1.66 | 9.11±0.68 | 39.57±2.61 | 14.73±0.66 | 19.90±6.30 |
| 11 | 413.0±1.1 | 245.0±1.32 | 25.14±0.34 | 37.02±1.82 | 33.26±1.73 | 27.30±1.65 |
| 12 | 405.0±1.17 | 201.0±1.10 | 22.66±0.82 | 36.82±0.34 | 24.38±0.87 | 33.10±2.12 |
| 13 | 384.0±1.41 | 215.0±1.70 | 13.96±0.21 | 32.46±2.12 | 33.87±0.54 | 39.40±1.63 |
| 14 | 357.0±1.32 | 282.0±0.92 | 16.61±0.25 | 37.52±1.45 | 31.18±1.12 | 69.40±1.09 |
| 15 | 3590±1.28 | 268.0±0.54 | 19.07±0.32 | 37.84±1.22 | 31.47±1.54 | 94.11±3.03 |
| 16 | 502.0±1.45 | 314.0±1.43 | 21.46±0.33 | 21.82±0.98 | 32.60±1.15 | 91.50±1.75 |
| 17 | 416.0±1.74 | 263.0±1.22 | 14.56±0.65 | 15.52±1.10 | 12.63±1.82 | 18.10±1.20 |
| 18 | 542.0±1.04 | 301.0±1.81 | 15.80±0.83 | 22.65±1.22 | 7.98±0.32 | 72.90±3.50 |
| 19 | 385.0±1.14 | 247.0±1.42 | 18.87±0.67 | 11.65±1.07 | 16.17±1.15 | 107.00±2.51 |
| 20 | 507.0±1.20 | 266.0±1.27 | 20.54±0.43 | 18.76±0.76 | 7.68±2.11 | 90.40±3.80 |
| 21 | 518.0±1.19 | 401.0±1.23 | 25.78±0.64 | 12.42±0.28 | 14.61±1.40 | 104.10±2.27 |
| 22 | 487.0±1.33 | 310.0±0.83 | 16.28±0.42 | 19.22±0.95 | 8.52±1.13 | 99.80±1.61 |
| 23 | 411.0±1.50 | 346.0±0.36 | 28.07±0.58 | 23.35±1.82 | 15.17±1.09 | 120.40±2.12 |
| 24 | 443.0±1.12 | 416.0±1.22 | 28.94±0.65 | 17.16±1.11 | 19.67±1.75 | 88.40±2.09 |
| 25 | 478.0±1.48 | 361.0±1.27 | 25.76±0.64 | 13.31±1.27 | 12.68±1.10 | 54.50±0.69 |
| 26 | 514.0±1.40 | 401.0±1.65 | 22.64±0.85 | 12.54±1.99 | 9.12±0.98 | 92.40±1.75 |
| 27 | 523.0±1.14 | 374.0±1.32 | 29.03±0.24 | 11.21±0.87 | 10.12±1.57 | 90.80±1.50 |
| 28 | 353.0±1.02 | 286.0±0.86 | 17.18±0.66 | 13.56±0.58 | 9.06±0.99 | 80.42±3.12 |
| 29 | 245.0±1.11 | 201.0±0.64 | 14.18±0.43 | 31.69±1.14 | 9.78±0.38 | 55.61±1.32 |
| 30 | 294.0±1.40 | 222.0±1.19 | 20.11±0.74 | 29.08±1.05 | 23.30±1.17 | 62.58±1.21 |

