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Growth Performance of *Moringa oleifera* and *Moringa ovalifolia* in Central Namibia Semi-Arid Rangeland Environment

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Abstract

The objective of this study was to compare the field growth performance of *Moringa oleifera* and *Moringa ovalifolia* in semi-arid environment of central Namibia rangeland. This part of Namibia has both arid and semi-arid climates. These climates require the growing of drought-resistant fodder trees to aid in the provision of animal feed or supplement. This is paramount to livestock farmers who are striving to meet the feed demand of their animals especially during winter and drought periods. It is upon this background that both *Moringa* species were grown to evaluate their field growth performances. *Moringa oleifera* grew faster with 224.9 cm and 281.45 cm heights than *Moringa ovalifolia* that had 77.025 cm and 113.2 cm heights in 2014/2015 summer season (October 2014 to April 2015) and 2015/2016 summer season (October 2015 to April 2016), respectively, although *Moringa ovalifolia* is native to Namibia. In Namibia, summer usually starts October and ends April the follow year after which winter follows. *Moringa oleifera* grew significantly higher ($P < 0.05$) in heights compared to *Moringa ovalifolia*, though they belong to the Moringaceae family and were grown under the parallel conditions. Therefore, *Moringa oleifera* would serve as a better alternative for improving rangelands' productivity under these adverse climatic and environmental conditions since it can grow faster than *Moringa ovalifolia*, whose characteristic leads to the rapid establishment of trees and large quantity of leaf-biomass production.

Keywords

Folder, Drought-Tolerant Trees, Supplement, Winter

1. Introduction

There are 13 known species of moringa trees belonging to the Moringaceae family [1]. These species are divided into three groups based on the shapes of their trunks: slender trees, bottle trees and tuberous shrubs. *Moringa oleifera* of India, *Moringa concanensis* of India, Pakistan and Bangladesh, and *Moringa peregrina* of Arabia, Red Sea area, Egypt, Sinai, Israel and Sudan belong to the slender trees. *Moringa ovalifolia* of Namibia and Angola, *Moringa drouhardii* and *Moringa hildebrandtii* of Madagascar; *Moringa stenopetala* of Ethiopia and Kenya belong to the bottle trees. And the last group include *Moringa Arborea* of Kenya; *Moringa rivae* of Kenya and Ethiopia; *Moringa borziana* of Kenya and Somalia, *Moringa pygmaea* of Somalia; *Moringa longituba* of Kenya, Ethiopia and Somalia; and *Moringa ruspoliana* of Kenya, Ethiopia and Somalia which belong to tuberous shrubs and trees of northeast Africa [1] [2] [3]. Although *Moringa* has such many species, *Moringa oleifera* is the most adapted plant worldwide compared to other species. It has also been established that among the known species, *Moringa oleifera* is the most widely known worldwide [3]. Many researches have been done on its uses and numerous beneficial properties in the plant kingdom [2] [4].

Moringa oleifera is a fast growing drought-resistant tree that is native to the southern foothills of Himalayans in Northern India [2] [5]. It is commonly known as horse-radish or drumstick tree in English [3] [6]. It grows rapidly even in poor soils, arid and/or dry lands [7] [8]. Although native to India, it has been planted around the world and is naturalized in many countries [9] [10]. For instance, it is cultivated throughout Senegal commonly as a living fence around compounds in villages [11]. Other examples of *Moringa* growing in African countries showed that the seeds germinate within 5 to 12 days and transplanted at the height of 60 to 90 centimeters (cm). *Moringa oleifera* can tolerate up to 6 months of dry season reasonably well; however, prolonged stress from lack of water can lead to loss of leaves [2] [9]. It has a high growth rate and capacity to produce large quantities of fresh biomass [9]. A research at the International Trypanotolerance Centre in Banjul, *Moringa oleifera* yielded biomass in excess of 15 tonnes dry matter/hectare (DM/ha) in a 60-day growing cycle [12].

On the other hand, *Moringa ovalifolia*, which is described as a bottle tree because of its trunk, is a native tree to Namibia and Angola. This species is generally uncommon, but widespread in western Namibia, as far south as 26˚S; scattered localities in the Karstveld and occasionally in the south, but common in the central areas. It grows in the wild in both countries. It is a deciduous tree with a distinctive, squat, swollen stem and branches and is commonly known as "ghost tree or phantom tree". The roots, bark and wood are eaten by goats and also browsed by giraffe [3] [13] [14] [15]. Under cultivation, *Moringa ovalifolia* grows fast in the first three weeks of development at nursery level after which growth becomes slower for roots development [16].

