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Moringa oleifera Lam.: Panacea to several maladies

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Moringa oleifera Lam.: Panacea to several maladies

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ABSTRACT

Moringa oleifera Lam. (Moringaceae), a 'miracle tree' is grown in many countries of tropics and sub-tropics. It has proved to be an excellent source of phytonutrients and has therefore nutritional and medicinal applications for both human and animals. It is a cost-effective, easily procurable and a rich source of multi-vitamins (vitamin A, B and C), proteins, calcium, potassium and possess a unique combination of zeatin, quercetin, sitosterol, kaempferol and caffeoylquinic acid. The unopened floral buds, immature pods and leaves are used for various culinary preparations worldwide. Every part of this tree possesses some or the other nutritional and medicinal property. It is a reservoir of dietary supplements and act as cardiac and circulatory stimulant with antioxidant, anti-inflammatory, antipyretic, antiepileptic, antitumor, anticancer, diuretic, antihypertensive, antispasmodic, hypocholesteremic, antidiabetic, antibacterial, antifungal, antiulcer and hepatoprotective properties. Apart from medicinal benefits it is deployed in re-forestration program, used as fodder for livestock, as a biosorbent for heavy metals and in water treatment. The seed-oil is frequently used in lubricants, skin lotions and is a promising biodiesel. This review focuses on the explicit economic importance of this versatile and super food tree which miraculously combats malnutrition and serves humanity.

Keywords: *Moringa oleifera*, Miracle tree, Drum-stick, Nutritive value, Biodiesel.

INTRODUCTION

Since the inception of human civilization man has been searching for food which can keep him healthy and active. In this modern era of research and technology this futile search still continues to discover novel herbal drugs and alternate source of nutritional supplements. One such promising tree which has successfully cleared all the tests of nutritional benefits, medicinal properties, environmental and consumption safety is the perennial, multipurpose, softwood-tree '*Moringa oleifera*' of the monogeneric family Moringaceae. *M. oleifera* is reputedly known as 'horseradish' tree, 'drumstick' tree, 'ben-oil tree' or 'benzoil tree', 'cabbage tree', 'mother's best friend' and 'miracle tree'. It is a native of Indian sub-continent and is cultivated worldwide owing to its numerous utilities [1-3]. A single *Moringa* tree can provide leaf as a source of nutrition for human and livestock, seed-oil for cooking and biodiesel, seed-cake for water purification and wood to build shelter. Every part of this tree is edible and the leaves, roots, seeds, root-bark, stem-bark and pods have medicinal properties. The unopened flowers are eaten as vegetable or used to make tea which provides adequate amounts of calcium and potassium. The young pods are also used in various culinary preparations and pickles [4]. *Moringa* was highly valued in the ancient world. The history of *Moringa* dates back to 150 B.C. which reveals that the ancient kings and queens preferred *Moringa* leaves and fruit in their diet to sustain mental alertness and healthy skin. The ancient Maurian warriors of India were fed with *Moringa* leaf extract in the warfront. The elixir-drink was assumed to add them extra vigour and relieve them of the trauma incurred during war [5].

The nutritional value of *Moringa* leaves is of utmost importance because a single gram of leaf powder is packed with 25 times the iron of spinach, 17 times the calcium of milk, 15 times the potassium of bananas, 10 times the vitamins of carrots, 9 times the protein of yoghurt, and 0.5 times the vitamins of oranges. Apart from vitamins and minerals *Moringa* leaves have been characterized to contain a desirable nutritional balance of minerals, amino acids, and fatty acids [3,6]. Moreover, they contain various antioxidant compounds such as ascorbic acid, flavonoids, phenolics, and carotenoids [7,8,9]. *Moringa* tree products have been used to combat malnutrition, especially among infants and nursing mothers. Three non-governmental organizations in particular—Trees for Life, Church World Service and Educational Concerns for Hunger Organization have advocated *Moringa* as “natural nutrition for the tropics. The practice of *Moringa* consumption, with full credence has been in tradition among many tribes of Asia. As the authenticity of *Moringa* benefits have been confirmed through several years, therefore, many pharmaceutical and herbal healthcare industries sell various *Moringa* products like *Moringa*-capsules, *Moringa*-tea, *Moringa*-oil, *Moringa*-soap, *Moringa*-shampoo, *Moringa*-antiwrinkle cream etc. *Moringa* is actually a versatile tree and a nature’s medicine cabinet [10]. It contains various glycosides of thiocarbamate and isothiocyanate class. Moringyne, pterygospermin, niaziridin, 4-(α -L-rhamnopyranosyloxy) benzyl isothiocyanate, 4-(α -L-rhamnopyranosyloxy) benzyl glucosinolate, etc [11] are some of the therapeutically proven compounds, reported in *Moringa*. Many diseases and chronic symptoms can be overcome by the virtue of its antihypertensive, antiasthmatic, diuretic, anticancer, antibiotic, antiulcer, analgesic, central nervous system (CNS)-depressant, antiepileptic, antiinflammatory, antihelminthic and antiurolithiatic properties [3,4,12-14]. Apart from human health the other promising uses include biosorption of toxic metal ions, water purification through particle sedimentation, plant growth enhancer through leaf juice sprays, biodiesel production from seeds and biogas production from leaves [15-19]. Nowadays, various workshops are conducted worldwide for dissemination of information on the nutritional, medicinal and various other promising benefits of *Moringa*. In a nut-shell, *M. oleifera* is an asset to mankind and therefore rightly called as a “Miracle tree” [2].

