A Review of the Potential of *Moringa oleifera* Plantations for Economic Diversification and Climate Change Mitigation in Yobe State, Nigeria

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ABSTRACT

The biggest worldwide concern today is providing food security for a growing population. In addition, the growing agricultural activities including farming and infrastructural development is putting pressure on the scarce land resources paving way for land degradation and ultimately climate change. For generations, the variety of plants has been essential to human health and well-being, providing food, nutrition, medicine, shelter, and energy. Only 7000 of the approximately 39,000 known plant species are grown or gathered for food. Governments in Sub Saharan Africa view Moringa as a preferred "developmental tree" with the ability to address a number of socioeconomic issues, including food insecurity, poverty, and malnutrition. It is a pantropical plant also known as the Horse radish tree. The objective of this review is to outline the use of Moringa oleifera plantation as a means of diversifying economy and improving food security and mitigating climate change in the Sahelian state of Yobe. A systematic literature review is adopted as a method to search on secondary materials in published journals from google scholar, PubMed, science direct, Springer and Taylor and Francis. Journals and articles covering from 2015 to 2026 were mostly searched using the key terms Moringa cultivation, food security, climate change and economic diversification. Results obtained indicate that numerous studies were conducted detailing the nutritional and therapeutic qualities of Moringa were published in mainstream scientific publications within the last eleven years (2015-2026). The literature search is limited to Moringa cultivation and economic uses only excluding other economic trees and culinary herbaceous plant. The review emphasizes Moringa's economic significance in combating starvation and its promise as a commercially viable tree species in Yobe State, advocating for the establishment of Moringa plantations to address desert encroachment. It highlights the many propagation methods of the plant including direct planting of seeds in the field or growing the seeds in the nursery. It also highlights the asexual means of propagating the plant through macro propagation methods such as budding, cutting and layering and also highlights micro propagation of the plant through the use of cell tissue culture system.

Keywords: *Economic diversification, Moringa oleifera, climate change, plantations*



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INTRODUCTION

In Yobe state the issue of expansion and encroachment of desert and land degradation resulting in poor farming harvest remains a major challenge. According to recent studies, the desert in Yobe covers 15,120 kilometers of its 47,153-kilometer total land area. According to additional research by Thakur (2020) wind erosion poses a threat to 2,500 kilometers in the northern part of the state that borders the Niger Republic. Food security remains a significant concern in a world of rapid population growth and climate change challenges. Thus, the fight against food insecurity remains an ongoing challenge for many developing countries, such as Sahelian countries including Nigeria (Mahamane, 2025). Only 7000 of the approximately 390,000 known plant species are grown or gathered for food (Fidrianny, 2021). Governments in Sub Saharan Africa view Moringa as the preferred "developmental tree" to address a number of socioeconomic issues, including food insecurity, poverty, and malnutrition. Similarly, in an effort to reduce malnutrition in underprivileged areas, the South African government has been assisting the production of Moringa in certain regions of the nation (Mashamaite, 2021). It is often acknowledged that neglected and underused species (NUS) are important resources for advancing sustainable development and facilitating the shift to resilient and sustainable agri-food systems. Major crops and underused crops, are the two general categories into which crops can be divided. These phrases are used interchangeably to describe crops that policymakers, plant breeders, and researchers have not given much thought to. Moringa oleifera Lam. is one example of a NUS. Native to the Indian subcontinent. M. oleifera is a deciduous tree that grows quickly and belongs to the Moringaceae family (Bilali, 2024). Intentional programs including the Moringa Fund, trees for life, Global Moringa network, Moringa initiative, and Moringa News were created to enhance production, particularly for human nutrition, and to promote value addition and marketing (Bania, 2023). According to survey data, natural resources are being overused at an unsustainable rate, which has led to an even larger loss of natural biodiversity and deforestation in the area as a whole (Mangar, 2022). For centuries, humans have been dependent on the diversity of plants for food, nutrition, medicine and shelter, as well as for an energy source and for their overall well-being (Mashamaite, 2021). One of humanity's most urgent problems in the twenty first century is feeding the world's population. Africa's socioeconomic sector still heavily relies on agriculture. Indeed, the primary sector's contribution is demonstrated by the World Bank's most recent data. (Gandji, 2018). The cultivation and utilization of Moringa is increasingly being advocated for as a sustainable climate-smart solution to the above articulated climate change-associated socioeconomic, health and environmental problems (Horn, 2022). One of the best and most recent literature reviews on the species was conducted by Leone et al. (2015), and it covers the species' pharmacology, ethnopharmacology, genetics, culture, and phytochemistry (Gandji, 2018). One of man's most beneficial "multi-purpose "plants is Moringa oleifera Lam. Both rural and urban people rely on trees for their livelihoods, and almost every portion of the tree has some sort of benefit (Fidrianny, 2021). Despite the fact that Moringa trees are common in tropical regions, particularly in Northern Nigeria, and are frequently utilized as fences surrounding farms and compounds, not much has been done to improve their large-scale production, processing, marketing, and investment as an industrial raw material in Nigeria. Few attempts have been made to commercialize the tree for its other products, such as oil for edible and cosmetic purposes, natural coagulant from the seeds, and other ancillary uses from almost all parts of the plant, with the exception of medium scale cultivation of the tree in Nigeria for the production of leaves as an alternative green vegetables source for human nutritional and other medicinal uses. It was renowned for its versatility, broad adoption, and simplicity of set up. Nutrients vital to humans and animals are abundant in its leaves, pods, and blooms.

Literature review

Origin of *Moringa oleifera*

Moringa oleifera is the most widely cultivated species of a monogeneric family, the Moringaceae, which is native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan. Because of its high resistance to stress conditions, it is now widespread in much of the world, including America. (Ruiz, 2016) It is reputedly known as "cabbage tree", 'drumstick tree" or "horseradish tree", 'benzoil tree', 'miracle tree' and 'mother's best friend tree' (Thakur, 2020). The ancient Greeks, Egyptians, and Romans all used it. In many tropical and sub-tropical climates, such as Southern California, Southern Florida, and the West Indies, it is now extensively grown and has naturalized (Ayon Bhattacharya, 2018). It grows abundantly in the Western Himalayas and Oudh, but it is extremely prevalent in Bombay, the capital where it may be found in every backyard garden, waste plot, and village (Owon, 2021). There are numerous names for the tree in various parts of the world. Clarifier tree, horse radish tree, and drum stick tree (referring the enormous drumstick-like pods) are just a few of its unusual uses. In Nigeria, it is known as Zogale in Hausa, where as in East Africa, it is nicknamed mom's best friend. The Marghi people called it Allam. It was known as Ewe ile by the Yoruba people. The Igbo people called it Okwe Oyibo. Moringa is derived from the Tamil word Oleifera which also means "oil bearing "in Science. India and Arabia are the origins of the M. oleifera. From south Asia to West Africa, is now widely used in landscapes throughout the tropical regions of the world (Figure1). In some areas of the East and South Africa, it is particularly noticeable. Although M. oleifera is not a



Figure 1: World map showing countries where *Moringa* is extensively grown (green) source (Koul, 2015).



