# Moringa frequently asked questions

M.E. Olson[a]

Instituto de Biología, Universidad Nacional Autónoma de México, Tercer Circuito s/n de Ciudad Universitaria, México DF 04510, Mexico.

***Abstract***

**The moringa tree *Moringa oleifera* is increasingly being studied for numerous properties of applied interest. In the course of work on these properties, many questions arise from both scientists and potential consumers. Here I address some of the most common such questions. I explain that moringa's correct scientific name is *Moringa oleifera* Lam., and that *Moringa pterygosperma* is not a synonym but an illegitimate name. The wild range of *Moringa oleifera* is unknown but it might be native of lowland northwestern India. It is cultivated in all tropical countries, but it is probably best to avoid saying that it is "naturalized" because some uses of this word imply that the plant has become invasive. There are thirteen described species in the genus *Moringa*, but additional new species probably await description, especially in northeast Africa. Traditionally, leaves of *Moringa oleifera, M. concanensis,* and *M. stenopetala* are eaten, and the tubers of young *M. peregrina* are sometimes eaten roasted. All other species have local medicinal uses. Current commercial use so far emphasizes *M. oleifera* dried leaf meal in capsules, often touting protein content. Simple calculations show that capsules have negligible protein nutritional value. Such use in pill form rather than as a food leads to the frequent question of whether moringa has "side effects". A review of studies shows that moringa has low levels of trypsin inhibitors, tannins, saponins, and lectins, meaning that there is no reason to expect that normal levels of consumption would lead to discomfort from these compounds. Nearly 40% of moringa calcium may be present in the form of oxalates, but current data suggest that these are insoluble, excreted, and do not contribute to the formation of kidney stones. Goitrogenic glucosinolates are probably absent, and if present are probably in very low concentrations. Moringa might have abortifacient potential, especially in concentrates. Given its usefulness and relative lack of antinutritional factors, there is global interest in growing moringa, so I examine its climate preferences. *Moringa oleifera* is a plant of the lowland dry tropics, growing best in places where annual low temperatures do not dip below 15°C, rainfall is less than 1500 mm and distributed in one or two rainy seasons, and below 500 m a.s.l. I conclude by underscoring the need for studies of all of these aspects across the entire diversity within *M. oleifera* and across the genus.**

**Keywords:** *Moringa,* taxonomy, nomenclature, climate preference, side effects, nutrition

## INTRODUCTION

*Moringa oleifera* ("moringa") is of global interest for its nutritional, nutraceutical, and industrial applications, but there are many aspects of basic moringa biology for which information is difficult to come by. This difficulty means that many papers in the applied moringa literature often, and understandably, repeat some misconceptions regarding the plants. To help make this information available in one place, I treat some of these key issues here, as a series of questions.

## WHAT IS MORINGA'S CORRECT SCIENTIFIC NAME?

As with many useful plants, there is some degree of confusion over moringa's correct scientific name, and, especially in the popular literature, even how to write it. It should go

[a]E-mail: molson@ib.unam.mx

without saying that the correct scientific name format needs to be followed, and this is *Moringa oleifera* Lam., with the genus capitalized, the species epithet in lower case, both the genus and species italicized, and the authority not italicized but capitalized and abbreviated following botanical convention. This means that uses like *Moringa Oleifera Lam* and related variants that are found a bit too often in the moringa literature are incorrect. "Lam." is short for "Lamarck" and this is sometimes written out, but botanists have a conventional set of abbreviations for authors and the correct one is "Lam." in this case (Lamarck, 1783; McNeill et al., 2012).

Another frequent naming issue regards *Moringa pterygosperma*. This name is often cited as a "synonym" of *M. oleifera*, sometimes used interchangeably with it, and even as though it were another species entirely. *Moringa pterygosperma* is none of these. It is an incorrect name, not a synonym, of *M. oleifera*. Briefly, the situation is as follows. In the late 1600s, Adriaan van Rheede tot Drakenstein (van Rheede, 1698), posted with the Dutch East India Company in southwestern India, published an early description and illustration of *Moringa oleifera* as "mouringou" (along with the name in various languages, including "moringa" in Portuguese). In his 1753 *Species Plantarum*, Linnaeus cites Rheede, and calls the plant "*Guilandina moringa,*" mistaking it for a legume, *Guilandina* being a genus of legumes. Soon botanists realized that *Moringa* was not a legume, so the genus *Moringa* was erected, taking the name from *Guilandina moringa* (Adanson, 1763). Adanson did not assign the plant a species name, however. Finally, in 1783, Jean-Baptiste Lamarck, of Lamarckian evolution fame, gave the plant for first time the name *Moringa oleifera*, referencing Linnaeus, Rheede, and others. In this way, the name *Moringa oleifera* was established as the official name for the plant. Because it was Lamarck who first used this term, he is cited as the "authority" or author of the name.

In 1791, Joseph Gaertner published the second volume of his *De Fructibus et Seminibus Plantarum*, the most detailed work on seeds at that time. Gaertner overlooked that the plant we know as *Moringa oleifera* had already been named by Lamarck. Not only did Gaertner give a new name, *Moringa pterygosperma*, to a plant with a legitimate name, but he also went so far as to cite the very publications in which the plant was given its name. Giving a new name to a plant while blandly citing its previous legitimate publication is such an affront to students of botanical nomenclature that these superfluous names are often not even included in lists of legitimate botanical synonyms (e.g., Olson, 2010). *Moringa pterygosperma* is thus considered not a synonym but a superfluous name for *Moringa oleifera*. Therefore, there is no reason ever to use the name *Moringa pterygosperma*.

**WHERE IS MORINGA NATIVE, CULTIVATED, AND NATURALIZED?**

The introduction of nearly every paper on *Moringa oleifera* applied properties includes a brief overview of moringa's geographical distribution. Some of these are as accurate as can be given current knowledge (e.g., Morton, 1991) and some are extravagant in their biogeographical implausibility, often stating that moringa is native to "northern Africa", "eastern Asia", "Arabia", "Iran", "Afghanistan" even Caribbean islands, and all number of other places where it is definitely not native. Much of this confusion is understandable. Useful plants are moved around by people and in highly transformed tropical landscapes that have been inhabited for millennia, it is hard to tell wild from introduced plants. Even the concepts of "wild" versus "cultivated" or "naturalized" are often unclear.

