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Moringa: Source of nutrition and health benefits

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ABSTRACT

Moringa oleifera Lam (Moringaceae) is a highly desired plant that can be found in a variety of tropical and subtropical environments. The plant is used as a good source of food, i.e., root, stem, leaves, flower, fruits and seeds. The leaves, roots, seed, bark, and flower of this plant have anticancer, antipyretic, antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, antidiabetic, hepato-protective, antibacterial properties. Moreover, various parts of this plant are employed for the therapeutic purposes in the indigenous system of medicine against cardiac problems, and the antifungal properties are efficiently utilized for the treatment of a wide range of ailments. The plant is the store house of enormous nutrients. The Fresh leaves juice contains Vit-A, Vit-C, Vit-B complex, Calcium, minerals, Carotenoids and essential amino acids. Different parts of the *M. oleifera* plants, such as leaves, flowers, fruits, seeds, and roots, contain a significant amount of protein, ß-carotene, important minerals, and various phenolic compounds. The high yield is obtained by purpose full agriculture of Moringa. It is a miracle plant which cans helps to fight malnutrition. The present review article gives thorough information on the phytochemical compounds and pharmacological activities of *Moringa oleifera*, a therapeutic plant. The information provided in this study will be valuable in future investigations aimed at developing a revolutionary therapeutic medicine for the wellbeing. The aim of the research study is to highlight awareness about the cultivation of the plant as the indigenous plant by purpose full agriculture that can boost up health.

Keywords *Moringa oleifera*, cultivation, malnutrition, Phytochemicals Constituents, pharmacological activities

INTRODUCTION

Moringa is an advantageous plant with tremendous source of nutrients that has been already recognized in the society. Now it is the need to popularize this plant. The plant is scientifically known as Moringa oeilifera *Lamm*. belongs to family Moringinaceae and order – Brassicales, in dicotyledonous angiosperms. Fortunately, it has immense environmental adaptations that lives about 20 years and reaches a height of 5 to 10 m in a short period of time, reaching 4 m in 6 months. Commonly it is known as drum stick, horse radish tree, ben oil tree, sehjan, sondna, etc (1).

Botanical Description

Moringa is a deciduous fast-growing tree reaching up to 8 m in height. It bears a twisted trunk having smooth yellow bark with an umbrella like crown. Moringa has bipinnate or tripinnate compound leaves 2.5 cm in length with ellipsoid leaflets having dark green on the upper surface and pale green underneath. Its creamy-white fragrant flowers are arranged in loose inflorescences approximately 15 cm long. Drumsticks are capsule fruit long, three-sided measuring approximately 90 mm in length and 12 mm in width. The brown seeds are enclosed in the drumstick that germinate within a week under suitable conditions(2).

Taxonomic Rank Classification

Kingdom: Plantae
Subkingdom: Tracheobionta
Superdivision: Spermatophyta
Division: Magnoliophyta
Class: Magnoliopsida
Subclass: Dilleniidae
Order: Capparales
Family: Moringaceae
Genus: Moringa
Species: Oleifera (3)

Cultivation

The plant propagation is carried out by seeds, hardwood cuttings and transplants. Its seeds sown in shallow depths approximately 2 cm can germinate within two weeks and hardwood cuttings of mature trees ranging from 1–2 m long, 4–16 cm thick root easily under moist conditions(4).In one of the studies it has been observed that trees grown from seeds

develop deeper root systems enhancing drought resilience as compared to cuttings producing shallower roots but establish more rapidly(5, 6).The plant process of germination and vegetative growth are optimal depending on the temperature and weather condition that is suitable approximately 30/20 ◦C.

The plant has rapid growth of 3 m in approximately three months resulting in several harvest phases thus improving regrowth. Studies shown that moderate pruning results in increased leaf biomass(7).

