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MORINGA OLEIFERA: A REVIEW ON NUTRITIONAL ATTRIBUTES, THERAPEUTIC APPLICATIONS AND VALUE-ADDED PRODUCT GENERATION

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ABSTRACT

Moringa oleifera, a perennial tree of Indian origin, is cultivated in several tropical and sub-tropical countries because of its ability to grow under unfavourable conditions such as poor soil, lower requirement of water and managemental practices. The leaves and pods of the plant are highly rich in essential nutrients such as protein, vitamin, essential amino acids, macro and micro elements in addition to the presence of diverse nutraceutical molecules such as antioxidant, flavonoids, isothiocyanates, phenolics etc. The presence of bioactive principles in different parts of the Moringa plant prompted the people to use it as part of traditional medicines for the cure of several human ailments such as diabetes, intestinal worms, hyperlipidaemia, high blood pressure, muscle spasm, constipation, ringworm, etc. With the growing health consciousness coupled with phobia against modern chemical based therapeutic, there is increasing demands for plant sourced nutraceuticals. Evidently, this gives opportunity for development of Moringa based product for welfare of human society. The current review made an effort to summarize the research advancement on different aspects of *Moringa oleifera* focussing on taxonomy, cultivation, nutritional attributes, therapeutic values, and value-added products of this divine tree.

Keywords: *Moringa oleifera*, Nutrient composition, Medicinal values, Value added products.

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INTRODUCTION

In the global list of tree species, *Moringa oleifera* occupies significant niche because of its numerous applications for the benefits of the human society since immemorial. Albeit, the tree is originated from the Sub-Himalayan tract of northern India, nevertheless, it is currently found in South Africa, Northeast Africa, Madagascar, Ethiopia, Sudan, Philippines, Afghanistan, Bangladesh, Nepal, Pakistan, Sri Lanka, Latin America, and Southwest Asia (Meireles et al., 2020; Trigo et al., 2020). It is popularly known as 'drumstick' or 'horseradish' tree and bears immense significance for the production of typical thin pod resembling to 'drumstick', an important ingredient for the preparation of tasty and delicious dishes in Asia and Africa. Often, it is called as the "Tree of Miracles", because its each and every part (leaves, roots, flowers, pods and seeds) is consumed by the human being (Jagadeesan et al., 2020). The Moringa is also known as "Ben-oil tree" or "Benzoil tree", "Cabbage tree", "Mother's best friend" (Koul and Chase, 2015). The name 'Moringa' originates from the Tamil word 'murunnggi' or the Malayalam word 'muringa' (Quattrocchi et al., 2000). There are approximately fourteen species under the genus 'Moringa', viz., *M. arborea, M. longituba, M. borziana, M. pygmaea, M. hildebrandtii, M. drouhardii, M. longituba, M. peregrina, M. stenopetala, M. rivae, M. ruspoliana, M. ovalifolia, M. Concanensis* and *M. oleifera* (Rani et al., 2018). Among those fourteen species, *M. Oliefera* is the most prominent over the world because its parts are invaluable source of nutrients and phytochemicals.

Since the date of civilization, tree is considered as an integral part of human life around the world. In that perspective, numerous trees are being examined for several centuries not only for the production of food and wood, but also for dietary supplements and herbal medicines (Sujatha and Patel, 2017). In that time tested and century old competitive evaluation process, *M. oleifera* has emerged out as the front runner tree species because its part are rich protein, vitamins, minerals, carotenoids besides bioactive molecules of therapeutic significance. In fact, the Moringa tree is serving the needs of the human society since several centuries and holds a greater significance with respect to economic, nutritional, medicinal and social values.

Nowadays, human of all ages is repeatedly facing one or other kinds of stress of different degrees all over the world. In view of the growing consumer awareness coupled with phobia against chemical based modern therapeutics, the people of current generation want plant sourced biomolecules for their health and wellbeing as they believe in the principle of "Prevention is better than cure" (Samanta et al., 2015; Jahan et al., 2019). Besides the presence of vital nutrients, the plant parts of Moringa are rich in phytochemicals; effective against several human ailments including diarrhoea, diabetes, fever, dysentery, hepatitis, bronchitis, hypertension, cancer, epilepsy, colitis, common cold, anaemia, ulcers or external soars, headache, dental caries, arthritis and so on (Hsu et al., 2006). It is noteworthy to mention that therapeutic applications of Moringa is documented in ancient Ayurvedic literatures, namely Charak Samhita,

Sushruta Samhita, Ashtanga Sangraha, Bhel Samhita, Harita Samhita (Kumar et al., 2015). Following unravelling the mystery on the functionality of plant bioactive molecules, there is an unexpected surge across the world for the demands of plant derived products, including Moringa origin products (Meireles et al., 2020). In view of the above perspectives, the current endeavour has been made to present the review on *Moringa oleifera* focussing on update on taxonomic classification and cultivation, history on usages of Moringa tree, distribution and local name, nutritional values, bioactive plant compound, therapeutic application, value added products etc.

