Moringa (*Moringa oleifera*) production: A possible solution to South African food security challenges.

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INTRODUCTION

Moringa tree (*Moringa oleifera*) is a legume perennial plant grown mainly in semiarid, tropical and subtropical regions of the world (Gopalakrishnan, Doriya and Kumar, 2016). It is originated in India and now distributed in tropical and subtropical regions of the world. *Moringa oleifera* is the most widely cultivated specie of the genus Moringa, which is the only genus in the family of Moringaceae. It is known by several names in different countries, but is popularly called the "drumstick tree" for its pods that are used by drummers ; "horseradish tree" for the flavor of its roots and "ben oil tree" for its oil extracted from the seed (Palada and Chang, 2003). Moringa products have a high commercial value thus making its cultivation a potential cash earning opportunity that can enhance the livelihoods of farmers especially in rural areas. *Moringa oleifera* is a remarkably fast growing tree and highly valued plant due to its exceptionally high nutritional content and medicinal properties which can resolve the health care needs in several situations (Mabapa, Ayisi and Mariga, 2017; Anwar, Latif, Ashraf and Gilani, 2007). It is reported that every plant part (leaves, flowers, stem, seeds, bark and roots) is useful. *Moringa oleifera* has medicinal properties that play an important role in addressing the health problems in the world. It is an antioxidant, anti-inflammatory, antidiabetic and antimicrobial agent (Gopalakrishnan et al, 2016). The plant is also referred to as the "miracle tree" because of the high positive impact it has on people's livelihoods. The plant is tolerant to drought, low soil fertility, light frost and resistance to pests and diseases making it adaptable to harsh growing conditions which most trees cannot withstand. However, the plant is sensitive to waterlogged area and cannot produce under those conditions (Mabapa et al, 2016).

PRODUCTION AREAS IN SOUTH AFRICA AND GROWTH OF THE INDUSTRY

The main production area of *Moringa oleifera* in South Africa is Limpopo, with few farms located in Mpumalanga low-veld, Gauteng and KwaZulu-Natal Provinces. Other areas include the North West and part of Free State and Eastern Cape.

Fig 1a: Moringa project at Huma village in Moruleng, North West Province

Globally, the moringa industry is worth about 5.5 billion US dollars which is equivalent to R92.5 billion. The industry is expected to grow over the next five years as demand for organic food, healthier lifestyle and nutritional supplements grow. In South Africa, the moringa industry is providing exciting opportunities for business thereby creating job opportunities which positively impact on the economic growth of the country (City Press article, 30 September 2020).

PLANT DESCRIPTION

Moringa oleifera is a small, fast-growing evergreen or deciduous tree that usually grows and reaches the height of up to 10 or 12 m. It has a spreading, open crown of fragile branches, feathery foliage of tripinnate leaves, and thick, corky, whitish bark (Ahmed *et al*, 2018; Roloff, 2003 and Ganatra *et al*, 2012).

Leaves

Moringa oleifera leaves are described as bipinnate or more commonly tripinnate, up to 45 cm long (Fig. 1). These are compound leaves with leaflets of 1 – 2 cm long. The leaflets are finely hairy, green and almost hairless on the upper surface, paler and hairless

beneath, with red-tinged mid veins, with entire (not toothed) margins, and are rounded or blunt-pointed at the apex and short-pointed at the base (aestivation is opposite). The twigs are finely hairy and green, becoming brown (Ahmed et al, 2018 and Ganatra 2012).

Fig 1. Moringa leaves

Flowers

Flowers are fragrant, bisexual, yellowish white in colour and borne on slender, hairy stalks in spreading or drooping axillary clusters (panicles) 10–25 cm long. Individual flowers are approximately 0.7 to 1 cm long and 2 cm broad, with five unequal yellowish-white, thinly veined, spathulate petals, five stamens with five smaller sterile stamens (staminodes), and a pistil composed of a one-celled ovary (Ahmed *et al*, 2018; Ganatra *et al*, 2012).

Fig 2. Moringa flowers

Fruits

Fruits are tri-lobed capsules and are frequently referred to as pods. Pods are pendulous, brown, triangular, and so splits into three parts (lengthwise) when dry, 30 – 120cm long and 1.8 cm wide. Fruits production mainly occurs in March and April. Each fruit contain around 26 seeds during their development phase. Immature pods are green in color and turn brown on maturity. Matured pods split open longitudinally along the three angles, releasing the dark brown, round seeds (Ahmed, 2018).

