



Introduction and expansion of *Moringa oleifera* Lam. in Botswana: Current status and potential for commercialization

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ABSTRACT

A survey was conducted to document the history of introduction of *Moringa oleifera*, its current uses as well as potential for expansion and commercialization in Botswana. The study was conducted between February and December 2018 in Gaborone by interviewing a total of 20 households who have planted trees of *Moringa* in their backyards. A semi-structured questionnaire was developed, field tested, revised based on the feedback from the field test, and used for the interview. The results showed that the species was introduced to Botswana relatively recently, and most of the respondents started growing the trees in the last five years. The majority of the respondents (80%) are familiar with the *Moringa* plant, and 90% of them know about its medicinal values for which they planted the trees. However, there seems to be limited knowledge about the nutritional value of the species among the respondents. Different parts of the tree are used to treat, mainly, diabetes, high blood pressure and rheumatism. The leaves are used to treat most of these ailments although the seeds, stems, bark, roots and fruits have also been reported to have medicinal values. Some of the respondents indicated that they use the raw or boiled leaves as vegetable, and prepare soup and stew from the young green fruits and use them as salad. The most common mode of utilization is using the leaf for preparation of *Moringa* tea. The *Moringa* tree does not need intensive management, establish easily, adapt well to the arid climate of Botswana and grow with minimal care. Most of the interviewed households indicated that there is no challenge associated with growing the trees. Despite the general difficulty of cultivating crops in the country due to the harsh hot climate and shortage of water, the species needs little attention to grow, and there is no particular problem associated with production of the trees. Majority of the respondents indicated that there is a big potential to expand and commercialize *Moringa* in Botswana if people are made aware of its benefits. The study revealed that *M. oleifera* is grown in Gaborone though it is generally underutilized despite its huge potential. There is a huge knowledge gap about the nutritional uses of *Moringa*. Given the potential food and non-food applications of *Moringa*, there is an urgent need to promote its cultivation and utilization so that it can contribute its share in Government efforts to ensure food security in Botswana.

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1. Introduction

Moringa oleifera Lam. (hereafter referred to as *Moringa*) is a tropical plant belonging to the family *Moringaceae* and grows throughout the tropics. The genus *Moringa* consists of 13 species (Fuglie, 1999; Abdulkarim et al., 2005; Olson, 2017) of which *Moringa oleifera* and *Moringa stenopetala* (Seifu, 2014; Teketay, 1995) are the most widely used species. *Moringa oleifera* is native to sub-Himalayan tracts of northern India and is commonly referred to as 'horseradish tree' or 'drumstick tree' (Fuglie, 1999; Keatinge et al., 2017). *Moringa* is a multipurpose tree of significant economic importance as it has several industrial and medicinal uses (Makkar and Becker, 1996; Keatinge et al., 2017).

Moringa oleifera is a small deciduous tree of 2.5–10 m in height (Chuang et al., 2007). It is a fast-growing, drought-tolerant plant well adapted to drier areas of the tropics (Fuglie, 1999; Keatinge et al., 2017) and tolerates annual precipitation ranging from 250 to 3000 mm (HDRA, 2002; Patricio and Palada, 2017), annual temperature of –1 to 48 °C and pH of 5.5 to 7.5 (Patricio and Palada, 2017). It thrives in subtropical and tropical climates and grows best on dry sandy loam soil (Duke, 1983; Patricio and Palada, 2017). The plant is propagated either by seed or planting limb cuttings of 1–2 m long (HDRA, 2002; Ebert and Palada, 2017).

Almost all parts of the tree have been utilized for various purposes. The leaf, flower, fruit, bark and roots have been used as natural medicines for treatments of inflammation, paralysis and hypertension (HDRA, 2002; Chuang et al., 2007). Its seed is reported to have strong coagulative and anti-microbial properties (HDRA, 2002; Chuang et al., 2007). The seeds are sources of oil or used in

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curry powders and used in clarification of wastewater (Makkar and Becker, 1996; HDRA, 2002). Seeds yield 38–40% of a non-drying oil, known as Ben Oil, used in arts and for lubricating watches and other delicate machinery (Duke, 1983; HDRA, 2002; Ebert and Palada, 2017). The oil is clear, sweet, odorless and never becomes rancid (Duke, 1983; Ebert and Palada, 2017). The seed oil has been used as salad dressing and has a pleasant taste, highly edible and resembles olive oil in its physico-chemical properties (Abdulkarim et al., 2005) and can be used as a possible substitute for the expensive olive oil. The oil is also useful in the manufacture of perfumes and hairdressings (Duke, 1983; Ebert and Palada, 2017). Other uses of Moringa include its use as cleaning agent, fertilizer, gum, honey clarifier, natural pesticide and pulp for paper. Its use in alley cropping, honey production, soil conservation, making rope and tannin for tanning hides has also been reported (Fuglie, 1999; HDRA, 2002; Ebert and Palada, 2017). Given its drought-tolerance, fast-growing habits, high nutritional value, potential to alleviate malnutrition in developing countries and multitude of other uses, Moringa is often termed as “the miracle tree”.