The problem is that Namibia is both arid and semi-arid country with less

rainfall and persistent drought occurrences that adversely affect rangeland productivity and subsequent livestock production. Schalkwyk [17] and Agra Professional Services [18] described Namibia as the driest climate country in sub-Saharan Africa. Sijssens [19] discussed that the production of additional fodder from dry-land, cultivated grass pastures and plantations of drought-tolerant fodder shrubs should become a priority in Namibia; hence, emphasizing that livestock production should no longer be dependent solely on highly sensitive native rangeland but also include other sources of fodder. Therefore, this study aimed to compare the field growth performances of *Moringa oleifera* and *Moringa ovalifolia* grown in central Namibia rangeland to be used for improving rangeland productivity since both species are drought-tolerant trees.

2. Materials and Methods

2.1. Study Site

A *Moringa* orchard of 0.21 hectares (0.11 hectares for *Moringa oleifera* and 0.10 hectares for *Moringa ovalifolia*) was established in 2014 at the Neudamm Experimental Farm of the University of Namibia, about 30 km east of Windhoek, with an area of 10, 187 hectares. The research was carried out over two summer-growing seasons (2014/2015 and 2015/2016), October 2014 to April 2015 and October 2015 to April 2016. Neudamm Campus is located at 22˚30'07"S and 17˚22'14"E, and at an altitude of 1762 meters above sea level. The farm's temperature ranges between a minimum of −7˚C and a maximum of 44˚C and received annual average rainfall of 229 mm and 247.8 mm in 2014/2015 and 2015/2016 summer seasons, respectively [20].

The vegetation of Neudamm Farm is classified as highland savannah (semi-arid savannah) and characterized by grasses, shrubs and trees that are well spread over the farm. An annual grass like *Melinis repens* and perennial grasses like *Schmidtia pappophoroides, Anthephora pubescens* and *Brachiaria nigropedata* are well represented on the farm. Different types of trees like *Acacia brownii*, *Acacia erioloba*, *Acacia mellifera* as well as shrubs like *Grevia flava*, are found on Neudamm Experimental Farm. The estimated carrying capacity is about 12 hectares per large stock unit or 45 kg per hectare biomass [21] [22] [23].

2.2. Experimental Design

A completely randomized design (CRD) was used for this study for both *Moringa oleifera* and *Moringa ovalifolia*. Two-months old 120 *Moringa oleifera* and 64 *Moringa ovalifolia* seedlings were transplanted in February 2014 on the field at spacing distances of 2.5 m × 2.5 m and 3 m × 3 m for *Moringa oleifera* as suggested by Fuglie and Sreeja [24] and Radovich [5], and 3 m × 3 m, 3.5 m × 3.5 m, 4 m × 4 m and 4.5 m × 4.5 m for *Moringa ovalifolia* between rows and plants, respectively. The four spacing distances for *Moringa ovalifolia*'s four blocks were meant to determine the appropriate spacing distances between rows

and plants since there is no knowledge of its domestication. For *Moringa oleifera,* the field was divided into two plots with four blocks within each plot. Fifteen seedlings were transplanted in each block, which summed up to 120 trees. *Moringa ovalifolia,* on the other hand had four plots and/or blocks with 16 plants each, summing up to 64 seedlings.

2.3. Field Preparation and Seedlings' Transplantation

As an old cereal production site, clearing of grass and ploughing were done concurrently on the field using a tractor, which incorporated the grass into the soil. Since it was during rainy season, the field was left for the grass to rot within a month before transplanting as suggested by Onwueme and Sinha [25]. After a month, holes were dug at 50 cm diameter and 50 cm depth for the purpose of loosening the soil and retaining moisture in root zones as well as enabling seedlings roots to develop rapidly. The holes were left open for rain to fall, after which seedlings were transplanted the following day in the morning and at sunset to avoid sun stress. Five kilograms (kg) of cow manure was thoroughly mixed with topsoil and used for transplanting the seedlings in the field [24]. The seedlings were about 60 days old with average heights of 19 cm for *Moringa oleifera* and 13 cm for *Moringa ovalifolia* at transplanting. Transplanting was completed within 2 weeks.

Watering was done once a week during the first growing season (2014/2015 summer), and once fortnightly during the second growing season (2015/2016 summer). Watering was done weekly for the first growing season because the trees were younger with shadow roots and needed water at closer intervals compared to the second growing season when the trees were bigger with established tap roots, thus, needing less water to survive. In Namibia, the winter season starts from April and ends September, which is followed by summer. During winter, watering was done biweekly for both first and second seasons (2014 winter and 2015 winter) to avoid freezing of the trees and subsequent mortality. Fuglie and Sreeja [24] discussed that *Moringa oleifera* trees do not need much watering, except in very dry conditions when it must be done regularly for the first two months and afterwards only when the trees are obviously suffering.