Fig 3. Moringa pods

Seeds

Matured seeds are round, approximately 1cm in diameter and covered by a brownish semi-permeable seed hull. Viable seed germinate within 2 weeks. The white wings of the hull are also present which run from top to bottom at 120 intervals. Depending on the size of a tree and other factors, each tree can produce approximately 15000 to 25000 seeds per year. Each matured seed has an average mass of 0.3 grams (Roloff, 2003; Ganatra *et al*, 2012; Ahmed *et al* 2018).

Fig 4. Matured *Moringa oleifera* seed already shelled from the pods

Roots

Moringa oleifera seedlings develop a swollen, tuberous, white taproot which has a characteristic pungent odor, and very sparse lateral roots. Trees grown from seeds develop a deep, stout taproot with a wide-spreading system of thick, tuberous lateral roots (Roloff, 2009; Sharma *et al*, 2002; Ganatra *et al*, 2012).

Fig 5. *Moringa oleifera* root system

Bark, wood and stem

The bark is whitish-grey, thick, soft, fissured and warty or corky, becoming rough.

When cut open, the bark exudes a whitish gum which changes to reddish-brown colour later on exposure. The wood is soft, light in weight and easy to break (Roloff, 2002; Ganatra *et al*, 2012).

Fig 6. Fully matured *Moringa oleifera* stem

CLIMATIC REQUIREMENTS

Temperature

Moringa plant can withstand and survive harsh climatic conditions and drought. However the plant needs more sunlight and warm temperature to grow and produce optimally. It is adapted to semiarid, tropical and subtropical areas with a temperature range of between 25 to 35 ^{0}C. Moringa plants will tolerate high temperature and survive light frost conditions, hence the plant widely cultivated in all the continents of the world (El-Sayed and Mahmoud, 2018; Roberts 2002)

Rain fall

Despite its drought resistance, Moringa plant requires evenly distributed rainfall during the growing season. It can still perform well under low rainfall of at least 400 mm/annum. Additional supply of water in the form of irrigation is required during dry period and in areas where rainfall is less than 300 mm per annum.

SOIL REQUIREMENTS

Soil provides bases for seed germination and plan growth. It absorbs and stores rainwater and provides nutrients (DMP, 2009). Soil condition will influence moringa growth and production.

Moringa can survive in a wide range of soil types. According to research findings, Moringa can survive in barren soil without being much affected by drought. However a deep, well drained fertile loam soil is the best for Moringa production. The plant is sensitive to shallow and waterlogged soils and cannot produce under those conditions. The plant performs well under soil PH ranging from 5-9. Soil fertility plays an important role in the production of Moringa plants (Mabapa et al, 2016; El-Sayed et al, 2018).

MANAGEMENT

Soil Preparations

Moringa requires thorough land preparation and a well-prepared seedbed. The land need to be cleaned by removing trees and shrubs. If planting density is high, the land must be ploughed and harrowed to a maximum depth of 30cm. Ploughing and harrowing have the following advantages (READ, 2012):

- Ploughing buries crop residues that would otherwise habour pests and diseases
- It creates rough surface suitable for rainwater penetration
- Deep ploughing breaks the shallow compacted soil for roots penetration, adequate nutrients distribution and gaseous exchange
- Harrowed soil provides finer seedbed; ideal for small seed germination
- Hard and heavily structured soils can be loosed through harrowing action
- It creates uniform seedbed thereby eliminating the weeds.

Fig 7. Ploughing of soil as part of the primary cultivation

Propagation

Moringa can be propagated mainly through seeds or cuttings. It is planted either by

- Direct seeding
- Transplanting
- Stem cuttings

Direct seeding or propagation is preferred technique when plenty of seed is available and labour is limited. This is the fastest way to grow Moringa trees from seeds as this method avoids the shock of transplanting. Another advantage of direct seeding method is that it results in high germination percentage which is more than 85%. Moringa develop more easily and grows stronger with direct sowing because of a well-developed strong root system that allows the seedling to extracts much needed soil nutrients and moisture. When the farmer choses direct sowing, it is important to ensure that two to three seeds are sown per hil at a depth of 2cm. Two weeks after germination, select the strongest seedling per hill and thin out or remove the rest.

Compared to trees propagated from seed, trees from stem cuttings grow much faster but develop shallow root system that makes them more susceptible to moisture stress and wind damage. Cuttings are prepared from branches of a tree that is healthy and at least one year old. Cuttings can be 45 to 150 cm long and 10 mm thick. Cuttings can be planted directly in a well prepared seedbed or in plastic bags in the nursery. When planting directly in seedbed, Plant one third of the cutting length in the soil leaving the remaining

two third. For an example, if the cutting is 80cm long, 20cm length should be planted into the soil. Stem cuttings are used when the availability of seed is limited but labor is plentiful.