TAXONOMIC CLASSIFICATION AND CULTIVATION

Indeed, originated from India, *M. oleifera* is widely introduced and naturalized across many tropical and subtropical countries. Currently, it is being grown for a range of purposes including human consumption, livestock/ aqua feed and industrial applications. The taxonomic classification of *M. oleifera* is as follows (Trigo et al., 2021):

Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Subphylum: Angiospermae
Class: Dicotyledonae
Order: Capparidales
Family: Moringaceae
Genus: Moringa
Species: *Moringa oleifera*

According to the criteria of Angiosperm Phylogeny Group IV (APGIV), the Moringaceae family is now come under order *Brassicales*, the order which includes species of both radish and cabbage.

M. oleifera is a drought resistant, fast growing softwood tree, primarily growing in semi-arid tropical and subtropical countries. It could be grown by direct seeding, transplanting or by stem cuttings (Leone et al., 2016). Owing to its lower requirements for nutrients, water and other managemental practices, cultivation of Moringa is very popular among wide categories of farmers. It is reported to be grown in areas up to 1000 m altitude having annual rainfall around 750 to 2250 mm. Albeit, *M. oleifera* tolerates a wide range of soil pH (4.5 to 8.0), nevertheless, it is unable to thrive water logging and frosts (Hsu et al., 2006). It may be grown up to the height of 12 m with an approximate diameter of 60 cm (Orwa et al., 2009). The leaves are alternate, oddly bi-

or tri-pinnate compound, triangular in outline and 20 - 70 cm long. The flowers are up to 12 mm long, white or creamy white in colour. The fruit of Moringa is trilobite capsule shaped and length varies from 20 to 60 cm. The fruits are ripened about three months after flowering. The pods turn into brown after maturity. Each Moringa pod contains approximately 12 to 35 seeds, having average weight around 0.3 g. A single Moringa tree is able to produce 15,000 to 25,000 seeds per year (Foidl et al., 2001). As the carbon dioxide absorption rate of the *M. oleifera* plant is twenty times higher than that of general vegetation, therefore, the tree has great prospects to counteract the adverse effects of climate change and important avenue for livelihood improvement (Daba, 2016; Villafuerte and Villafurte-Abonal, 2009).

HISTORY ON USAGES OF MORINGA TREE

According to the available archaeological evidences, the ancient people of Indus valley civilization (3300-1700 BC) were selectively cultivating the crops that are rich in heath promoting phytonutrients (Samanta et al., 2011). Further, around 460 to 370 BC, the "Father of Medicine", Hippocrates opined that "Let Food be Thy Medicine and Medicine be Thy Food"; emphasizing the importance of the plant based therapeutic molecules for health and wellbeing, besides their nutritional significance. Evidently, it substantiates the stronger advocacy of food based herbal remedies during ancient times for "Good Health and Wellbeing"; today's SDG 3 of the United Nations. Other school of thought presumed usages of plants as medicines originates ~ 60,000 years ago, particularly in the mid-Palaeolithic age (Solecki, 1975). Out of the 3,91,000 vascular plants (Wills and Bachman, 2016), *M. oleifera* is the prominent one with greater economic significance (Senthilkumar et al., 2018). In the past, leaves and fruits of Moringa were part of human diets in some countries to take care their skin and mental health. During the period of 322 to 180 BC, the soldiers of Mauryan kingdom were offered Moringa leaf extract in the battlefield, because it contained numerous phytochemicals, which relieves pain, beats stress and supplies additional energy (Fuglie, 2001; Jahn, 1996; Manzoor et al., 2007). The oldest civilizations of the world particularly, Greek, Roman and Egyptian are also reported to extract oil from Moringa seed for its usages on skincare and perfumes (Senthilkumar et al., 2018).