What is meant by the "wild" distribution of a plant is the area in which the plant evolved and spread before humans arrived. Its wild habitat is the natural floristic assemblage at the geographical site that the plant would grow in even in the absence of human intervention. So, even though it is common to see moringa trees growing and re-seeding on the outskirts of villages here in Mexico, or in Pakistan, in Madagascar, west Africa, and many other places, this does not mean that they are growing wild in these places. I will treat this issue in detail in a later work, but I will note that at the moment, based on the literature and my own field work, there is so far evidence for wild stands of what is currently regarded as *Moringa oleifera* only in hilly lowlands of northwestern India (Figure 1). Innumerable reports of "wild" moringas in other parts of India have in my field and herbarium work turned out to be cultivated plants or remnants of old cultivation. Given its proximity to northwestern India, it would not be surprising to find wild moringas in eastern Pakistan but so far there are no convincing reports (Stewart, 1972; Pakistan Plant Database www.tropicos.org/Project/Pakistan). So, though there is still much to be learned, based on the literature (e.g., Dastur, 1951; Verdcourt, 1986; Olson, 2010) and ongoing field work, it is safest to say that moringa is "possibly native to northwestern India".

Figure 1. Putatively wild plants of *Moringa oleifera* in subtropical deciduous forest in lowland northwest India.

That said, moringa is cultivated in all tropical countries, and it is often said that it is "naturalized" in these countries. "Naturalized" is a vexed term because under some usages it is synonymous with weedy or invasive. In others, it can refer to plants that reproduce themselves in a non-native area, especially around human environments, without entering into undisturbed habitat (Colautti and MacIsaac, 2004). This is the case of *M. oleifera*, which does re-seed itself around houses, vacant lots, road, and the margins of agricultural fields in many places in the world. What has never been observed anywhere in the world are moringas invading intact primary habitat. This is very important because it means that there is no reason to think that moringa will become an ecological nuisance, displacing native flora. Plants considered weeds or other nuisances can be banned or their movements otherwise restricted by governments, hampering research and trade. Therefore, because of its various connotations, I suggest avoiding the term "naturalized" and using only "cultivated."

To summarize: moringa is putatively *wild*, as far as is currently known, in the lowlands of northwestern India. Moringa is *cultivated* in other parts of the Indian subcontinent, tropical Asia, Africa, Madagascar, the Americas, Australia, and Oceania. It is not known to be *invasive* or a *weed* anywhere. Finally, it is best to avoid saying that moringa is *naturalized* anywhere.

## HOW MANY SPECIES OF *MORINGA* ARE THERE?

Reports of the numbers of species of *Moringa* vary widely, ranging up to 14 (Verdcourt, 1986). Based on my field and herbarium work, there are 13 currently described species (Table 1). Verdcourt's "species 14" turned out to be *Moringa longituba* upon visiting the locality (Figure 2). There are probably several undescribed species, especially in northeast Africa. *Moringa rivae* ssp. *longisiliqua* is very different in flower color from *Moringa rivae* ssp. *rivae* and is very poorly collected. It might represent a distinct species, but material is so fragmentary that it is difficult to say. Specimens from southeast of Berbera, Somaliland, (Glover and Gilliland 1194, in the Kew and East African herbaria) were referred to *M. pygmaea* by Olson and Carlquist (2001) but they might represent *M. borziana* or possibly an undescribed species. Much more exploration is needed to map out the wild distributions of *Moringa* species and the taxonomy of the species. Based on current knowledge, though, there are 13 described species, listed in Table 1.

Table 1. Currently described species of *Moringa*.

| |
|---|
| *Moringa arborea* Verdc. |
| *Moringa borziana* Mattei |
| *Moringa concanensis* Nimmo |
| *Moringa drouhardii* Jum. |
| *Moringa hildebrandtii* Engl. |
| *Moringa longituba* Engl. |
| *Moringa oleifera* Lam. |
| *Moringa ovalifolia* Dinter and A. Berger |
| *Moringa peregrina* (Forssk.) Fiori |
| *Moringa pygmaea* Verdc. |
| *Moringa rivae* Chiov. |
| *Moringa ruspoliana* Engl. |
| *Moringa stenopetala* (Baker f.) Cufodontis |

Figure 2. Verdcourt's "*Moringa* sp. 14" on the Kenya-Somalia border east of Wajir turned out to be *Moringa longituba*.

**WHICH SPECIES OF *MORINGA* ARE EDIBLE?**

*Moringa oleifera* is the most widely grown species, cultivated around the world for a variety of products. In addition to *M. oleifera*, three species are known to have some degree of edibility, *M. stenopetala*, and to a lesser degree *M. concanensis* and *M. peregrina*. *Moringa stenopetala* is the second most-cultivated species of *Moringa*. It seems to be found native only in a handful of localities around Lake Turkana (Mbaluka and Brown, 2016), in the Great Rift Valley of northwestern Kenya and southwestern Ethiopia. Slightly to the northeast, it forms part of a system of permaculture agroforestry in southern Ethiopia in the region of the Konso people. This area is at the upper elevational margin of the dry tropics, around 1600 m a.s.l. People there grow annual vegetable crops in the rainy season, but plant *Moringa stenopetala* trees abundantly in their towns. *Moringa stenopetala* has a very large, water storing trunk and holds on to its leaves well into the dry season. These are eaten by the Konso as an important dry season food (see Jahn, 1991; Förch, 2002; Jiru et al., 2006). Though its growth rate and yields are impressive, *M. stenopetala* grows more slowly than *M.*

*oleifera* and its yields are lower. Its seed yields are lower and the thick, spongy seed coat of *M. stenopetala* makes it even harder to extract the oil, with lower yields and, apparently, lower quality seed oil and much lower water clarification properties. *Moringa stenopetala* leaves have a tougher texture to eat than the very soft leaves of *M. oleifera*. Whereas *M. oleifera* grows tall and mast-like during its first year, *M. stenopetala* tends to form many stems from the base, forming a huge shrub if it is not shaped aggressively.