Transplanting allows flexibility in field planting but requires extra labor and cost in raising seedlings. Newly transplanted seedlings should be irrigated immediately and more regularly for two months in order to promote early root development. The farmers should be careful not to over-irrigate the plants because that may cause flooding or water logging leading to plant death.

The ideal spacing for leaf production is 50-60 cm within a row x 1m apart. Most farmers prefer 1mx1m plant spacing. Farmers use 3 to 5 m spacing if the intention is to produce more flower and seeds (Palada and Chang 2003; Chedza, 2012; Roberts 2002).

Fertilisation

Moringa grows well in most soils without the additions of fertilizer, however it responds well to both organic and inorganic fertilizers. Being a leguminous crop in its nature, moringa is fertiliser self-sufficient because of its ability to fix its own nitrogen. Once the plant has established, the extensive and deep root system of moringa is able to reach and extract nutrients from the deep soil horizons. As a guide, the farmer needs to apply 300 grams of a commercial fertilizers mix (NPK) in order to achieve an optimum growth. Soil sampling and analysis is important to determine the nutrient and pH status of the soil before planting. Large amounts of compost, well decomposed manure or mineral fertilizers are needed to maintain high yield. The use of organic fertilizers not only improves the chemical properties of the soil but also has a positive impact on the physical and biological condition of the soil. Application of Poultry manure compost has been found to increase the productivity of Moringa trees. In an experiment performed in Nigeria, application of 30 t/ha of poultry manure proved to be the best on growth and leaf yield of Moringa plants (Adebango et al, 2017; Palada *et al*, 2003; El-Sayed et al, 2018).

Irrigation

The newly transplanted trees need to be irrigated immediately to promote early root development. In dry and arid climates, irrigate regularly for the first two months. Drip irrigation is the most appropriate irrigation system that can be used in moringa plantation because it saves water and delivers nutrients to the crop right to the root zone. Localised water application prevents leaching of fertilizers and loss of water through evaporation. It is a perfect irrigation system to use in South Africa because it is a water scarce country. Once established, moringa rarely needs watering. The well-rooted tree tolerates drought and needs irrigation only when persistent wilting is evident (Pugal Subramanian, 2016).

8. *Moringa oleifera* seedlings getting water through a drip irrigation system

Pest and diseases

Moringa plant is resistant to most disease and pest problems but outbreaks do occur under certain conditions, for an example diplopia root rot may appear in waterlogged soils, causing severe wilting and death of plants. The tree is a host to a powdery mildew disease which causes significant damage to papaya crops in India.

Moringa oleifera plants will always attract cattle, sheep, pigs, and goats and wild animals because they love it due to its high nutritive value (fig 9). Animals feed on moringa seedlings, pods and leaves and can destroy the field if left unfenced (Palada *et al*, 2012).

Further research about Moringa insects pests and diseases is needed in South Africa in order to get full understanding about the relationship that exist between different types of insects, diseases and the moringa plant.

Fig 9. Sheep and goats feeding on Moringa trees in an agroforestry system

Weed control

A weed is any plant growing where it is not wanted and in competition with cultivated plants. It is considered undesirable in a particular situation, "a plant in the wrong place".

Just like other crop, moringa trees are susceptible to weed plants. Weeds compete with moringa trees for soil nutrients, moisture and light. They also serve as hosts of pests and diseases which might affect moringa tree growth and development thereby impacting on yield. Continuous monitoring and control of weeds in moringa plantation is regarded as best practice because it promotes normal growth and gives rise to good yield.

Cultivate the soil thoroughly before planting to suppress early weed growth. Apply straw or plastic mulch around the base of each young tree to suppress weed germination and growth. Organic or plastic mulch also helps to conserve moisture for a better growth. The field must be weed-free by regular cultivation between beds and rows. A cover crop can also be introduced in order to fight weeds and conserve moisture. Planting of vegetables in allays also help to control weeds.

Moringa oleifera leaf and seed water extracts is effective in biological control of some of the broad and narrow grassy weed species. In an experiment conducted in Egypt to evaluate the effect of leaf and seed water extracts of *Moringa oleifera* on the growth and flowering of certain broad and narrow weeds, it was discovered that leaf and seed water extract of M. oleifera at concentrations from 6% to 15% caused complete death to the tested weeds, *Beta vulgaris* (Broad weed) and *Phalaris minor* (Narrow weed); (El-Rokiet *et al,* 2017). No herbicide has been registered to control weed in moringa plantation.