Figure 2: Comparative bioactive compounds concentration in *Moringa oleifera.* Adapted from (Alegbeleye, 2018).

nitrogen fixing tree, it does have an average protein content of 5% to 10% in its fruits, flowers, and leaves. These components are all commonly consumed as vegetables and provide great food for both people and animals, much as green beans (Alhassan, 2022). Given that it produces protein, oil, and carbs and is packed with vitamins and minerals, Horse Radish tree (Moringa oleifera, moringaceaea) may be the most valuable underdeveloped tree on Earth, at least from a humanitarian standpoint. (Zirmire, 2018). East and South Africa is where it is most noticeable. At least from a humanitarian standpoint, the moringa tree (Moringa oleifera, Moringaceae) may be the most valuable undeveloped tree on Earth .it produces protein, oil, and carbohydrates and is packed with vitamins and minerals. M. oleifera is steadily gaining popularity as an economic crop, with market demand for Moringa products increasing annually. In 2021, the world market for Moringa products was estimated at USD 7.79 billion (Figure 1). With an annual growth rate of 9.63%, it is expected to grow to USD 14.80 billion in 2028 (Dela, 2024). Humans have been searching for food that keeps them active and healthy since the beginning of civilization. This ongoing effort to find new herbal medicines and alternative nutritional sources continues even today in an era of research and technology. The perennial, multipurpose, softwood tree, is one such promising tree that has proven its nutritional benefits, therapeutic qualities, and safety for the environment and consumption. Because of its many uses, it is grown worldwide (Koul, 2015 Since one gram of powdered Moringa leaves (Figure 2) contains 25 times more iron than spinach, 17 times more calcium than milk, 15 times more potassium than bananas, 10 times more vitamins than carrots, 9 times more protein than yogurts, and half the vitamins of oranges, the nutritional value of these leaves is extremely significant. Of the roughly 13 species of trees in the moringacea family, Moringa oleifera Lam. is the most well-known. It is a multifunctional plant grown for food and feed, as well as for medicinal purposes (Ma, 2020). Medicinal plants have been used as a natural source of biologically active compounds. The horse radish tree, or Moringa oleifera Lam., is a multipurpose tree that grows quickly and is widely grown in the tropics and sub-tropics of Africa and India. It is a member of the Moringaceae family. As the “Natural Nutrition of the tropics,” Moringa oleifera is a significant food product that has attracted considerable attention. In South Asian traditional medicine, nearly every part of this plant – root,

Table 1: Taxonomic classification of *Moringa* plant. Source: Dutta A.C. (2009).

Taxonomic classification	
kingdom	plantae
subkingdom	*Tracheobionta* (vascular plants)
super division	*Supermatophyta* (seed plants)
Division	*Magnoliophyta* (angiosperm)
Class	*Magnoliopsida* (Dicotyledons)
subclass	*Dilleniidae*
order	*capparales*
family	*Moringaceae*
Genus	*Moringa*
species	*Oleifera, pterygosperma*

Table 2: Some of Moringa bioactive compounds and their properties source: (Oleg, 2018).

Chemical constituents	**properties**	**Plant part**
Flavonoids: Quercertin, kaempferol	Inhibit production of tumour necrosis factor, inhibit mutations and prevent carcinogenesis	Flower
Y- tocopherol	Inhibit lipid peroxidation, metabolize peroxides, prevent atherosclerosis	Whole plant
Oleic acid	Prevent cardiovascular diseases	seeds
Terpenoids	Hypoglycemic and antihyperglycemic activity	Whole plant
4-(G-L-rhamnosyloxy) benzyl isothiocyanate	Anti-tumor promoter, anti-microbial	seeds
B-sitosterol-3-0-ß-D-glucopyranoside	Anti-tumor promoter	seeds
Glucomoringin	Anti-colon carcinogenic activity	Leaves
Benzyl Isothiocyanate	Anti-cancer activity	Leaves
Glucosinolates	Chemo preventive activity by inducing apoptosis	Leaves
Niazimicin	Anti-cancer activity	Leaves
pterygospermin	Hyperthyroidism, chrohn; s disease, anti herpessimplex virus arthritis, rheumatism, gout, cramp, epilepsy	seed
Morphine, moriginine	Anti-ulcer and anti-inflammatory agent	Root bark

(Murthy, 2021).

bark, gum, leaf, fruits (pods), flowers, seed, and seed oil has been utilized to treat a variety of illnesses (Sekhar, 2018). Skin infections, anemia, nervousness, asthma, blackheads, blood impurities, bronchitis, catarrh, chest congestion, cholera, and numerous other ailments have all been treated with Moringa for ages and in numerous cultures worldwide (Ma, 2020).

Botanical classification of moringa

Moringa oleifera or Moringa pterygosperma are the botanical names for Zogale.This indicates the species name and genus. The plant is fast growing tree that is resistant to drought, making it interesting for dry and semi-arid environments of northern Yobe state (Table 1). The tree is known by many traditional names, including drumstick and horseradish. Moringa oleifera seeds have round or triangle shape and are found inside pods (Owon, 2021). M. oleifera is one of the most popular plants that can grow in a variety of environments due to its ability to resist to harsh conditions such as high temperatures and limited water availability (Anzano, 2021).

Morphological description of the tree

The horseradish tree can grow up to 6 to 9 meters (20 to 30 feet) in height.Up to 60 cm (24 in) long, the lacy compound leaves (leaves composed of several leaflets along a stem) have many leaflets that are roughly 1.5 cm (0.6 in) long.The leaves are referred to as tripinnate when they are threefold pinnate, meaning that the secondary axes generate the tertiary axes that bear the leaflets (Dutta, 2009). They have fragrant clusters of white flowers, branching fern-like leaves, and corky gray bark. According to Leone (2016), the dagger-like fruits can occasionally reach a length of 45(18 inches (Carla Trigo, 2021). The leaves have a pale green lower surface and a dark green upper surface. From the point where the leaf joins the stem, the fragrant, cream-coloured blooms, which are 2.5cm (1in) diameter, grow in loosely branching clusters called panicles. Each flower has five petals and five sepals, which resemble petals. One petal is larger than the others and stands upright. The fruit is a thin capsule that resembles a pod. It has black, triangular seeds with three wings that are dispersed by the wind (Leone, 2016). Loose panicles that droop 10 to 25 cm in length are created in the axilla by Moringa inflorescences. Up to 12 mm long, the bisexual zygomorphic flowers are fragrant, white or cream in colour and contain five pale green sepals, five white petals, five stamens with anthers, and five without (staminoid) (Sekhar, 2018). A lot of insects are needed for successful pollination, and the delayed stigma receptivity causes the flowers to be highly cross-pollinated (Leone, 2016). The Moringa oleifera Lamarack

tree is a perennial angiosperm that grows quickly. It can reach heights of 7 to 15 meters and chest heights of 20 to 40 cm in diameter. This tree is easy to grow and is well known for requiring little water and nutrients from the soil, making it resilient to drought and poor soil conditions (Alegbeleye, 2018). It grows quickly and can reach a height of 12 meters. Despite having low quality lumber, this perennial softwood tree has been used for generations for both industrial and traditional medicinal purposes. Moringa oleifera's antimicrobial components have been utilized to treat a variety of bacteria. Aqueous (El-sherbiny G. M., 2024). In many developing countries around the world where malnutrition is a serious problem, it is said to be a great native source of highly digestible protein, calcium, iron, potassium, vitamins, trace metal ions, essential amino acids, antioxidants, and carotenoids that can help combat cancer (Alegbeleye, 2018). Horseradish trees, known as oil of ben trees, are deciduous trees that lose all of their leaves every year. It gets its name from roots, which have a horse radish -like flavor and scent and can be sliced and used as a relish or vegetable. The tree is a popular ornamental due to its lovely foliage and clusters of flowers, especially because it grows well in a range of soil types (Leone, 2015). Every component of the plant can be used, including the leaves for nutritional supplements, the seeds for water purification, and the oil for biofuel, the trunk for gum production, the flowers for honey, and more.