The plant can be cultivated for its immature seed pods (called "drumsticks"), leaves, and/or seeds/kernels used for oil extraction and water purification. Exception to green fruits/seed pods, the leaves (leaflets, stalks, and stems), seeds, flowers, and roots are edible as well. It has numerous applications in cooking across world regions (8-10).The consideration for availability of food stuff and to fulfil its demand in near future will be a great challenge for nations. Therefore, exploration for alternative food resources should be initiated from nature. In addition to search for an economical resource, a nutritive one is a big challenge. The indigenous source of food would be healthier and harmless for all. This can lead to their domestication and agricultural practice thus introducing new food crops(11).

Different parts of the plant including leaves, fruit, flowers and young branches are utilized intensely as a nourishing vegetable in various nations including India, the Philippines, Hawaii, Pakistan, and many African countries. Various nations have been utilizing it for their usual sustenance almost for 5000 years(12-14). Agricultural perspective claims that the trees developed from seeds have longer roots (which helps with stability and availability to water) than those grown from cuttings, which have much shorter roots(15, 16).

Another research study highlights that plants obtained through direct seeding did not exhibit adequate development or adaptability, making this propagation method unsuitable for establishing a commercial plantation. The planting distances, selected to reduce input use and promote environmental sustainability, further highlighted the limitations of seed-derived plants, which proved to be less competitive and more vulnerable. This would also lead to increased costs for farmers interested in investing in the species, making direct seeding a less viable option from an economic standpoint. Therefore, the study, focus shifted to identifying the most effective treatments in terms of plant development and leaf production. In 2022, the cultivation cycle was established with newly transplanted plants, which were ultimately harvested by cutting the main stem 20 cm above ground level.Research studies proved that the plant has been identified for its use in nutrition, biogas production, fertilizer, etc(17, 18).

The remarkable feature of the plant is tolerating drought for its growth(19). Various studies claim that M. oleifera is among the most economical and reliable alternatives for virtuous nutrition(20). All plant parts are used for their vital nutrients. Its leaves are considered for high content of beta-carotene, minerals, calcium, and potassium(21). It is known that the tree grows rapidly in loamy and well-drained sandy soils, preferring a height of 500 m above sea level(22). Moreover, it may grow in a diverse soil conditions that is neutral to a slightly acidic pH (6.3-7.0). Its mature seeds are planted as they have no dormancy period with the ability to germinate for a year(3). The tree height ranges from small to medium in size, the leaves are trifoliate, flowers are born on an inflorescence 10–25 cm long 18 cm while fruits are usually trifoliate and commonly referred to as "pods"(23).

Its trunk usually grows straight but is occasionally poorly formed, the branches are usually disorganized resembling the canopy umbrella-shaped; the brown seeds have a semi-permeable hull, and each tree has a capacity of about 15,000–25,000 seeds per year(24). Plants mature seeds and young fruits/pods are used to produce an edible oil called ben oil containing high concentration of behenic acid(25). Its seeds cake resulting from oil extraction can be used as a fertilizer/compost or for water purification(26). Due to the flocculation process, the seed cake is used to produce potable water. Dimeric cationic proteins of moringa seeds absorbs water impurities and colloidal particles that are removed as sludge through settling or filtration. Many remote and developing regions that have no access to potable water networks use this manageable and affordable method. Moringa seed oil extracted can also be used as a biofuel (27, 28).

It is extensively distributed worldwide, usually in Asia, Africa, the Caribbean, Latin America, the Pacific Islands, Florida, Madagascar, Central America, Cuba, the Philippines, Ethiopia and Nigeria(17, 29). It can easily grow in tropical and subtropical regions at a temperature of about 25–35 ºC(15) (16) specifically in indirect sunlight with slightly acidic to alkaline soil and without waterlogging. The tree initiates to bear fruit at 6 to 8 months(30).