The leaf extracts were found to regulate thyroid status and cholesterol levels in rats (Chuang et al., 2007). The leaves and flowers of *M. oleifera* are also consumed as nutritious vegetable by millions of people in the tropics. The leaves of Moringa have high nutritional value being rich in carotene, iron, vitamin C and various essential amino acids (Makkar and Becker, 1996), and it is, particularly, important as human food because the leaves appear towards the end of the dry season when few other sources of green vegetables are available. Moreover, the leaves and young branches are used as fodder for livestock and it is commonly planted in Africa as a live fence (Duke, 1983; Ebert and Palada, 2017).

Seed and leaf extracts of *M. oleifera* have been reported to have anti-fungal properties (Chuang et al., 2007). Pterygospermin, a bactericidal and fungicidal compound, isolated from Moringa has a lethal dose of LD₅₀ subsequently injected into mice and rats (Duke, 1983; Ebert and Palada, 2017). An *in vivo* study showed that an aqueous extract made from seeds of *M. oleifera* is effective against *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *E. coli* (Fuglie, 1999). This study further showed the seed extract to be equally effective as Neomycin against *S. aureus*. Similar results were obtained with aqueous extracts from the roots of *M. oleifera* (Fuglie, 1999).

Moringa oleifera has been given a lot of attention because of its high nutritional values, medicinal properties and industrial applications. Although the exact date of introduction of Moringa to Botswana is not known, it is generally believed that it was introduced recently to Botswana (Kwaambwa et al., 2012). Despite its recent introduction, Moringa is widespread throughout the country, including Gaborone areas, and it is now common to see Moringa plant in the backyards of many households in the city (Kwaambwa et al., 2012). It was reported that *M. oleifera* was introduced to Botswana from different places in particular from India, Netherlands, Malawi, Tanzania and Kenya (Nduwayezu et al., 2007).

Despite the multipurpose uses of *M. oleifera* elsewhere in the tropics, it seems that people in Botswana are not fully aware about the potential uses of *M. oleifera* in particular its use as vegetable. This study was, therefore, conducted to document the history of introduction of *M. oleifera*, its current uses as well as potential for expansion and commercialization in Botswana.

2. Materials and methods

2.1. Description of the study area

The study was conducted in Gaborone city, which is located at 24° 39' 29" S and 25° 54' 44" E–24.66°S and 25.9°E between Kgale in Botswana and Oodi Hills on the confluence of Notwane River in the southeastern corner of Botswana (Morton et al., 2008). It is located

at about 15 km away from the South African border. The city lies at an elevation of 1010 m above sea level. Gaborone has a hot semi-arid climate.

The city of Gaborone is situated in the southeastern part of Botswana at some 100 km south of the Tropic of Capricorn. The topography is undulating to flat, with height differences of approximately 50 m. The Segoditshane and Notwane Rivers carry water through the city for a short period each summer (Jonsson, 2004). From a moderate population of 4000 at independence in 1966, Gaborone is today a city of roughly 200,000 inhabitants. Population projections for 2020 range between 300,000 and 1,000,000, depending primarily on socio-economic factors.

Vegetation density differs substantially in different parts of the city. Areas with abundant vegetation are mainly due to gardens that are irrigated at great expense. In other areas, the plots are not vegetated at all. The natural vegetation around Gaborone consists of deciduous trees and bushes (Jonsson, 2004), which means that the amount of biomass varies depending on season.

The regional climate of Gaborone, and for Botswana as a whole, is of hot, semi-arid type, or BSh according to the Köppen climate classification (Jonsson, 2004). The climate, is thus, influenced by the subtropical high-pressure belt, yielding dry winters (Jonsson, 2004) with a large daily temperature range and wetter summers. The belt is actually two cells, one in the Atlantic Ocean and the other in the Indian Ocean (Jonsson, 2004). The Indian cell is centered at 65° E in winter and 90° E in summer. The high-pressure influence over Botswana, thus, weakens during summer, and the easterly airflow travels a longer distance over the ocean before reaching the mainland. Consequently, the development of cumulus clouds is facilitated in this air mass and may yield thunderstorms. In addition, the southern edge of the high-pressure belt migrates from 35 to 40° S during the summer, further reducing the stability (Jonsson, 2004). Thus, precipitation is associated with the movement of the intertropical convergence zone.