Superphosphate fertilizer with a P content of 83 g/kg (Wonder superphosphate granular) and nitrogen fertilizer with an N content of 280 g/kg (Limestone Ammonium Nitrate—LAN) were applied at the rate of 0 g, 100 g, 200 g and 300 g a month after transplanting to boost the roots system development as well as the leaves [5] since winter was to begin two months ahead. Both *Moringa* species were cultivated in the same field of 0.21 hectares (ha) but divided into two parts in which *Moringa oleifera* site had dimensions of 73 m × 15 m = 1096 m^2 (0.11 ha), while *Moringa ovalifolia* area was measuring 60.4 m × 15 m = 906 m^2 (0.10 ha).

2.4. Soil Composition of the Field

The results of soil analysis for the determination of the amount of nutrients and

their properties are found in Table 1. The result shows the soil pH, electrical conductivity or soluble salts (EC), organic matter (OM), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sodium (Na) and soil texture in percent (%) and parts per million (ppm). The 30 to 60 cm soil depth range had higher nutrient contents than 0 to 30 cm soil depth range, except OM and P were higher (0.87% and 24.60 ppm), respectively. Johnston and Steen [26] said that phosphorus must be adequate, readily available reserves in the soil; however, most un-manured soils contain too little readily available phosphorus to meet the large demand of crops, particularly during certain growth periods such as root development of seedlings and flowering for yield. Therefore, fertilizers containing phosphorus must be added to the soil to boost plant growth, development and yields. The soil analysis result shows pH of 7.22 and 7.67 for 0 to 30 cm and 30 to 60 cm depths respectively, which were slightly basic. Fuglie and Sreeja [24] emphasized that *Moringa* tolerates a wide range of soil conditions, but prefers a neutral to slightly acidic pH of 6.3 - 7.0. The pH unit measures the degree of acidity or basicity of a solution. Most living things depend on a proper pH level to sustain life. Different crops need different pH levels but grow best if the soil they are planted in is maintained at an optimal pH [27]. The particle size analysis revealed that the soil is sandy (84.2% at 0 - 30 cm depth and 82.1% at 30 - 60 cm depth) with low silt and clay (<10% each).

2.5. Data Collection Procedures

Trees' heights were measured for data collection. Heights were measured for 20 *Moringa oleifera* and 20 *Moringa ovalifolia* trees at 30-day and 60-day intervals to determine the growth rates (heights) during the two summer-growing seasons (October 2014 to April 2015 and October 2015 to April 2016). The 30-day intervals

Table 1. Soil nutrients and properties.

Type of Analysis	Sample No.		
	Units	0 - 30 cm depth	30 - 60 cm depth
pH		7.22	7.67
Electrical Conductivity or Soluble Salts (EC)	mS/cm	80	87
Organic Matter (OM)	%	0.87	0.65
Phosphorus (P)	ppm	24.60	12.30
Potassium (K)	ppm	295	384
Calcium (Ca)	ppm	572	586
Magnesium (Mg)	ppm	95	107
Sodium (Na)	ppm	5	8
Texture	-	Loamy sand	Loamy sand
Sand	%	84.2	82.1
Silt	%	8.2	9.7
Clay	%	7.6	8.1

were used to measure the two *Moringa*-species trees during the first summer-growing season (October 2014 to April 2015), while 60-day intervals were used in the second season (October 2015 to April 2016) to evaluate the trees' elongation. In Namibia, rainfall is strongly seasonal since more than 99% of rain falls occur in the summer months [28], which support plants' growth and development.

2.6. Data Analysis

Statistical Package for Social Sciences (SPSS® version 23) and Microsoft Excel® version 13 were used to carry on all the analyses. The generalized linear model (GLM) was used to analyse growth rates of *Moringa oleifera* and *Moringa ovalifolia* in which heights of trees were used as dependent variables while months and years were used as independent variables.

3. Results

Figure 1 presents *Moringa oleifera* and *Moringa ovalifolia* growth rates as measured by heights of trees for the two summer seasons (2014/2015 and 2015/2016), October 2014 to April 2015 and October 2015 to April 2016. The results showed the average heights of trees for each summer growing season in the orchard. *Moringa oleifera* had greater maximum height of 224.9 cm than *Moringa ovalifolia* with 77.03 cm in the month of April, whereas the lowest heights were 36.75 cm and 5.40 cm, respectively, in November 2014. In 2015/2016 season, *Moringa oleifera* had an average best growth in height of 281.45 cm in March, compared to that of *Moringa ovalifolia* that had 113.2 cm in April. On the other hand, the minimum heights of 70.05 cm and 22.0 cm were recorded for *Moringa oleifera* and *Moringa ovalifolia*, respectively in October 2015.