MATERIALS AND METHODS

Recent review study is based on collected publications from 1984 to 2025. It includes different databases, original research studies to search the literature. The study describes the process of cultivation, benefits, phytochemical bioactive compounds, pharmacological activities and nutritional benefits. It highlights that Moringa is miracle plant and can be recommended for various ailments. It can be of vast commercial value for the under developed countries. It also promotes the cultivation of the plant in masses to utilize its vast application. Numerous alternative system of medicine claim ethno medicinal properties of the plant for curing diseases for centuries. Approximately every part (leaf, pod, bark, gum, flower, seed, seed oil, and root) of this plant has been used to treat one disease or another(31).

PHYTOCHEMICALS

Research studies further confirmed that dried leaves contain the highest concentrations of phosphorus, magnesium, iron, and potassium, along with significantly greater levels of fats,

fiber, carbohydrates, and caloric content than fresh leaves and extract powders. This enhanced nutrient density underscores the value of dried *M. oleifera* leaves as a concentrated dietary supplement. Moringa dried leaves contain approximately 29.4 g/100 g protein content of dried forming excellent plant-based protein source(32).The plant comprises of different active compounds like glucosinolates, flavonoids and phenolic acids(33, 34). Some studies also show that it contains carotenoids, tocopherols(35, 36). Other research studies highlights that leaves also contains alkaloids, saponins, tannins, steroids, phenolic acids, alkaloids, carotenoids, polyphenols, isothiocyanates, phytates, glucosinolates, flavonoids and terpenes(37). Among theglucosinolates, benzyl4-O-(α-L-rhamnopyranosyloxy)-glucosinolate is the most pre dominant (glucomoringin)(34).

Most importantly, leaves include 11 phenolic acids (gallic acid, caffeic acid, chlorogenic acid, o coumaric acid, p-coumaric acid, ellagic acid, gentisic acid, sinapic acid, syringic acid)(29, 30, 38, 39). and their derivatives (coumaroylquinic acids and their isomers, feruloylquinic and cafeoylquinic),26 flavonoids(presentmainlyasflavonolandglycoside:quercetin,rhamnetin, campferol, apigenin and myricetin(37). Flavonoids include flavonolglycosides (glycosides, rutinosides and malonylglycosides) of quercetin “kaempferol”0.05–0.67%) isorhamnetin and lignans (isolariciresinol,medioresinol,epipinoresinolglycosidesand secoisolariciresinol) (33, 40).

The plant is a rich source of several phytochemicals, such as phenols, flavonoids, vitamins, minerals, quercetin, and kaempferol. In addition, it also contains carotenoids, phenolic acids, alkaloids, glucosinolates and isothiocyanates(41).It leaves provide powerful antioxidants(42, 43), free radical scavenging(44), anti-inflammation, anti-eNOS expression(45, 46), anti-mutagenic, anti-proliferative, anticancer(47, 48), hepatoprotective(49), carbohydrate metabolism promoter(50), and repairs DNA(48) moreover, MO leaves are a rich source of essential amino acids(51, 52).

Moringa oleifera has shown encouraging prospective as anti- cancer research, including its effects on Oral squamous cell carcinoma. Extracts from *Moringa*, particularly its leaves and seeds, contain bioactive compounds like quercetin and kaempferol, which have demonstrated anti-cancer properties(48, 53). Research studies suggest that *Moringa* extracts can inhibit the proliferation of cancer cells, induce apoptosis (programmed cell death), and reduce oxidative stress, which plays a significant role in cancer development(54).

Its leaves contain high levels of phenolics and glucosinolates, tocopherols, carotenoids, polyunsaturated fatty acids, minerals, and vitamins. Studies also demonstrated that MO leaves contain 35 compounds(41, 55). It is utilized in purifying the blood and liver, enhancing cardiac function, deworming, and improving fat metabolism to aid in weight reduction(56). Its various components are believed to have antidiabetic, anticancer, anti-inflammatory, antispasmodic, antihypertensive, reducing cholesterol, antioxidant, hepatoprotective, antimicrobial, and antifungal properties(57).