Gaborone has a mean annual temperature of 20.7 °C and a mean annual precipitation of 538 mm (Jonsson, 2004). Of this amount, 84% falls from October to the beginning of April, suggesting that clear skies are predominant during the rest of the year. The mean wind speed reaches its maximum in November and its minimum in April. The former is a result of the frequent cold-front passages on the sub-continent in this transitional month (Jonsson, 2004). Daytime wind speed is high in the subtropics due to the intense insolation causing strong convection and turbulence.

2.2. Methods

2.2.1. Key informant interviews

A survey was conducted between February and December 2018 by purposively choosing and interviewing a total of 20 key informants in Gaborone city who are knowledgeable about Moringa. The respondents participated in the survey were selected based on the presence of Moringa tree in their backyards. A semi-structured questionnaire was developed, field tested, revised based on the feedback from the field test, and used for the interview.

The questionnaire was designed to generate data on reasons for growing Moringa, history of introduction of Moringa to Botswana, knowledge about Moringa, management practices and challenges associated with growing Moringa, utilization of Moringa, mode of preparation and forms of use, marketing of Moringa, opportunities for commercialization of Moringa in Botswana, types and sources of planting material, and parts of the Moringa plant used. In addition, field observation was carried out by the researchers in order to assess natural regeneration of Moringa and performance of the plant in the study area. Secondary data about Moringa was referred to supplement the primary data generated through the survey.

2.3. Data analysis

Data generated through the key informant interviews were sorted and analyzed using descriptive statistics, such as means and percentages using STATISTIX 8 (STATISTIX 8, 1985-2003).

3. Results and discussion

3.1. Demographic profile of the respondents

Most of the respondents interviewed were household heads over 30 years of age. In terms of gender, 45% of the respondents were male and 55% were female. The majority (65%) of the interviewed respondents either completed high school or attended tertiary education. It seems that educational status of the households had influence on their knowledge (Table 1) and awareness about the Moringa plant.

The respondents that participated in this study were selected based on the presence of Moringa plant in their backyard (Fig. 1). In terms of country of origin, 75% of the respondents interviewed were locals (Batswana) and 25% were expatriates from Malawi, Zambia, Mozambique, Zimbabwe and South Africa. The expatriate respondents indicated that they got the knowledge and experience about the Moringa plant from their home countries. Most of the respondents indicated that Indian and Chinese people residing in Gaborone frequently ask them for leaves of Moringa. The high demand of Moringa leaf by the Indian and Chinese people indicates their knowledge about the benefits and uses of Moringa. Given the origin of *Moringa oleifera*, which is the Indian subcontinent and the wide spread of the plant in Asia, it is expected that people from these parts of the world are familiar with the Moringa plant and its uses.

3.2. Knowledge and experience of *Moringa oleifera* cultivation

Moringa was introduced to Botswana relatively recently. Although some respondents indicated that they started growing Moringa 10 years back, most of the respondents started growing Moringa in the last 4 years (Table 2). Majority of the respondents (80%) are familiar with the Moringa plant, and they are aware that it has some kind of benefit. However, about 20% of the interviewed respondents indicated that they are not familiar with Moringa, and the Moringa plant in their compound has grown by itself (naturally

regenerated) or they planted it like any other shade plant without knowing its benefits. This observation is in line with the report by Kwaambwa et al. (2012), which showed that most respondents who participated in a study conducted to assess and promote the cultivation and utilization of *M. oleifera* in five SADC countries namely Botswana, Namibia, South Africa, Swaziland and Zambia knew and heard about the Moringa plant and its various benefits; however, the level of usage of Moringa in these countries was found to be low. In order to promote the cultivation and utilization of Moringa, a coordinated effort needs to be made by all concerned bodies to popularize and create awareness about the plant through education of the general public about the nutritional, medicinal and industrial applications of Moringa.

Moringa oleifera originated in India and it has spread to Africa and other continents because of its medicinal and superior nutritional values. Majority of the respondents (85%) do not know about the origin of the plant. Moreover, none of the interviewed respondents had participated in Moringa related workshops or seminars in the past. However, all of the respondents are willing to receive information/technology about Moringa and participate in Moringa related workshops. The willingness of the participants to take part in Moringa related workshops and to receive Moringa related technologies is a good opportunity to promote the plant because it suggests that at least there will not be a big resistance to uptake (adopt) Moringa/Moringa-related technologies by the end users in the future. One of the challenges in disseminating a new technology and/or product to an area is the reluctance and resistance by the communities to take up the proposed new innovation. Mwangi and Kariuki (2015) reported that perception of farmers towards a new technology is a key precondition for adoption of new agricultural technology by smallholder farmers in developing countries. The farmers who have already started growing Moringa and are willing to receive Moringa-related technologies will play a multiplier effect in the dissemination and promotion of Moringa in Botswana because one of the drivers for adoption of agricultural technologies is peer effects or learning from other farmers. Kasirye (2013) reported that peer effects and/or activities of other farmers in the community play a big role in influencing farmers to use improved agricultural technologies (improved seeds or fertilizers) in Uganda.