*Moringa concanensis* is the closest living relative of *M. oleifera*. It is native throughout the lowland dry tropics of eastern and southern Pakistan, much of India, and a few small localities in Bangladesh. It looks somewhat like *M. oleifera* and is often confused with it. It often has thicker outer bark than *M. oleifera* and the leaves have slightly longer pinna segments that are once-pinnate as compared to *M. oleifera*. The common assertion that *M. concanensis* has twice pinnate leaves and that *M. oleifera* has 3-pinnate leaves and that this feature readily distinguishes the species (Qaiser, 1972; Bhandari, 1990; Verdcourt, 1986) is not quite true. It is based on the small and fragmentary leaves that are often pressed for herbarium specimens. Small leaves of *M. concanensis* are indeed often 2-pinnate, but the large, mature leaves of *M. concanensis* often have 3-pinnate sections (Figure 3). Large, mature leaves of *Moringa oleifera* are always 3-4 pinnate. What distinguishes them most clearly are the long leaf tips in *M. concanensis,* which consist of a long section of pairs of leaflets, often 3-8, in contrast to *M. oleifera*, which at the leaf tips usually has only 1 or 2 pairs of leaflets.

Figure 3. *Moringa concanensis* leaves. On the left, a small twice pinnate leaf. On the right, a very large leaf, showing that when large, there are often 3-pinnate sections, even in *M. concanensis*.

The young pods, and sometimes leaves and flowers of *M. concanensis* are occasionally eaten locally (e.g., Arinathan et al., 2007), but in general this species is regarded as medicinal, including intervening in cholesterol levels, diabetes, and parasite infections, much like other species of *Moringa* (e.g., see Anbazhakan et al., 2007, though their description of the species seems at odds with its morphology).

*Moringa peregrina* is, in turn, the closest living relative to *M. oleifera* and *M. concanensis* (Olson, 2002). It is a slender trunked or bushy tree with wispy leaves that drop their leaflets at maturity. In this way, the mature leaves are made up of just the naked, woody rachises. The oil contained in the hard-shelled, wingless seeds is laboriously collected and saved for medicinal use, at least in Oman, where it is reportedly taken by the cupful for stomach complaints. The only edible part seems to be the tubers of young plants, which are roasted and eaten (Miller and Morris, 1988).

Only *M. oleifera, M. stenopetala, M. concanensis*, and *M. peregrina* are known to have any degree of edibility. The other species are all used medicinally locally, though. In Madagascar *Moringa drouhardii* and *M. hildebrandtii* are classic tomb ornamentals in southern and western Madagascar (see Olson and Razafimandimbison, 2000). The bark of the trees is often scraped and gouged. Local people told me that they use the bark in decoctions for bronchial complaints. I asked them if they ever ate the leaves or the seeds, and they told me that they are regarded as poisonous. *Moringa ovalifolia*, from Namibia and Angola, also seems to be used medicinally but never as food. The northeast African endemics *M. arborea, M. borziana, M. longituba, M. rivae,* and *M. ruspoliana* are all used medicinally. The roots all seem to be used to treat intestinal parasites in goats and camels, and skin afflictions in animals. *Moringa pygmaea* is so geographically restricted and so poorly known in general that, while it might be used similarly, there is no documentation of this. No part of any of these species is known to be eaten.

**DO MORINGA PILLS OR CAPSULES HAVE PROTEIN NUTRITIONAL VALUE?**

The most common product on the moringa market comes in the form of dried leaves in capsules. A very common claim in support of the sale of these capsules is that *Moringa oleifera* leaves have high levels of protein. Examining these claims makes it clear that moringa capsules are unlikely to provide dietarily significant amounts of protein. Moringa capsules usually contain about 400 mg of dried moringa leaf powder. Moringa leaf powder that includes mostly leaflets, and not the woody petiole and leaf rachises, contains about 20-30% protein. 25% of 400 mg = 100 mg protein. World Health Organization standards suggest that an average adult needs 105 mg protein $kg^{-1}$ body weight $day^{-1}$. Therefore, an 80-kg adult needs some 8,400 mg protein $day^{-1}$. Assuming that all of the protein in moringa is available to the body, dividing the average daily need by the amount of protein in moringa (100/8400×100) shows that a moringa capsule contains about 1.2% of the protein needed every day. Meeting daily protein intake would require more than 80 moringa capsules. Therefore, it is clear that moringa capsules are neither a significant protein source and nor a cost-effective one.

**DOES INGESTING MORINGA PRODUCE SIDE EFFECTS?**

Because moringa is often commercialized as a capsule rather than as a vegetable, many consumers ask whether "taking" moringa produces side effects. In answering this question, it is helpful to stop thinking of moringa as a medicine and think of it as a nutritious vegetable. This will help think properly how to eat moringa, as well as guide expectations regarding "side effects". Briefly, there are generally no side effects to eating a vegetable, but people have different reactions. Soybeans, for example, provide high quality protein, but many people are allergic to them. I am unaware of any reports of moringa allergy, but there is no reason to assume that it is impossible (though there is some evidence to suggest that moringa actually helps counteract some allergic responses, see for example Mahajan and Mehta, 2007; Agrawal and Mehta, 2008). But "side effects" refer to a reasonably dependable, undesirable secondary effect, and there are numerous compounds in plants that can cause such unwanted effects. I briefly examine the contents of *Moringa oleifera* and conclude that there is little reason to expect side effects from eating moringa, though its abortifacient potential at high concentrations requires more research. I examine several antinutritional compounds as follows:

**Trypsin inhibitors**

Trypsin is an important digestive protease. Natural selection has favored the production of protease inhibitors in plants, apparently as a defense mechanism, deterring animals from eating them. There have not been many studies on trypsin inhibitors in *Moringa*, and those that have been done have been carried out only on very limited samples. Based on these studies, though, protease inhibitors seem to be found only in moderate amounts in *M. oleifera* leaves, and the ones that are there seem to be very heat-sensitive, so a quick cooking deactivates most of them (Vanderjagt et al., 2000). Some nutritious foods, such as soybeans, are notorious for their trypsin inhibitors (e.g., Guillamón et al., 2008). In fact, many legumes with very high protein contents are not eaten precisely because they have such high levels of trypsin inhibitors and other antinutritional factors. Unlike these species, *Moringa oleifera* is not known for its indigestibility. So, based on the available evidence and a long history of consumption by people, trypsin inhibitors do not seem to be present in side-effect producing quantities in *M. oleifera*.