Economic Importance of Moring tree

M. oleifera holds significant promise in various industrial sectors, such as agriculture, food, and cosmetics, owing to its rich nutritional content and versatile applications (Mahaveerchand, 2024). Moringa oleifera tree is one of the world's most useful trees, cultivated in the tropics and subtropics (Badasa, 2023). This tree has some useful purposes from the roots to the flowers. The long, green, ridged bean-like pods that resemble the real "horseradish" are called "drumstick" and the long, bean-like fruits can grow up to three feet in length and reach lengths of six inches. Almost all parts of Moringa tree has extraordinary advantages to human body (Table 2), its seeds have hypotensive action, acts as chelating in case of arsenic toxicity (Oleg, 2018). Gum (from tree trunk), honey, sugar cane juice- clarifier (powdered seeds), honey (flower nectar), medicine (all plant parts), ornamental plantings, biopesticide (soil incorporation of leaves to prevent seedling damping off) pulp (wood), rope (bark), tannin for tannin hides (bark and gum), and water purification (powdered seeds) are some of the other primary uses for the species (Table 2).

METHODOLOGY

Systematic literature review was adopted for this paper. Literature were searched using google search engine such a google scholar, PubMed, ScienceDirect, Taylor and Francis journals and other relevant materials such as text books, chapters and pamphlets. Using the keywords Economic diversification, Moringa oleifera, climate change, plantations. Relevant Materials were searched on *Moringa oleifera* from 2015 to 2026. The materials searched for materials that particularly covers Moringa oleifera and how the plant is used for plantation to mitigate encroaching desert in the Sahelian state of Yobe and improve on nutrition of the people to attain food security. A systematic literature review is adopted as a method to search on secondary materials in published journals from google scholar, PubMed, science direct, Springer and Taylor and Francis. Journals and articles covering from 2015 to 2026 were mostly searched using the key terms Moringa cultivation, food security, climate change and economic diversification. 55 journal articles were consulted for the review. Results obtained indicate that numerous studies were conducted detailing the nutritional and therapeutic qualities of moringa were published in mainstream scientific publications within the last eleven years (2015-2026). The literature search is limited to *Moringa* cultivation and economic uses only excluding other economic trees and culinary herbaceous plant. The review emphasizes Moringa's economic significance in combating starvation and its promise as a commercially viable tree species in Yobe State, advocating for the establishment of Moringa plantations to address desert encroachment.

RESULTS AND DISCUSSION

The world's biggest threats in recent years have been the growing human population and the loss of natural resources, which has resulted in undernutrition, famine, and ill health. Findings of these literature reveals that every single part of Moringa has a medicinal value and is utilized in some capacity. It is a great source of bioactive compounds and nutrients (Table 3). The leaves, roots, seeds, and green pods of the Moringa plant have all been discovered to be beneficial in the production of nutraceuticals, medicines, and water and biodiesel purification (Murthy, 2021). Nearly every component of the plant is utilized as fodder and as vitamins and nutrients for human consumption. In developing nations, It is challenging to raise cattle sustainably due to a reliance on certain traditional ingredients that are either imported or costly if they are available locally (Ibrahima, 2024). Therefore, it is essential for sustainable commercial animal production to use non-conventional feed resources that are grown locally and at relatively low costs. An experiment was conducted to ascertain the chemical makeup of the various portions of moringa oleifera, including the leaves, stalks, and whole plant (leaves+ stalks). The result of the experiment reveals that all parameters in the leaves, with the exception of organic matter and ash, stalks, and whole leaves (leaves + stalks)

Table 3: Bioactive compounds with their amounts, Molecular formula and Molecular weight adapted from (Ab, 2024).

S.NO	Bioactive compounds	Amount	Molecular formula	Molecular weight
1	Vitamin A	1.28mg	C20H30 O	286.55
2	Vitamin B1	0.06mg	C12 H12CIN4OS	265.36g/mol
3	Vitamin B2	0.05mg	C_{12} $H_{20}N_4O_6$	376.36g/mol
4	Vitamin B3	0.8mg	C_6H_5NO	123.10g/ml
5	Vitamin C	220mg	$C_6H_8O_6$	176.12g/mol
6	Vitamin E	448mg	$C_{29}H_{50}O_2$	430.71g/mol
7	Chlorophyll	80mg	$C_{55}H_{70}MgN_4O_6$	907.472.5g/mol
8	Arginine	6%	$C_6H_{14}N_4O_2$	174.20g/mol
9	Histidine	2.1%	$C_6H_9N_3O_2$	155.16g/mol
10	Lysine	4.3%	$C_6H_{14}N_2O_2$	146.19g/mol
11	Tryptophan	1.9%	$C_{11}H_{12}N_2O_2$	204.23g/mol
12	Phenylalanine	6.4%	$C_9H_{11}NO_2$	165.19g/mol
13	Methionine	2%	$C_5H_{11}NO_2S$	149.21g/mol
14	Threonine	4.9%	$C_4H_9NO_3$	119.12g/mol
15	Valine	7.1%	$C_5H_{11}NO_2$	117.15g/mol

(Ab, 2024).

showed significant variations between harvests ($P<0.05$). Accordingly, Moringa oleifera can be suggested as a substitude forage source in light of its feed value and nutrient content (Ibrahima, 2024). Moringa has a wide range of other applications. Generally speaking, it is regarded as a vegetable, a medicinal plant, and a source of vegetable oil in poor countries. The plants are used for ecosystem services (e.g., soil improvement, erosion control, ornamental, boundary/barrier/support, intercropping, pollution control, etc.). as well as for animal feed, biogas, fuel, blue dye, fencing, fertilizer, foliar nutrients, green manure, gum, honey, and sugarcane juice clarifier, medicine, biopesticide, pulp, rope, tannin, water purification etc (Mridha, 2015). In the indigenous medical system, several parts of this plant including the leaves, roots, seed, bark, fruit, flowers, and immature pods have anti tumour, antipyretic, antiepileptic, anti-inflammatory, anti-ulcer, antispasmodic, diuretic, anti-hypertensive, cholesterol lowering, anti-oxidant, anti-diabetic, hepatoprotective, anti-bacterial, and anti-fungal properties (Ibrahima, 2024). They also act as cardiac and circulatory stimulants. In addition to being used for oil extraction, the seeds are also consumed raw, roasted, powdered, and added to tea or curries. In many of the world's so-called developing regions, where undernourishment is a serious concern, this tree has recently been promoted as an exceptional indigenous source of highly digestible protein, calcium, iron, vitamin C, and carotenoids that can be used (M. Mridha, 2015). Additionally, they serve a variety of purposes, including use as a supplement, improving the condition of the soil. The most common and important source of income is oil, which is also produced by Moringa plants. Most of the bioactive phenolic chemicals that are now available are members of flavonoid groups, including kaempferol and quercetin (M. Mridha, 2015). Moringa leaves have the potential to be a natural supply of anti-oxidants because of their observable ability to shield cells from free radicals, according to findings published in a number of publications (Prajapati, 2022). The leaves are rich in nutrients, including 27 percent protein, calcium, iron, potassium, phosphorus, β- carotene, and vitamins C and A (Prajapati, 2022). The Moringaceaea family includes the genus Moringa, which is fast growing, multipurpose tree species that can be either deciduous or evergreen. Because of its many therapeutic and non-therapeutic uses, Moringa oleifera, sometimes referred to as the "tree of life 'or "miracle tree" is regarded as an important herbal plant. The 13 species that make up the Moringa family are M. oleifera, M. arborea, M. rivae, M. ruspoliana, M. drouhardii, M. hildebrandtii, M. concanensis, M. borziana, M. longituba, M. pygmaea, M. ovalifolia, M. Peregrina and M. stenopetala. Of these M. oleifera has gained notoriety. One of moringa's special qualities is its ability to withstand drought. (Pareek, 2023). Consist of 13 species and is well known for its many medicinal qualities, anti-microbial activity, and high nutritional value for human consumption, animal feed, fodder, forage and green manure from leaves, animal food and fertilizer from treated seed cake, fuel wood, oil from seeds as industrial use, reforestation, environmental use (agroforestry, boundary, barrier or support, shade, and shelter) ; use as materials (varved material, dye/tannin, essential oils, fiber, gum. Resin, lipids, wood/timber, rope, etc.) from tree trunks; ornamental; pest control, water purification, honey, and sugarcane juice clarifier from powdered seeds, biopesticide, a source of vegetable oil, etc., especially different plant parts (leaves, roots, seed, bark, fruit, flowers, and immature pods) are used for the treatment of various ailments in many indigenous systems of medicine. Several developing nations worldwide (Mridha, 2015). Nonetheless, the significance of zogale extends beyond its nutritional worth. According to research, Zogale seed oil can be used as lubricants, and the flower seeds following oil extraction can be used to make fertilizer. As a result, the plant has significant economic worth in addition to being a food source. However, the tree's bark yields