Ninety-five percent of the respondents indicated that they are not aware about the existence of different Moringa varieties/species, and they do not know which Moringa species is in their backyard. The respondents indicated that they heard about Moringa for the first time from the news through mass media (radio and TV), through word of mouth (from friends and people) and some from the Internet. This finding is in agreement with the report by Kwaambwa et al. (2012) who indicated that in Botswana, people are generally aware about the Moringa plant through television program, hearing from neighbors and from government Department of Forestry and Range Resources.

About 65% of the respondents indicated that they are aware about the nutritional values of Moringa. However, 35% of the respondents said they do not know about the nutritional benefits of Moringa and that it can be consumed like vegetable. On the other hand, the majority (90%) of the respondents knew about the medicinal values of Moringa, and they said that it is the reason why they planted the tree. Speaking about the medicinal value, some respondents indicated that Moringa leaf is used to treat diabetes and hypertension. Kwaambwa et al. (2012) reported that people in Botswana are aware of the nutritional and medicinal benefits of the tree although there are serious misconceptions, especially about the claims that Moringa is used to cure HIV/AIDS.

3.3. Management practices and challenges of growing *Moringa oleifera*

The Moringa plant does not need intensive management practices to grow. It easily establishes and adapts to the arid hot climate

Table 1
Age, gender, educational status and ethnic groups of Moringa growers in Gaborone.

Respondents	Group	Proportion of respondents (%)
Age (years)	• 20–29	5
	• 30–39	40
	• 40–49	5
	• 50–59	30
	• 60 and above	20
Gender	• Male	45
	• Female	55
Educational status	• Elementary school	10
	• Junior secondary school	25
	• High school	20
	• Certificate	5
	• Diploma	10
	• BSc degree	20
	• MSc degree	5
	• PhD degree	5
Ethnic group/Country of origin	• Local (Batswana)	75
	• South African (white)	5
	• Zambian	5
	• Malawian	5
	• Mozambique	5
	• Zimbabwean	5



A (Source: Photo by Eyassu Seifu)

B (Source: Photo by Demel Teketay)

Fig. 1. *Moringa oleifera* planted in the backyard of a household in Gaborone city: (A) Mature tree with leaves, flowers as well as green and dry pods; and (B) close-up of flowering branch showing a visiting bee.

of Botswana and grows with minimal care. According to the respondents, the major management practice applied is watering the plant during the seedling stage (Table 3). Once it establishes

well, it does not need much care. This observation is in line with the report of Roshetko et al. (2017) who stated that in Indonesia, farmers grow *Moringa* most often in-home gardens with little or no

Table 2

Knowledge and experience of *Moringa oleifera* production and willingness to receive *Moringa* related technologies by households in Gaborone.

Variable	Response	Proportion of respondents (%)
Familiar with <i>Moringa</i>	• Yes	80
	• No	20
Knowledge about the origin of the plant	• Yes	15
	• No	85
Participation in <i>Moringa</i> workshops/seminars	• Yes	5
	• No	95
Where did you hear about <i>Moringa</i> the first time?	• News on the radio in 2010/2011	5
	• Through word of mouth (different people)	40
	• From Malawi	5
	• Visit to Brazil	5
	• From Zimbabwe	5
	• From the Internet	5
	• Mass media (TV & radio)	5
Knowledge of nutritional uses of <i>Moringa</i>	• Yes	65
	• No	35
Knowledge of medicinal value of <i>Moringa</i>	• Yes	90
	• No	10
Why did you plant <i>Moringa</i> ?	• For medicine especially diabetes and hypertension	15
	• For its nutritional and medicinal values	30
	• Planted as a shade	10
	• Naturally regenerated (dispersed)	5
Awareness about the presence of different <i>Moringa</i> varieties/species	• Yes	5
	• No	95
Years of growing <i>Moringa</i>	• 1 year	5
	• 2 years	20
	• 3 years	10
	• 4 years	15
	• 5 years	15
	• 6 years	10
	• 10 years	5
	• No	0
Willingness to receive information/technologies about <i>Moringa</i>	• Yes	100
	• No	0

Table 3
Management practices, challenges encountered, pests and diseases of *Moringa oleifera*.