Various research studies have proved its anticancer properties of the leaves, fruits, flowers, stems, and roots (54, 58, 59). Leaves showed remarkably high amount of protein as compared to other leaves, being consumed as food. It also contains essential amino acids and a high amount of provitamin A(20) with plentiful source of polyunsaturated fatty acids such as omega-3 and omega-6, making them essential in various cardiovascular functions and vitalizing the body. It also contains less saturated fatty acids and a high amount of monounsaturated fatty acids(60).

This plant is considered to be a good source of nutrients that are necessary for growth and development. Moringa leaves, which contain four times more calcium and two times more digestible protein than milk, can be used as calcium and protein supplements. The moringa leaves are also rich in minerals such as potassium, zinc, magnesium, iron and copper(61).

In one of the research study, when malnourished children were administered 10 g of dried moringa leaf powder daily, a significant increase in weight gain was reported and promoted rapid recovery compared to control in 6 months. The M. oleifera leaves have adequate sources of phytochemicals such as phenolic acids, flavonoids, tannins, saponins, alkaloids, etc., and their derivatives are known for their anti-cancerous properties(62).

Another research study was also conducted in Sprague-Dawley rats to evaluate the acute toxic potential of Moringa leaf powder. The experiment also found that oral administration of dried leaves up to 2000 mg/kg had no harmful or lethal effect on the human body(63). It is noted that supplementation with 100 mg/dL of *Moringa oleifera* leaf per day has a similar effect to treatment with vitamin E at 50 mg/dL per day(5), contains more vitamin C than an orange and more calcium than dairy products, however a significant part of this calcium is present in the form of calcium oxalate crystals, which cannot be used by the body and is eliminated directly without being absorbed(2). In addition, *Moringa oleifera* is high in potassium and iron; even more than bananas and spinach respectively.

Fresh leaves from *M. oleifera* are a good source of vitamin A. It is well established that vitamin A has important functions in vision, reproduction, embryonic growth and development, immune competence, and cell differentiation(63, 64).Moringa has been shown to aid in depression, anxiety, and exhaustion(25). The high number of bioactive compounds might explain the pharmacological properties of M. oleifera leaves. Leaves have been used for the treatment of various diseases, from malaria and typhoid fever to hypertension and diabetes. *M. oleifera* is a rich source of flavonoids that gives protection to various chronic diseases, including cardiovascular diseases, diabetes, and cancer. Flavonoids, present in the plant, have a benzo-γ-pyrone ring as a

common structure. The main flavonoids found in *M. oleifera* leaves are myricetin, quercetin, and kaempferol(65).

Moringine, an alkaloid present in Moringa relaxes bronchioles. It resembles ephedrine in action and is useful in the treatment of asthma(66). The use of *M. oleifera* in diabetic patients improved glucose tolerance by decreasing postprandial sugar levels after one, two, and three months of treatment(67).The leaves of *M. oleifera* are a possible source of phytochemical compounds with analgesic properties(68). *M. oleifera* bark had shown antipyretic properties against *E. coli*-induced pyrexia to have antipyretic efficacy in rabbits, supporting its ethnopharmacological use as an antipyretic herb(69).Isothiocyanate and niaziminin, present in Moringa are responsible for antihypertensive action(70).*M. oleifera* blend may lower cholesterol and triglyceride levels by limiting cholesterol absorption and that it might be developed as a standardized blend for the dietary supplement market(71).

Moringa extracts have characteristics that may aid in the prevention of cancer. It also contains niazimicin, a chemical that inhibits the growth of cancerous cells(34). Moringa appears to protect the liver from anti-tubercular medication damage and can speed up the healing process(66).

Aqueous extract of Moringa indicates its antiprogestational action(72). *M. oleifera* exhibited antiulcer and anti-secretory property in an ethanolic root-bark extract of *M. oleifera* and is used as a source for an antiulcer medication(73). Recent in vivo studies have shown that supplementation with *M. oleifera* seed powder exerts antihypertensive effects in spontaneously hypertensive rats, with improvements in blood pressure regulation and cardiac function. Study suggests that the cardio depressive effects of *M. oleifera* may involve the activation of muscarinic M2 receptors, leading to reduced cardiac contractility and enhanced vasodilation, ultimately lowering peripheral resistance and blood pressure(74).