Table 4: Fatty acid compositions contents of Moringa Spp oils. Adapted from (Özcan, 2020).

Fatty acids %	Concentration
Lauric	0.1-2.87
Palmitic	5.73-17.06
margaric	0.03-3.70
palmitoleic	0.80-7.6
stearic	67.9-85.0
Oleic	0.27-22.66
Linoleic	0.20-32.53
Arachidic	0.6-5.0
sEicosenoic	1.5- 9.64
Behenic	2.52- 7.24
Lignoceric	1.3- 10.98

coarse fiber that is used to make cordage, paper, and mats. A gum made from corky bark is used in India to print calico, which is a type of cotton fabric with figured designs. In terms of economics, cooked Zogale (Moringa) leaves have been used as food in many homes. Because Moringa oleifera is so resistant to adverse growth conditions, such as drought, poor soil quality, and several pests and diseases, it is the perfect plant to promote at home level (Rojas, 2022). Additionally, they grow extremely quickly, if left untrimmed, they typically reach a height of three to five meters annually. If properly nourished, it is one of the fastest growing biomasses on Earth and can reach a height of 7 meters annually. Additionally, if given proper care, trees in warm areas can remain evergreen and continue to supply food to low income people even during periods when other food sources are limited (Rojas, 2022). Around the world, these plants are typically utilized in traditional herbal therapy to treat a variety of illnesses, including diabetes, hypertension, and stomach issues (Rojas, 2022). The leaves, seeds, roots, and blossoms of the Moringa tree can all be consumed by humans and animals. Rich in protein, calcium, β-carotene, and antioxidants, the leaves are utilized in traditional medicine as well as for human and animal nutrition. Instead, M. oleifera seed kernels have garnered scientific attention due to their high oil content (up to 40%), high quality fatty acid composition (oleic acid >70%), and considerable resistance to oxidative degradation during refining (Carla Trigo, 2021). Table 4 lists a few physico-chemical traits of Moringa spp. seeds and oils. It has been discovered that Moringa oleifera is a potentially new oil source (Özcan, 2020). Ben oil" or "Behen oil" are the commercial names for the oil.

According to Leone (2016), its qualities make it appropriate for both commercial and human use. These components could also be dried, ground into powder, and used in a variety of culinary recipes. Moringa according to recent research, these leaves may be able to lessen the death and suffering brought on by hunger and its associated illnesses (Ma, 2020). This crop has been spread worldwide (Asia, Africa, Central, and South America) and this fact has led to it being given different names (Carla Trigo, 2021). Over the past few decades, merging nations all over the world have had a greater need for food to combat hunger and malnutrition. The indigenous people of northern India and several regions of Africa have long been aware of the numerous advantages of Moringa oleifera. Despite having low quality lumber, this perennial softwood tree has been used for ages for both traditional, industrial and medicinal purposes (Figures 3A-C). In earlier historical periods, farmers and scholars were drawn to it because of its many applications and possibilities. Moringa oleifera leaves have been used for both preventive and curative reasons, according to Ayurvedic traditional medicine, which claims that the plant may prevent many body ailments (Leone, 2015). In addition to being planted in West, East, and South Africa, tropical Asia, Latin America, the Caribbean, Florida, and the pacific islands, it is already a significant crop in Ethiopia, India, the Philippines, and Sudan. Humans have traditionally eaten all portions of the Moringa tree because they are edible (Mahamane, 2025). Moringa is increasingly becoming an essential tree due to its numerous uses, easy propagation, fast growth and wide edaphic and climatic adaptability (Mashamaite, 2024).

Nutritional Value of *Moringa*

There are about 30,000 edible plant species present of, only 30 are used to feed the world, *Moringa oleifera* inclusive (Thakur, 2020). Because of its unique phytochemical make up and possible medical uses, *Moringa oleifera* are plant species also known as the drumstick tree, horseradish tree, and ben oil tree, has captured the attention of both researchers and health enthusiasts (Table 5). Moringa oleifera's reputation as a nutritional powerhouse and a source of many health benefits is rooted in its phytochemical variety (Siahaan, 2023). Two alkaloids, moringinine and moringine, make up its stem bark. Zinc (Zn), sodium (Na), iron (Fe), Calcium (Ca), Potassium (K) , Copper (Cu) , Manganese (Mn), and Magnesium (Mg) make up the leaves. A significant amount of carbohydrates (63.11%), crude proteins (17.01%), ash (7.93%), fatty acid (1.69%), crude fat (2.11%), and crude fiber (7.09%) are present in Moringa leaves which have an energy value of 144oKcal/100g. Copper (6.10ppm), manganese (81.65 ppm) , phosphorus (30.15 ppm) , Zinc (60.06 ppm), iron

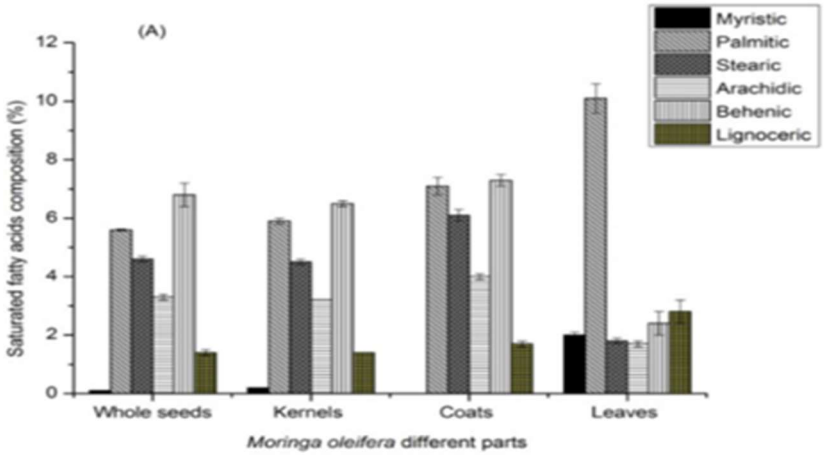


Figure 3 (A): Saturated Fatty acids composition (%) of the different parts of *Moringa oleifera*