Variable	Response	Proportion of respondents (%)
Planting material used	• Seed	45
	• Seedlings	25
	• Branch/stem cuttings	10
Managements practices applied	• Watering during seedling stage	45
	• Watering during Winter	5
	• Watering during Pruning	20
	• Uses chicken litter as a fertilizer	10
	• No harvesting of the leaves	10
Time of flowering/ fruiting	• September	10
	• December	15
	• January	10
	• February	5
Frequency of harvesting leaves	• Not frequent	5
	• Harvest any time when required	10
	• Harvest regularly	5
	• No harvesting of the leaves	5
Challenges associated with growing Moringa	• No challenges	60
Pests and diseases	• No pests and diseases (Moringa repels insects)	45
	• Some birds eat Moringa leaf	5
	• Termites	5
	• Some worms eat the leaf and lay their eggs on the leaf	10
	• Some bugs eat the leaves	5
	• It naturally regenerates from seeds	10
Regeneration	• It sprouts from cutting or stumps	40
		5

management or inputs. Some respondents indicated that they prune the plant in order to enable it develop more branches and, thus, more leaf yield. Few respondents indicated that they apply chicken manure as fertilizer.

The Moringa plant can be propagated using seeds and stem cuttings. Most respondents interviewed indicated that they use seeds as a planting material. However, some indicated that they use branch/stem cuttings and/or seedlings of Moringa as planting material (Table 3). This is in agreement with the findings of Kwaambwa et al. (2012) who reported that in Swaziland, Moringa is mainly cultivated from seeds and very few plants are grown from branch cuttings. Roshetko et al. (2017) also reported that farmers in Indonesia cultivate Moringa on-farm by either stem cuttings or direct sowing of seeds.

Most of the interviewed households indicated that there is no challenge associated with growing the Moringa plant. Despite the general difficulty of cultivating and growing crops in the country due to the harsh hot climate and shortage of water, Moringa needs little attention to grow, and there is no particular problem associated with Moringa production. Moringa is a hardy plant that easily regenerates from seeds and sprouts from cuttings or stumps. During the field visit of this study, Moringa plant was observed growing by the road sides in Gaborone city, indicating its ability to regenerate naturally. It was reported that Moringa is able to survive harsh growing conditions and can be recommended to resource-poor smallholder farmers (Mabapa et al., 2017) who are not able to practice high input agriculture. According to Mudywiwa et al. (2013), Moringa can grow on marginal lands as it is resilient to harsh growing environments, including drought and poor soil quality.

According to most of the respondents, there are no known pests or diseases that attack the Moringa plant. This agrees with findings of Roshetko et al. (2017) who reported that Moringa does not suffer greatly from insect attacks or diseases. However, few respondents indicated that termites attack the Moringa tree and some bugs, birds and worms eat the leaf (Table 3). This is in line with the report by Nduwayezu et al. (2007) who indicated that termites and other plant damaging insects attack *M. oleifera* grown in Sebele Botswana. Mudywiwa et al. (2013) reported that Moringa growers in Zimbabwe experienced problems with sap sucking pests [red spider mites (*Tetranychus urticae*) and aphids (*Aphis* spp.)], caterpillars, termites (*Isoptera* spp.) and blight (*Phytophthora infestans*) though a high proportion of growers encountered no pest and disease problems.

The informants reported that the Moringa plant flowers/fruits in the months of December–February (Table 3). The Moringa growers in Gaborone do not frequently harvest the leaves since most are not aware about the nutritional values of the leaf. However, some respondents indicated that they harvest the leaves only when it is required.

3.4. Uses of *Moringa oleifera*

The major benefits of Moringa reported by the respondents include its medicinal value, human food, animal feed, shade and as an ornamental plant. Among these, the medicinal value of Moringa stands first. Most of the respondents indicated that they grow Moringa mainly for its medicinal value. According to the respondents, different parts of the Moringa plant are used to treat wide ranges of ailments, such as diabetes, hypertension (high blood pressure), rheumatism (arthritis), relieve menstrual and stomach pain, clean the kidney, ulcers, cure HIV/AIDS, boost the immune system, flue, facilitate digestion, relieve itching eye, tuberculosis, heal burned skin and wound, prevent constipation and relieve joint pain. The leaves are used to treat most of these illnesses. The seeds, stem, bark, roots and fruits also have medicinal values (Table 4). According to Roshetko et al. (2017), leaves, pods and roots of Moringa are used to make traditional medicines for heartburn, constipation and eye irritation in Indonesia