Taxonomic position

Moringa is the only genus in the family *Moringaceae* and *Moringa oleifera* is the most extensively studied and cultivated species.

Kingdom	- Plantae
Super kingdom	- Tracheobionta
Super division	- Spermatophyta
Division	- Magnoliophyta
Class	- Magnoliopsida
Sub class	- Dilleniidae
Order	- Capparales
Family	- Moringaceae
Genus	- <i>Moringa</i>
Species	- <i>oleifera</i>

Distribution

Moringa oleifera is a native of India. Its cultivation extends in the Himalayan foothills of south Asia from north eastern Pakistan to north-western Bengal in India and north-eastern Bangladesh at an elevation of 1400m above sea level (Fig. 1). It is extensively grown near houses in Assam, Bengal and Peninsular India and also maintained as a coppice. Its cultivation and usage has gained momentum in South East Asia, West Asia, Arabian Peninsula, East and West Africa, West Indies and Southern Florida, Central and South America from Mexico to Peru including Brazil and Paraguay [20]. About 33 species have been reported in the family *Moringaceae* [21]. Among those, thirteen species namely, *M. arborea*, *M. borziana*, *M. concanensis*, *M. drouhardi*, *M. hildebrandtii*, *M. longituba*, *M. oleifera*, *M. ovalifolia*, *M. peregrina*, *M. pygmaea*, *M. rivae*, *M. ruspoliana*, *M. stenopetala* are well known and found worldwide (Table 1). The Table 2 contains a list of common names of *M. oleifera*. India is the largest producer of *Moringa*, with an annual production of 1.1 to 1.3 million tonnes of pods from an area of 380 km². Among the states, Andhra Pradesh leads in both area and production (156.65 km²) followed by Karnataka (102.8 km²) and Tamil Nadu (74.08 km²). In other states, it occupies an area of 46.13 km².

Habit

Moringa oleifera is a fast-growing evergreen or deciduous tree and attains a height of 10-12 metres. It bears drooping, fragile branches covered with thick, corky, whitish bark [22]. *Moringa* does not require much water for

growth and so can be grown in dry regions where there is scanty or uneven rainfall. Although, it tolerates a wide range of soil conditions, but prefers a neutral to slightly acidic (pH 6.3 to 7.0), well-drained sandy or loamy soil. Figure 2 shows a part of young branch with green leaves, flowers and immature pod. The Table 5 consists of morphological description of different parts of *Moringa* tree.

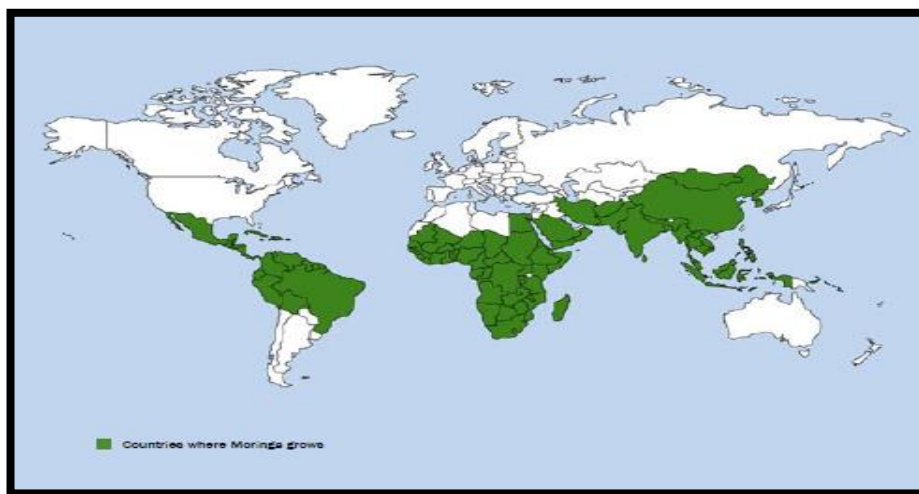


Figure 1 World map showing countries where *Moringa* is extensively grown (green)

Nutritional properties

Moringa is a super food tree with a remarkable source of proteins, calcium (Ca), Iron (Fe) and vitamin C. It contains all the essential nutritional elements that are vital for human beings and livestock [3,18,23]. It has been demonstrated that the dry leaves of *M. oleifera* contain 7 times more vitamin C than orange, 10 times vitamin A than carrot, 17 times calcium than milk, 15 times potassium than bananas, 25 times iron than spinach and 9 times proteins than yogurt. In addition, it contains vitamin B, chromium, copper, magnesium, manganese, phosphorus and zinc. Being a rich source of proteins *Moringa* leaves are recommended by doctors, nutritionists and community health workers to cope with the problems of malnutrition worldwide [3,4,24]. Due to these assets, there are several *Moringa* supplements now available in the market [25-27]. *Moringa* contains 40.139 mg total carotenoids /100g fresh leaves, of which 47.8% (18.9 mg/100g) is β -carotene, which is adequate for the dietary requirements of children, adults and lactating mothers as shown in Table 3 [28,29]. Moreover, 100g of the dried leaves contain 660 mg ascorbic acid, 28.2 mg iron, 2,003 mg calcium, 630 mg phosphorus, 1,120 mg oxalic acid and 0.9 g fibre. Studies on *Moringa* has revealed its potential to combat vitamin A and other micronutrient deficiencies [28,30,31]. *Moringa* leaves also possess amazingly higher methionine + cysteine (43.6 g kg^{-1} protein) contents which are similar to that of human milk, cow's milk and chicken egg. Makkar and Becker (1997) [32] studied the nutritional status of different parts of *Moringa* plant. They analysed that the leaves contained 260 g kg^{-1} crude protein while soft twigs and stems contain 70 g kg^{-1} and 60 g kg^{-1} crude protein, respectively. The degradation ability of crude protein in rumen per 24 h was about 64, 79 and 67% of the total dry matter present in the leaves, twigs and stems, respectively. No trypsin, lectins and amylase inhibitors, cyanogenic glucosides and glucosinolates were found in leaves but, a negligible amount of tannins i.e., 12 g kg^{-1} was observed. In comparison to soybean leaves, *Moringa* leaves contain higher amount of essential amino acids which fulfils the optimal standardized requirements of World Health Organization (WHO).