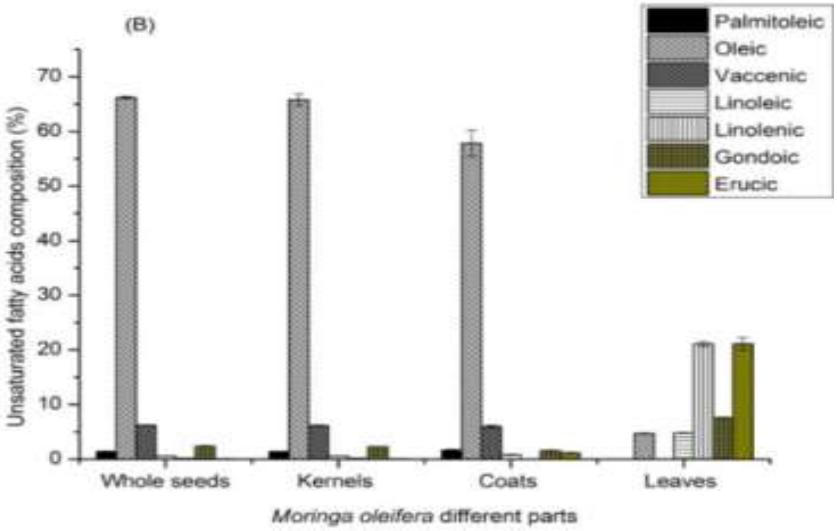


Figure 3 (B): Unsaturated fatty acid content of whole seeds, kernels, coats and leaves.

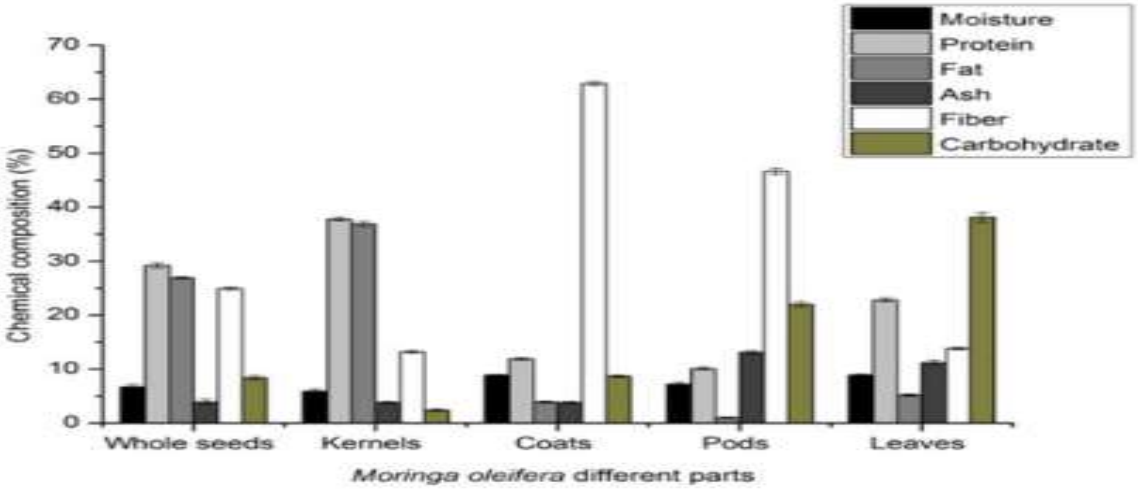


Figure 3 (C): Chemical composition (%) of the different parts of Moringa oleifera (Whole seeds, kernels, coats, podsand leaves) adapted from (Owon, 2021).

Table 5: Phytochemical compounds in *Moringa* Leaf Extract. Source (Siahaan, 2023).

Number	Compound	Result
1	Alkaloids	+
2	Flavonoids	+
3	saponins	-
4	Tannin	+
5	Terpenoids	+

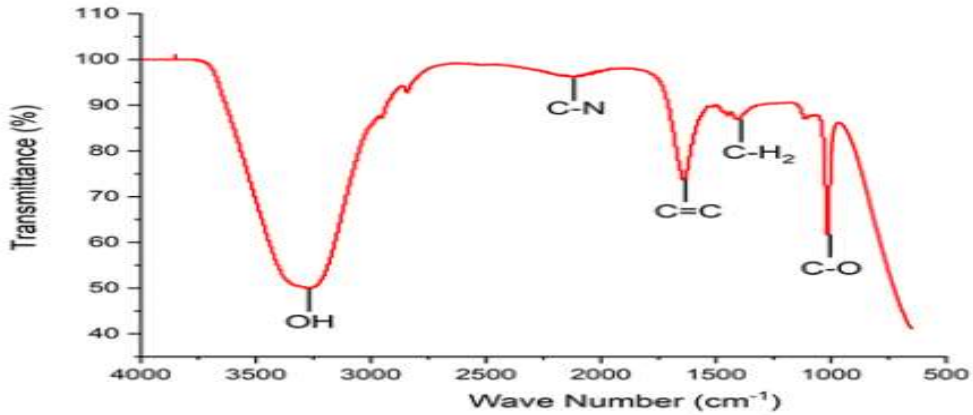


Figure 4: Spectrum of Moringa *Oleifera* Leaf Extract. Adapted from (Siahaan, 2023).

(107.48 ppm), Sodium (192.95 ppm), Potassium (0.97 ppm),Magnesium (0.38%) , and calcium (1.91%) are among the other vital elements found in the leaves Kamran (2020) (Figure 4).

Phytochemistry of Moringa

Moringa comes from a Tamil term called murungai, which means "twisted pod."Due to its high nutritional content and wide range of medicinal applications, the plant is currently grown for a variety of purposes (Fidrianny, 2021). There are several different types of phytochemicals in Moringa, these include flavonoid, which are well known for their anti-inflammatory and antioxidant qualities; terpenoids, which have been demonstrated to possess anti-microbial and anti-cancer qualities; tannins which effectively combat infections and reduce inflammation, anthocyanins, which are well-known for their anti-inflammatory and antioxidant qualities, and proanthocyanidins,which have strong anti-oxidant qualities and support cardio-vascular health (El-sherbiny, 2024). Plants include a wide variety of physiologically active phytochemical substance. Extracts prepared using aqueous organic solvents often had stronger antioxidant activity and more total phenolics and flavonoids, with leaves showing better antioxidant qualities than other portions (Abdallah, 2024). Because they include bioactive chemicals and multifunctional healing agents, items made from a variety of herbs and plants are generally regarded as safe to eat. Roughly 70-80% of people worldwide, particularly in poor nations, use herbal medicine to prevent and treat illnesses, according to research from the Food and agriculture Organization (FAO) (El-sherbiny, 2024).

Additionally, roughly 25% of synthetic medications are made from medicinal plants. According to reports, the stem bark contains octacosanoic acid, vanillin, b-sitostenone, 4-hydroxymelin, and the alkaloids moringine and moringinine, 3 which have been linked to better glucose tolerance. The leaves of Moringa oleifera have been used to extract and characterize niazimin, which is thought to have hypotensive qualities (Alegbeleye, 2018). Over the past few decades, developing nations have seen an increase in demand for food to address the issues of hunger and malnutrition. Due to dietary deficiencies in vital nutrients, the great majority of people in Asian and African nations suffer from malnutrition (Kashyap, 2022). Moringa is a genus of medicinal plants that has been used traditionally to cure wounds and various diseases such as colds and diabetes (Zahirah, 2018).