**Tannins**

Tannins are polyphenols that interact with proteins, often binding to them and making them insoluble. When proteins are not in solution, they cannot be digested. So, like protease inhibitors, tannins appear to have arisen and been maintained in plants as antiherbivory agents. Makkar and Becker (1997) found tannins in concentrations of about 12 g $kg^{-1}$, which the authors regarded as only representing a moderate concentration. Note, though, that the studies that have been conducted on moringa have been carried out on samples gathered only in a few geographical regions and therefore might not reflect the variability found across the species. Also, the results of chemical studies can vary tremendously depending on the exact extraction and sample preparation method used (Hagerman, 1988). This also means that it is sometimes hard to compare between studies. For example, Albrecht and Muck (1991) measured tannin contents in a variety of legumes and found that tannin contents varied from 0 to 27 g $kg^{-1}$. This would seem to bear out Makkar and Becker's (1997) conclusion that the 12 g $kg^{-1}$ in *Moringa oleifera* leaves is indeed "moderate". However, given that their methods differed slightly, it is hard to know just how *Moringa oleifera* tannin levels compare to those in other foods. In addition, because Makkar and Becker only used a single sample, it is hard to know how much variation there is in tannin concentrations across *Moringa oleifera* and the different products made from moringa that people consume. However, in contrast to things like grapes, persimmons, or raw nuts, which are notorious for their tannin content, moringa has no such reputation despite millennia of consumption. So, given the information available, the tannin concentrations seem low enough that they are unlikely to produce unwanted reaction under normal consumption.

**Saponins**

Fungi seem to be particularly susceptible and saponins might be an evolutionary response by plants to fungal attack (Osbourn, 1996). They apparently act by disrupting lipid cell membranes. Like tannins, they are unpleasant tasting and potentially toxic. Makkar and Becker (1996) showed that *Moringa* contained some saponins (see also Richter et al., 2003). They found saponin levels higher than those in soybean, but reported that the toxicity of the saponins in moringa seems to be very low. Like all aspects of moringa, systematic studies across the variability within *M. oleifera* and across the genus are needed, but based on the available evidence there would seem to be no reason to avoid eating *Moringa* in a normal diet because of its saponin content (see also Makkar and Becker, 1997; Gidamis et al., 2003).

**Lectins**

Lectins are glycoproteins that, when eaten by people, bind to the mucopolysaccharides protruding from the membranes of the cells in the intestinal wall. Well known lectins include ricin and phytohemagglutinin. Lectins are again compounds that plants, being sessile organisms that cannot run away when confronted by a predator, defend themselves against attack (Peumans and Van Damme, 1995). Makkar and Becker (1996) found no traces of lectins in their analysis, though the seed does, famously, have coagulating proteins. These are the proteins that are used in moringa water purification (see Sutherland et al., 1994, also Coelho et al., 2009 for other moringa lectin uses). So, even though moringa is so rich in proteins, lectins do not seem to be important components of the chemical repertoire of moringa leaves.

**Calcium oxalate**

It is often said that moringa has "more vitamin C than oranges, more calcium than yogurt, etc…" Olson and Carlquist (2001) showed that there was abundant calcium in all moringa parts – but in the form of calcium oxalate crystals. These crystals are another line of plant defense, this time against chewing or piercing insects. For humans, calcium oxalate is worrisome because in the best case it is not available to the body and in the worst case can contribute to formation of kidney stones (Finkielstein and Goldfarb, 2006). For years it was not clear how much of the "more calcium than yogurt" was actually nutritionally inaccessible calcium oxalate. Radek and Savage (2008) quantified the proportion of calcium in moringa in the form of oxalate, and it turned out to be a 38%. This percentage would seem dismayingly high, but two important observations emerge from their study. First, Radek and Savage showed that moringa leaves contain only non-soluble oxalates. This means that even though there are large amounts of oxalates in moringa leaves, it is found in a form that is simply excreted by the body. Oxalates that are excreted do not circulate in the body, and therefore cannot contribute to kidney stone formation. Second, Radek and Savage showed that moringa has total calcium values that are extremely high (>20 mg $g^{-1}$ of dry leaf). So, even with more than a third of the calcium being unavailable, moringa offers substantial levels of calcium that are potentially bioavailable. Powdered milk has approximately 13 mg $g^{-1}$ of calcium (USAID, 2006). So, moringa leaf powder would seem to compare favorably not only with powdered milk in terms of protein content but also in terms of calcium. Even if all of the protein or even all of the non-oxalate calcium in moringa turns out not to be readily digestible (and here more research is needed), the much lower cost of moringa means that it is a protein and calcium source that is more inexpensive and with a much lower environmental impact than milk. Thus, although a large proportion of the calcium in moringa is bound up in oxalates, most of these oxalates are likely simply excreted, meaning that they do not contribute to kidney stones. And, in addition to calcium oxalate, there is still a substantial amount of calcium that is probably bioavailable.

**Glucosinolates**

Beyond its well-proven nutritional benefits, one of the main promising aspects of *Moringa oleifera* is its battery of antioxidant glucosinolates, or mustard oils. Glucosinolates are the spicy, sulfur-containing compounds that give radish, cabbage, wasabi, papaya, and other Brassicalean plants their spiciness, pungency, or sometimes slightly fetid smell. They are what seem to give moringa its potential promise in cancer chemoprevention (Guevara et al., 1999; Fahey et al., 2004; etc.), glucose regulation for diabetics (Kar et al., 2003; Ndong et al., 2007), and other potential applications.