DISTRIBUTION AND LOCAL NAME

M. oleifera is native to the sub-Himalayan foothills of Indian subcontinent. Realizing its beneficial roles, particularly disease ameliorating properties, the Moringa tree has been propagated to various tropical and sub-tropical countries of the world, including Middle East, Africa, America, Asia, Caribbean Islands (Sujatha and Patel, 2017). On

eastern direction, the Moringa plant spreads to China, Cambodia, and Philippines, while towards western direction, it reaches to Egypt, West Africa, Brazil, Mexico, Peru, and West Indies (Matic et al., 2018). By virtue of producing around 1.1 to 1.3 million tons of pods, India is the largest producer of Moringa and major contributing states are Andhra Pradesh, Karnataka and Tamil Nadu (Koul and Chase, 2015). Because of its typical nature of "never die", the tree in Africa is termed as "Nebedaye". Stronger adaptability to different soil and climate, easy propagation, and lesser managemental requirements are the major drivers for its wider distribution across the globe. As a result, the Moringa tree is known by different names in different languages across the world (Table 1).

NUTRITIONAL VALUE OF LEAVES

The *M. oleifera* is well known for its multiplicity of usages (Meireles et al., 2020). The tag "miracle tree" perfectly matches with the crop as its each and every part (leaves, flowers, seeds, pods, bark, roots) is useful to the human being as a source of essential nutrients. Since several thousand years, *M. oleifera* has been reported to be consumed in different culinary ways. Owing to the higher contents of protein (particularly the sulphur containing amino acids), vitamins (A, B and C) and minerals (Calcium, Iron), the leaf powder is one of the highest marketable items of the Moringa plant (Table 2). Often, Moringa leaves are reported to contain seven times higher vitamin C than oranges, ten times more vitamin A than carrots, seventeen times more Calcium than milk, nine times more protein than yoghurt, fifteen times more Potassium than banana, twenty-five times more Iron than spinach (Gopalkrishna et al., 2016; Trigo et al., 2020). The leaves of the plant could be eaten as fresh or cooked. As the leaves are rich in essential nutrients, pregnant or lactating mother could consume the dried powder leaves for their health as well as baby's growth and development in underdeveloped countries suffering from malnutrition (McBurney et al., 2004). The leaves (either fresh or dry) of Moringa could also be used for animal feeding (Samanta et al. 2011), particularly in dairy cows (Sancheza et al., 2006). The Moringa leaf extract is also reported to be used in fish feed formulation (We et al., 2020).

Table 1. Name of Moringa tree in different languages

Language	Termed as
Adia (Benin)	Kpashima
Arabic	Saisam, Rawag
Bengali	Sajna, Sojna, Sujana
Burmese	Daintha, Dandalun, Dandalonbin
Chinese	La mu, Lat mok
Daggai (Cameroon)	Paizlava
English	Drumstick tree, horseradish tree, Mother's Best Friend, West Indian Ben
Fiji	Sajina
French	Acacia blanc, Neverdie, Moringa aile, Ben aile, Benzolive
Germany	Behenbaum, Behenussbaum, Flugelsaniger Bennusssbaum, Pferderettichbaum
Hindi	Shajna, Munaga, Munga ara, Sahijna, Sarinjan, Sarinna
Indonesia	Kelor
Italian	Sandaloceruleo
Konkani	Moosing, Mosing
Latin	*Moringa oleifera*
Malayalam	Sigru, Moringa, Muringa, Morunna, Murinna
Marathi	Sujna, Shevga, Shivga
Moree/ Mossi (Burkina Faso)	Alsamtiga, Argentiga, Arzan taiga
Nepali	Sitachini, Sohijan, Shobhanjan
Oriya	Munigha, Sajina
Portuguese	Acacia branca, Cedra, Marungo
Punjabi	Sejana
Sanskrit	SigruShobhanjan, Sobhan jana, Shobanjana, Danshamula
Sara (Chad)	Kagn'dongue
Spanish	Paraiso blanco, Paraiso frances, Reseda
Swahili (Kenya)	Mkimbo, Mlongo, Mronge, Mrongo, Shingo
Tamil	Murungai, Morunga
Telegu	Mualga, Sajana, Tella-Munaga
Thai	Kaanaeng-doeng, Ma khonkom, Ma rum
Urdu	Sahajna

Table 2. Nutrient profile of dried Moringa leaves (Meireles et al., 2020)