It has the potential to end malnutrition and is a cheap, easily accessible source of important nutrients and nutraceuticals. Because of its tuberous roots, which provide it a great tolerance to drought and desert circumstances, moringa frequently seen as a crucial famine food (Yadav, 2019). Nearly every part of the Moringa tree, including the roots, leaves, blossoms, green pods, and seeds, can be used for therapeutic purposes, the manufacturing of functional foods, nutraceuticals, water purification, and the generation of biodiesel (Zahirah, 2018).

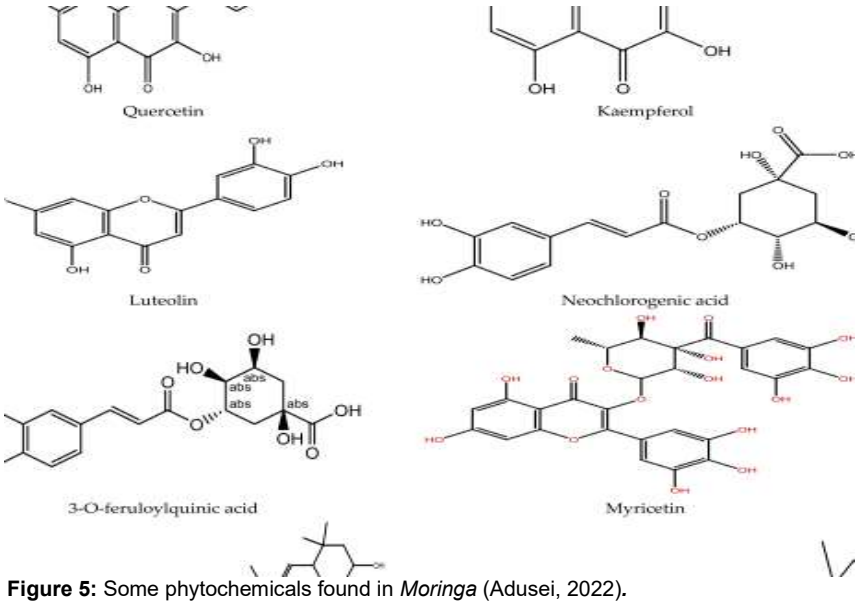


Figure 5: Some phytochemicals found in *Moringa* (Adusei, 2022).

Medicinal value of moringa

Since the beginning of time, people have used plants with therapeutic qualities to treat illnesses. Due to their perception that natural medicine is safer than synthetic medicine, interest in natural pharmaceuticals started to grow around ten years ago (Adusei, 2022). Therapeutic phytochemicals, which can spur the development of new medications, are the reason why medicinal plant research and uses are growing daily. Because of its widespread use as a nutritive plant with a high nutritional content and as a dietary supplement to combat child malnutrition, Moringa oleifera is referred to as a miracle tree (Kashyap, 2022). Additionally, they serve a variety of purposes, including as a dietary supplement, improving the condition of the soil, and being used in water purification systems (Figure 5). The most common and important source of income is oil, which is also produced by Moringa plants (Sales, 2017). Most of the bioactive phenolic chemicals that are now available are members of flavonoid groups, including kaempferol and quercetin. Moringa leaves have the potential to be a natural supply of antioxidants because of their observable ability to shield cells from free radicals, according to finding published in a number of publications (Prajapati, 2022). Additionally, proteins, water coagulation, and fatty acid methyl esters (FAME) from M. oleifera seeds are examined to investigate their potential industrial uses in the manufacturing of biodiesel and water purification systems. In order to help people, prevent and treat illnesses, medicinal plants have emerged as natural sources of chemicals with pharmacological and nutritional qualities. Alkaloids, tannins, flavonoids, steroids, saponins, coumarins, quinones, and resins are some of its secondary metabolites that give it therapeutic potential. Moringa leaves (Moringa oleifera Lam.) are rich in bioactive substances with significant therapeutic potential (Nida, 2024). The slogan "Natural nutrition for the tropics" has been promoted by three non-governmental groups < trees for life, Church World service, and Educational concerns for Hunger organization, to encourage the use of several plant species, including M. oleifera, as foo sources (Adusei, 2022). Moringa oleifera has also been promoted by World Health Organization (WHO) as an alternative to imported food source to treat malnutrition (Daba, 2016). More than 90 nutritious chemical constituents, such as proteins, lipids, carbohydrates, and dietary fibers, are found in M. oleifera (Table 2).in order to combat malnutrition, particularly in children and new born, it is utilized as food source in the tropics (Sales, 2017). Moringa oleifera is considered a mystical plant due to its numerous medicinal uses (El-sherbiny, 2024). The plant was occasionally referred to as “mothers’ best friend” or “Miracle tree” because of its therapeutic qualities (Aim, 2024). Numerous phytochemicals, including quercetin, curcumin, capsaicin, resveratrol, Taxol, and others, have demonstrated antibacterial, anti-oxidant, anti-cancer, anti-hepatitis C virus, and anti-inflammatory properties (Sales, 2017)

. Their diverse range of therapeutic effects has made them attractive candidates in the current drug development process. Furthermore, natural compounds derived from plants have demonstrated therapeutic potential against range of cardiovascular conditions as well as brain and neurological illnesses, including Parkinson’s, Alzheimer’s, and Huntington’s diseases (Aim, 2024). M. oleifera has been found to exhibit strong anthelmintic properties, and its gum is used as an anti-filarial agent. The most common parasite species that M. oleifera targets are helminths,