**Table 2** Qualitative Characters of Leaf Stalk and Seed in *M. oleifera*

| OTUs | Leaf Stalk Colour | Leaf Stalk Surface | Seed Shape | Seed Colour | Wing Form |
|---|---|---|---|---|---|
| 1 | Tan | Glabrous | Ovate | tan | Prominent |
| 2 | Tan | Glabrous | Isodiametric | tan | Prominent |
| 3 | Tan | Glabrous | Isodiametric | tan | Prominent |
| 4 | Tan | Glabrous | Isodiametric | tan | Prominent |
| 5 | green | Glabrous | Isodiametric | cream | less prominent |
| 6 | green | Glabrous | Isodiametric | tan | Prominent |
| 7 | Tan | Hairy | Isodiametric | tan | Prominent |
| 8 | Tan | Hairy | Ovate | tan | Prominent |
| 9 | Tan | Hairy | Ovate | tan | Prominent |
| 10 | Tan | Hairy | Ovate | cream | Prominent |
| 11 | Tan | Hairy | Ovate | cream | Prominent |
| 12 | Tan | Hairy | Ovate | cream | Prominent |
| 13 | Tan | Glabrous | Ovate | cream | Prominent |
| 14 | Tan | Glabrous | Ovate | cream | Prominent |
| 15 | green | Glabrous | Isodiametric | tan | Prominent |
| 16 | green | Hairy | Ovate | cream | less prominent |
| 17 | green | Hairy | Isodiametric | cream | less prominent |
| 18 | green | Hairy | Isodiametric | cream | Prominent |
| 19 | Tan | Glabrous | Ovate | tan | Prominent |
| 20 | Tan | Glabrous | Ovate | tan | Prominent |
| 21 | Tan | Glabrous | Ovate | tan | Prominent |
| 22 | green | Glabrous | Ovate | Tan | Prominent |
| 23 | green | Glabrous | Isodiametric | Tan | Prominent |
| 24 | green | Glabrous | Isodiametric | Tan | Prominent |
| 25 | green | Glabrous | Isodiametric | Tan | Prominent |
| 26 | green | Glabrous | Isodiametric | Tan | Prominent |
| 27 | green | Glabrous | Isodiametric | Cream | Prominent |
| 28 | green | Hairy | Ovate | Cream | Prominent |
| 29 | green | Hairy | Ovate | Cream | Prominent |
| 30 | green | Glabrous | Ovate | Cream | Prominent |