The descriptive statistics of *Moringa oleifera* and *Moringa ovalifolia* monthly and bimonthly growth in heights (cm) for the 2014/2015 and 2015/2016 summer growing seasons, respectively is presented in Table 2. *Moringa oleifera* grew

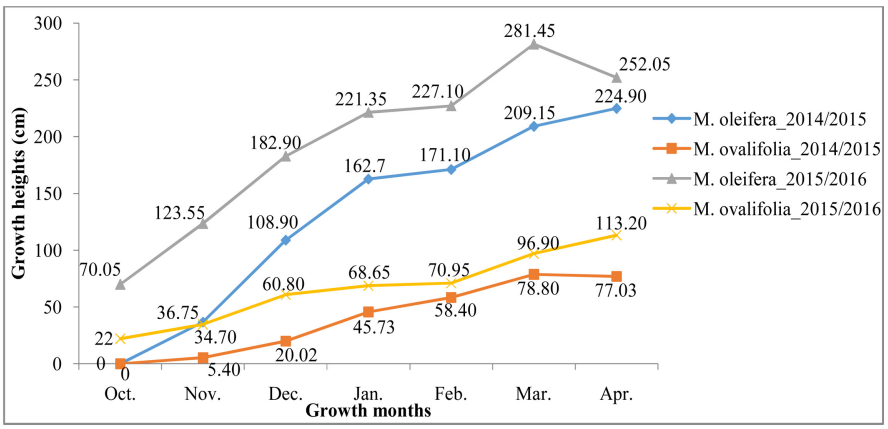

Figure 1. Monthly average increase in heights (cm) of *Moringa* species in 2014/2015 and 2015/2016 summer seasons.

Table 2. *Moringa* species monthly heights (cm) for 2014/2015 and 2015/2016 seasons.

Heights	*Moringa* spp.	N	Mean	Std. Deviation	Std. Error Mean
Heights 2014/2015	*M. ovalifolia*	7	40.7664	32.76196	12.38286
	M. oleifera	7	130.2071	86.07771	32.53432
Heights 2015/2016	*M. ovalifolia*	7	66.7471	32.02384	12.10387
	M. oleifera	7	194.0643	74.51054	28.16234

faster with mean heights of 130.21 cm in 2014/2015 season and 194.06 cm heights in 2015/2016 season. *Moringa ovalifolia*, as slow-growing trees had a mean height of 40.77 cm in 2014/2015 season and 66.747 cm in 2015/2016 season.

The independent sample t-test of monthly growth of *Moringa* species in heights for 2014/2015 and 2015/2016 summer seasons is shown in **Table 3**. The test results showed that mean monthly and bimonthly height increments were significantly different ($P < 0.05$) within the two *Moringa* species and between the summer-growing seasons of 2014/2015 and 2015/2016, which differences can be seen in **Table 2**.

4. Discussion

The highest growth in heights for *Moringa oleifera* (281.45 cm) and *Moringa ovalifolia* (113.2 cm) were observed in 2015/2016 season (October 2015 to April 2016), compared to 2014/2015 season (October 2014 to April 2015) with heights of 224.9 cm and 77.03 cm, respectively (**Figure 1**). The results can be attributed to the more robust establishment of the root systems of the trees in 2015/2016 than 2014/2015 when the trees were younger with shallow root system establishments. However, the results of this study for both species had lower heights due to the shorter growing summer seasons in Namibia (September to April) as discussed by Pallett [28]. Nevertheless, *Moringa oleifera* grew faster and had higher heights compared to *Moringa ovalifolia* in both 2014/2015 and 2015/2016 summer-growing seasons (**Table 2**). *Moringa oleifera* is an extremely fast-growing tree and can reach a height of 400 cm in a year, and, eventually, 600 to 1500 cm [5] [29].

Central Namibia having both arid and semi-arid climates, plants grow more rapidly during summer seasons (October to April) after which winter (May to September) sets in and negatively affects the plant growth. This explains the maximum heights in March and April and the minimum heights in October and November for the two *Moringa* species. In 2014/2015 summer season, the lowest heights of 36.75 cm and 5.4 cm for *Moringa oleifera* and *Moringa ovalifolia*, respectively were observed in November 2014 because the trees sprouted late after the winter dormancy since they were younger. Also in 2015/2016 summer season, lowest heights of 70.05 cm for *Moringa oleifera* and 22 cm for *Moringa ovalifolia* were recorded in November 2015 since the trees were older and sprouted earlier. Korsor, Ntahonshikira, Bello, and Kwaambwa [30] discussed

Table 3. Independent sample test of *Moringa* species seasonal heights for 2014/2015 and 2015/2016.