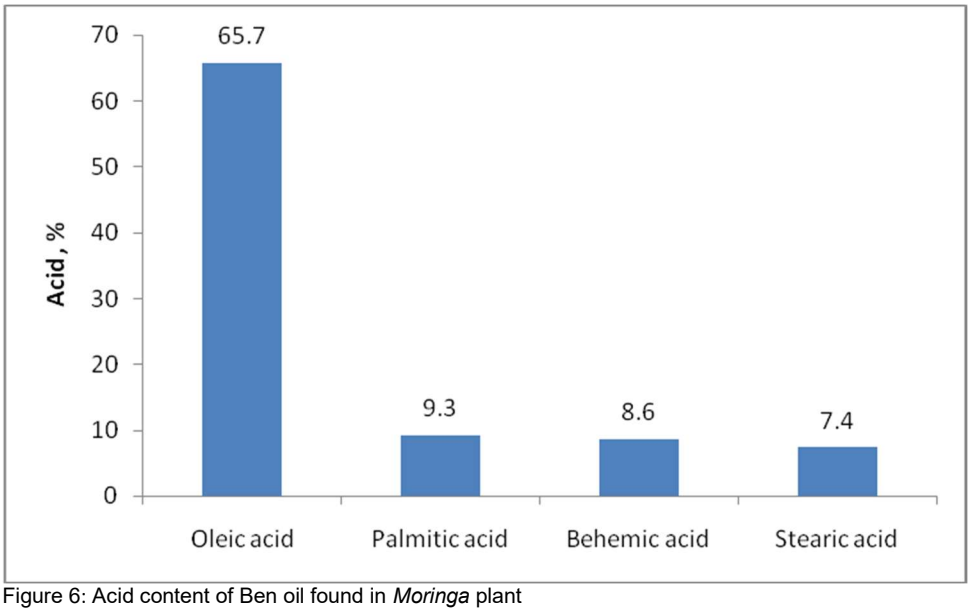


Figure 6: Acid content of Ben oil found in *Moringa* plant

such as trypanosomes, schistosomes, and Dracunculiasis. Because of the soluble lactin in its seed extract, M. oleifera has demonstrated some antiprotozoal activity and larvicidal properties in vitro. It causes mortality in Aedes aegypti because it impedes the larva development process and has hemo-agglutinating properties. M. oleifera water extract is known to exhibit larvicidal, pupicidal, and adult mosquito killing qualities against Culex quinquefasciatus. It has anti-malarial properties. The plants ethanolic extracts exhibit significant anthelmintic activity, which, at different dosages, can paralyze and kill worms (Pareek, 2023). According to experiments, different concentrations of Moringa extract cause the worms to paralyze and die in different amounts of time. For example, 25mg/ml takes 14.32±2.2 min and 63.47±12.6 min, 50 mg/ml takes 8±1.6 min and 52.33±3.1 min, and 100 mg/ml takes 6±1.2min and 45±11.4 min, respectively (Fatima, 2014). Moringa has antifungal, diuretic, stimulant, purgative, galactagogue, rubefacient, and antiscorbutic properties. A comparatively large output of 36%Ben oil is provided by the Moringa seeds (Figure 6). According to Fatima (2014), the oil's composition includes 65.7% oleic acid, 9.3% palmitic acid, 7.4% stearic acid, and 8.6% behenic acid. The seeds have anti-aging, body cleansing, anti-cancer, gout, asthma, hiccups, and hypertension benefits. It also aids in sperm count growth. Additionally, rheumatic and gouty joints, as well as arthritic aches, can benefit from oil produced from Moringa blossoms. Additionally, its leaves are used to treat rheumatism, back pain, gout, asthma, hiccups, and skin ulcers and sores (Ab, 2024).

In addition to being beneficial for diabetes, ulcers, constipation, and blood pressure stabilization, moringa leaves are thought to improve the flow of mother's milk. One substance found in moringa is called pterygospermin. Particularly for skin infections, it possesses potent fungicidal and antibacterial properties. Furthermore, it slows down skin aging. The antibacterial and anti-inflammatory qualities of moringa are beneficial for both acute and chronic edema. Children who do not receive breast milk frequently exhibit symptoms of malnutrition. Lactogogues are typically provided to nursing women in an effort to boost their milk production. Lactogogue is a phytosterol based precursor of the hormones needed to stimulate reproduction. Because moringa contains phytosterols like stigmasterol, sitosterol, and kampestrol, it is regarded as a great source of hormone precursors. These kinds of substances cause the mammary gland's estrogen receptors to become active, which leads to the growth of -milk producing ducts. Children under the age of three who suffer from malnutrition can be treated with it (Ab, 2024).

Propagation methods of Moringa it

Moringa is a fast-growing, softwood, drought-resistant plant representing the most cultivated species in the world and several African countries (Mahamane, 2025). It is a multipurpose tree with the potential to reduce the dependence on expensive conventional protein supplements, in addition to its relative ease of propagation by both sexual and asexual means (Mallenakuppe, 2019). Moringa can be propagated by both sexual and asexual means. Moringa seeds are the most common method of propagation. Seeds can be soaked in water for 24 hours before planting to enhance germination (Figure 7). They can be directly sown into the soil or started in seedbeds or



Figure 7: Growing Moringa explants in pots (containers before transfeering to field. adapted from (Mathapati, 2024).



Figure 8: Growing *Moringa* using tissue culture . adapted from (Dela, 2024).

containers (Mathapati, 2024). Plants obtained from seeds vary in genotype and phenotype, which leads to variations in yield quality and quantity Moringa can be propagated vegetateively. it can be grown by cutting as it belongs to the plant species known as "easy -to-root-plant species". These plant species have been reported to be propagated without application of rooting hormones (Bukar, 2022). Though widely used seed propagation leads to variability. This force growers to propagate the plant using vegetative means such as layering in order to produce true-to-type plants with consistent yield and quality (Balakumbahan, 2024).

Micro propagation

Through micropropagation, it is now possible to provide clean and uniform planting materials in plantations for several plant species such as Moringa. Micrografted seedlings are commercialized to avoid the serious crop loss caused by infection of soil-borne diseases for fruit trees and several vegetables. An alternative to propagate plants in less time and greater number is through plant tissue culture (Figure 8). This is a biotechnological technique which allows the establishment, maintenance and development of any part of the plant, from an

individual cell to a complete plant. This is done under artificial axenic conditions, hence the establishment of an in vitro tissue culture, this method has many advantages over the conventional methods of propagation. This method of plant tissue culture or cell tissue culture is also known as micro propagation (Avila-treviño, 2017). Tissue culture-derived moringa plantlets have a very weak root system. During ex vitro transfer, their roots are easily injured when taken out of the agar-solidified medium, resulting in poor water and nutrient absorption. They also wilt rapidly just minutes after uprooting from the culture medium, primarily due to their thin leaves with less cuticular waxes and opened stomates, resulting in poor regulation of water loss (Dela, 2024).

Moringa for Agroforestry purpose

In addition to maintaining environmental stability, forests are important for generating economic advantages (Bilali, 2024). A forest is an ecosystem in and of itself, made up of all living and non-living elements, not just a collection of trees. There are five reasons why forests are important (a) they help control the climate and water resources; (b) they provide habitat for plants and animals; (c) they provide variety of essential goods like wood, food, ; and (e) they offer recreational opportunities and other services (Ma, Z.F. 2020). 90% of firewood and 60% of timber come from agroforestry. Plants like Moringa, Acacia, Neem, Ber, Mulberry, Dalbergia, Poplar, Simbal, Olive, and others are the most crucial ones that are advised for agroforestry. With several advantages, "Moringa" is the most promising tree for dry and semi-arid climates (Horn, 2022).

Moringa as agent for water treatment

Considered a pantropic tree of hot semi-arid regions (annual rainfall 250-1500mm), Moringa can withstand a variety of environmental conditions, including hot, dry, hot humid, and wet ones. It can withstand mild frosts, but it cannot withstand freezing temperatures. This tree can withstand droughts and thrives in a variety of harsh conditions that other fruit, nut, and tree crops would not be able to handle. Considered a wonderful natural emollient, moringa seed oil has been used in cosmetics and contains a high content of oleic acid (> 73%) and virtually no colour or odour. A biodiesel with characteristics that meet the international biodiesel criteria is also produced using the seed oil as a basic material. Research (Santos, 2015). In previously untreated water, seeds from Moringa oleifera, regarded as one of the most beneficial trees in the world, can reduce bacteria by 90.00 to 99. When ground into a powder, moringa tree seeds can be utilized as a water-soluble extract in suspension, creating a powerful natural clarifier for extremely murky and untreated pathogenic surface water (Sarode, 2023). This method improves potability and decrease water turbidity, or cloudiness, which makes the final product more aesthetically pleasing and microbiologically suitable for human consumption (Mashamaite C. V., 2024).

Cultivation of moringa

With the exception of soggy soils, moringa is a drought tolerant plant that may be grown in a variety of soil types. Because they drain well, sandy loam and slightly alkaline clay soils are thought to be the ideal media for this plant (Mangar, 2022). According to the authors' own observations, M. oleifera cannot grow properly in wet conditions because its roots rot. During the germination phase, this species can withstand water with an electrical conductivity (EC) of 3 dS m-1, but as it progresses, its tolerance to saline water rises. Thus, with the exception of wet circumstances, moringa may be produced in a variety of climates, including hot, humid, dry tropical, and subtropical areas. With sufficient nutritional content, it can function better in marginal situations (Mangar, 2022). Given the plant's immense usefulness, it is worthwhile to cultivate it on large scale (in commercial quantities) in order to reap its many benefits.