**Table 3** Quantitative Characteristics of the Pod and Seed in varieties of *M. oleifera*

| OTUs | Pod Length (mm) | Pod Width (mm) | Stalk Length (mm) | Stalk Width (mm) | No. Of Seed /Pod | Pod Index | Seed Length (mm) | Seed Width (mm) |
|---|---|---|---|---|---|---|---|---|
| 1 | 299.0±1.79 | 17.80±1.75 | 99.33±26.97 | 5.52±0.26 | 13.00±1.87 | 3.66±0.29 | 13.28±0.30 | 10.69±0.20 |
| 2 | 379.6±0.99 | 17.86±0.46 | 83.56±11.71 | 5.26±0.37 | 14.80±0.49 | 3.20±0.31 | 10.69±0.40 | 9.28±0.52 |
| 3 | 218.6±0.94 | 17.79±0.45 | 81.45±4.58 | 5.09±0.34 | 5.40±0.24 | 4.76±0.27 | 11.61±0.63 | 10.64±0.31 |
| 4 | 202.6±0.32 | 15.51±0.19 | 66.74±2.10 | 4.83±0.31 | 5.60±0.24 | 4.30±0.84 | 15.03±0.78 | 10.63±0.45 |
| 5 | 399.8±0.48 | 21.31±0.32 | 102.99±2.24 | 6.95±0.32 | 20.00±0.32 | 3.58±0.06 | 10.35±0.71 | 8.86±0.42 |
| 6 | 394.1±0.32 | 20.31±0.23 | 104.45±2.87 | 5.80±0.20 | 20.00±0.32 | 3.65±0.05 | 10.38±0.27 | 9.47±0.75 |
| 7 | 290.2±3.48 | 19.49±0.87 | 91.16±23.04 | 5.13±0.19 | 11.40±1.75 | 4.52±1.15 | 11.21±0.22 | 9.21±0.91 |
| 8 | 382.0±076 | 20.65±1.52 | 97.17±3.15 | 6.94±0.34 | 20.00±1.32 | 3.55±0.10 | 12.01±0.50 | 10.01±0.47 |
| 9 | 434.4±0.90 | 23.71±0.82 | 86.64±5.74 | 6.45±0.43 | 22.20±1.16 | 3.02±0.16 | 11.47±0.38 | 9.74±0.33 |
| 10 | 374.4±1.99 | 22.01±1.29 | 90.70±9.03 | 5.68±0.22 | 17.40±1.23 | 3.46±0.31 | 11.29±0.75 | 8.82±0.40 |
| 11 | 292.0±1.18 | 20.14±0.40 | 102.90±10.20 | 6.35±0.54 | 20.00±1.12 | 3.92±0.43 | 12.71±0.54 | 9.74±0.48 |
| 12 | 352.1±0.87 | 18.36±0.34 | 66.80±4.92 | 4.92±0.23 | 13.10±0.18 | 3.09±0.23 | 10.62±0.41 | 10.14±0.37 |
| 13 | 325.4±1.11 | 17.28±0.29 | 92.62±6.61 | 6.42±0.50 | 16.20±0.54 | 3.39±0.32 | 10.33±0.28 | 10.11±0.15 |
| 14 | 281.0±0.09 | 18.28±1.15 | 95.17±17.10 | 5.14±0.76 | 15.50±0.61 | 3.31±0.54 | 10.44±0.34 | 10.62±0.47 |
| 15 | 246.0±0.70 | 18.71±1.10 | 82.44±2.87 | 5.40±0.21 | 5.00±0.32 | 5.04±0.42 | 11.27±0.17 | 10.98±0.17 |
| 16 | 208.2±0.48 | 17.88±1.65 | 64.88±2.52 | 4.22±0.42 | 6.10±0.96 | 3.75±0.32 | 11.31±0.40 | 10.61±0.38 |
| 17 | 198.7±0.82 | 15.14±0.74 | 92.48±7.81 | 4.38±0.32 | 5.20±0.58 | 4.10±0.56 | 10.49±0.31 | 8.14±0.43 |
| 18 | 391.8±1.15 | 14.92±0.21 | 63.41±3.72 | 5.82±0.45 | 16.20±0.88 | 3.19±0.53 | 15.05±0.68 | 11.12±0.80 |
| 19 | 401.1±1.75 | 21.58±1.23 | 71.23±2.88 | 7.00±0.56 | 21.00±1.12 | 3.76±0.23 | 14.11±0.47 | 10.21±0.41 |
| 20 | 382.0±1.10 | 20.14±1.82 | 111.41±16.55 | 8.11±0.23 | 20.50±1.72 | 3.70±0.91 | 10.21±0.87 | 10.08±0.50 |
| 21 | 410.0±1.47 | 19.83±1.11 | 103.53±4.65 | 6.20±0.75 | 20.10±1.10 | 3.51±0.40 | 11.41±0.57 | 11.10±0.66 |
| 22 | 406.2±1.29 | 20.17±1.23 | 98.44±12.31 | 5.33±0.81 | 19.50±1.01 | 3.56±0.60 | 12.13±0.60 | 11.14±0.33 |
| 23 | 333.5±1.34 | 21.15±0.85 | 99.23±5.69 | 5.84±0.33 | 16.30.±1.25 | 4.32±0.56 | 13.11±0.49 | 10.69±0.20 |
| 24 | 362.0±0.98 | 19.68±0.83 | 129.92±20.12 | 6.92±0.65 | 10.20±0.24 | 2.92±0.76 | 10.58±0.39 | 10.01±0.43 |
| 25 | 371.3±0.64 | 25.43±0.70 | 59.82±6.71 | 7.13±0.47 | 20.10±1.22 | 3.24±0.43 | 11.60±0.67 | 10.34±0.32 |
| 26 | 495.0±1.32 | 18.42±1.02 | 85.47±3.92 | 6.17±0.43 | 23.40±1.40 | 3.40±0.22 | 10.55±0.23 | 10.21±0.11 |
| 27 | 224.2±1.66 | 22.92±1.12 | 98.33±10.11 | 5.79±0.36 | 6.00±0.10 | 3.21±0.12 | 11.01±0.43 | 9.45±0.45 |
| 28 | 364.4±1.12 | 25.59±1.92 | 101.93±14.22 | 6.14±0.39 | 17.00±1.33 | 3.62±0.54 | 11.43±0.64 | 10.20±0.21 |
| 29 | 312.2±1.00 | 23.95±1.21 | 121.59±12.76 | 5.05±0.44 | 19.10±1.73 | 2.66±0.30 | 10.21±0.72 | 8.80±0.08 |
| 30 | 452.1±1.34 | 24.93±0.99 | 96.69±10.34 | 5.42±0.42 | 22.10±0.45 | 2.94±0.84 | 10.67±0.54 | 9.70±0.55 |

**Table 4** Groups of OTUs of M. oleifera according to the method of analysis

| Method of Analysis | Cluster Membership | | | | |
|---|---|---|---|---|---|
| | group 1 | group 2 | group 3 | group 4 | group 5 |
| Average Linkage | 1, 5, 9, 11, 21, 22, 24, 25, 27, 28, 29, 30 | 2, 4, 7, 15, 16, 18, 19, 20 | 3, 6, 26 | 8, 23 | 10, 12, 13, 14, 17 |
| Complete Linkage | 1, 5, 21, 24, 25, 28, 29, 30 | 2, 9, 11, 19, 22, 27 | 3, 6, 26 | 4, 7, 12, 13, 14, 17, 18, 20 | 8, 10, 15, 16, 23 |
| Single Linkage | 1, 5, 9, 11, 21, 22, 24, 25, 27, 28, 29, 30 | 2, 4, 7, 15, 16, 18, 19, 20 | 3, 6, 26 | 8, 23 | 10, 12, 13, 14, 17 |
| Centroid Linkage | 1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30 | 6 | 8 | 15, 16 | 23 |

The qualitative characters of the seeds are shown in Table 2. The seeds shape pattern shows two major variations of either ovate or isodiametric among the OTU's. For instance, the seed shapes of OTUs 1, 4, 5, 7, 8, 9, 10, 11, 17, 18, 19, 23 and 25 are ovate and the remaining OTUs have isodiametric shape (Table 2). A remarkable distinguishable feature of seeds wing striation was found in OTUs 5, 11 and 12 with less prominent wing form. The seed colour also varies from tan to cream in all the OTUs studied. However, other continues features in the fruit pod of all the OTUs studied include green immature pod colour, brown mature pod colour, linear pod shape which pointed on both ends and the pods surfaces are scarbid.