The medicinal value of *M. oleifera* has been widely recognized and it has traditionally been used to treat various illnesses in different parts of the world (Fahey, 2005; Anwar et al., 2007; Gopalakrishnan et al., 2016). The role of Moringa in the treatment of various human ailments is also known in SADC countries. Kwaambwa et al. (2012) reported that Moringa is used to treat different ailments, such as ulcers, headaches, influenza and general body malaise in Swaziland. Moringa is claimed to cure HIV/AIDS in countries such as South Africa, Swaziland and Botswana (Kwaambwa et al., 2012), which is a common misconception because this claim has not been scientifically proven. The medicinal uses of Moringa mentioned by the respondents in the current study are in agreement with the report by Kwaambwa et al. (2012) who indicated that people in Botswana use Moringa to cure a number of ailments, such as ankle and knee diseases, pain, high blood pressure, flu, diabetes, asthma, arthritis, skin diseases and wounds, HIV/AIDS, stomach cramps, cancer, weakened immune system and leg wounds as well as for cleansing the body and reduce fatigue or tiredness. They also reported that the leaf powder improves appetite and indigestion, cleanses the body and reduces fatigue or tiredness.

The medicinal values of Moringa reported in the current study area are also in agreement with the findings of Stevens et al. (2013,2015) who indicated that *M. oleifera* has high ethno-medicinal value in Nigeria and used in the treatment of fever, ear infection, eye infection, high blood sugar (diabetes mellitus), high blood pressure, common cold, male impotency and skin diseases.

It should be noted that most of the claims reported in the present study about the medicinal values of Moringa have not been scientifically proven and, thus need further investigation.

Table 4Plant parts used, method of preparation, form of use and purpose of uses of *Moringa oleifera* in Gaborone.

Use category	Parts used	Mode of preparation	Form of use	Purpose of use
Food	Leaf	• Mix Moringa leaf with spinach (2x)	• Eat after cooking	• Human nutrition
		• Mix leaf with papa	• Eat as is	• Human nutrition
		• Harvest leaves from the plant	• Eat the raw leaf	• Human nutrition
		• Boil to prepare tea	• Tea extract	• Human nutrition
		• Prepares Moringa tea by adding one spoon of Moringa powder and boil it		
	Fruits	• Harvest Moringa leaf dry it and make powder	• Sprinkle the Moringa leaf powder on salads, soup, rice and pap.	• Human nutrition
		• Cook the fresh Moringa leaf	• Eat as vegetable	• Human nutrition
		• Harvest fresh leaves	• Chew raw leaf	• Has high Vitamin C content
		• Dry Moringa leaf and pound it into powder	• Sprinkle it on different foods and consume	• Human nutrition
		• Harvest Moringa leaf, cook it alone or after mixing with other vegetable	• Consume it as vegetable	• Human nutrition
Medicinal	Seed	• Harvest fresh Moringa leaves	• Chew the leaves raw	• High Vitamin C content
		• Chop the fruits with the seeds when it is still green and mix it with beans and steam it	• Eat it as a salad	• Human nutrition
		• Chop young green fruits and boil it	• Use as soup and stew	
		• Chop and cook the green fruit	• Eat as vegetable	• Gives energy
		• Harvest immature fruits, chop and boil them	• Drink as tea	• Human nutrition
	Leaf	• Harvest immature fruits, chop and cook them	• Eat as vegetable	• Has high Vitamin C and Vitamin B contents
		• Harvest green fruits, chop and mix them with salad and other vegetable	• Eat as salad	• Human nutrition
		• Collect the dry seed, grind it into powder	• Use the powder in cooking	• Human nutrition
		• Put the fresh leaves in boiling water for one minute and cool it and drink the water	• Drink the extract	• Diabetes
		• Prepare dried Moringa powder and add/mix with any meal	• Eat the Moringa fortified meal.	• Rheumatism
Seed/Leaf	Seed	• Dry Morniga leaf and prepare powder	• Take two tea spoons of Morniga leaf powder everyday	• Cleaning the kidney
		• Prepare Moringa leaf powder	• Mix it with vegetables, prepare Moringa tea and soup	• Heals diabetes (reduces blood sugar level), ulcer and stomach problem
		• Mix Moringa leaf with cucumber carrot, garlic and ginger, and add small amounts of orange juice to prepare Moringa juice	• Drink Moringa juice	• Treatment of arthritis, diabetes and high blood pressure
		• Harvest Moringa leaf, dry and grind it into powder, and put the powder into tea	• Drink Moringa tea	• To relieve menstrual pain, stomach pain
		• Put fresh Moringa leaf in a boiling water for 10 min and drink it	• Drink the extract	• For kidney problem, diabetes and high blood pressure
	Leaf	• Put Moringa leaf in lukewarm water, cool it and, then, apply it in the eye	• Apply the extract	• Prevents against HIV virus, flue and facilitates digestion
		• Prepare Moringa drink by mixing Moringa leaf powder with tata, sugar and lemon	• Drink the juice	• Relieves menstrual pain
		• Prepare Moringa Mageu (available in Choppies Supermarket)	• Drink Moringa Mageu	• To relieve itching eye; it removes dirt (stone) from the eye
		• Harvest fresh Moringa leaf	• Chew the raw leaf	• It boosts the immune system and cleans the stomach
		• Dry Moringa leaf, pound it into powder	• Mix Moringa powder with cooked foods and consume	• Relieves stomach pain
Seed/Leaf	Seed	• Dry Moringa leaf, grind it into powder and make tea	• Chew raw leaf	• Relieves hangover
		• Harvest Moringa leaf, dry it and pound it into powder and make tea	• Tea extract	• Lowers high blood pressure, good for digestion and kidney problems
		• Harvest fresh leaf	• Tea extract	• Prevents arthritis and boosts the immune system
		• Prepare Moringa seed powder and leaf powder	• Eat the raw leaf	• Prevents high blood pressure (Hypertension) and diabetes
		• Prepare Moringa seed oil	• Use the powders in cooking	• Relives stomach pain and chest complaints.
	Leaf	• Harvest the dry seeds	• Apply the oil on burned skin/wound	• Cures HIV/AIDS and tuberculosis
		• Crush and grind it	• Eat the dry seeds	• Heals burned skin and wound
		• Chop the young fruits and mix them with tomato, onion and peanuts	• Decoction	• Diabetes
		• Harvest the leaves from the tree, dry and mix them with hay, and give them to animals	• Drink the extract	• Rheumatism
		• Harvest fresh leaf	• Serve raw/dry as forage	• Cleaning the kidney
Feed	Leaf	• Harvest the leaves from the tree, dry and mix them with hay, and give them to animals	• Live hade	• Ease flue, cleans the stomach, prevent constipation, relieves kidney problem
		• Plant in the backyard	• Ornamental	• Relieves joint pain and clears the stomach
Shade Ornamental	Whole plant	• Plant in the backyard	• Live hade	• Shading
	Whole plant	• Plant around the house	• Ornamental	• Esthetic

