Moringa (Moringa oleifera Lam): A Review on its Importance Worldwide

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Abstract: Moringa is a plant whose cultivation began in Asia but has spread widely throughout the world. It is fast growing and drought tolerant. The uses of moringa are multiple and multiform. It is used in human and animal food and also is a medicinal plant that has antimicrobial activities and treats several types of diseases. In addition to this, it has other environmental and industrial uses that make it very important. This paper highlights its origin and geographical distribution, bio-ecology, chemical composition, uses, and pests that affect it.

Keywords: Moringa (Moringa oleifera), biology, composition, use, pests.

Origin and geographical distribution

Moringa (Moringa oleifera) is a plant native to the sub-Himalayan regions of northern India and Pakistan. It has been introduced to all tropical and subtropical regions and has naturalized in many African countries (Bosch, 2004; Vélez-Gavilán, 2017). It is widely cultivated in Ethiopia, the Pacific Islands, Florida, Sudan, the Caribbean, the Philippines, West Africa, South Africa, Asia and Latin America. It is therefore very popular and has several names around the world. The generic name comes from the Tamil name morunga (Olson, 2010).

Global moringa production was estimated at 46,000,000 tons in 2017, up from 32,000,000 t in the previous year or an increase of 43.75% (Nils-Gerrit, 2020). India is the world's largest producer of moringa with an annual production of 1.1 to 1.3 million tons of tender fruit on an area of 38,000 hectares (Rachana et al., 2020).

Systematic position and botanical description

Moringa belongs to the family Moringaceae, the genus Moringa and species Moringa oleifera Lam (Synonym: Moringa pterygosperma Gaertn (1791). It is a diploid plant with 2n chromosomes = 28 which has a good aptitude for polyploidy (Ramachandran et al., 1980). Thus it has been possible to create tetraploid individuals that have superior agronomic characteristics and higher biomass yield than diploids, and could represent excellent forage feedstocks for improved biomass and nutrition (Zhang et al., 2020).

The genus Moringa comprises 13 species of more or less different origin (Table I). But according to Bosch (2004), some of them are endemic to the Horn of Africa. These species are widely cultivated in Asia and Africa for their multiple uses. But Moringa oleifera and Moringa stenopetala are the most cultivated species (Gandji et al., 2018; Eyassu and Teketayb, 2020).

Moringa oleifera is a shrub that can reach 10 m high with opposite, tripinnate and deciduous leaves. This means that the old leaves turn yellow and fall off at the foot of the tree. Each leaf is up to 50 cm long, often up to about 90 cm long (Orwa et al., 2000; Bosch, 2004).

The white flowers are very numerous at the end of the branches and are bisexual. They have 5 sepals and 5 petals of unequal size, yellowish white. The ovary is carried by a very short peduncle and has a
The fruits are elongated 3-valved capsules, 10-50 cm long, with 9 ribs, brown at maturity, and containing numerous seeds (Bosh, 2004). In some varieties, the fruits can be up to 120 cm long. These capsules are pointed with a triangular cross section. They contain oily black seeds of one centimeter in diameter in a typical three-winged seed coat. The unripe green pods are fleshy but become fibrous and greyish when ripe and remain attached to the tree. The seeds are globular with 1 to 1.5 cm in diameter. The bark is smooth and is light gray in color that becomes darker with age. The branches and shoots are few but the crown is wide. The takes the shape of an umbrella. *Moringa oleifera* has a mostly deep root system (Bosch, op. cit).

**Bio-ecology**

*Moringa* tolerates a wide range of environmental conditions. It grows best between 25 and 35° C, but tolerates temperatures around 48° C. It does not tolerate frost (Adamou, 2015).

It produces new shoots quickly from the trunk after cutting (Orwa et al., 2009).

It is a drought resistant tree that is also fast growing (Hocking, 1993). It grows well in areas receiving annual rainfall of 250 to 1500 mm with an average altitude between 0 and 600 m. But it can adapt to altitudes up to 1200 m in the tropics or even higher. Indeed, Bosch (2004) reported that in Zimbabwe, a naturalized stand at 2000 m altitude has adapted well to the environmental conditions. *Moringa oleifera* adapts to a wide range of soils (well-drained clay to silty clay). It prefers neutral to slightly acidic pH soils (Patricio and Palada, 2017; Vélez-Gavilán, 2017). However, it tolerates a soil pH of 5 to 9 (Palada and Chang, 2003).