Nutrients	Proportion per 100 g
Carbohydrates (g)	36±9.2
Protein (g)	24±5.8
Total lipid (g)	6±2.5
Dietary fibre (g)	20.6 to 28.6
Vitamin A (µg)	3639±1979
Thiamine (mg)	2.6
Riboflavin (mg)	1.29 to 20.5
Vitamin E (mg)	56 to 113
Vitamin C (mg)	172±37.7
Total folate (µg)	540
Calcium (mg)	1897±748.4
Phosphorus (mg)	297±149
Sodium (mg)	220±180
Potassium (mg)	1467±748
Iron (mg)	32.5±10.7
Zinc (mg)	2.4±1.1
Copper (mg)	0.9±0.48

BIOACTIVE PLANT COMPOUND

The bioactive plant compound (BPC) refers to any non-nutritive plant sourced molecule that exhibits positive effects following its consumption (Matic et al., 2018). It includes a molecule that is present in small quantity in plants and could play a critical role for good health and wellbeing in both human and animals. Ideal plant sourced bioactive molecules are secondary metabolites, which are not essential for plant growth, nevertheless, it plays an important role for the plant's survivability (Kennedy et al., 2011). The *M. oleifera* has been reported to be rich in numerous bioactive molecules such as vitamins, carotenoids, polyphenols, phenolic acids, flavonoids, alkaloids, glucosinolates, isothiocyanates, tannins and saponins (Leone et al., 2015; Mbikay et al., 2012; Vergara-Jimennez et al., 2017). The antioxidant activity of Moringa is due to the presence of higher contents of flavonoids, namely rutin, quercetin, rhamnetin, kaempferol, apigenin, and myricetin (Rani et al., 2018). The predominant glucosionalate present in *Moringa spp.* is 4-O-(α-L-rhamnopyranosyloxy)-benzyl glucosinolate; popularly known as glucomoringin. Enzymatic hydrolysis of glucosionalte leads to production of iosthiocyanate; responsible for anticancer, antimicrobial and anti-inflammatory effects (Park et al.,

2011; Padla et al., 2012; Waterman et al., 2014). The phenolic acids of *Moringa spp.* include gallic acid, ellagic acid, ferulic acid, caffeic acid, o-coumeric acid, chlorogenic acid, para-coumeric acid, sinapic acid (Leone et al., 2015a; 2015b).

NUTRITIONAL VALUE OF SEED AND POD

The Moringa finds its place as most favoured cultivated tree species to the people of different centuries because edible parts of the plant are tasty, nutritious and possess desirable flavour. In that direction, seeds and pods of Moringa are no way behind the leaves and reported to be rich in protein, vitamins and critical minerals (Table 3).

Table 3. Nutrient profile of Moringa seed and pods (Gopalkrishna et al., 2016)

Nutrients	Dried Moring plant parts	
	Seed	Pods
Protein (g/100g)	35.97	2.5
Fat (g/100g)	38.67	0.1
Carbohydrates (g/100g)	8.67	3.7
Fiber (g/100g)	2.87	4.8
Vitamin B1 (mg/100g)	0.05	0.05
Vitamin B2 (mg/100g)	0.06	0.07
Vitamin B3 (mg/100g)	0.2	0.2
Vitamin C (mg/100g)	4.5	120
Vitamin E (mg/100g)	751	-
Calcium (mg/100g)	45	30
Magnesium (mg/100g)	635	24
Phosphorus (mg/100g)	75	110
Potassium (mg/100g)	--	259
Copper (mg/100g)	5.2	3.1
Iron (mg/100g)	--	5.3
Sulphur (mg/100g)	0.05	137

THERAPEUTIC VALUES

Approximately, 80% of the world's population relies on natural herbs for healthcare because of the ease of accessibility, affordability and finally free from unwarranted side effects (Tshabalala et al., 2019). Owing to the presence of numerous

phytochemicals and richness of vital nutrients, most of the plant parts of *Moringa spp.* are used in traditional medicine since ancient times (Table 4). The raw or crushed seeds of Moringa could be used for the remedy of stomach pain, ulcer, poor vision, joint pain (Popoola and Obembe, 2013). The seeds or its extract are recorded to overcome the adverse effects caused by aging and cancer (Singh et al., 2009). Application of ethanolic extract of Moringa seed alleviates broncho-alveolar inflammation by lessening the infiltration of inflammatory cells in lungs, coupled with reduced secretion of inflammatory mediators in the airways of asthma-induced rats (Mahajan et al., 2007). Dosing with Moringa seed powder resulted into reduced nocturnal heart rate, followed by improvement of cardiac diastolic function in experimental animals (Randriamboavonjy et al., 2016).