Pruning

Pruning is a silvicultural and horticultural practice. It involves the removal of unwanted roots, leaves and branches. Pruning is important in tree maintenance because it helps keep the tree healthy and the environment safe. Pruning encourages better and faster growth for some plants. Moringa respond positively to pruning. Moringa should be pruned to promote branching, increased yields, and facilitate harvesting. If left to grow without being pruned, the fast-growing tree will grow straight and tall producing leaves and pods only on the primary stem making harvesting of leaves, flowers and pods difficult. To encourage the development of many branches and pods within easy reach from the ground, prune the apical growing shoot when the tree is 1.0–2.0 m high usually 3 to 5 months after planting. Pruning is done easily by using a sharp cutting knife, pruning shear, looper or pruning saw to make smooth cuts. New shoots will emerge from just below where the cut is made (Fig.10). Thereafter, cut the growing tips of the branches so that the tree will become bushier. Another pruning strategy is to cut back each branch by 30 cm when it reaches 60 cm in length. This will produce a multi-branched shrub. Older trees that are unproductive or too high for easy harvesting can be cut at ground level to promote new shoots and regrows. It is recommended thatfarmers prune their trees at least twice a year (Palada *et al*, 2003 and Chadza, 2012).

a

b

Fig 10 a & b. The emergence of new shoot below the pruned area (Palada et al 2003 and DARD 2020)

USES

Moringa oleifera is a perennial tree with great environmental and economic importance in industrial and medical area. It contains more than 92 nutrients, 46 types of anti-oxidants, 36 anti-inflammatory agents as well as vitamins, minerals and good source of protein including fair amount of sulfur containing amino acids (Sharma, 2019). It has been nicknamed "a miracle plant" because of its multiple uses as follows:

As source of food

According to UN, about 870 million people do not have enough to eat. The most vulnerable people cannot access enough of the major macronutrients (carbohydrates, fats and protein). It is estimated that more than two billion suffer from "hidden hunger" in which important micronutrients such as vitamins and minerals are deficient from the diet with a consequent risk of physical and mental impairment. Between now and 2050, the world population will increase by one third and this might lead to more hunger and malnutrition especially in developing countries.

Due to its high drought and disease resistant properties and ability to grow faster, *M. oleifera* is often used as a famine food in several African communities (Mabapa *et al*, 2017). It is increasingly considered as one of the world's most valuable natural resources, as the main constituents of the tree have several nutritive ingredients. Several studies revealed that Moringa has a high nutritional content and can serve as a good source of food both for livestock and people (Mabapa et al, 2017, Advanced Biofuel Centre, 2016). Leaves, flowers and pods are edible and contain essential minerals and vitamins. Moringa can be used as an alternative food source in poor communities. Moringa is used in many African countries in feeding programs to fight food insecurity and malnutrition. Research shows that adding Moringa powder to food for lengthy period of time helps improve weight in malnourished children.

Nutritional analysis has proven that Moringa leaves provide the following Vitamins and minerals, Fig.11 (Gopalakrishnan et al, 2016; Treesforlife.org; Anon 2010):

Moringa leaves contain 7 times more vitamin C than oranges, vitamin C fights a host of illness including colds and flue.

Leave contain 10 times more vitamin A than carrots. Vitamin A protects important organs such as eyes, skin, and heart against various diseases and helps to fight diarrhea.

Moringa leaves also provide 17 times more calcium than milk. Calcium plays an important role in building strong bone and teeth and helps prevent condition called osteoporosis.

Leaves contain 2 times more protein than yoghurt. Protein is the building blocks of our body cells.

Moringa leaves have 15 times more potassium than bananas. Potassium in the body is essential for the normal functioning of the nervous system and brain.

Moringa oleifera also contain other important vitamins and minerals which include Vitamin B complex (B1, B2, B3) Chromium, Copper, Iron, Manganese, Phosphorus, Potassium, Protein and Zinc.

According to Trees For life. Com, small leaves have the potential to save the lives of millions of people in the world especially in the African continent where poverty and malnutrition is still evident. It is important that people need to be encouraged to grow at least 2 to 3 trees of Moringa at the backyard for subsistence in order to provide enough food rich with essential Vitamins and minerals for household consumption

Figure 11. Nutritive value of Moringa leaves (Treesforlife.org)

Used as medicine

Moringa oleifera is one of the plants with a great phytochemical profile, and it is considered to be in the top 10% out of 500,000 species being used for conventional

medicines (Tshabalala *at al,* 2019). It has a diverse range of medicinal properties which include antioxidant, Anticarcinogenesis, antiinflamantory, antispasmodic, diuretic, antiulcer, antibacterial, antifungal etc (Sulaiman *et al,* 2008 and Ganatra *et al*, 2012). Several types of bioactive compounds such as glucosinolates, flavonoids, phenolic acids have been isolated from M. oleifera and used to fight various health conditions.