In the tropics, it blooms permanently. It is a highly allogamous plant and its pollination is provided by bees, the most involved of which are the so-called carpenter bees of the species *Xylocopa latipes*, *X. pubescens* or *Xylocopa* and *Amegilla* (Jyothi et al., 1990; Orwa et al., 2009; Krieg et al., 2017). Some birds such as *Nectaria zeylanica* and *N. asiatica* are also mentioned among the active pollinators (Orwa et al., 2009) while Bhattacharya and Mandal (2004) reported that insects belonging to the orders Thysanoptera, Hymenoptera, Lepidoptera, and Coleoptera are required for proper pollination.

*M. oleifera* can also reproduce vegetatively (Csurhes and Navie, 2016) and in vitro propagation has been tested with promising results (Fürster et al., 2013; Avila-Treviño et al., 2017).

In India, trees shed their leaves in December-January, then regrow in February-March. Flowering can occur twice a year or even year-round depending on seasonal temperature and rainfall conditions. Fruiting occurs between April and June, but can also extend throughout the year under regular irrigation conditions (ICFRE, 1995).

The plant obtained from seeds has a longevity of 20 years while this parameter is 10 to 15 years for trees obtained from cuttings (Godino et al., 2017). But Olsoen (2017) reports that in temperate regions some varieties can be grown for a single season.

Pollen viability is greater than 88%. *M. oleifera* seeds have almost no dormancy and lose viability only two years after harvest (Csurhes and Navie, 2016).

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**Table I: Moringa species and origin**

<table>
<thead>
<tr>
<th>Species</th>
<th>Area of origin</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Moringa arborea</em> Verdc.</td>
<td>Kenya</td>
</tr>
<tr>
<td><em>Moringa Rivae</em> Chiov.</td>
<td>Kenya et Ethiopia</td>
</tr>
<tr>
<td><em>Moringa stenopetala</em> Cufod.</td>
<td>Kenya et Ethiopia</td>
</tr>
<tr>
<td><em>Moringa borzjana</em> Mettei.</td>
<td>Kenya et Somalia</td>
</tr>
<tr>
<td><em>Moringa longituba</em> Engl.</td>
<td>Kenya et Somalia</td>
</tr>
<tr>
<td><em>Moringa pigmeae</em> Verdc.</td>
<td>Somalia</td>
</tr>
<tr>
<td><em>Moringa ovalifolia</em> Dinter and A. Berger</td>
<td>Namibia et Angola</td>
</tr>
<tr>
<td><em>Moringa drouhardii</em> Jum.,</td>
<td>Madagascar</td>
</tr>
<tr>
<td><em>Moringa hildebrandtii</em> Engl.</td>
<td>Madagascar</td>
</tr>
<tr>
<td><em>Moringa perigrina</em> Forssk.</td>
<td>Saudi Arabia, Red Sea and Dead Sea</td>
</tr>
<tr>
<td><em>Moringa concanesis</em> Dalzel et A. Gibson</td>
<td>Sub-Himalayan regions of the Indian sub-continent</td>
</tr>
<tr>
<td><em>Moringa oleifera</em> Lam.</td>
<td>Sub-Himalayan regions of the Indian sub-continent</td>
</tr>
</tbody>
</table>

Chemical composition of moringa

Recent analyses have shown that mature moringa seeds contain 38-54% edible oil with a high level of unsaturated fatty acids with oleic acid being the most abundant. It contains saturated fatty acids such as palmitic, lauric, stearic, linoleic and linolenic acids. The main sterols in *M. oleifera* seed oil are β-sitosterol, campesterol, stigmasterol and Δ5, avenasterol (Özcan, 2020).

*M. oleifera* leaves are high in protein (22.99-29.36%), low in fat (4.03-9.51%), fiber (6.00-9.60%) and ash (8.05-10.38%). The vitamin C content of fresh leaves varies between 187.96 and 278.50 mg/100 g while the calcium level is between 1.322 and 2.645%, phosphorus from 0.152 and 0.304 g/100 g, and potassium from 1.317 of 2.025 g/100 g (Sulltana, 2020). Xavier (2018) noted that moringa is very rich in minerals (calcium, potassium, iron, magnesium), vitamins A, C, E, very good quality proteins (containing the 9 essential amino acids) and antioxidants.