Glucosinolates are potentially important in connection with side effects because some of them lead to the formation of goiters. Therefore, a natural question is whether glucosinolates in *Moringa oleifera* have the potential to cause goiters (Abuye et al., 2003). Moringa is a member of *Brassicales*, the great order of mustard-oil producing plants. This means that it is a relative, though a bit distant, of the mustard family, *Brassicaceae*. Many *Brassicaceae* are well known for containing progoitrin, which, when eaten and then split apart in the initial stages of digestion, releases goitrogenic oxazolidonethiones. However, progoitrin has never been identified in any *Moringa* species. Likewise, no *Moringa* species is known to have high levels of glucosinolates constructed around an indole group (Faizi et al., 1995; Guevara et al., 1999). Indole glucosinolates are also important goiter-causing compounds. As a result, there is no evidence that points decisively toward a risk of goiters from consuming moringa. However, it could be that some thiocyanates, the sulfur- plus cyan-group containing compounds common in moringa, just might be goitrogenic in very high concentrations, well beyond those found in a normal diet. This is significant because some commercial moringa products include concentrates that very well might concentrate some substances excessively, an issue potentially of concern also with regard to abortifacient potential.

**Abortifacient potential**

One aspect of moringa biology that requires attention is its potential to provoke abortion. Moringa is a traditional abortifacient in India (Nath et al., 1992) and does seem to provoke uterine changes in rats that have had their ovaries removed and so otherwise lack female hormones (Shukla et al., 1989). In addition, there is a fair amount of research examining the ability of moringa to cause abortions in rats. As with most research on moringa's medical and nutritional potential, many have methods that are hard to interpret.

For example, Sethi et al. (1988) appear to have ground up moringa leaves, extracted the contents with ethanol and then dried this tincture down (see also Nath et al., 1992). They then administrated 175 mg of this paste per kg of rat body weight. For a 65-kg human, this would mean taking 11 g of this hyper-concentrate. It is not at all clear how many kilos of fresh moringa leaves would be needed to make 11 g of such an extract, but it likely exceeds the amount that a person would ingest in any meal. Centuries of use as an edible food have established moringa as a nutritious addition to human diets, apparently including pregnant women, but it is clear that more research would be helpful. Moringa's potential abortifacient potential at very high doses illustrates the important point that well-meaning usages such as concentrates that go far beyond proven dietary doses could reveal potential undesirable effect. Given this evidence, it seems clear that dietary use of moringa should concentrate on moringa as a vegetable, a use that is known to be safe and nutritious; concentrates and extracts should be avoided until more is known about abortifacient potential.

**WHERE CAN MORINGA BE GROWN?**

Because moringa is such a useful plant, people worldwide would like to grow it. Here I provide some information regarding where moringa grows best, its climate preferences, and considerations for growing in marginal areas. First, moringa is a tropical plant. It only grows truly well in the tropics, and the dry tropics at that. The key factors are temperature and moisture; latitude and elevation inevitably intervene as well. We will look at these individually.

The first key aspect is the annual low temperature. Just because it gets hot in Death Valley, or Iowa, or Paris does not mean moringas will grow well there. This is because what limits moringas most severely is the yearly absolute (not mean) low temperature. Moringas do not tolerate frost well. More importantly, they do not grow well in places that get below 10°C or so, and only then when such low temperatures are rare. 15°C as a general low is ideal. On the Jalisco coast, at the site of the International *Moringa* Germplasm Collection (www.moringaceae.org), the lowest low is 17°C, ideal for moringa. There are occasional lows, at 3 am at the coldest time of year. Ten (10) degree weather for days on end is as bad for moringas as a frost. Good average daily temperature ranges are in the 20- to 35-degree range. The annual high is important insofar as it is related to the average, but is not an important consideration in selection areas for growing moringa. Moringas in general do not suffer from high temperature, and often do not even drop their leaves under high temperature if there is water in the soil. In any case, tropical areas have more moderate climates than deserts and other extreme places, so anywhere with the minimum that is high enough for a moringa will have absolute high temperatures that are also in the correct range.

As to rainfall, practically any tropical area that meets the temperature requirements will meet the minimum rainfall needs of moringa. The problem in the tropics is likely to be too much rainfall. Moringas do best in areas that receive less than 1.5 m of rain per year and where the rain falls in one or two concentrated seasons during the year, not evenly all year round. The wet tropics, as in rainforest areas, places where things like cacao, mangosteen, tea, oil palms, or allspice grow well are usually too wet for moringas to grow satisfactorily. Moringas do not tolerate well water puddled around their roots, or heavy, fine soil with little oxygen around the roots. On the other hand, they respond well to well drained, well aerated soil. Fast draining gravelly soil is ideal, and they will also do well in sandy soils. However, they will do poorly even on the best soils if they remain waterlogged. For example, deep volcanic soils are often perfect for moringas, but if they are in a high rainfall area the plants will suffer anyway.

With regard to latitude and elevation, moringa is a tropical lowland plant. Moringas in general grow best from sea level to 500 m a.s.l. or so. In some places, moringas can grow acceptably up to about 1000 m. Growth at these elevations will generally not be acceptable for commercial production but might be satisfactory for domestic use or as an ornamental. The trees can often survive but definitely not thrive between 1000 and 1500 m. Above 1500 m is completely out of the question as far as serious moringa cultivation goes. Remember that moringa is a tropical plant and these elevations apply to tropical latitudes, between 23 north and south latitude or so. Moringas really do not grow well outside of these latitudes and certainly not at higher elevations.

I offer some tables (Tables 2-4) giving combinations of temperature and rainfall in areas where I have seen moringa growing well. These illustrate the point that *M. oleifera* prefers warm climates with very high low temperatures. The highs can be high, but the lows need to be high. Rainfall tends to be low, 1500 mm or often much less, and is highly seasonal, usually with 8 months or so of very dry weather. Moringa is a lowland plant, growing best below 500 m a.s.l.

*Moringa oleifera* will hang on in many marginal places, even flower and fruiting sparingly in places like southern California, the Mexican or Kenyan high plateaus, or the Canary Islands. They can be cultivated, at great expense and massive carbon footprint, in greenhouses in cold places like Europe (Förster et al., 2015), or, perhaps even more unsustainably, with outdoor gas heaters (Figure 4). Given the very fast growth rates of *Moringa oleifera*, it seems possible that it could be cultivated as an annual in temperate regions with adequate yield. Some cultivars are grown in India as annuals for their edible pods, so with their long summer day lengths it could be possible to reach adequate temperate zone yields despite the inappropriate climate.

