Seeking to attain the UN's Sustainable Development Goal 2 worldwide: the important role of *Moringa oleifera*

J.D.H. Keatinge[a], A.W. Ebert, J.d'A. Hughes, R.-Y. Yang and J. Curaba

World Vegetable Center, Shanhua, Taiwan.

Abstract

In Sustainable Development Goal 2, the UN has sought to abolish both hunger and malnutrition by ensuring the continuous supply of sufficient, wholesome food enabling people to shift towards adopting healthier, well-balanced diets. In addition, it calls for the establishment of new ways to reduce current food wastage, farming in a manner which conserves biodiversity and environmental services, increases enterprise profitability through new business models and empowers women. Finally, it seeks for governments to create coherent policies at all levels allowing these positive changes in farming systems to take place in every country. Moringa will play a key role in helping these desirable visions be attained. Moringa is a reasonably unique species as its fresh leaves and pods are both edible and extremely micronutrient dense. Its dried leaves are a good micronutrient source in food fortification for chronically underfed and malnourished children. It is a fast growing, productive tree that adapts well to a range of environments, especially in hot, semi-arid regions and is, thus, a climate-resilient crop. It grows well in a wide range of production systems from a densely planted green vegetable repetitively harvested crop, to a fully-grown tree crop which can be harvested periodically when needed. Use of this diversity of production systems in specialized environments can promote in-situ germplasm conservation, soil conservation, sustainable production systems, enhanced profitability and a continuous source of vitamins and minerals for small-holder farm families, and often – all of these attributes together. This species is thus a boon to women small-holders as it enables them to better provide their children with highly nutritious food direct from the family home garden or by procurement in the local market. Likewise, its good productivity and wide range of adaptability helps to develop resilience in farm enterprises and to ensure better enterprise profitability and sustainability.

Keywords: sustainable production, income generation, agrobiodiversity, improved nutrition, traditional vegetables

INTRODUCTION

The Lancet Series on nutrition (Black et al., 2013) has reported that malnutrition in the developing world remains an extremely severe problem with several hundred million women and children suffering from chronic micronutrient deficiencies resulting in compromised human health and development. It is evident now in 2015 that much less progress in this area has been achieved than was earlier sought through the Millennium Development Goals (FAO, 2014; Mason et al., 2001).

It is therefore evident why the new UN Sustainable Development Goal 2 (SDG 2) now emphasizes not only the attainment of food security but also the need for improved nutrition and a shift towards healthier diets from diverse sustainable agricultural systems (Sustainable Development Solutions Network, 2013). In particular, there is the need to ensure the maintenance and availability of a continuous supply of wholesome food for all people to permit well balanced diets to assure good human health and to avoid, in particular,

[a]E-mail: dyno@keatinge.co.uk

the insidious inter-generational transfer of malnutrition from mothers to foetuses (Cogill, 2015).

The WHO (2003) recommends a daily intake of 400 g of fruit and vegetables per person per day to protect against diet-related non-communicable diseases (NCDs) yet such consumption is rarely achieved in many countries, especially amongst the poor of developing countries (Hughes and Keatinge, 2013). Yet, increasing the production and consumption of fruit and vegetables is one obvious pathway to improve dietary diversity and quality especially in diets that are dominated by high energy foods that are poor in micronutrients (Oyebode et al., 2014). Recently, Cogill (2015) has indicated that "the identification and use of indigenous foods and food practices has been recognized as critical to mitigating some of the negative aspects of recent trends in nutrition as well as enabling us to celebrate the associated cultural traditions, flavors, textures and smells" (United Nations, 2013).

The potential for indigenous and traditional vegetables now to become a key lever to address serious micronutrient malnutrition is made manifest globally (Keatinge et al., 2011, 2015) and particularly in Africa (Ojiewo et al., 2013; Yang et al., 2013) and in Asia (Keatinge et al., 2014; Hughes and Keatinge, 2015). Yet, these crops which are receiving now greater research attention (Dinssa et al., 2015) must not follow the same trends of declining nutrient-density from breeding as has been the fate of many global fruit and vegetables that have been selected principally for yield, shelf life and appearance in the USA and Europe (Davis, 2009).