The green leaves of moringa contain carbohydrates (9.1 g), dietary fiber, fat, and protein. The same study showed that they are also rich in vitamins such as vitamin A, thiamine (B1), riboflavin (B2), niacin (B3), pantothenic acids (B5), vitamin B6, folic acid (B9), vitamin C as well as minerals such as calcium, iron, magnesium, manganese, phosphorus, potassium, sodium and zinc. They are also rich in essential amino acids: Threonine, Valine, Methionine, Leucine, Isoleucine Phenylalanine, Histidine, Lysine and Arginine (Mukunzi et al., 2011; Mune, 2016; Abass et al., 2018; Kumar, 2018; González-Burgos, 2021; Sarr et al., 2015). The table II shows the nutrient composition of moringa organs.

### Table II: The nutrient composition of leaves, leaf powder, seeds and pods

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Fresh leaves</th>
<th>Dry leaves</th>
<th>Leaf powder</th>
<th>Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories (cal)</td>
<td>92</td>
<td>329</td>
<td>205</td>
<td>26</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>6.7</td>
<td>29.4</td>
<td>27.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>1.7</td>
<td>5.2</td>
<td>2.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>12.5</td>
<td>41.2</td>
<td>38.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Fiber (g)</td>
<td>0.9</td>
<td>12.5</td>
<td>19.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Vitamin B1 (mg)</td>
<td>0.06</td>
<td>2.02</td>
<td>2.64</td>
<td>0.05</td>
</tr>
<tr>
<td>Vitamin B2 (mg)</td>
<td>0.05</td>
<td>21.3</td>
<td>20.5</td>
<td>0.06</td>
</tr>
<tr>
<td>Vitamin B3 (mg)</td>
<td>0.8</td>
<td>7.6</td>
<td>8.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Vitamin C (mg)</td>
<td>220</td>
<td>15.8</td>
<td>17.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>448</td>
<td>10.8</td>
<td>113</td>
<td>120</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>440</td>
<td>2185</td>
<td>2003</td>
<td>30</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>42</td>
<td>448</td>
<td>368</td>
<td>24</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>70</td>
<td>252</td>
<td>204</td>
<td>365±8.66</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>259</td>
<td>1236</td>
<td>1324</td>
<td>259</td>
</tr>
<tr>
<td>Copper (mg)</td>
<td>0.07</td>
<td>0.49</td>
<td>0.57</td>
<td>5.20±0.15</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>0.85</td>
<td>25.6</td>
<td>28.2</td>
<td>5.3</td>
</tr>
<tr>
<td>Sulphur (mg)</td>
<td>–</td>
<td>–</td>
<td>870</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Source: Gopalakrishnan et al., (2016)

Usage

*Moringa oleifera* was already used by the ancient Egyptians, Romans and Greeks in human food and medicine. Today, it is part of traditional diets in many countries in the Southeast Asian regions (Senthilkumar et al., 2018).

The leaves, flowers, fruits, and roots are used as vegetables in many lands (Morton, 1991; Kumssa et al., 2017; Hanaa and Gamal, 2013).

The leaves, a good source of vitamin C and minerals, are used to feed livestock. Filipino women consume moringa leaves mixed with chicken or shellfish soups to improve their taste. They are also eaten with the pods at different stages of maturity as vegetables. The soft pods are cooked or marinated and used in culinary preparations. The fresh pods, after being roasted, also make an appetizing dish. The seeds are also eaten after being fried and taste similar to peanuts (Özcan, 2020).

The seed oil contains all the fatty acids contained in olive oil (Lalas and Tsaknis, 2002). In Egypt, the oil obtained from moringa seeds has been used as edible oil in the Red Sea region (Hanaa and Gamal, 2013). *Moringa oleifera* is an important food that has received much attention as a natural food for children in the tropics (Anwar et al., 2007). The seed cake remaining after oil extraction can be used as fertilizer. The seed oil can be used as a biofuel (Rashid et al., 2008).

Moringa can be used as a natural non-toxic polypeptide for settling mineral and organic particles in drinking water purification, for cleaning vegetable oils, or for settling fibers in the juice and beer industries (Zaku et al., 2015). In some cases, the seeds are used as primary coagulants in wastewater treatment (Ndabigengesere and Subba-Narasiah, 2010).

In medicine, all the organs of the plant have also been used for centuries. Studies have revealed its antimicrobial, anti-inflammatory, antioxidant, anti-
ulcer, anti-diabetic and anti-cancer properties (Al-Asmari et al., 2015; Anthanont et al., 2016). It is also known to boost the immune system and treat HIV-related symptoms (Xavier, 2018). It can help to prevent certain chronic diseases such as cancer and cardiovascular diseases (Sy et al., 2018).