Traditional cultures in various parts of the world have long used Moringa as herbal medicine to cure different types of health problems. Leaves, bark, flowers, fruits, seeds and root are used as a medicine to treat various health problems. Moringa leaves are used to treat gastrointestinal problems, head ache, inflammation, anemia, lung infection, skin and eye infections. It stabilizes sugar level and reduces high blood pressure. The roots can help with ovarian cancer, urinary problems and kidney stones, to stimulate appetite, treat sexual dysfunction, arthritis and asthma.

Fig 12. Moringa capsules

Livestock Feed

Moringa leaves, branches, seed and stem are used as a good feed supplement for livestock because they have high nutritive value. Moringa leaves contain high concentration of digestible crude protein and other essential elements and Vitamins.

According to Treesforlife.org., adding moringa leaves to cattle feed found to have increased their daily weight gain and milk production in the case of dairy cows (Fig 13 and 14).

Fig 13. Feeding Moringa leaves to dairy cattle increase milk production: (Gir cow farming 2018)

Vitamins available in moringa leaves play an important role in the heath of livestock. Vitamins contribute significantly to the immune systems of the animals thus preventing the development of many diseases in the livestock (Tshabalala, Ncube, Madala, Nyakudya, Moyo, Sibanda and Ndhlala, 2019).

Due to climate change characterised by occurrence of droughts and low rainfalls recorded in most regions of South Africa, supplying feed for livestock by farmers has increasingly become a major challenge, particularly during dry seasons. In some Provinces such as the Limpopo Province in South Africa, smallholder farmers are being encouraged to cultivate *M. oleifera* to supplement their livestock feed due its high nutritional value and its cash-earning potential (Mabapa et al, 2017). Moringa leaves are also fed to chicken, sheep, goats, pigs, horses and etc. Avoid feeding seed oil cake to cattle as it contains phytochemicals that can be harmful.

Fig 14. Moringa dry leaves are fed to cattle

As a source of organic fertilizer and plant enhancer

Moringa seed cake and leaf extract serve as a good source of organic and bio-fertilizer for many crops. Moringa leaf extract is used as a bio-fertiliser and effectively stimulate growth of some crops and alleviate the adverse effect of water deficit stress during drought (Hanafy, 2017)

Moringa is a legume plant and has the ability to fix its nitrogen from the atmosphere. It plays an important role in building up the soil fertility by leaving more nitrogen into the soil. Fresh leaf juice can be extracted and used as a natural plant growth hormone called Zeatin from cytokinine group (Fig. 15). Zeatin increases growth and yields of crop by 25 to 35% (Mall and Tripathi, 2017). The spray hormone has been tested and found to be effective on crops such as sugar cane, green pepper, onions, melons, sorghum, maize, beans, cow peas, sunflower to improve growth, fruiting, yield and promotes long shelf life on produce (Mall and Tripathi, 2017;Treesforlife.org).

Fig 15. Zeatin hormone spray from *Moringa oleifera* leaf juice improves bell pepper growth

Oil

Moringa seeds contain between 30-40% oil, with 13% saturated fats and 82% unsaturated fatty acids. About 65-73% of moringa oil is oleic acid with olive and sunflower oils having 75% and 40% respectively. Just like olive oil, moringa oil contains 1-2% of beneficial essential fatty acids such as omega 3 and omega 6. Oil extracted from seeds is known as Ben oil and is used in cooking as a substitute of olive oil (Fig. 16). It is also used as a lubricant of fine machinery e.g analog watch; and in the manufacture of soaps, perfumes and hair care products (Gopalakrishnan et al, 2016).

Fig 16. Pure *moringa oleifera* oil produced from seeds

Moringa oleifera seed oil is also used in the manufacturing biodiesel which is regarded as environmental friendly oil obtained from the sustainable energy source compared to petroleum fuels. Biodiesel is a renewable and clean-burning fuel that is made from plants or animals or recycled restaurant oil for use in diesel vehicles (Fig. 17). It is consisting of long chain fatty acids esters through the process called the transesterification whereby the glycerine is separated from the fat or vegetable oil. The process leaves behind two products namely, methyl esters and glycerine. Unlike ordinary diesel, biofuel has many environmentally beneficial properties.