Table 2. *Moringa oleifera* temperature preferences in degrees Celsius, showing that moringas grow best in areas with very high minimum temperatures.

| Locality | Mean annual temp. | Max. temp. | Min. temp. |
|---|---|---|---|
| Tiruchirappalli, India | 29 | 37 | 21 |
| Rupnagar, India | 24 | 40 | 7 |
| Tehuantepec, Mexico | 28 | 35 | 20 |
| Antanimeva, Madagascar | 24 | 33 | 13 |
| IMGC, Jalisco, Mexico | 26 | 33 | 16 |
| Mandera, Kenya | 29 | 40 | 20 |
| Kitui, Kenya | 25 | 35 | 16 |
| Accra, Ghana | 27 | 32 | 22 |
| Barranquilla, Colombia | 28 | 33 | 23 |
| Chiquimula, Guatemala | 26 | 35 | 18 |
| Depto. León, Nicaragua | 27 | 35 | 20 |

Table 3. *Moringa oleifera* precipitation preferences (ppt in cm), showing that moringas grow best in areas that have relatively low and seasonal rainfall.

| Locality | Mean Ann Ppt | Ppt wet Mo | Ppt dry Mo | Ppt wet qtr | Ppt dry qtr |
|---|---|---|---|---|---|
| Tiruchirappalli, India | 860 | 192 | 9 | 453 | 39 |
| Rupgnagar, India | 944 | 307 | 8 | 694 | 55 |
| Tehuantepec, Mexico | 860 | 216 | 2 | 511 | 7 |
| Antanimeva, Madagascar | 665 | 165 | 2 | 457 | 10 |
| IMGC, Jalisco, Mexico | 818 | 225 | 1 | 566 | 13 |
| Mandera, Kenya | 247 | 85 | 1 | 138 | 3 |
| Kitui, Kenya | 421 | 128 | 1 | 205 | 5 |
| Accra, Ghana | 786 | 194 | 10 | 421 | 57 |
| Barranquilla, Colombia | 778 | 192 | 0 | 437 | 2 |
| Chiquimula, Guatemala | 696 | 158 | 0 | 384 | 3 |
| Depto León, Nicaragua | 1458 | 386 | 0 | 855 | 1 |

Mean Ann Ppt = Mean annual precipitation; Mo = month and Qtr = quarter, i.e. 3 month period, so it rains 192 mm in the wet month in Barranquilla, 437 in the wet quarter, 0 mm in the driest month, and 2 mm in the driest quarter.

Table 4. *Moringa oleifera* elevational preferences in m a.s.l.

| Locality | Elevation |
|---|---|
| Tiruchirappalli, India | 84 |
| Rupnagar, India | 260 |
| Tehuantepec, Mexico | 41 |
| Antanimeva, Madagascar | 146 |
| IMGC, Jalisco, Mexico | 74 |
| Mandera, Kenya | 221 |
| Kitui, Kenya | 574 |
| Accra, Ghana | 8 |
| Barranquilla, Colombia | 40 |
| Chiquimula, Guatemala | 339 |
| Depto León, Nicaragua | 87 |

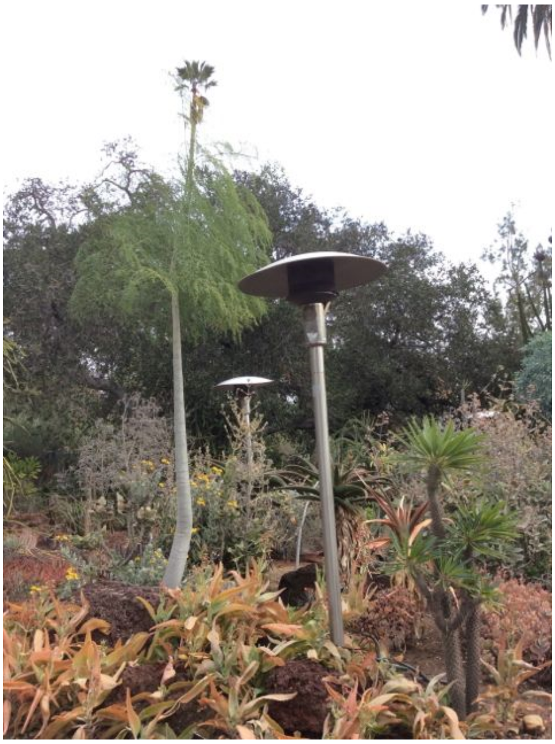

Figure 4. *Moringa drouhardii* being grown outside with the benefit of gas heaters, The Huntington, San Marino, California.

**CONCLUSIONS – THE NEED FOR FURTHER STUDIES**

Even though people have been eating moringa for thousands of years, all aspects of moringa need more study. Most of the studies that have been carried out have examined very small samples of moringa germplasm. Virtually no effort has been made to study samples from across the entire genus *Moringa* and including the full genetic diversity of *M. oleifera*. The studies that have been carried out are hard to compare with one another and their methods make their relevance to human nutrition difficult to interpret at times (for example, the massive abortifacient doses given to rats). Any studies in humans have involved very few subjects. Relatively few of these studies are in prestigious international journals. With the ease of communication afforded by tools such as email and videoconferences, plus the relative ease of sending material or traveling, there is every reason to expect that moringa scientists can forge a global collaboration to produce globally comprehensive applied and basic data. Only in this way can we take moringa science from its current situation of indicating great promise but based on very local studies; only in this way can we take moringa from being a plant of great promise and much anecdotal evidence to one with the full backing of solid scientific research.

**ACKNOWLEDGEMENTS**

This work was supported by Trees for Life and by project IT200515 of the Programa de Apoyo a Proyectos de Investigación e Innovación Tecnológica, UNAM.

## Literature cited

Abuye, C., Urga, K., Knapp, H., Selmar, D., Omwega, A.M., Imungi, J.K., and Winterhalter, P. (2003). A compositional study of Moringa stenopetala leaves. East Afr Med J *80* (*5*), 247–252 10.4314/eamj.v80i5.8695 PubMed.