In many countries, Moringa is grown mainly for its nutritional value where the leaves are consumed as vegetable (Teketay, 1995; Fuglie, 1999; HDRA, 2002; Seifu 2014). In Indonesia, for example, Moringa leaves are primarily used as a food (Roshetko et al., 2017). Also, in many SADC countries, Moringa leaves are predominantly used as food (Kwaambwa et al., 2012). However, most of the people in Botswana are not aware about the nutritional value of Moringa. Although the nutritional use of Moringa is not popular in Botswana, some of the respondents indicated that they are aware about its value in human nutrition. Some of these respondents indicated that they use the leaves as vegetable and eat it after cooking or even raw. Others said that they sprinkle Moringa leaf powder (Fig. 2) on different foods, such as salads, soup, rice and pap and consume it. Some informants reported that they prepare soup and stew from the young green fruits and use them as salad. These responses are in agreement with the report by Roshetko et al. (2017) who indicated that in Indonesia, Moringa is eaten either fresh or cooked, added to soups, mixed with other vegetables and is cooked with or without coconut milk. It should be noted that the most common mode of use of Moringa in Botswana (Gaborone) is as tea from Moringa leaves/fruit. Some respondents believe that Moringa leaf has high vitamin C content (Table 4). In addition to the medicinal and nutritional uses of Moringa, some respondents also reported its use as animal feed, shade and ornamental plant.

Some of the nutritional uses of Moringa indicated by the respondents in the current study are in line with earlier reports. Stevens et al. (2013,2015) reported that *Moringa oleifera* is widely utilized as food in Nigeria, mainly, as vegetable in soup, as salad or herbal tea. A recent study conducted on the nutritional composition of *M. oleifera* leaves collected from Gaborone city revealed that the leaves are rich in nutrients and have high amounts of protein and ash (Masitlha, 2018), which suggests that Moringa leaves can serve as an important protein and mineral supplements in the diet and can be consumed as vegetable in Botswana. Thus, more work needs to be done to create awareness about the nutritional value of Moringa and promote its consumption in Botswana.

3.5. Opportunities for commercialization of Moringa in Botswana

Most people in Botswana are not aware about Moringa and its uses. Majority of the respondents indicated that there is a big potential to expand Moringa production in Botswana if people are taught about the importance of Moringa and made aware about its benefits. Most of the respondents indicated that Moringa has a chance to be commercialized if



Fig. 2. *Moringa oleifera* leaf powder prepared by one of the respondent households (Source: Photo by Demel Teketay).

people are educated about the uses and applications of Moringa. In order to commercialize Moringa, awareness creation and promotion is needed.