- Is produced from renewable resources
- Biodiesel causes less environmental pollution compared to petroleum diesel fuel. It reduces lifecycle greenhouse gases by 85 percent. Reduces smog and makes the air healthier to breath. Reduces hydrogen carbon emissions by 67 % .
- Has lower toxicity compared to petroleum diesel,

- Biodiesel is biodegradable.
- It has more health benefits. Pollutants from petroleum engines, when released in the air, form smog and make many people get sick and die every year.
- It can be produced and distributed locally rather than depending on the foreign suppliers of oil which expensive to import. Locally produced biodiesel creates jobs and also boost the local economy.
- Biodiesel is clean-burning and provide exceptional engine performance with more lubricity while also emitting less carbon dioxide and other toxic gasses.
- It can be used in existing diesel engines without modification

  (ESI Africa, 2020; Conserve Energy Future, 2020).

It is estimated that yield of 20 metric tons of moringa pods per hectare per year can be produced and processed to 3000 and 4000 liters of biodiesel per hectare per annum. Moringa has attracted attention as pressure mounts to find sustainable alternative energy source to help meet world's renewable energy targets and cut greenhouse gas emissions. Research on the production of biodiesel is ongoing at various institutions and universities in South Africa and abroad (Advanced Biofuel Centre, 2016, Pacific Biodiesel, 2019, National Biodiesel Board 2020).

Fig 17. Biodesel is used in agricultural machinery to improve farm productions

Biogas

Biogas is the mixture of gases produced by the breakdown of organic matter in the absence of oxygen, primarily consisting of methane and carbon dioxide. Biogas can be produced from raw materials such as agricultural waste, manure, plant materials, municipal waste, food waste and etc. biogas is a renewable energy source. It is estimated that more than 4400 cubic meters of methane gas could be produced per hectare of Moringa plantation per year (www. TFLJournal.org). Methan gas can help to address the problem of electricity loadshedding in South Africa by providing cheap alternative source of heat energy for cooking food, heating-up water and warming-up our homes in winter. Moringa can be a sustainable source of energy compared to burning of fossil fuels in coal powered electricity stations that end-up polluting the atmosphere and promotes global warming which is a serious environmental concern.

Water purifier

Moringa seed powder or seed cake remaining after oil extraction is an effective natural coagulant in the treatment of contaminated water (Tripath *et al*, 2012). The seed or powder coagulant binds the microscopic colloidal particles and bacteria to form clump particles (Pritchard et al, 2010). These particles settle at the bottom and the purified supernatant can be poured off. It is reported the seed coagulant has the capacity to remove almost 99% of bacteria (Villafurt-Abonal, 2009). Approximately 2 to 3 table spoons of seed powder can purify 20 liters of water.

This is a good development since people in impoverished rural areas still share drinking water with animals from dirty sources such as wells, boreholes, rivers, dams and lakes .

Fig 18. Two plastic water bottles showing untreated water and seed treated water respectively

Used in an agroforestry system

Moringa trees can be used in an alley cropping which is an Agroforestry farming system. Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (FAO, 2015). *M. oleifera* is a rapid grower and produces high yield of biomass within a short period of time. It is characterised by long tap root system, few lateral roots and provides minimal shade for other plants that grow underneath the canopy. All this makes it a well suited tree for alley cropping system (Treeforlife.org, 2011).

Moringa trees can intercropped with vegetable, field crops or fodder plants. By so doing, a farmer has an advantage of producing multiple produce (fodder, wood, food, meat etc) in the same piece of land in one season thus increasing yields and profit while at the same time controlling runoff and soil erosion thereby reducing losses of water, soil organic

matter and nutrients (Fig. 19). The system also prevents pests and diseases and improves soil fertility since *Moringa oleifera* is a legume that can fix its own nitrogen.

Fig 19. Alleycropping: Moringa based Agroforestry system

Used as a Bio-pesticide or organic pesticide and fungicide

Moringa is also used as a natural organic or bio-pesticide to protect crops against various pathogens. Organic pesticides are usually considered as those pesticides that come from natural sources. They are obtained from organisms including plants, bacteria and other microbes, fungi, nematodes, *etc*. They are often important components of integrated pest management (IPM) programmes, and have received much practical attention as substitutes to synthetic chemical plant protection products.

According to Muhammed 2009, biopesticides are one of the groups of safe insecticides which have a broad spectrum of anti-pest activity, relatively to specific mode of action, low mammalian toxicity and more tendency to disintegrate, in nature or metabolic in a biological system. Organic insecticides are generally less harmful to the environment and their use avoids the development of insect resistance. Further the presence of multiple active ingredients that act synergistically and exhibit various mode of action prevents resistance developments in pest populations. Bio-pesticides are readily available for use by resource poor famer who cannot afford to buy costly synthetic pesticides . Moringa leaves are reported to be effective, cheap, and easily available for the control of stored

product pests. In a research trial conducted in Nigeria to assess *Moringa oleifera* as a bio-pesticide against *Podagrica spp* on Okra vegetable crops, it was found that different concentration of *Moringa oleifera* leave aqueous extract has significant control effect on insect *Podagrica* spp. Moringa oleifera leaf extract applied on wheat aphids significantly reduced aphis infestation on wheat plants (Damilola and Temitope, 2020, Manzoor et al, 2015).