It is now important that governments concerned with the issue of eliminating malnutrition promulgate an appropriate policy environment in order to ensure that the changing trends in global food consumption resulting from increased urbanization, changing socio-demographic factors, trade liberalization and food industry marketing are effective in encouraging people to adopt appropriate healthy diets with adequate crop diversity. This must also include better policy harmony between different concerned ministries within governments. Failure in either of these regards may lead to less hunger per se and yet may encourage chronic human ill-health through encouraging diets with an excess of high energy staples and oils and an insufficiency of fruit and vegetables. This insidious combination is presently feeding a growing world epidemic of obesity, type II diabetes and resultant NCDs which needs to be immediately halted if real progress is to be made in the attainment of SDG 2 (Wahlqvist et al., 2009; Kearney, 2010; Keatinge et al., 2010; Cogill, 2015).

THE ROLE OF MORINGA

The *Moringaceae* comprises 13 species mostly endemic to the Horn of Africa of which several are included in the AVRDC genebank collection (*Moringa oleifera, M. stenopetala, M. peregrina* and *M. drouhardii*) (AVRDC, 2004). Further descriptions of the full range of species are provided by Ebert (2011). Commonly, these species are referred to as the drumstick or horseradish tree in English. Yet, only a few of these species are used for human/animal consumption either for agricultural, biomass, industrial, nutraceutical or medical purposes (mostly *M. oleifera* and *M. stenopetala*). Taxonomic identification was performed on 27 accessions from the AVRDC genebank using 524 unambiguously polymorphic bands and a dendrogram was created consisting of four clusters (AVRDC, 2003). Cluster I included all *M. oleifera* accessions. The *M. oleifera* accessions from Thailand were all clustered in one sub-group of cluster I (I-A) and might have evolved in geographic isolation from other *M. oleifera* accessions from India, Philippines, Tanzania and Taiwan clustering in sub-groups I-B and I-C. Other species such as *M. stenopetala* and *M. peregrina* were quite distinct in clustering from *M. oleifera* accessions (Figure 1).