Table 4. Therapeutic application of *Moringa oleifera* plant parts (Anwar et al., 2007)

Plant parts	Purpose
Root	Antilithic, rubefacient, vesicant, carminative, laxative, anti-inflammatory, cardiac/circulatory tonic, used against articular/ lower back/ kidney pains etc.
Leaf	Purgative, used for piles, fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh, anti-diabetic etc.
Stem bark	Rubefacient, vesicant and used to cure eye diseases, prevents enlargement of the spleen and formation of tuberculous glands of the neck, destroys tumors and heals ulcers.
	The juice from the root bark is put into ears to relieve earaches and also placed in a tooth cavity as a pain killer.
Gum	Used for dental caries.
	Gum, mixed with sesame oil, is used to relieve headaches, fevers, intestinal complaints, dysentery, asthma etc.
	Treatment of syphilis and rheumatism.
Flower	Higher medicinal value as a stimulant, aphrodisiac, abortifacient, cholagogue. Used to cure inflammations, muscle diseases, hysteria, tumors, enlargement of the spleen.
	Lowers serum cholesterol, phospholipid, triglyceride, VLDL, LDL cholesterol etc.
Seed	Seed extract reduces liver lipid peroxides and possesses antihypertensive compounds such as thiocarbamate and isothiocyanate glycosides.

In spite of wider usages of Moringa in traditional/ alternate medicine, data on human subjects is frugal. Later on, several research demonstrated significant decline in both fasting and postprandial blood glucose level of patients suffering from type-2 diabetes as a result of dosing with tablet of *M. Oleifera* dried leaf (Kumari, 2010; Nambiar et al., 2010; Ghiridhari et al., 2011). Moringa is also reported to be used for the treatment of sore throat,

ear infections, sprain, hypertension, cough, anxiety, headache, hysteria, skin infections, epilepsy, for intestinal worms, respiratory disorders, joints pain, anaemia, blackheads, bronchitis, lactation diabetes, abnormal blood pressure, chest congestion, asthma, fever, tuberculosis, hyperthyroidism and Herpes Simplex virus type -1 (Lipipun et al., 2003; Mishra et al., 2012; Singh and Singh, 2019).

VALUE ADDED PRODUCTS

Moringa oleifera is well known tree for producing leaves, pods, flowers and seed charged with essential nutrients (amino acids, micro and macro elements, vitamins, essential fatty acids) and diverse nutraceutical molecules (Gopalkrishna et al., 2016; Rockwood et al., 2013). This gives the opportunities to the entrepreneurs for development of numerous value-added products from plant parts of *Moringa oleifera*.

MORINGA LEAF POWDER

The Moringa leaf powder is one of the most sought value-added products from this divine tree as it possesses remarkable nutritional and medicinal properties (Mishra et al., 2012). Both young and matured leaves are suitable for powder making. As leaves could easily loose moisture after collection, the harvesting is routinely advocated in the early morning. Immediately after harvesting, the leaves are cleaned manually in order to remove stem, dirt and other extraneous material. Thereafter, the collected leaf samples are shade dried till it becomes crisp with moisture nearing to or less than 10% (Fig. 1). Then dried leaves are subjected to grounding to have uniform particle size of 100 µm (Jagadeesan et al., 2020). The dried Moringa leaf powder is exceptionally good source of provitamin A, vitamin B & C, minerals, sulphur containing amino acids such as methionine and cysteine. The leaf powder could be stored up to six months subjected to its protection from light and humidity.