Beside being used as biopesticide, M. oleifera leaves extract also possess some antibacterial and antifungal properties that protect some crop species against diseases.

As a source of honey

During the flowering season, Moringa flowers attract beneficial insects, honey bees being the dominant pollinators (Fig. 20 and 21). *Moringa oleifera* flowers are rich source of pollen and nectar for honey producing bees. Moringa flowers help to develop the honey beekeeping industry (Sharma, 2019).

Fig 20. Relationship between Moringa flowers and bees to produce honey

Fig 21. Moringa bee keeping

Moringa trees can help to combat desertification

Desertification refers to the persistent degradation of dryland ecosystem due to climatic variations and human activities. Desertification occurs as a result of long-term failure to balance human demand for ecosystem services and the amount the ecosystem can supply. Causes of desertification include overgrazing, deforestation, urbanization, climate change, veld fires and tillage practices that make soils vulnerable to wind (Fig. 23 and 24). The consequences of diversification include:

- Loss of productivity of the soil as a result of soil erosion and salinity. Loss of grazing land and vegetation which affects livestock and crop yields lead to malnutrition, hunger, low income and poverty.
- Reduced quality and quantity of water for domestic and industrial and agricultural use due to silting up of dams caused by soil erosion.
- Migration of people and wars due to lack of resources such as productive agricultural land and water.

One of the strategy to deal with challenges of desertification is to plant more trees that are adaptable to the local conditions, trees that grow fast, trees that are tolerant to harsh environmental conditions such as drought (Fig. 22). The presence of long and clubby taproot system that serves as a nutrient reservoir makes moringa tree to be tolerant to

drought. Moringa roots hold the soil together and help to reduce soil erosion caused by wind and rain. Due to above mentioned characteristic, Moringa trees can play a role in fighting desertification

Fig 22. planting of moringa tree in dry areas can combat desertification

Fig 23. Overgrazing causes desertification

Figure 24. Climate change causes drought and desertification

Moringa plantation as a carbon dioxide sink.

Carbon dioxide is the most commonly produced greenhouse gas. It is produced as a result of the burning of fossil fuels such as coal, petroleum and natural gas and released into the atmosphere as carbon dioxide gas. Carbon dioxide is also released naturally, through the decomposition process of plants and animals. Its concentration in the atmosphere is currently at 40% higher than it was when industrialization began. Carbon dioxide in the atmosphere is very effective greenhouse gas which absorbs infrared radiation emitted from earth's surface. The more carbon dioxide released into the atmosphere, the more infrared radiation is retained in the atmosphere and the average temperature of the Earth's lower atmosphere rises leading to a process called global warming. Higher temperature due to climate change has an impact on crop yields, both quality and quantity and indirectly impact on economic growth of the country.

Moringa trees can play an important role in mitigating the effect of climate change through the process called carbon sequestration (Fig. 25). Carbon sequestration is the process of capturing method and storing atmospheric carbon dioxide in plants, soil geological formation and the ocean. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change. Moringa trees serve as effective sink for carbon dioxide ($C0_2$) gas. Atmospheric $C0_2$ is transferred

naturally from the atmosphere to terrestrial carbon sinks such as moringa plantation through the process of photosynthesis. Carbon is stored in moringa tree parts and used during photosynthesis while at the same time releasing oxygen which is used by both human beings and animals during respiration. Afforestation (conversion of non-forested land to forest) and reforestation (conversion of previously forested land to forest of Moringa plantation) can be the answer in reducing the atmospheric carbon dioxide and mitigating climate change. Research found that Moring tree can absorb carbon dioxide at a rate that is fifty times higher when compared to the Japanese cedar tree and also twenty times higher than that of general vegetation (USGS, Selin, 2020, Anon, 2017).