The leaves are taken as a purgative. Applied in poultice they heal wounds and headaches. They are used against hemorrhoids, fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh. The juice of the leaves is believed to control glucose levels and cure glandular swelling (Morton, 1991; Fuglie, 1999). Aqueous extracts of M. oleifera leaves have been shown to be effective in the control of Biomphalaria glabrata, a species of snail that is the alternate host of Schistosomia mansoni, the parasite responsible for intestinal schistosomiasis in humans (Cláudio et al., 2014). Work conducted by Caceres et al., (2016) showed that raw juice from moringa leaf has antibacterial activity against Enterococcus faecalis among different strains tested, including Bacillus cereus, Staphylococcus aureus, Escherichia coli and Candida albicans, Candida utilis (Anand, 2016). El-Awady et al., (2015) also reported the comparative antibacterial activity of M. peregrina and M. oleifera leaf extracts. They note that methanol and ethanol extracts of M. oleifera have more pronounced activity against E. coli, S. aureus, Enterococcus sp, Aeromonas hydrophila, and P. aeruginosa than M. peregrina.

The effect of Moringa oleifera leaves, roots, bark and seeds were studied in vitro against bacteria, yeasts, dermatophytes and helminths pathogenic to humans. Fresh leaf juice and aqueous extracts of the seeds have been shown to inhibit the growth of Pseudomonas aeruginosa and Staphylococcus aureus (Zubair, 2020).

In some cases, traditional practitioners advise the use of moringa products in the treatment of high blood pressure and associated cardiovascular diseases (Iwara et al., 2014). The work of Al-Asmari (2015) revealed that Moringa oleifera leaf and bark extracts collected from the Saudi Arabian region possess anticancer activity that can be used to develop new drugs for the treatment of breast and colorectal cancers. The same is true of those of Jung et al., (2014) who worked on the soluble extracts of the leaves.

The boiled bark fights against kidney stones. It is used to treat eye diseases, delirious patients and prevents enlargement of the spleen and formation of tubercular glands in the neck. It is used to destroy tumors and to heal ulcers. The bark of the root relieves earache and toothache. It is used as an analgesic and has anti-tubercular activity (Siddharaju and Becker, 2003).

The gum from the trunk is also used against dental caries. Mixed with sesame oil, it relieves headaches, fevers, intestinal diseases, dysentery, asthma and sometimes syphilis and rheumatism (Fuglie, 2001). Moringa has been well known for centuries for the antiseptic properties of its sap for external use (Milla et al., 2021).

The flowers and seeds are used as stimulants, aphrodisiacs, abortifacients and chologogues. They treat inflammations, muscular diseases, hysteria, tumors and hypertrophy of the spleen. Their use lowers cholesterol, phospholipids, triglycerides and decreases the lipid profile of the liver, heart and increases the excretion of fecal cholesterol (Siddharaju and Becker, 2003; Lalas and Tsaknis, 2002). Moringa has antioxidant properties due to its content of bioflavonoids, carotenoids, vitamins C and E, and selenium (Chen, 2022).

In livestock feeding, Moringa oleifera could be used as a feed substitute in laying hens to improve egg quality and laying rate (Adouko et al., 2021).

In plant protection, moringa extracts accelerate plant growth, strengthen and improve plant resistance to pests and diseases (Hussain et al., 2013). It has also been demonstrated the nematocidal activity of ethyl acetate extracts of Moringa oleifera leaves against eggs and larvae of Haemonchus contortus and Nacobbus aberrans, nematodes of agricultural importance (Páez-León et al., 2022).

**Marketing of moringa**

Worldwide, moringa is sold in two main forms: leaf powder and seed oil.

The leaf powder is used as a dietary supplement and is one of the botanical products used as a green superfood. The main markets for the dietary supplements are the United States, followed by Western Europe and Japan.

Moringa oil is used in cosmetics along with several other oils. The main importer of the oil is the European Union, but the quantities involved are not available as they are buried in the overall exports of all cosmetic vegetable oils.

The market for moringa-based products is expected to grow with the increasing demand for natural cosmetics and organic health products from the United States and Canada (https://agriexchange.apeda.gov.in/Weekly_eReport/Moringa_Report.pdf). The global market for these products is estimated at 5.5 billions (DUS) in 2018. It is projected to grow by nearly 9% by 2025. In developing countries too, demand for these products is growing as is the case in such countries as India, China and Brazil (Maharshi, 2020).
Diseases and pests of moringa