DISCUSSION

Numerous human/animals including in vitro studies described in the preceding text indicate that various preparations of moringa leaves and other plant parts possess a wide range of physiological and pharmacological activities. Moringa leaves are an important source of antioxidants, tools in nutritional biochemistry that could be beneficial for human health. Various research studies suggest the therapeutic potential of moringa as a nutritional functional food for the treatment of inflammation-associated diseases and disorders. A majority of the results presented in various research studies shown significant improvements in blood glucose, both in fasting state and in response to a glucose tolerance test. The mechanisms of action revealed from the animal model experiments in some studies include the normalization of the gene expressions of enzymes involved in glucose metabolism resulting in the restoration of liver glycolytic activity and glycogen storage as well as reducing gluconeogenesis and improving insulin signaling. Regarding inflammation, positive effects of the oral administration of moringa and its extracts have been observed when measuring the expression of inflammatory cytokines in the liver and muscle, kidney and wound tissue of diabetic animals. Plant based food are considered relatively safe as they are likely to contain synergistic and/or side effect neutralizing combinations of activities. *Moringa oleifera*, known to be rich in multiple medicinally active chemicals, exhibiting a wide variety of pharmacological activities (75).

CONCLUSION

In view of its numerous benefits of moringa, this plant needs to be widely cultivated in most of the areas where climatic conditions favor its optimum growth. In this way, a maximum yield of its different useable parts could be achieved for the welfare of mankind. The analysis suggests a significant contribution of moringa to food security and nutrition, climate change mitigation/adaptation, farming systems resilience, and livelihoods. Its versatility and diverse applications and uses make moringa particularly interesting for developing countries like Pakistan. Although many bioactive chemicals have been found in Moringa, still our understanding of its complete reserve is still in its infancy. Future rigorous investigations aimed at detecting and commercializing *M. oleifera* bioactive chemicals could potentially lead to the development of products and treatment of various diseases. Therefore, there is a need to strengthen research on moringa to highlight its efficacy further. Investments in research, innovation, development and awareness regarding its cultivation may contribute to the transition towards sustainable and resilient health care systems.

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All authors have investigated and written the current work. All authors have read and agreed to the version of the manuscript.

COMPETING INTEREST:

The authors declare that there is no conflict of interest among authors.

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Fig: 1 Moringa Tree

Fig: 2 Moringa Leaves

Fig: 3 Moringa Pods

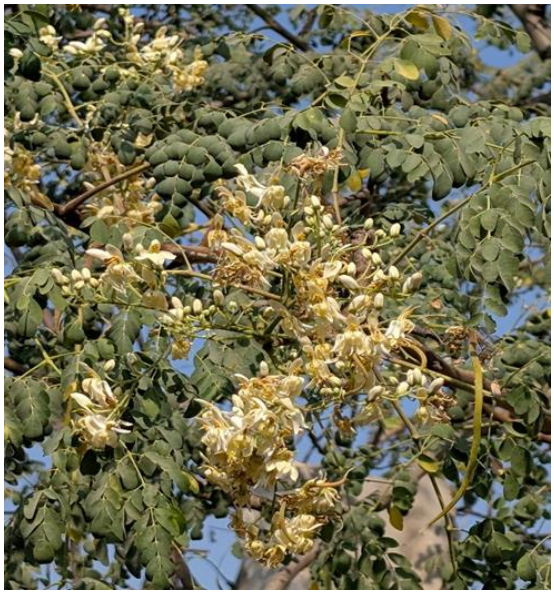

Fig: 4 Moringa Flowers

Fig:5 Moringa Seeds

Fig: 6 Mori