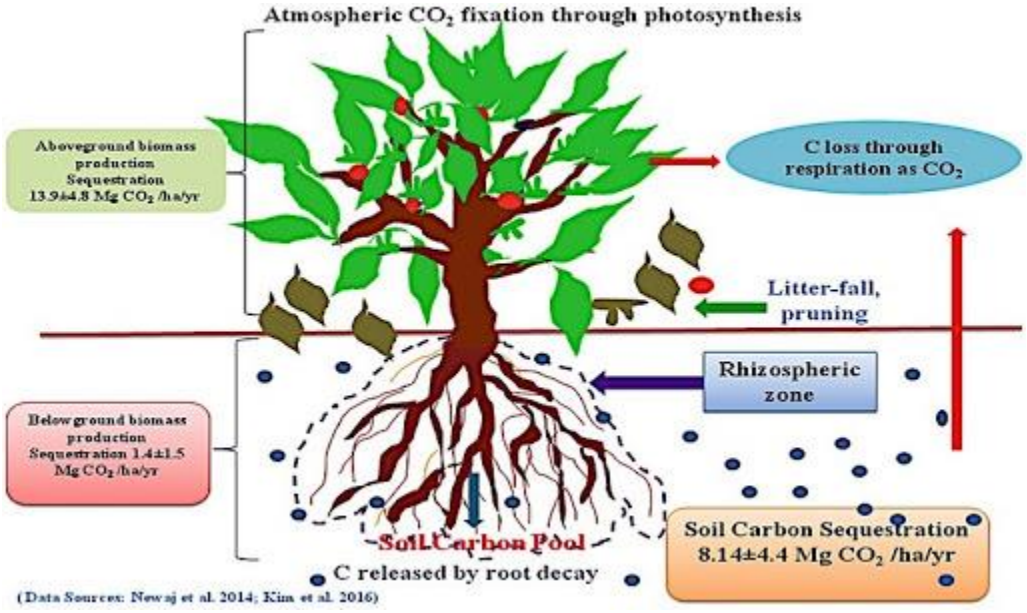

Fig 25. Moringa tree fixing atmospheric carbon dioxide through photosynthetic process.

Other uses

As a fast growing tree, *M. oleifera* is a potential source of soft, spongy wood supply which makes a poor firewood but suitable for paper and dye industry. The wood provides pulp that is good for paper, wrapping, textiles and cellphone. Another economic importance of M. *oleifera* is the production of exude suitable for making make blue dye (Ganatra *et al*, 2012; Treesforlife. Com, 2011).

The bark of the tree can be beaten into a fiber for production of ropes or mats. The gum can be used in tanning hides.

SIDE EFFECTS

Whilst no known toxicity is ascribed to the leaves, flowers and seeds, users are cautioned in reference to the root bark in particular. Toxins in the bark are potentially poisonous if consumed in large quantities. It is therefore advisable to remove the bark before using the roots as a medicine. There are suggestions that *M. oleifera* cannot be used in combination with other modern medicines in humans as this could result in chemical reactions that would interfere with the normal functioning of the some organs in the body (Sileshi *al et*, 2014).

HARVESTING

Leaves can be harvested after plants grow 1.5– 2.0 m, which usually takes 6 to 12 months after planting depending on the growth conditions promoting the normal growth of the plant. Leaf harvesting can be done manually by hand (Fig. 26). Hand harvesting is only possible when the plant is cultivated at a small scale or backyard. Hand harvesting involves snapping or pruning leaf stems from branches. Harvesting young shoot tips will promote development of side branches where cuts along the main branches are made. Plants are allowed to develop new shoots and branches before subsequent harvests. If plants are grown at closer spacing and higher density, cut plants about 10–20 cm above ground.

Fresh harvested leaves are then dried in a well-ventilated area which is not exposed to direct sunlight. This is done to avoid losing important nutritive value contained in the leaves and protect the leaves from dust and insect contamination. A fan can be used to speed up the drying process of leaves in room temperature condition. Dry leaves are either packed in containers and bags for storage and selling. Dried leaves can be

processed into leaf powder by pounding or crushing them. Fresh leaves that are treated as vegetables are tied in bundles and place them under shade or refrigerator to maintain freshness.

Flowers and pods are normally produced during the second year of growth. Harvest pods when they are young, tender, and green for consumption. So far there are no combine harvesters recommended for Moringa harvesting in South Africa (Palada, 2003; Chadza 2012).

Fig 26. Harvesting of leaves from branches in progress

Collecting and storing of ripe seeds

Pods with ripe seeds turn brown at maturity. If harvesting is delayed, ripe pods will either fall or split open and shed seeds to the ground. Ripe seeds are used for planting the next crop or for extracting oil (Fig. 27). When producing seed for oil extraction, allow the pods to dry and turn brown on the tree and harvest them immediately. Store seeds in well-ventilated container in a cool, dry, and shaded area. Depending on the handling facility, seeds will remain viable for planting for a period of 1 to 2 years (Palada *et al* ,2003)

Fig 27. Ripe and dry Moringa seeds

CONCLUSION

All districts in the North West Province are suitable for *Moringa oleifera* production. However the plants can do well in large parts of Bojanala district due to fairly good rainfall in summer and non-occurrences of frost in winter.

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