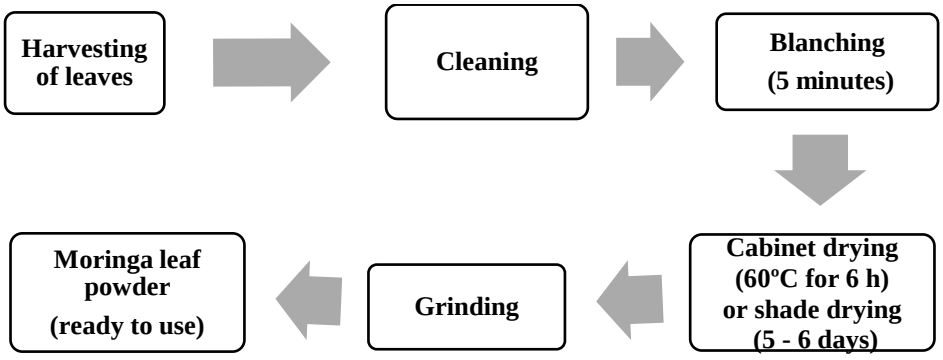

Figure 1. Steps for making of Moringa leaf powder (Reddy et al., 2020)

The leaf powder is reported to be used as an ingredient (5 to 10%) for the preparation of South Indian traditional dish i.e., “Idli” without compromising its sensory qualities

(Reddy et al., 2020). Further, the powder could also be used for the preparation of Moringa peanut chutney powder, Moringa chutney powder, Moringa rice powder, Moringa sambar powder, Moringa plain spread etc (Jagadeesan et al., 2020). Currently, a series of value-added products are being manufactured and marketed in India from Moringa leaves including Moringa leaf tablets, Moringa capsule, Moringa tea, etc (Sekhar et al., 2018).

MORINGA OIL

The seeds of *Moring oleifera* contains around 36% oil (W/W) with higher content of oleic acid and popularly known as "Ben oil" or "Behen Oil" (Leone et al., 2016). Looking at the fatty acid profile, it contains around 20.58% saturated fatty acids, 76.81% mono-unsaturated fatty acids and 1.25% poly-unsaturated fatty acids (Table 5). The saturated fatty acid component of Moringa oil is predominantly comprised of palmitic acid, followed by behenic acid, and stearic acid. In the bracket of poly-unsaturated fatty acids, the primary components are linoleic acid and linolenic acid. The oil present in the Moringa seed could be extracted either by solvent extraction or mechanical process.

Table 5. Fatty acid profile of Moringa oil (Leone et al., 2016)

Components	Proportion (%)
Saturated fatty acids (SFA)	21.18±2.24
Margaric acid (C17:0)	0.07±0.02
Stearic acid (C18:0)	4.97±1.03
Arachidic acid (C20:0)	3.23±0.70
Behenic acid (C22:0)	6.02±0.75
Lignoceric acid (C24:0)	0.36±0.63
Cerotic acid (C26:0)	0.92±0.39
Mono-unsaturated fatty acids (MUFA)	76.73±2.89
Palmitoleic acid (C16:1)	1.37±0.63
Oleic acid (C18:1)	73.57±3.38
Gadoleic acid (C20:1)	1.81±0.85
Erucic acid (C22:1)	0.11±0.06
Poly-unsaturated fatty acids (PUFA)	1.18±0.50
Linoleic acid (C18:2)	0.76±0.41
Linolenic acid (C18:3)	0.46±0.74

Irrespective of extraction process, the Moringa oil contains sterol comprising of β-sitosterol, stigmasterol, campesterol and avenasterol. Therefore, Moringa oil could be

the substitute for olive oil for human food consumption in addition to its application for non-food usages such as biodiesel, cosmetics, lubricant for fine machineries etc. According to the Indian Ayurvedic claims, the Moringa oil possesses anti-tumor, anti-pyretic, anti-epileptic, anti-inflammatory, anti-ulcer, anti-spasmodic, anti-oxidant, anti-bacterial, anti-fungal, cholesterol reducing, diuretic etc.

CONCLUSION

As *Moringa oleifera* could be grown and propagated with easy to do cultivation practices, initiatives should be taken for its large-scale extension activities with distribution of either seed or stem cuttings among the large population, both rural and urban setup. Owing to its richness with varieties of essential nutrients and bioactive molecules, tree parts (leaves, drumstick, flower, root) could be the used for solving health problems such as malnutrition, stunted growth, vitamin deficiency, mineral deficiency and lifestyle diseases. Stress is one that is faced by all classes of people across the world irrespective age group. As Moringa seed and leaves are rich in antioxidant, several value-added products could be generated to augment the stress. Taking into account the knowledge of traditional medicines coupled with growing demands of plant sourced bioactive molecules, the *Moringa oleifera* perfectly emerges as an ideal tree for extensive research and investigation for variety development, agronomic practices, harvesting protocol, value added product generation and testing, real time data on benefits of Moringa consumption, commercialization etc.

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