This plant is very simple to grow for the following reasons:

1. The tree grows incredibly quickly. It appears to flourish in unfeasible locations, including dry regions and poor soil, even close to the sea. Badasa et.al. (2023) asserts that the moringa plant is drought tolerant and can grow almost anywhere in the world including in arid regions, close to the sea, and on soil that is poor. Once established, the plant can even tolerate extreme drought.
2. In just one or two weeks, seeds develop easily.
3. Cuttings can be used to multiply the plant. Another option is to plant a branch of the plant, which will establish itself in a week or two.
4. Fruiting and flowering occur consistently and freely.
5. It thrives on sandy, dry soil. They have enlarged, white roots that are designed to hold water.
6. Create the perfect shade tree that is extremely resistant to drought. (Mashamaite C. V., 2024).

Venturing in the production of Moringa

Growing moringa trees from seed is simple. When the seeds are between one and two months old (approximately 30cm (12in) tall, 0.75cm (0.3in) in diameter, they may be moved into nurseries before being placed in well cultivated soils for commercial propagation (Radovich, n.d). Stem cuttings are another asexual method of propagating moringa (Badasa et..al.2023). Cuttings from wood that is at least a year old, 4–16 cm (1.66.3in) in diameter, and up to 1.5 m (5ft) long are ideal for propagation. Depending on client preferences, manufacturing volume, and accessibility technology, the

university of Ilorin Kwara state, Nigeria, can package moringa leaves for consumption in a variety of ways. Mangar, (2022) have found a number of customers' preferred options for moringa in Nigeria, including: - (1) Moringa powder (2) Moringa leaf powder in teabags (3) moringa fortified fruit juice and honey (4) Moringa fortified tablets and capsules (5) Moringa fortified candies materials from fresh moringa leaves(Mangar,2022). Being indigenous to India and other Asian nations, the Indian populace is well aware of the plant's numerous nutritional, therapeutic, and economic benefits.The production of the plant has been attempted by the Indian populace. An estimated $6 billion is made from the 1.5 million tons of moringa produced in India each year (Santos, 2015).

Cultivation of moringa in Yobe State

Yobe State lies between latitudes 10°30'N and 13°30'N and longitudes 10°00'E and 12°30'E in the arid/semi-arid northern region of Nigeria. The total land area of Yobe is 47,153 km². Except for the southern region of Gujba and Fika LGs, where the terrain is primarily rocky, Yobe state's topography is primarily flat. The State's northern region has undulating dunes and is largely sandy. One of the state's most significant geographical features is the Yobe River, from which the state got its name. Two million people are predicted to live there in 2005, up from an estimated 1.4 million in 2003. Sahel savannah predominates in the state's far northeastern region, whereas Sudan savannah makes up the majority of the vegetation. Rainfall occurs from May to October, and the majority of the year is warmer and drier. Like many other plants, including garden croton, sugar cane, roses, and tapioca, it is easy to cultivate from stem cuttings. Cuttings from these plants strike roots at the base of moist soil and produce adventitious buds that grow when placed in the soil. Due to its drought resistance, the plant is extremely easy to grow. The threat of desertification is one of the main ecological issues facing Yobe State. According to official sources, the state government has spent over N5 billion in the past ten years to combat ecological issues. According to (Mahaveerchand, 2024)., incorporating Moringa stenopetala leaf meal into the diet of Rhode Island Red chicks led to a notable ($P < 0.05$) boost in feed and crude protein consumption, average weight gain, feed efficiency ratios, and protein efficiency ratios compared to a control diet. The antimicrobial and antioxidant properties of Moringa oleifera have been explored by various researchers. Jabeen et al. noted that the antimicrobial activity of Moringa oleifera seed extracts might be attributed to lipophilic compounds that can bind to the cytoplasmic membrane. The authors also proposed that Moringa oleifera seeds could contain antibiotic metabolites, including carboxylic acids, 2,4-diacetyl phloroglucinol, and enzymes that degrade cell walls and chitinases. Luqman et al. explained the antioxidant effects of Moringa oleifera leaf extract and its fruit.

The researchers determined that incorporating Moringa stenopetala leaf meal into the diets of growing chicks at levels of up to 6% to replace high-cost conventional protein sources does not adversely affect the chicks. Mahamane, (2025) found that when 10% and 20% of Moringa oleifera leaf meal was included in the diets of laying hens as a replacement for sunflower seed meal, there was a significant ($P < 0.05$) increase in feed intake and dry matter feed intake, while egg mass production decreased. The percentage of egg production declined as the level of Moringa oleifera leaf meal increased. The feed conversion ratio (kg feed/kg egg) worsened with the addition of 20% Moringa oleifera leaf meal to the laying hen diet. Egg weight increased considerably ($P<0.05$) when 5% moringa oleifera leaf meal was added, but decreased at 20%. There are documented uses for practically every part of the plant in medicinal formulations. According to more recent studies, extracts exhibited antiviral action that seemed to be mediated by interferon-like protein molecules. It is possible to press moringa seeds to produce a premium oil with both industrial and nutritional uses. According to reports, the oil has a pleasing flavor similar to that of olive oil. Sweet, odourless, and somewhat yellowish, it can be refined and used as salad oil. Known in the industry as oil of ben or Behen, it is also used as an industrial oil for lubricating fine time pieces and making perfumes (Daba M. 2016).

Conclusion

In summary, it is evident that the moringa plant originated in Arabia and India. This well-known dicotyledonous plant is mostly planted in tropical climates, but it has since spread to many other regions of the world. Numerous individuals, including the Indians and the ancient Romans, have recognized the plant's numerous significant advantages which includes its usage as food- particularly the leaves and flowers, medicine, as a water treatment agent, to combat desertification, and ameliorate land degradation. More than 300 illnesses could be cured by the herb. The plant grows quickly, is drought resistant, and can be multiplied via seeds and cuttings. In Yobe state and the nearby states of Borno and Jigawa, where desertification is a serious problem, it is therefore viewed as a viable option for halting the spread of the desert and providing food and riches for the average person. Due to high land-to-man ratio, the potential of farm forestry and taungya to expand Moringa oleifera processing and boost value addition to enhance societal welfare is rapidly taking center stage. The joint production of forestry and moringa tree/agricultural crops on forest grounds, known as taungya, should be promoted. The Taungya system always had some fundamental characteristics and needed specific prerequisites to be adopted. The preconditions are obviously socio-economic in character, as evidenced by the population's low standard of life and land hunger. The tree also yields very soft wood, which is suitable for

firewood but not ideal for charcoal. Therefore, when cultivated in large amounts, it can alleviate the demand on other trees that people depend on for their firewood. “Because moringa is a tree that grows very quickly, it needs to be pruned regularly starting from a young age; otherwise, it will become tall and hard to harvest. The branches that are trimmed from the plant can be utilized as firewood. The agricultural systems discussed here have not received much economic confirmation. However, socioeconomic factors must to be given top attention on any future research agenda. When developing new technologies, farmers’ assessments of the practices’ social acceptability should be a key factor. Few studies discuss the social role of the resource and how it might help reduce rural poverty, despite the fact that many have been done on the Moringa Oleifera (Miracle tree). Therefore, it is recommended that future research investigations in Nigeria take a quick look at the cutting-edge viewpoints (such as micropropagation in situ and ex situ propagation or Plant tissue culture (PTC), science, and application in terms of the economic potential of moringa oleifera as a commercial tree species.

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