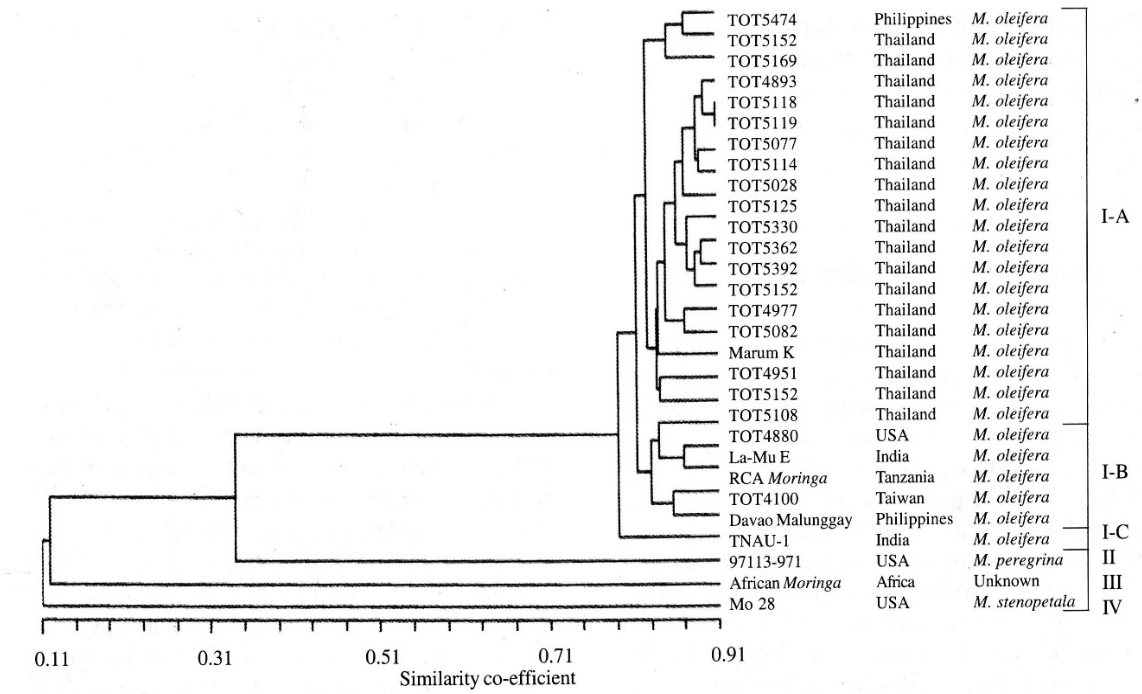

Figure 1. Cluster analysis of drumstick tree (*Moringa* spp.) accessions maintained by AVRDC – The World Vegetable Center, based on Random Amplified Polymorphic DNA (RAPD) data. Source: AVRDC (2003).

The range of uses is very considerable and encompasses all above and below-ground plant parts (leaves, pods, stems, bark and roots). Other than its principal use as food or feed, it can amongst other uses include beneficial fluid clarification qualities, as a bactericide agent in hand washing, tanning and dyeing functions, pharmaceutical uses, biopesticide attributes and use as fertilizer and it is evident that the yet undeveloped potential for use of the *Moringaceae* is very substantial (Emongor, 2012). In this paper, we restrict our analysis largely to food and feed issues with specific reference to both nutritional benefits and possible anti-nutritional factors and thus issues principally germane to the attainment of SDG 2. It also includes issues concerned with the effective agronomy of crop production which itself is highly diverse ranging from use as a continuously harvested open field short-statured green vegetable crop to a component of home gardens and its broader agro-forestry dimensions, including as an alley crop.

Emongor (2012) has reported that *M. oleifera* leaves and pods are outstanding natural sources of digestible protein, minerals such as calcium, iron, magnesium, potassium, phosphorus, sulphur, manganese and zinc, vitamins (provitamin A-β-carotene, vitamin B-choline, vitamin B_1-thiamine, vitamin B_2-riboflavin, vitamin B_3-nicotinic acid, vitamin C-ascorbic acid and vitamin E-tocopherols) and essential amino acids (arginine, histidine, tryptophan, phenylalanine, leucine, methionine, threonine, valine, glutamic acid and glycine).

In addition, the species contains carbohydrates and fiber (Mensah et al., 2012). Clearly therefore, this is a highly nutrient dense vegetable which has a potentially critical role in helping to provide humans and animals with significantly higher nutrient supplies from a small quantity of moringa leaves added in their regular diets. In particular, this role of nutrient and vitamin richness can be exploited in cases where infants and young children are seriously undernourished and malnourished. In a survey of 120 species of Asian vegetables (AVRDC, 2005) moringa was reported as one of the most promising species for overcoming malnutrition with good nutritional quality (Yang et al., 2007). Description of the nutrient quality of other *Moringa* spp. is presented by Yang et al. (2006).

Many other authors have reported a substantial variability in the chemical and mineral composition, nutritional values of a range of above ground moringa plant parts from Sahelian countries, East Africa and South Asia. Yet all agree that moringa is a highly nutrient dense crop which is valuable for improved human nutrition (Melesse et al., 2009; Anjorin et al., 2010; Yaméogo et al., 2011; Aja et al., 2013; Verma and Nigam, 2014; Mahima et al., 2014).

CHALLENGING CHILD MALNUTRITION WITH MORINGA SUPPLEMENTS

In Burkina Faso where severe infant malnutrition can be common, moringa leaf powder when used, on infants sick with energy deficiency (marasmus), protein deficiency (kwashiorkor), diarrhea and/or vomiting, as a nutritional supplement of 10 g of moringa leaf powder in addition to porridge feeding as nutritional care resulted in a higher average weight gain and a quicker recovery rate than the porridge-alone control group (Zongo et al., 2013). Mensah et al. (2012) indicate beneficial consumption of this vegetable as leaves amongst primary-age school students in Nigeria.