Moringa leaves have high percentage of antioxidants (260 mg/ 100 g) along with polyphenol contents (260 mg/100g), quercetin (100 mg/100 g), kaempferol (34 mg/100 g) and β -carotene (34 mg/100 g). Arabshahi et al., 2007 [33] compared the leaf antioxidant activity of *Moringa oleifera*, *Mentha spicata* and tubers of *Daucus carota* on the basis of oxidation of linoleic acid and sunflower oil. It was observed that *Moringa* leaves had highest antioxidant activity of 83% and 44% under both lipid systems, respectively. A similar study reported that *Moringa* leaves possess superior antioxidant activity than amla (*Embllica officianalis*) and rasins (*Vitis vinifera*) which are themselves reputed natural source of antioxidants [34]. The methanol and ethanol extracts of *Moringa* leaves have best antioxidant properties with a high percentage of 80 and 70, respectively [35,36]. Contrary to previous reports,

Sreelatha and Padma (2009) [37] reported that aqueous extract of both mature and young *Moringa*-leaves possess considerable antioxidant activity.



Figure 2 A young branch of *Moringa oleifera* tree with flowers and pod

Like the mineral composition climatic variations does affect the antioxidant activity of *Moringa* leaves [36]. Apart from seasonal variation, different leaf development stages influence nutrient contents of *Moringa* leaves. It was analysed that protein, vitamin A, glucosinolate content and antioxidant activity were higher in plants of hot-wet season, while iron, vitamin C, and phenolic contents were higher in cool-dry season plants. Mature *Moringa* leaves are more nutritious than young ones which showed minimum losses after drying. *Moringa*-fodder possesses high nutritional value with 22.8% crude protein, 30.8% neutral detergent fibre (NDF) and 22.8% acid detergent fibre (ADF). The seeds are also rich in crude protein, crude fat, carbohydrate and ash, at a concentration of 332.5 g kg⁻¹, 412.0 g kg⁻¹, 211.2 g kg⁻¹ and 44.3 g kg⁻¹, respectively [38,39]. In a nut-shell *M. oleifera* leaves meal are good feed sources for hens, broiler chickens, livestock, fish, rabbits etc [40-43].

Moringa seed contains appreciable quantity of oil, popularly known as 'Ben-Oil' in dehulled (~42%) and shelled seeds (25-37.5%), respectively, depending on the extraction methods (ethanol, methanol or acetone), soil-type and environment conditions. This oil is used in lubricants, perfume industry and cooking purposes. It has an appreciable shelf life hence avoids rusting and oil sticking in machines [44,45]. It contains 0.5–3% free fatty acids, approximately 13% saturated and 82% unsaturated fatty acids. The oils rich in unsaturated fatty acids like oleic acids are more acceptable as these are more stable against oxidative rancidity and ensures low risks of coronary diseases [12,46]. Normally, the vegetable oils contain 40% oleic acid contents, while ben-oil has a tremendous concentration of oleic acid of 70 to 75% depending on climate and genetic variation which is comparable with olive, canola, sunflower and safflower oils [47,48]. *Moringa* cultivation on one hectare land yields ~3000 kg of seeds

which ultimately yields ~900 kg oil, while 3000 kg soybean seed yields 600 kg oil which is approximately 30% less than ben-oil yield [49]. The seed extract has antimicrobial properties and it is highly acceptable for perfume, hair care and cosmetics industry around the world [50-52]. Similar to *Moringa* leaf meal, the seed meal (after oil extraction) being a rich source of energy/calories is used in poultry industry. Similar to antioxidant activity, the ben-oil yield and composition is also significantly affected by genetic variation, edaphic and climatic conditions. The tocopherol contents of ben-oil from saline and non-saline areas show significant difference. Soil salinity does not affect the composition, physical characteristics and efficacy of *Moringa* seed oil except tocopherol contents and fatty acids [48,53]. Higher concentration of tocopherol (Vitamin E) in *Moringa* seed oil indicates the potency and higher antioxidant activity [12,54]. Because of its fat contents and highly constant oxidative stability, ben-oil is a good alternative to vegetable oil [48]. Different vegetable oils have shown reduction in oil contents when extracted from plants grown in water deficit areas and similarly the best quality *Moringa* seed oil can be found near the rivers and streams [55,56]. The *Moringa* plants of irrigated areas yielded about 36.8–40.4% while the drought areas yield only 30.36–34.66 % oil [47,48,57].