For a country like Botswana, which has an arid climate, Moringa is the next super food. It can be expanded and commercialized and, even, consumed by the local people. According to the respondents, there is a big potential and market for Moringa in Botswana; however, the only problem currently is that people do not know about it. If people are taught about the benefits of Moringa, there is a possibility to commercialize it in Botswana. Some respondents said that they will support commercialization of Moringa in Botswana provided that it is institutionalized, and its production is promoted like growing other crops, e.g. sorghum.

Some of the indicators of the potential to commercialize Moringa in Botswana include the fact that people are already buying Moringa products (Moringa juice and mageu) imported from South Africa (Fig. 3). If there is demand and market for Moringa, then, there will be opportunity to commercialize Moringa in the future. A respondent from Mozambique, living in Gaborone, indicated his experience of Mozambique where they sale Moringa and export it to Europe. Another indicator of the bright future for commercializing Moringa is that many people are growing Moringa in Botswana and some have already started selling it.

Some of the respondents indicated that they are willing to embark on Moringa business if there are markets for Moringa. Marketing of Moringa is not developed in Botswana. Out of the total respondents interviewed, only two indicated that they once sold Moringa (seedlings and fresh leaves). This suggests that awareness creation and advocacy work need to be undertaken in order to promote production of Moringa and create market for Moringa products.

In general, a lot of work is needed in order to promote Moringa in Botswana. One strategy to popularize Moringa in the country is to organize and conduct workshops that will discuss the benefits of Moringa, including its nutritional and medicinal uses, use in water treatment, its oil production potential and many other uses of the plant. In such workshops, demonstrations about the different products that can be prepared from Moringa can further enhance the uptake of Moringa-related technologies and develop the interest of the participants on Moringa. In addition to workshops, broadcasting the benefits of Moringa through mass media such as television and radio and also using social media such as Facebook, WhatsApp and Twitter will help spread the information about Moringa to reach larger audiences. Preparation of brochures and pamphlets would also help disseminate Moringa information easily. Moreover, provision of planting materials, such as seeds and/or seedlings to interested farmers would help promote cultivation of the plant in the country. Preparation of field/farmers day (Moringa day) to demonstrate Moringa plantation could also be one strategy to promote the plant.

In order to create market for Moringa and Moringa products, marketing and promotion work needs to be undertaken by all concerned parties. Provision of short-term trainings on processing of Moringa to Moringa growers and/or those who embarked on Moringa business will enhance marketing of the plant and its products. Higher learning institutions in the country that offer training in the area of Food Science and Technology can play important roles in developing Moringa processing technologies and in providing short-term trainings to needy stakeholders. Such institutions have the capacity to undertake research on processing and value addition of Moringa. Moreover, there is need to develop quality standards and efficient packaging and storage of Moringa products so that they access both local and global markets.

4. Conclusions

The study revealed that *M. oleifera* is widely grown in Gaborone city although the plant is generally underutilized despite its huge potential. Most of the respondents who participated in the study indicated that they heard about the benefits of Moringa even though many of them are not currently using the Moringa plant for its



Fig. 3. Moringa juice (A) and magueu (B) imported from South Africa and sold in supermarkets in Gaborone (Source: Photo by Eyassu Seifu).

perceived benefits except planting it for shade in their backyards. There is a huge knowledge gap about the nutritional and medicinal uses of Moringa. Other applications of Moringa, such as its role in water treatment and its oil production potential, are not totally known by the participants. Elsewhere, Moringa is grown primarily for its food value where its leaf is consumed as vegetable. However, in Botswana, knowledge about the nutritional value of Moringa is minimal and most people do not consume Moringa as green vegetable. The major mode of utilization of Moringa is using the leaf for preparation of Moringa tea.

The trees do not need intensive management, establish easily, adapt well to the arid climate of Botswana and grow with minimal care. Most of the interviewed households indicated that there is no challenge associated with growing the trees. Despite the general difficulty of cultivating crops in the country due to the harsh hot climate and shortage of water, the species needs little attention to grow, and there is no particular problem associated with production of the trees.

Most of the households interviewed indicated that they are willing to plant the tree and receive information and Moringa related technologies. Although the Botswana government started promoting the Moringa plant some years back, currently, there are no governmental and non-governmental organizations involved in the promotion of Moringa in the country. Given the potential and many of the food and non-food applications of Moringa, there is an urgent need to aggressively promote the cultivation and utilization of the plant in the country. In order to promote marketing of Moringa, there is a need to provide training to communities on processing of products, such as leaf and seed powders, extraction of oil from the seed and packaging of the products. The participants indicated that Moringa has a huge potential to ensure food security in the country; however, most people are not aware about the benefits of Moringa. They further indicated that if the general public is made aware about Moringa and if people are educated about the uses of Moringa, there will be bright future and potential to commercialize Moringa in Botswana.

Declaration of Competing Interest

The authors declare that there is no conflict of interest.

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