Similarly, in Asia, specifically southern India, Srikanth et al. (2014) have reported significant health gains amongst severely protein-energy malnourished children when treated over a two-month period with a 30 g daily supplement of *M. oleifera* fresh leaves. They estimate that for children of 1-3 years of age that all the daily requirements of Ca, 75% of their required Fe and half of their protein needs can be derived from 100 g of fresh moringa leaves. In addition, substantial amounts of their required K, Cu and vitamins A and C are likely also to have been made available by this quantity of product.

Some NGOs in West Africa such as World Vision are now advocating the addition of supplementary moringa powder to Plumpy'nut® which is a commercial high protein food supplement for chronically malnourished children but there remains some doubt about possible associated anti-nutritional factors (de Pee and Bloem, 2009).

Maternal nutrition status affects not only embryo growth and fetal development, but also the health during early childhood and subsequent years (Wu et al., 2004). When a foetus is malnourished in the early (and later) stages of pregnancy, it may adapt its metabolism to cope with malnutrition by reducing the amount of insulin and glucose produced. That, in turn, leads to increased risk of chronic health conditions later in life, such as type 2 diabetes.

Women should eat properly before planned pregnancy and when becoming pregnant and this is often overlooked with regard to nutrition supplementation because pregnancy is often not planned or women are often not aware of the very early stages of their pregnancy. Supplementation with nutrient rich vegetables such as moringa and other indigenous vegetables for under-nourished women in the months before marriage can help to improve nutrition and reduce the risks of fetal malnutrition in the first trimester of pregnancy (Keatinge et al., 2015).

MORINGA AS A FOOD AND FEED FOR MALNOURISHED FAMILIES

In Bangladesh, where average vegetable consumption is low at 120 g $person^{-1}$ day^{-1}, Rahim et al. (2015) report that both *M. oleifera* and *M. stenopetala* are commonly cultivated, often as a component of home gardens or as living fences, and eaten throughout Bangladesh. This is particularly the case in the northwestern region where it is a major asset in the battle against the widespread malnutrition found in this country and is essentially a staple for 20% of the population in these areas. Both leaves and pods are consumed. Leaves are eaten in curries and pickles, the pods in soups and seed are consumed like groundnuts.

Similarly, Seifu (2014) indicates that in southern Ethiopia *M. stenopetala* is commonly eaten in the dry season when few other green vegetables are available. In this area amongst the Konso, Gamo and Gofa peoples, moringa leaves are eaten almost every day in spinach form, together with cereal staples. Most homesteads have such trees as part of their home gardens. Even though consumption of moringa leaves and/or pods as food have been reported in the diets of many Asian and African countries, information on the amount consumed and the significance of its contribution to the dietary quality and public health remain to be documented and researched. Moringa may only be consumed by a small group of people, among whom the indigenous knowledge about moringa food preparation and consumption was passed on from generation to generation.

The nutritional values and traditional uses of moringa merit greater promotion. Karsten (2002) has examined the bioavailability of iron from moringa. She concluded that simple vegetable meals with moringa can provide sufficient bioavailable iron in family diets though the amount may be influenced with what it is cooked and eaten. Water-boiled leaves and oil-fried leaves were higher in terms of bioavailable iron than raw or dried leaves. When cooked with tomato and soybean or mungbean, iron bioavailability was increased. These studies are further extended to other moringa species in Yang et al. (2006).

In Ghana, research has been conducted examining *M. oleifera* leaf powder as a source of flavoring or as a protein supplement in Frankfurter sausages (Teye et al., 2013). Fortification of each kg of pork or beef with up to 6 g of leaf powder has been largely found acceptable to the human panelists in terms of taste. Yet, at the highest levels of supplementation the sausages were somewhat green in appearance from the leaf powder and this was deemed to be less acceptable to the public who associate this color with rotten meat.

MORINGA AS A FEED SUPPLEMENT FOR LIVESTOCK

Moringa leaves are used as a cheap additive for protein enrichment in several livestock feeding regimes. *M. oleifera* was used by Olaniyi et al. (2013) as a substitute for groundnut cake in up to 12.5% of the diet of African sharptooth catfish (*Clarias gariepinus*) in Nigeria. Fish fed on the highest percentage of replacement showed the best feed conversion and protein efficiency and had the highest weight gain in the experiment.