Table 1: Geographic distribution of documented thirteen *Moringa* species [21]

Species	Geographical location
Slender trees	
<i>M. concanensis</i> Nimmo	India
<i>M. oleifera</i> Lam.	India
<i>M. peregrina</i> (Forssk) Fiori	Fiori Red Sea, Arabia, Horn of Africa
Bottle trees	
<i>M. drouhardii</i> Jum.	Madagascar
<i>M. hildebrandtii</i> Engl.	Madagascar
<i>M. ovalifolia</i> Dinter & A. Berger	Namibia and S.W. Angola
<i>M. stenopetala</i> (Baker f.) Cufod	Kenya and Ethiopia
Tuberous shrubs and herbs of North Eastern Africa	
<i>M. arborea</i> Verdc.	North Eastern Kenya
<i>M. borziana</i> Mattei	Kenya and Somalia
<i>M. longituba</i> Engl.	Kenya, Ethiopia, Somalia
<i>M. pygmaea</i> Verdc	North Somalia
<i>M. rivae</i> Chiov.	Kenya and Ethiopia
<i>M. ruspoliana</i> Engl.	Kenya, Ethiopia, Somalia

Table 2: Some common names of *Moringa oleifera*

Language	Common names
Latin	<i>Moringa oleifera</i>
Sanskrit	Subhanjana
Hindi	Saguna, Sainjana
Punjabi	Sainjana, Soanjana
Bengali	Sojne danta
Gujarati	Suragavo
Marathi	Shevga
Tamil	Morigkai
Telugu	Mulaga, Munaga,
Malayalam	Muringa, Sigru
Ayurveda	Haritashaaka Tikshnagandhaa, Raktaka, Akshiva
Unani	Sahajan
Arabian	Rawag
French	Moringe à graine ailée, Morungue
Spanish	Àngela, Ben, Moringa
Portuguese	Moringa, Moringueiro
Chinese	La Ken
English	Drumstick tree, Horseradish tree, Ben tree

Phytochemistry

Phytochemical analysis of *M. oleifera* has shown the presence of a range of unique compounds with several medicinal, nutraceutical and pharmaceutical properties (Table 4). The ethanolic extract of leaves contain two nitrile glycosides, three mustard oil glycosides niazirin, niazirinin, niaziminin A and B and 4-[(4'-o-acetyl- α -L-

rhamnosyloxy) benzyl] isothiocyanate [58]. They also contain 4-(α -L-rhamnopyranosyloxy)-benzylglucosinolate and three monoacetyl-isomers of glucosinolate. Quercetin which is one of the most biologically active flavonoids is found as quercetin-3-o-glucoside and quercetin-3-o-(6'-malonyl-glucoside). It acts as a potent polyphenol antioxidant and immune system modulator. Its immune support attributes are enhanced by its synergistic association with vitamin C. Quercetin is the natural compound that assists optimal bone health, scavenge free radicals in the body which damage cell membranes, alter the DNA, and even cause cell death. Quercetin appears to protect against the damage caused by LDL ("bad") cholesterol and may help prevent death from heart disease. By its anti-inflammatory action it helps to stabilize the cells that release histamine in the body. They also contain 3-caffeoylquinic acid, 5-caffeoylquinic acid and kaemferol is found as Kaemferol-3-o-(6"-malonyl-glucoside [59]. The caffeoylquinic acid has anti-hypertensive and anti-cancer properties while kaemferol exhibits anti-diabetic, anti-bacterial, anti-viral anti-cancer and cardio-protective properties. *Moringa* stem is a source of vanillin, 4-hydroxymellein, β -sitosterol, β -sitisterone and octaconic acid and the bark contains 4-(α -L-rhamnopyranosyloxy)-benzylglucosinolate [59]. The exudates (gum) of *Moringa* plant contain D-mannose, D-xylose, D-galactose, D-glucuronic acid, L-arabinose and L-rhamnose. A new compound (leucoanthocyanin) leucodelphinidin-3-o- β -D-galactopyranosyl (1-4)-o- β -D-glucopyranoside, has been reported in gum [60]. The roots of *M. oleifera* have high concentrations of both 4-(α -L-rhamnopyranosyloxy)-benzylglucosinolate and bezylglucosinolate which are supposed to be possess anti-cancer properties [59].

Table 3: Vitamins, minerals and amino acids content per 100 gm of *Moringa oleifera* leaves

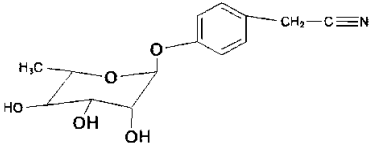
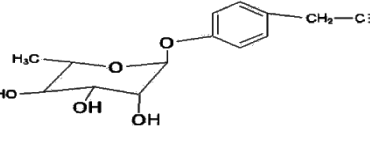
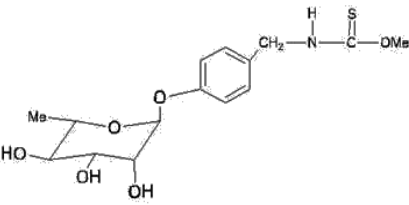
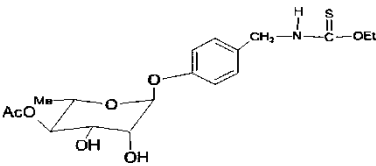
Nutrient component	Fresh leaves	Dried leaves
Vitamins		
Carotene (Vit. A)*	6.78 mg	18.9 mg
Thiamin (B1)	0.06 mg	2.64 mg
Riboflavin (B2)	0.05 mg	20.5 mg
Niacin (B3)	0.8 mg	8.2 mg
Vitamin C	220 mg	17.3 mg
Minerals		
Calcium	440 mg	2,003 mg
Calories	92 cal	205 cal
Copper	0.07 mg	0.57 mg
Iron	0.85 mg	28.2 mg
Magnesium	42 mg	368 mg
Phosphorus	70 mg	204 mg
Potassium	259 mg	1,324 mg
Zinc	0.16 mg	3.29 mg
Amino acids		
Arginine	406.6 mg	1,325 mg
Histidine	149.8 mg	613 mg
Isoleucine	299.6 mg	825 mg
Leucine	492.2 mg	1,950 mg
Lysine	342.4 mg	1,325 mg
Methionine	117.7 mg	350 mg
Phenylalanine	310.3 mg	1,388 mg
Threonine	117.7 mg	1,188 mg
Tryptophan	107 mg	425 mg
Valine	374.5 mg	1,063 mg
Others		
Carbohydrates	12.5 g	38.2 g
Fat	1.70 g	2.3 g
Fiber	0.90 g	19.2 g