Moringa was considered a plant resistant to most pests and diseases. But given its wide distribution worldwide, several enemies are now known, some more important than others (Mritha and Barakah, 2017). The most common diseases are root rot caused by Diplodia sp, twig canker due to Fusarium pallidoroseum, and fruit rot whose causal agent is Cochliobolus hawaiiensis (Mandokhot et al., 1994; Rajangam et al., 2001; Patricio and Palada, 2017; Carbungco et al., 2017). Six other minor disease-causing fungi were found on fruit by Mritha and Barakah (2015) in Saudi Arabia. These are Aspergillus niger, A. flavus, Alternaria alternata, Fusarium oxysporum, Macrophomina phaseolina, and Rhizopus stolonifer. Previously, Zhao et al., (2012) identified an endophytic species of Nigrospora in moringa roots for the first time. Another disease causing elliptical or elongated spots with reddish-brown margins has been encountered. It is caused by Drechslera hawaiiensis (Rajangam et al., 2001). In South India, a microscopic fungus, Leveillula taurica (powdery mildew), has been catalogued as responsible for severe damage to papaya and moringa nurseries (Ullasa and Rawal, 1984). Root rot (Armillaria sp) affects roots under high soil moisture conditions (Ramasubramania et al., 2016) while anthracnose (Colletotrichum chlorophyti) has been found on moringa leaves (ZhiYing et al., 2017; Gatan, 2020). Several other fungal diseases have been reported. These include Ceratospora spp, Septoria lycopersici and Alternaria solani (Muller and Rebelo, 2011).

In Mexico, moringa is also attacked by plant pests such as Mistletoe (Phoradendron quadrangulare) of the Viscaceae family and Dendrophthoe falcata (Moreno-Ramirez et al., 2018; Thriveni et al., 2010).

Moringa pests fall into two categories: defoliators and carphophagous. In India, various defoliator caterpillars are reported. These include the budworm, Noordia moringae and the mealybugs, Diaspidotus sp and Ceroiplastodes Cajani, which inflict serious damage on plants (Fuglie, 2001). Black aphid (Aphis craccivora), borer (Diaxenopsis apomecyonoides) and fruit fly Gitonia sp. are also mentioned as important pests in the Indian subcontinent (Zaku et al., 2015). In a survey conducted in Burkina Faso, Dao et al., (2016) identified 5 pests on moringa. These were the snail (Cepaea sylvatica), three insects (Euproctis pasteopa, Noorda blitalis, Scolopteryx libatrix) and a mite (Tetranychus urticae). Another mite species (Tetranychus neocaledonicus) was reported by Ojiajo et al., (2011) as a pest of moringa. Under irregular irrigation, Macroterms spp and Microtermes spp termites plague the plots and destroy the plants, especially at the roots, shoots and twigs (Saint Sauveur and Broin, 2010). In some plantations in India, the bark caterpillar (Indarbela tetraonis) digs zig-zag galleries that weaken the attacked plant. A study conducted in northern Nigeria by Yusuf and Yusif (2014) revealed the existence of Ulopesa phaothoracica as a defoliator of M. oleifera and that it could be a concern for growers there.

Another study in the same country showed that Zonoceras variegatus is a pest of Moringa (Akanbi et al., 2007). In Burkina Faso, Dao et al., (2020) found the same locust feeding on Moringa leaves. Pillai et al., (1979) identified Helopeltis antonii, as a pest of moringa while Verma and Khurana (1974), four years earlier, recorded Indarbela tetraonis as a new pest of moringa grown in India.

In Niger, moringa is attacked by two main enemies, two pests (Noorda Blitalis and Tetranychusurticae) and a disease caused by Lasiodiplotid theobromae (Haougui et al., 2013). The moringa caterpillar has been known in the country for a long time but was only identified in 2011 as Noorda Blitalis by Ratnadass et al., (2011). It has been observed in all moringa production areas of the country. It can cause yield losses of 100% during a season: it devours all the new leaves that form. It is more severe in the rainy season than in the rainy season and does not spare any of the two most planted varieties (Haliliou, 2022). Nematological analyses by Haougui et al., (2017) in the peri-urban area of Niamey revealed the presence of 11 genera of plant-parasitic nematodes in the rhizosphere of Moringa oleifera among which the most frequent and abundant were Meloidogyne spp, Helicotylenchus spp and Hoplolaimus spp.

CONCLUSION

Moringa is one of the most useful tropical trees. The relative ease with which it propagates (sexual and asexual reproduction) and its low demand for nutrients and water make it easy to produce and manage. The introduction of this plant into a plot that has a biodiverse environment can be beneficial to both the farm owner and the environment. Therefore, any moringa improvement program must take into account diseases and pests to avoid damage to the plantations and the economic losses they inflict on the crop.

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