Similar findings are reported by Melesse et al. (2013) when *M. stenopetala* leaf meal is used as a cheaper protein supplement to replace roasted soybean meal in the diet of chicks of the South African Koekoek chicken breed. Several growth parameters such as slaughter weight and carcass quality were improved. Likewise, a study in broiler chickens by Du et al. (2007) concluded that moringa might be a good potential feed additive as it improved the immune response of the birds. Gebregiorgis et al. (2012) indicate that for sheep in Ethiopia the addition of *M. stenopetala* leaves to a Rhodes grass basic diet (*Chloris gayana*) was a positive intervention. Greater proportionate amounts of moringa significantly improved sheep growth performance.

MORINGA AS A FACTOR IN COMPLIMENTARY MEDICINAL STUDIES AND AS A SOURCE OF ANTI-NUTRITIONAL FACTORS

Auwal et al. (2013) summarize the potential traditional medicinal values from Nigeria of *M. oleifera* but scientific supporting evidence to demonstrate these effects are neither easily available nor often probably go much beyond being supported by traditional knowledge. They claim that treatments with this species can be "a cardiac and circulatory stimulant, possess antitumor, antipyretic, antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antidiabetic, hepatoprotective, antibacterial and antifungal properties". In their study using albino rats over a three week period they demonstrated that aqueous seed extract treatments with moringa were able to increase the red and white blood cell count over the control group which was solely fed chick mash. They concluded that in haematological conditions such as anaemia the moringa supplementation was likely to be a positive treatment.

Anti-nutritional factors are reported from the roots of *M. oleifera* in Nigeria by Igwilo et al. (2014) as further supporting evidence for the value of traditional medicine with antibiotic, anti-tumor and anti-oxidative outcomes. Quantities of oxalates and phytates were determined from root samples and likewise the tannin, saponin and cyanogenic glycoside contents. The relative richness of the concentration of these chemicals led the authors to conclude that anti-nutritional factors were present and that this may bolster the value of the species in traditional medicine. Several other authors have examined the phytochemical profile of *M. oleifera* and determined the presence of glucosinoates and flavanoids (Amaglo et al., 2010) in many plant parts from Ghana; tannins, steroids, triterpenoids, saponons, anthraquinones, alkaloids and reducing sugars from Ugandan leaf material (Kasolo et al., 2010) and glucosinolates in leaves from Niger (Bellostas et al., 2010).

Bioactive phytochemicals can sometimes have dual functions, exerting either positive, negative or no effect depending on the dosage and ways of how the materials are processed and utilized. Evidence supporting potentially positive effects of moringa was generated mostly from in vitro or animal models. More research is needed, for example in compound identification and quantification and regarding the effects of moringa consumption on metabolic parameters, dietary quality and nutritional and health outcomes. This would help to support and decide on moringa interventions for better nutrition. In particular, moringa has been promoted and used for nutrition supplementation for malnourished children and pregnant women in various projects. Well defined forms and dosages of moringa leaves for supplementation are critical for scaling up.

MORINGA CULTURAL PRACTICES

The range of potential systems in which moringa can be usefully grown makes recommendations on approved agronomy problematic to summarize. However, Palada and Chang (2003) working at AVRDC have produced a functional guide to suggested cultural practices. They recommend that the crop be grown in tropical or sub-tropical environments at elevations generally below 600 m in altitude. Soil should not be subjected to poor drainage and a well prepared seedbed is required for good early growth. Direct seeding, transplanting and using hard stem cuttings are all possible ways of establishing the crop which may be more determined by labor availability than biology. Micropropagation has also been shown to be feasible in *M. oleifera* (Shokoohmand and Drew, 2013). The closer the row spacing, the greater the potential for continued harvests of young edible shoots at 14-21 day intervals. If it is projected that trees will be grown to maturity then the row spacing must be adequate to allow for trees growing to a height of several meters.