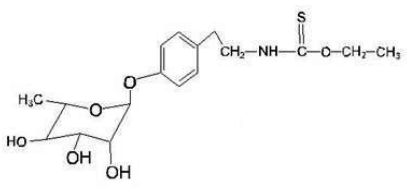
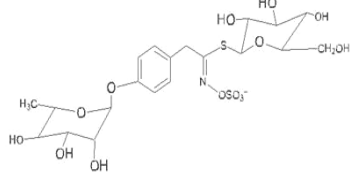
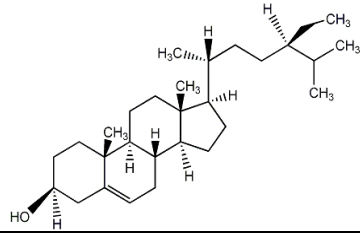
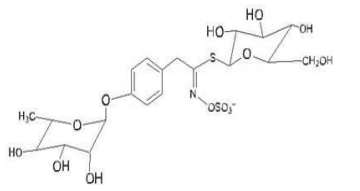
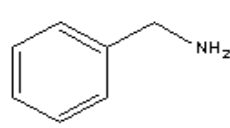
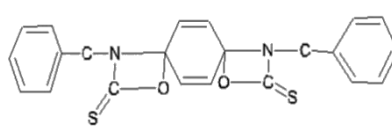
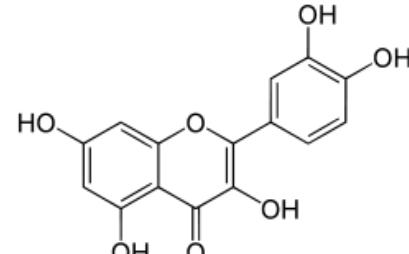
*Figures shown for vitamin A are carotene content for fresh leaves and beta-carotene content for dried leaves.

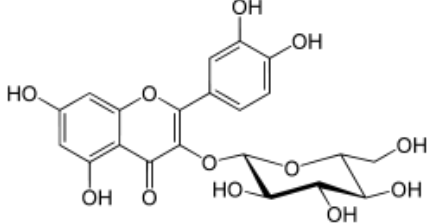
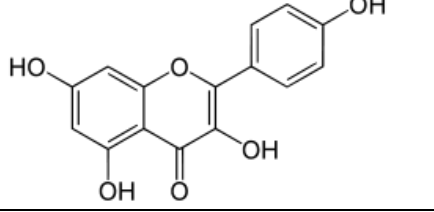
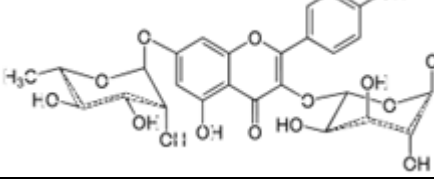
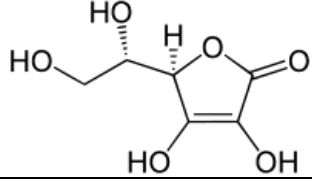
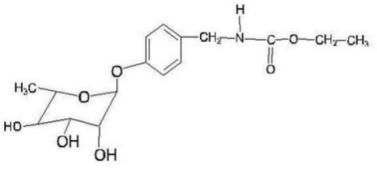
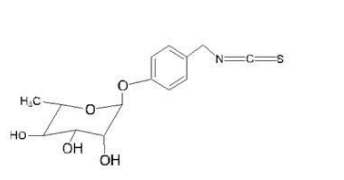
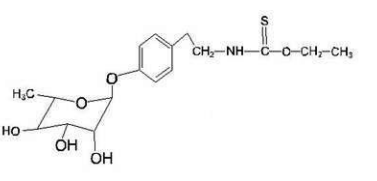
The extracts of the flowers contain D-glucose and D-mannose in the ratio of 5:1 along with proteins and ascorbic acid. They also contain polysaccharides which on hydrolysis give D-glucuronic acid, D-glucose, and D-galactose in a molar ratio of 0.9: 1:1.9 [61]. The pods contain nitriles, isothiocyanate compound, thiocarbamates, β -sitosterol, o-[2'-hydroxy-3'-(2"-heptenyloxy)]-propylundecanoate, o-ethyl-4-[(α -1-rhamnosyloxy)-benzyl] carbamate and methyl-*p*-hydroxybenzoate [58,62]. The mucilage from pods contains sugars (galactose, dextrose, xylose) and minerals (sodium, potassium, magnesium, calcium) salts of glucouronic acid [63]. The mature seeds contain 211.2 g carbohydrate, 412.0 g crude fat, 332.5g crude protein, and 44.3 g ash per kilogram dry matter. Although the essential