Moringa spp. heights (season)	Mean Difference	Pooled Std. Error Difference	t	df	Sig. (2-tailed)
Heights (2014/2015)	89.4407	34.81116	2.569	12	0.025*
Heights (2015/2016)	127.3171	30.65324	4.153	12	0.001***

Assumes unequal variance between groups; * = significant at 0.05; *** = significant at 0.001 alpha level.

that younger *Moringa* trees take long time to sprout after the winter dormancy compared to older trees, which is due to shallow and deep roots establishment, respectively. Billings [31] emphasized that all environments and all stressors are not equal with regard to their effects on plant growth and reproduction; nor do all kinds of plants equally adapt to environmental changes or have the same level of coping with stress factors. Favourably, the two *Moringa* species are drought-resistant trees and do better despite the scarcity of water when fully established as described by Morton [7].

Within species, heights were lower in each species in the first growing season than in the second season. In the 2015/2016 growing season, *Moringa oleifera* had the highest average heights of 281.45 cm against 224.9 cm in the 2014/2015 growing season. *Moringa ovalifolia* likewise elongated faster in 2015/2016, with a maximum of 113.2 cm in the month of April, while 2014/2015 had a maximum of 77.025 cm in the same month. Just as in the highest, the lowest heights (cm) for *Moringa oleifera* were observed during the 2014/2015 growing season as 36.75 cm recorded in November 2014 while for the 2015/2016 season, a minimum height of 70.05 cm was recorded in October 2015. Similarly, the lowest heights for *Moringa ovalifolia* were 5.4 cm in November 2014 and 22 cm in October 2015 (**Figure 1**), which clearly indicates that the more the trees mature, the faster they sprout and elongate after the winter season.

These differences in heights between the two summer-growing seasons can be attributed to two factors; namely, the ages of the trees and the cutting and/or harvesting intervals. That is, in the first growing season of 2014/2015, trees were younger/smaller and measured at 30-day intervals after which they were harvested and cut back for regrowth. This may have affected the elongation of the young trees. In the second growing season (2015/2016), trees were older/bigger and measured and harvested and/or cut at 60-day intervals for regrowth. This may have contributed to the highest heights for 2015/2016. Besides the differences between the 30-day and 60-day harvesting and cutting intervals, the differences in heights between the two growing seasons can also be attributed to the root systems becoming better established; that is, roots of young trees are shallow in the soil compared to roots of older trees that are deeply rooted, which enables them to elongate faster, thus promoting more vegetative growth. Fuglie [2] reported that in the first year, *Moringa oleifera* will grow up to 500 cm in height and if left alone, it subsequently reaches 1200 cm in height, with a trunk of 30 cm circumference over the years. The analysis reveals that both *Moringa*

oleifera was significantly higher ($P < 0.001$) than *Moringa ovalifolia* in mean monthly height increments over the two seasons. This implies that the two species had different heights in the two seasons. Based on the field observations, *Moringa oleifera* grew faster on average than *Moringa ovalifolia*, and this was statistically significant. The lower height of *Moringa ovalifolia* might be attributed to the first focus on underground growth of the roots into tubers to preserve energy for rough conditions (winter/drought) as described by Korsor *et al*. [16]. Thus, the hypothesis (H_{02}) that *Moringa oleifera* does not differ in growth performance (heights) with *Moringa ovalifolia* was rejected because they differ significantly.

5. Conclusion

Moringa oleifera and *Moringa ovalifolia* are drought-resistant trees that withstood the harsh climate of Namibia. Although both trees grew well in this harsh environment, *Moringa oleifera* grew faster in heights compared *Moringa ovalifolia* that grew slowly. *Moringa oleifera* had the higher heights of 281.45 cm for March 2016 and 224.9 cm for April 2015, while *Moringa ovalifolia* was lower with 113.2 cm and 77.025 cm for April 2016 and 2015 respectively. As young trees for the two *Moringa* species, but especially for *Moringa ovalifolia*, these heights estimates will change as the trees grow older. Their characteristics to survive in water-scarce environments qualified them to grow in arid and semi-arid climates as the case with Namibia. More research studies need to be done in this respect to establish the heights of *Moringa ovalifolia* when fully grown alongside *Moringa oleifera*.

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Conflicts of Interest

The authors declared that there are no conflicts of interest regarding the publication of this paper.

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