As moringa has an extensive rooting system its ability to mine the soil for nutrients is effective but for greater leaf production, applications of compound fertilizer and/or compost and manure are required. These should be put around the base of the plant. Moringa is a tree better adapted to medium to dry rainfall environments but the potential for irrigation needs is discussed by Muhl et al. (2013) with specific reference to reproductive needs. If pod production is the major marketing objective then some irrigation pre-flowering may be valuable. It is also desirable to irrigate newly planted seedlings to promote establishment and root development. Likewise, if the crop is seen to be wilting, irrigation will be a sensible practice. For weed control, Palada and Chang (2003) recommend the use of straw or plastic mulch around the base of the young trees and the maintenance of weed control between rows by cultivation.

Pests and diseases seem to be a less serious problem than in most other vegetables. Mites, termites, leaf miners, whiteflies and caterpillars can all cause difficulties if infestation is large and spraying would then be a sensible option for control. Young seedlings are attractive to cattle, pigs, goats etc., so plots should be protected from grazing animals.

Palada and Chang (2003) recommend that trees should be pruned to stimulate vegetative growth through the removal of the apical growing shoot when the tree reaches a height of 1-2 m. Older and unproductive trees can be pruned back to ground level as new shoots can emerge at ground level. This may be after 10 years (Palada, 1996).

Harvesting intervals are system dependent but leaves are often harvested when the plants are around 2 m which might be after a year's growth. Snapping the leaf stems and young shoot tips from the trunk will promote the development of new side branches and better yields subsequently. Fresh harvested leaf bundles need to be shaded to maintain market quality and leaflets can be sundried and stored as required. Pods are normally harvested during the second year of growth when they are young, green and tender. Mature pods offer seeds which can be used for planting subsequent crops or they can be processed by extraction for their oil.

Mature pods should be harvested before they split open and seeds fall to the ground. Seeds can be stored in well-ventilated sacks in cool, shaded areas and viability is expected to be retained for a 2-year period. Palada et al. (2007) report a range of yields of young shoots from 20-40 t ha^{-1} $year^{-1}$ over a two-year period. Shoot yields in three accessions in the second year of the trial exceeded 40 t ha^{-1} $year^{-1}$.

Patricio et al. (2013) have tested the adaptation of moringa in the Central Philippines and report variability in behavior amongst accessions of varied geographic origin. Two accessions from Thailand resulted in the highest leaf fresh weight from two prunings exceeding 2 kg $plant^{-1}$. They noted that only minor insect damage was observed. They conclude that some of the accessions evaluated are suitable for commercial multiplication.

ECONOMIC AND TECHNICAL EVALUATION OF MORINGA CROPPING SYSTEMS

There is a considerable insufficiency in published analyses of the economic returns associated with moringa production (Ajayi et al., 2013). These authors specifically draw attention to the lack of economic analyses of this species when employed in the Taungya agroforestry system in Nigeria. Similarly, Adesina et al. (2013) make the same observation when considering the use of moringa as a feed source in sustainable aquaculture systems and the call for much needed further economic research in this area. Most production is still probably derived from home garden sources which are rarely subject to rigorous economic analysis. However, Azeez et al. (2013) have reported a study on the technical efficiency of moringa production in Osun state in Nigeria. They concluded that moringa production was sub-optimal in terms of resource use across several villages. They recommended that farmers need better support in terms of being able to source inputs (particularly improved seed) and credit and being able to attain good agronomic and marketing advice. Farmers with more than one year's experience were much more efficient at production than new growers. Receiving better advice from extension service personnel, opportunities for greater cooperative membership and the availability of cultivation equipment were all factors which they associated with more efficient production.

CONCLUSIONS

Moringa has substantial potential to become a globally important vegetable not only in terms of its value as a key component of good nutrition for humans and livestock in well balanced diets in the developing world but also in terms of likely profitability, highly diverse markets and its possibilities associated with its pharmaceutical value in improved human health.

There has been insufficient investment to date in ensuring that its agronomy is well understood and its relative resistance to pests and diseases compared to many other vegetables in open field cultivation is a major advantage which has certainly not yet been fully exploited. More rigorous research is needed on the economics of production, postharvest and marketing as well as a better understanding of how to make its significant nutrient density as bioavailable as possible in human and livestock diets.

Given such investment, the likelihood of moringa contributing substantially to the rapid attainment of Sustainable Development Goal 2 is very sure.

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