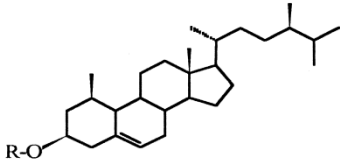
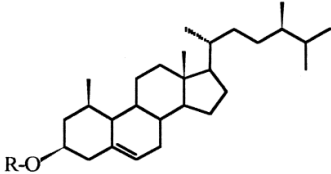
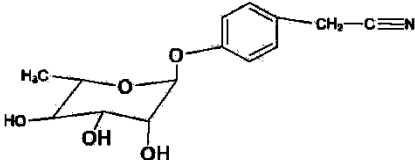
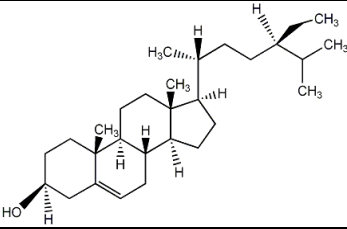
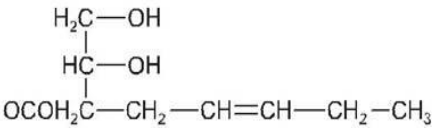
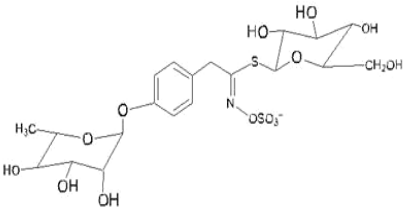
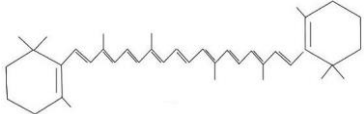
amino acids lysine, threonine and valine are not adequately present. But, the methionine + cysteine content (43.6g/kg protein) is exceptionally high which is similar to that of chicken egg, human and cow-milk [38]. Seeds do have elevated concentrations of both benzylglucosinolate and 4-(α -L-rhamnopyranosyloxy)-benzylglucosinolate which have potential action against cancers [59]. *M. oleifera* seeds hold 38.16% oil which further contains 0.01% Vitamin E and 0.014% beta carotene, a precursor of vitamin A [64]. Moringyne ($C_{15}H_{20}O_7$), a glycoside is also found in extracts of the seeds [65]. The benzene extract of semi-dried seeds is a source of mono-palmitic and di-oleic triglyceraldehydes [66]. The hexane-extracted oil content of seeds ranged from 38.0-42.0% while the protein, fibre and ash contents were found to be 26.50-32.00%, 5.80-9.29% and 5.60-7.50%, respectively [57]. The compounds, 4(α -L-rhamnosyloxy) benzyl isothiocyanate, 4(α -L-rhamnosyloxy) phenylacetone nitrile and 4(α -L-rhamnosyloxy) benzyl glucosinolate (and its thermal degradation product 4(α -L-rhamnosyloxy) phenylacetone nitrile) have been isolated from the hot water extract of raw seeds [67,68]. The physical and chemical characteristics of the oil are: iodine value: 68.00-71.80; refractive index (40°C): 1.4590-1.4625; density (24°C): 0.9036-0.9080 mg/ml; saponification value: 180.60-190.50 and unsaponifiable matter: 0.70-1.10%. The alpha, gamma and delta tocopherols present in the oil are 123.50-161.30 mg/kg, 84.07-104.0 mg/kg and 41.00-56.0 mg/kg, respectively. The oil contains 78.59% appreciable levels of oleic acid, followed by 7.0% palmitic, 7.50% stearic, 5.99% behenic and 4.21% arachidic acid [69].

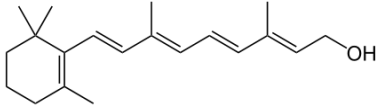
Table 4 Structures and properties of selected phytochemicals of *Moringa oleifera*

Plant part	Phytochemical	Chemical structure	Property	Reference
Leaves	Niazirin		Hypotensive activity	[1,12,59, 113,114, 115]
	Niazirin		Hypotensive activity	
	4-(4'-O-acetyl- α -L-rhamnopyranosyloxy)benzyl isothiocyanate		Antibacterial; Antitumor; Abortifacient properties; Anticancer; Hypotensive activity; Estrogenic; Antiprogestational; Hypoglycaemic; Antiulcer, Antihyperthyroidism; Hypocholesterolemic; Purgative and Antispasmodic effects	
	Niaziminin A and B		Blood pressure lowering activity; Antitumor activity	

	Niazimicin		Antispasmodic effects; Anticancer activity; Antibacterial; Anti tumour activity; Blood pressure lowering effect; Potent chemo preventive agent	
Bark	4-(α -L-rhamnopyranosyloxy)benzyl glucosinolate		Hypotensive; Anticancer; Antibacterial ; Antifungal activity	[12]
Stem	β -sitosterol		Anticancer property and hypotensive activity	[12]
Root	4-(α -L-rhamnopyranosyloxy)benzyl glucosinolate		Hypotensive; Anticancer; Antibacterial and Antifungal activity	
	Moringine		Cardiac stimulant; hypolipidemic property; bronchodilator activity	[12,98,114,115]
	Pterygospermin		Antimicrobial; antibacterial; anti fungal properties	
Flower	Quercetin		Antioxidant activity; Hepatoprotective activity	[12,98]