Adanson, M. (1763). Familles des Plantes. II Partie (Vincent, Paris).

Agrawal, B., and Mehta, A. (2008). Antiasthmatic activity of *Moringa oleifera* Lam: A clinical study. Indian J Pharmacol *40* (*1*), 28–31. PubMed http://dx.doi.org/10.4103/0253-7613.40486

Albrecht, K.A., and Muck, R.E. (1991). Proteolysis ensiled forage legumes that vary in tannin concentration. Crop Sci. *31* (*2*), 464–469 http://dx.doi.org/10.2135/cropsci1991.0011183X003100020048x.

Anbazhakan, S., Dhandapani, R., Anandhakumar, P., and Balu, S. (2007). Traditional medicinal knowledge on *Moringa concanensis* Nimmo of perambalur District, Tamilnadu. Anc Sci Life *26* (*4*), 42–45 PubMed.

Arinathan, V., Mohan, V.R., Britto, A., and Murugan, C. (2007). Wild edibles used by Palliyars of the western Ghats, Tamil Nadu. Indian J. Tradit. Knowl. *6*, 163–168.

Bhandari, M.M. (1990). Flora of the Indian Desert. Revised edition. (MPS Repros), pp.435.

Coelho, J.S., Santos, N.D., Napoleão, T.H., Gomes, F.S., Ferreira, R.S., Zingali, R.B., Coelho, L.C., Leite, S.P., Navarro, D.M., and Paiva, P.M. (2009). Effect of *Moringa oleifera* lectin on development and mortality of *Aedes aegypti* larvae. Chemosphere *77* (*7*), 934–938. PubMed http://dx.doi.org/10.1016/j.chemosphere.2009.08.022

Colautti, R.I., and MacIsaac, H.J. (2004). A neutral terminology to define 'invasive' species. Divers. Distrib. *10* (*2*), 135–141 http://dx.doi.org/10.1111/j.1366-9516.2004.00061.x.

Dastur, J.F. (1951). Useful Plants of India and Pakistan (D.B. Taraporevala Sons & Co.).

Fahey, J.W., Dinkova-Kostova, A.T., and Talalay, P. (2004). The "Prochaska" microtiter plate bioassay for inducers of NQO1. In Methods in Enzymology, Vol. 382, Parte B, H. Sies, and L. Packer, eds. (San Diego, California: Elsevier Science), p.243–258.

Faizi, S., Siddiqui, B.S., Saleem, R., Siddiqui, S., Aftab, K., and Gilani, A.H. (1995). Fully acetylated carbamate and hypotensive thiocarbamate glycosides from *Moringa oleifera.* Phytochemistry *38* (*4*), 957–963. PubMed http://dx.doi.org/10.1016/0031-9422(94)00729-D

Finkielstein, V.A., and Goldfarb, D.S. (2006). Strategies for preventing calcium oxalate stones. CMAJ *174* (*10*), 1407–1409. PubMed http://dx.doi.org/10.1503/cmaj.051517

Förch, W. (2002). Case study: the agricultural system of the Konso in South-Western Ethiopia. FWU Water Resources Publications (Germany: University of Siegen), http://fwu.fb10.uni-siegen.de/bkd/FWU_WRP.htm

Förster, N., Ulrichs, C., Schreiner, M., Arndt, N., Schmidt, R., and Mewis, I. (2015). Ecotype variability in growth and secondary metabolite profile in Moringa oleifera: impact of sulfur and water availability. J. Agric. Food Chem. *63* (*11*), 2852–2861. PubMed http://dx.doi.org/10.1021/jf506174v

Gidamis, A.B., Panga, J.T., Sarwatt, S.V., Chove, B.E., and Shayo, N.B. (2003). Nutrient and antinutrient contents in raw and cooked young leaves and immature pods of *Moringa oleifera* Lam. Ecol. Food Nutr. *42* (*6*), 399–411 http://dx.doi.org/10.1080/03670240390268857.

Guevara, A.P., Vargas, C., Sakurai, H., Fujiwara, Y., Hashimoto, K., Maoka, T., Kozuka, M., Ito, Y., Tokuda, H., and Nishino, H. (1999). An antitumor promoter from Moringa oleifera Lam. Mutat. Res. *440* (*2*), 181–188. PubMed http://dx.doi.org/10.1016/S1383-5718(99)00025-X

Guillamón, E., Pedrosa, M.M., Burbano, C., Cuadrado, C., Sánchez, M. de C., and Muzquiz, M. (2008). The trypsin inhibitors present in seed of different grain legume species and cultivar. Food Chem. *107* (*1*), 68–74 http://dx.doi.org/10.1016/j.foodchem.2007.07.029.

Hagerman, A.E. (1988). Extraction of tannin from fresh and preserved leaves. J. Chem. Ecol. *14* (*2*), 453–461. PubMed http://dx.doi.org/10.1007/BF01013897

Jahn, S.Al-A. (1991). The traditional domestication of a multipurpose tree *Moringa stenopetala* (Bak.f.) Cuf. in the Ethiopian Rift Valley. Ambio *20*, 244–247.

Jiru, D., Sonder, K., Alemayehu, L., Mekonen, Y., and Anjulo, A. (2006). Leaf yield and nutritive value of *Moringa stenopetala* and *Moringa oleifera* accessions: its potential role in food security in constrained dry farming agroforestry system. Paper presented at: The Moringa and Other Highly Nutritious Plant Resources: Strategies, Standards and Markets for a Better Impact on Nutrition in Africa (Accra, Ghana).

Kar, A., Choudhary, B.K., and Bandyopadhyay, N.G. (2003). Comparative evaluation of hypoglycaemic activity of some Indian medicinal plants in alloxan diabetic rats. J Ethnopharmacol *84* (*1*), 105–108. PubMed http://dx.doi.org/10.1016/S0378-8741(02)00144-7

Lamarck, J.-B. (1783). Encyclopédie Méthodique: Botanique (Liège Panckoucke).