The results of hierarchical clustering procedures are presented in form of phenograms (Figure 2), which is a diagram of relationships. The abscissa shows the spacing out of the accessions employed in the study while the ordinate on the other hand represent degree of similarity between and among the accessions. Figure 2 is a dendrogram of 36 X 30 data matrix obtained from a Complete Linkage Cluster Analysis using qualitative and quantitative morphological characters. Five phenetic clusters are recognised from the five methods of analysis used. The following are the groups; 1, 2, 3, 4 and 5 (Table 5 and Figure 2). Figure 3 presents a scree plot from a principal component analysis of the features in *M. oleifera*. It can be noticed that there is a break in the plot that separates the meaningful components from the trivial components. Components 2 and 3 are probably more meaningful with large eigenvalues, while components 16 – 26 with small eigenvalues. Generally, the scree plot had displayed several brakes.

### 3.2 Discussion

Computerized geometric and morphometric methods for quantitative analysis, measure, test and visualize differences form a highly effective, reproducible, accurate and statistically powerful instruments in systematics. Plant leaves are commonly used in taxonomic analyses and are particularly suitable to landmark based geometric morphometric [28]. In this study, intraspecific variations were prominent as evident in the morphological features of the examined varieties of *M. oleifera*. The observation was in line with earlier works of [29], [30] and [1] that used comparative morphology of different species in establishing relation among various taxa.

The general appearance of the leaves in *M. oleifera* varieties in all the OTUs is ramal, alternate, composite, bipinnate or tripinnate, with 2 to 6 pairs of opposite pinnae bearing opposite leaflet in 3 to 7 pairs. It also has broader terminal leaflet, green leaf lamina colour, entire leaflet margin (Fig. 1) and these suggest it to be an inherent character in *M. oleifera*. However, the consistent similitude of these features in all the OTUs makes them less significance in establishing variability of the samples, hence the exclusion from the cluster analysis. The qualitative morphological studies revealed a very close relationship between the thirty OTUs. In this study, intraspecific variation was more prominent as evident in the morphometric features of leaves and fruits of the OTUs (Table 3). Similarly, possession of terminal leaflet that is larger than other leaflet (Fig. 1), more or less glabrous, ovate to elliptic, rounded at apex and base, with the petiole being pubescent and generally with mean leaf sizes considerably variable even among samples from same location, agrees with the descriptions of [31], and [32]. According to [33], Moringa is heterogeneous in form and yields within each species because it is highly cross pollinated tree. Changes in plant morphological features in terms of variation have been attributed to small-scale evolutionary processes, a view supported by the works of [34] in different species of plants. In addition to this, leaf size variation in taxonomy forms a basis for evolutionary changes in plants. Also it can modify the distribution of leaf biomass between support and functional tissues [35]. Plants are generally agreed to have high phenotypic plasticity, and therefore one may not exclude the possibility of the observed differences in terms of leaf sizes being caused by direct influence of environmental conditions. But, [36] observed that phenotypic plasticity from differences in morphological sizes that can coincide with genetic variation.

Fruit morphology is one of the major qualitative and quantitative characters used in the delimitation and identification of each OTU. The major diagnostic features are the fruit pod shape and the number of seed(s) per fruit pod (Table 3). The shape of the *M. oleifera* fruit pods is linear and pointed at both ends in all the OTUs studied. Pod length in the accessions ranges from 198.7 (OTU 17) to 495.0 mm (OTU 26). It was observed from this study that the length of fruit pods commensurate the numbers of seeds per pod for instance; OTU 26 which has the highest average pod length of 495.0 mm, has the mean number of seeds of 23.40 and OTU 17 with the least mean length has almost the least seeds (5.20). Hence, the length and seed(s) number per pod vary amongst the OTU's (Table 3). Seeds ranged from 10.21 (in OTU 20) - 15.03 mm (in OTUs 4 and 18) in length and 8.14 (OTU 17) - 11.14 mm (OTU 22) in width.