	Isoquercetin		Antioxidant activity	
	Kaempferol		Antioxidant activity	
	Kaempferitrin		Antioxidant, antimicrobial and anti-inflammatory activity	
	Ascorbic acid		Antioxidant activity	
Pods/Seeds	O-ethyl-4-(α -L-rhamnosyloxy)benzyl carbamate		Antitumor activity	
	4(α -L-rhamnosyloxy)-benzyl isothiocyanate		Antitumor and Antimicrobial activity; Hypotensive; Anticancer and antibacterial activity	[12,114]
	Niazimicin		Antispasmodic effects; Anticancer activity; Anti tumour activity; Blood pressure lowering effect; Potent chemo preventive agent	

	3- <i>O</i> -(6'- <i>O</i> -oleoyl- β -D-glucopyranosyl)- β -sitosterol	 <p>R = 6'-<i>O</i>-oleoyl-β-D-glucopyranosyl</p>	Antitumor and Anticancer property	
	β -sitosterol-3- <i>O</i> - β -D-glucopyranoside	 <p>R = β-D-glucopyranosyl</p>	Anticancer property	
	Niazirin		Hypotensive activity	
	β -sitosterol		Anticancer property	
	Glycerol-1-(9-octadecanoate)		Anticancer property	
	4-(α -L-rhamnopyranosyloxy)benzyl glucosinolate		Hypotensive; Anticancer; Antibacterial and Antifungal activity	
Seed oil	β -carotene		Antioxidant activity	[12]

Vitamin A		Prevents blindness; Maternal mortality; enhances lactation (breast milk); Enhances immunity to fight infections	
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Medicinal properties



Leaves

Moringa oleifera is known for long time as an important nutritional supplement with a range of medicinal properties. According to India's ancient tradition of ayurveda, the leaves of the *Moringa* tree prevent 300 diseases. *M. oleifera* leaves works as antioxidant [33,37,70-74] which adds one more attribute to its known pharmacological importance. The best solvent for extraction of antioxidant compounds from *M. oleifera* leaves are methanol (80%) and ethanol (70%) [35]. The Table 5 shows an exhaustive summary of medicinal properties of different parts of *Moringa* plant. The fresh leaves can be rubbed against the temple to relieve headaches or applied as a poultice on shallow cuts to stop bleeding. *Moringa* leaf tea heals gastric ulcers and diarrhoea. Leaves treat fevers, bronchitis, eye and ear infections, and inflammation of the mucus membrane. The iron content of the leaves is high, and they are reportedly prescribed to overcome anaemia [12]. It's proved by research work that *M. oleifera* leaves extract is good to regulate the hyperthyroidism [75], antineoplastic agent to treat Sickle cell disease [76] and antiulcer agent [77]. It works as hypocholesterolemic agent in obese patients [78], antiproliferation and induction of apoptosis on human cancer cell [79] and was supported the study of Suphachai, (2014) [74] which provided evidence that *M. oleifera* leaves possess chemopreventive and cytotoxic properties. Therefore, it might prove beneficial as an alternative to anticancer drugs. *M. oleifera* leaves as ethnomedicine to treat diabetes mellitus [80], in addition the experimental findings by Soliman (2013) and Yassa (2014) [81,82] have indicated the potential benefits of using the aqueous extract of *M. oleifera* leaves as a potent antidiabetic treatment. As per the recommendation by the World Health Organization (WHO) 1-4 gram/day of *Moringa* leaf-powder is sufficient to meet the nutritional demands of an adult.

The findings of Ganatra et al., (2012b) and Panda et al., (2013) [83,84] suggests that the cardio-protective potential of the isolated alkaloid from *M. oleifera* leaves is mediated through its free radical scavenging property. Therefore, *M. oleifera* can be prescribed as food supplement for coronary artery disease patients along with their regular medicines [85]. *M. oleifera* also ameliorates alcohol-induced testicular toxicities with its antioxidant properties comparable to vitamin C [86]. An interesting study by Rao et al., 2001[87] demonstrates that pretreatment with the methanolic leaf extract of *M. oleifera* confers significant radiation protection to the bone marrow chromosomes in mice and leads to a 30 day prolonged survival after lethal whole-body irradiation. The study by Bakre et al., 2013 [88] has justified the traditional use of the *M. oleifera* leaves extract for the treatment of epilepsy. The leaves possess a dose-dependent CNS- depressant (sedative-hypnotic, anticonvulsant) effect possibly mediated via positive modulation of gamma-aminobutyric acid (GABA) receptor. It was reported by Shanker et al., (2007) [11] that *M. oleifera* leaves possess bio enhancer for drugs and nutrients (Niaziridin & Niazirin), which add another advantage for their use in pharmaceutical industry. The leaf extracts it should be kept in a cool place to prevent significant changes in chemical, physical and biological properties [89].

For antibacterial activity, it was found that different extracts of *M. oleifera* leaves are active against bacteria such as *E. coli*, *S. aureus*, *P. aeruginosa* and *B. cereus*, as these organisms range from pathogenic and toxigenic organism liable to cause food borne illnesses and food spoilage. The anti-bacterial properties of this plant is attributed to the possession of alkaloids, tannins and flavonoids and has been reported by many research groups [50,51,90-93]. It can be used as valuable drug in the treatment of infections caused by *E. coli*, *S. typhi* and *P. aeruginosa* [73,94,95]. Aqueous extract of *M. oleifera* leaves posses significant antimicrobial activity against gram positive and negative bacterial species. It is active against *E coli*, *S. aureus* and *B. subtilis* [96]. The extracts and juice of *M. oleifera* can be used to discover antibacterial agent for developing new pharmaceuticals to control studied human pathogenic bacteria responsible for severe illness [97].