Mahajan, S.G., and Mehta, A.A. (2007). Inhibitory action of ethanolic extract of seeds of *Moringa oleifera* Lam. on systemic and local anaphylaxis. J Immunotoxicol *4* (*4*), 287–294. PubMed http://dx.doi.org/10.1080/15476910701680137

Makkar, H.P.S., and Becker, K. (1996). Nutritional value and antinutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Anim. Feed Sci. Technol. *63* (*1-4*), 211–228 http://dx.doi.org/10.1016/S0377-8401(96)01023-1.

Makkar, H.P.S., and Becker, K. (1997). Nutrients and antiquality factors in different morphological parts of the *Moringa oleifera* tree. J. Agric. Sci. *128* (*3*), 311–322 http://dx.doi.org/10.1017/S0021859697004292.

Mbaluka, J.K., and Brown, F.H. (2016). Vegetation of the Koobi Fora region northeast of Lake Turkana, Marsabit County, northern Kenya. J. East Afr. Nat. Hist. *105* (*1*), 21–50 http://dx.doi.org/10.2982/028.105.0101.

McNeill, J., Barrie, F.R., Buck, W.R., Demoulin, V., Greuter, W., Hawksworth, D.L., Herendeen, P.S., Knapp, S., Marhold, K., Prado, J., et al. (2012). International Code of Nomenclature for Algae, Fungi, and Plants (Melbourne Code) (Koeltz Scientific Books).

Miller, A.G., and Morris, M. (1988). Plants of Dhofar: the Southern Region of Oman, Traditional, Economic and Medicinal Uses (Oman: Office of the Adviser for Conservation of the Environment, Diwan of Royal Court Sultanate of Oman), pp.361.

Morton, J.F. (1991). The horseradish tree, *Moringa pterygosperma* (*Moringaceae*): a boon to arid lands? Econ. Bot. *45* (*3*), 318–333 http://dx.doi.org/10.1007/BF02887070.

Nath, D., Sethi, N., Singh, R.K., and Jain, A.K. (1992). Commonly used Indian abortifacient plants with special reference to their teratologic effects in rats. J Ethnopharmacol *36* (*2*), 147–154. PubMed http://dx.doi.org/10.1016/0378-8741(92)90015-J

Ndong, M., Uehara, M., Katsumata, S., and Suzuki, K. (2007). Effects of oral administration of *Moringa oleifera* Lam on glucose tolerance in Goto-Kakizaki and Wistar rats. J Clin Biochem Nutr *40* (*3*), 229–233. PubMed http://dx.doi.org/10.3164/jcbn.40.229

Olson, M.E. (2002). Combining data from DNA sequences and morphology for a phylogeny of *Moringaceae.* Syst. Bot. *27*, 55–73.

Olson, M.E. (2010). *Moringaceae*: drumstick family. In Flora of North America North of Mexico, Vol. 7, Flora of North America Editorial Committee, eds (New York, New York, and Oxford, UK: Flora of North America Association), p.167–169.

Olson, M.E., and Carlquist, S. (2001). Stem and root anatomical correlations with life form diversity, ecology, and systematics in Moringa (*Moringaceae*). Bot. J. Linn. Soc. *135* (*4*), 315–348 http://dx.doi.org/10.1111/j.1095-8339.2001.tb00786.x.

Olson, M.E., and Razafimandimbison, S.G. (2000). *Moringa hildebrandtii*: a tree extinct in the wild but preserved by indigenous horticultural practices in Madagascar. Adansonia sér. *3* (*22*), 217–221.

Osbourn, A. (1996). Saponins and plant defence – a soap story. Trends Plant Sci. *1* (*1*), 4–9 http://dx.doi.org/10.1016/S1360-1385(96)80016-1.

Peumans, W.J., and Van Damme, E.J.M. (1995). Lectins as plant defense proteins. Plant Physiol. *109* (*2*), 347–352. PubMed http://dx.doi.org/10.1104/pp.109.2.347

Qaiser, M. (1972). Moringaceae. Flora of West Pakistan *4*, 80–85.

Radek, M., and Savage, G.P. (2008). Oxalates in some Indian green leafy vegetables. Int J Food Sci Nutr *59* (*3*), 246–260. PubMed http://dx.doi.org/10.1080/09637480701791176

Richter, N., Siddhuraju, P., and Becker, K. (2003). Evaluation of nutritional quality of moringa (*Moringa oleifera* Lam.) leaves as an alternative protein source for Nile tilapia (*Oreochromis niloticus* L.). Aquaculture *217* (*1-4*), 599–611 http://dx.doi.org/10.1016/S0044-8486(02)00497-0.

Sethi, N., Nath, D., Shukla, S.C., and Dyal, R. (1988). Abortifacient activity of a medicinal plant "*moringa oleifera*" in rats. Anc Sci Life *7* (*3-4*), 172–174 PubMed.

Shukla, S., Mathur, R., and Prakash, A.O. (1989). Histoarchitecture of the genital tract of ovariectomized rats treated with an aqueous extract of *Moringa oleifera* roots. J Ethnopharmacol *25* (*3*), 249–261. PubMed http://dx.doi.org/10.1016/0378-8741(89)90031-7

Stewart, R.R. (1972). An Annotated Catalogue of the Vascular Plants of West Pakistan and Kashmir (Karachi).

Sutherland, J.P., Folkard, G.K., Mtawali, M.A., and Grant, W.D. (1994). *Moringa oleifera* as a natural coagulant. Paper presented at: 20th WEDC Conference, Affordable Water Supply and Sanitation (Colombo, Sri Lanka).

USAID. (2006). Commodities reference guide. Fact sheet: non fat dry milk (USAID).

van Rheede, H.A. (1698). Hortus Indicus Malabaricus. Volume 6, Tome II. (Amsterdam: Johannis van Someren and Joannis van Dyck).

Vanderjagt, D.J., Freiberger, C., Vu, H.-T.N., Mounkaila, G., Glew, R.S., and Glew, R.H. (2000). The trypsin inhibitor content of 61 wild edible plant foods of Niger. Plant Food. Human Nutr. *55*, 335–346.

Verdcourt, B. (1986). Moringaceae. Flora of Tropical East Africa (Taylor and Francis).