Two different seeds shapes (ovate and isodiametric) were recognized with prominent or less prominent wing form (Table 2). The colour varied from tan to cream. These were found to be important diagnostic characters as it was in conformity to the results obtained by [38] on the Morphological variations of seeds among three Moringa species. Seed shape patterns appear to mark different evolutionary levels inside many taxonomic groups and variation of the seed characters is sufficient to distinguish taxa at sectional level. The variability in seed morphology especially of angiosperm and the relative constancy of seed structure in narrow taxonomic units permit the use of seed characteristics in taxonomic studies. Comparative seed morphology is important in seed testing, seed identification and crop improvement. In external topography; the important features of seeds are shape, size and seed coat surface, placement of the hilum, and presence or absence of such structures as aril, caruncle or elaiosome [37].

On the dendrogram (Figure 2), although branching occurred at low phenon levels which shows broad similarities among the varieties. There are some accessions (OTUs 6 and 8) that stand as outliers and do not correspond to any group of the five groups recognised. Also some accessions were found to overlap in all the groups.

Clearly, each component of the Principal Component Analysis (Figure 3) was a negative linear combination of twenty-five variables. Therefore, the evaluated features in *M. oleifera* could be explained with few numbers of new components that have no correlation with each other as can be seen in Figure 3.


**Figure 1** Morphology of leaf types in *Moringa oleifera* (a) and (b) Tripinnate (c) and (d) Bipinnate

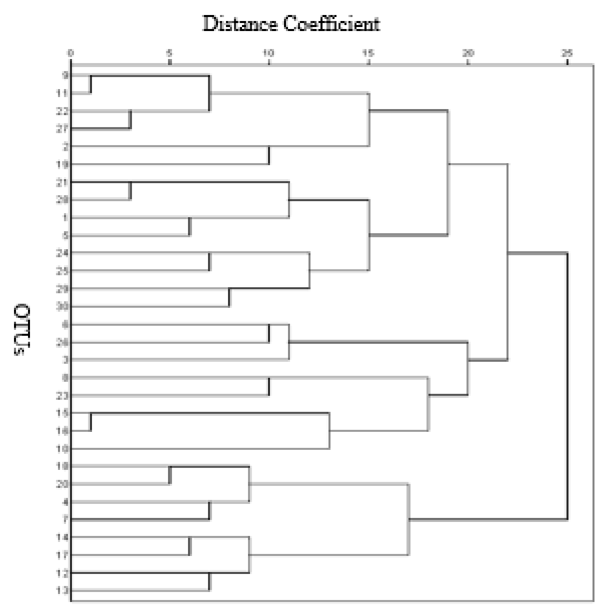



**Figure 2** Dendrogram of the OTUs of *M. oleifera* using Complete of Linkage (Furthest- Neighbour Method) Euclidean squared method

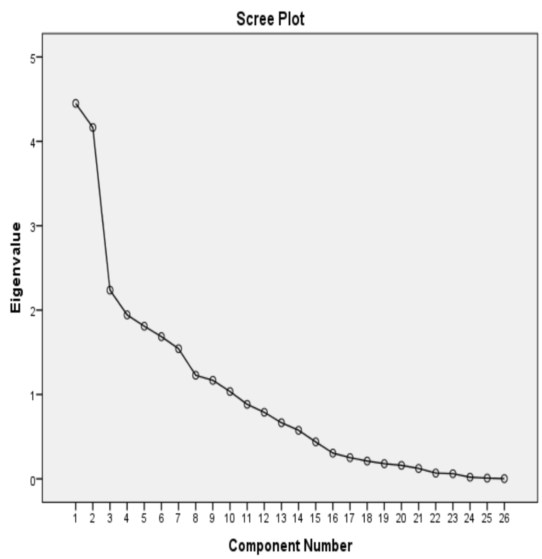



**Figure 3** Principal Component Analysis for Accessions *M. oleifera*

## 4.0 CONCLUSION

Wide range of morphological pattern existed among the studied accessions, ranging from the variation in leaf structures, fruit pod structures to seed structures. An accurate quantification and effective visualization of the main levels of morphological variation in these features is a key to gaining insight into the evolutionary and ecological processes of phenotypic diversification. It also provides the fundamental basis from which to develop more complex studies for achieving new perspectives on the interplay of phenotype, genotype and environment and a better understanding of ontogenetic and phylogenetic processes in plant variation. Similarly, the numerical analysis using morphological features in *M. oleifera* suggests the existence of variation among the samples which suggest that various infraspecific classification of *M. oleifera* can be made and may form a basis for the possibility of improving the crop by genetic breeding.

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