Table 5: Therapeutic and other promising uses of *Moringa oleifera*

Plant part	Description	Medicinal properties/ miscellaneous uses	References
Leaves	 <p>The leaves are imparipinnate, bipinnate or tripinnate, upto 4-5 cm long. The leaflets of these compound leaves are 1-2 cm long, rounded or blunt-pointed at the apex and short-pointed at the base (aestivation is opposite) with entire.</p>	<p>Cures teenage acne; used as a purgative; applied as poultice to sores; rubbed on the temples for headaches; used for piles, prostrate, reduce fevers, sore throat, bronchitis, eye and ear infections, scurvy and catarrh; leaf juice is believed to control glucose levels; applied to reduce glandular swelling, bacterial infection, urinary tract infection; used as antipyretic, anti-proliferative, hepatic tonic, antioxidant, antiseptic, anti-hypertensive, diuretic, hypocholestermia; used for radiation-induced oxidative stress; thyroid disorder, hepatorenal, colitis, diarrhoea, dysentery, rheumatism; For iron, protein, Vitamin/mineral deficiency; used as lactation enhancer and scurvy tonic; used against Epstein-bar virus (EBV) and Herpes simplex virus (HSV), HIV-AIDS, helminthes and trypanosome infection.</p> <p>Used as salads and in vegetable curries; powder used for scrubbing utensils; as fodder for livestock; as biosorbent. Leaf extracts increase <i>Rhizobium</i> root nodulation, nodule weight, and nitrogenase activity in mung bean (<i>Vigna mungo</i>).</p>	<p>[8,12,23,72,77,86,106,107,116-130]</p> <p>[18, 22,40-43,131]</p>
Stem (bark)	 <p>The bark of the tree is usually whitish-gray, thick, soft, fissured and corky. The wood is soft and light.</p>	<p>Rubefacient; abortifacient; vesicant and used to cure eye diseases and for the treatment of delirious patients; prevents enlargement of the spleen and formation of tuberculous glands of the neck; heal tumours and ulcers. The extracts have been used for digestion, common cold, snakebite, scorpion bite, birth control and scurvy. Decoctions for creams or emollients. The juice from the root bark is put into ears to relieve ear aches and dental caries.</p> <p>The corky bark yields a coarse fibre, which is utilized in making mats, paper, and cordage. Yields dyes, tannins for tanning hides. Stem pulp used for newsprint cellophane, and textiles. Stem used for fencing purpose.</p>	<p>[8,12,23,35,77,121,132-134]</p> <p>[22,23]</p>

Roots

The roots are tuberous and tap root with very sparse laterals and possess a peculiar pungent odour.

Antilithic; rubefacient, vesicant, carminative, anti-inflammatory, stimulant in paralytic affections; act as a cardiac/circulatory tonic; used as a laxative, aphrodisiac, treating dental caries, abortifacient and antispasmodic. Used for treating common cold, fever, asthma, flatulence, constipation, rheumatism, gout, diuresis, inflammations, articular pains, lower back or kidney pain and splenomegaly.

[8,12,23,83,98,107,116,121,124,135,136]

Flowers

The flowers are fragrant bisexual, yellowish-white in colour and are borne on slender stalks approximately on axillary clusters. Each flower is 0.7 to 1cm long and 2cm broad with five unequal yellowish-white, thinly-veined, spatulate petals, five stamens (staminodes), and a carpel composed of unilocular ovary and slender style.

High medicinal value as a stimulant, aphrodisiac, abortifacient, cholagogue; Used to cure inflammations, muscle diseases, hysteria, tumors, and enlargement of the spleen; lowers the serum cholesterol, phospholipid, triglyceride, vldl, ldl cholesterol to phospholipid ratio and atherogenic index; decrease lipid profile of liver, heart and aorta in hypercholesterolemic rabbits and increase the excretion of faecal cholesterol. Used for throat infection, common cold, rheumatism; Used as antihelminthic drug and diuretic tonic.

[12,23,35,103,104,106,121,137-139]

Unopened buds and flowers are consumed as vegetables (dishes like: lasagna, omelets, soups, sea food, pasta dishes, pizzas, pakoras etc.) eaten raw as salads or fried in moringa oil, used to make tea, Honey (flower nectar).

[4,22,33,102]

Fruits (pods)

Fruits are frequently referred to as pods which are pendulous, 30-120 cm long 1.8 cm wide. Fruit production mainly occurs in the month of April. The immature pods are green in colour, turn brown on maturity and split open longitudinally along their three angles, releasing the dark brown seeds.

Used as anti-inflammatory, antihelminthic, anti-hypertensive, and to cure diabetes, skin cancer and joint pain.

[3,8,12, 23,72,121,140,141]

Used in culinary preparations (in curries, sambars, kormas, dals).

[4]

The seeds are round with 1cm diameter with an average weight of 0.3 gm. It bears brownish semi-permeable seed hull, with three papery wings which run from top to

Seed extract exerts its protective effect by decreasing liver lipid peroxides; antihypertensive; used as antihelminthic, anti-tumour, antispasmodic, goitrogen, mineral/vitamin deficiency; for treatment of ulcer, rheumatism and arthritis.

[2,8,12,23,47,77,106,62,121,142,143]

Seeds

bottom at 120 intervals. Viable seeds germinate within 14 days. A mature tree can produce 15,000 to 25,000 seeds per year.

Eaten as snacks; oil for salads, cooking, for perfumes, skin lotions etc. Biofertilizer/biocompost. Powdered seed used as sugarcane juice clarifier; act as a natural flocculent; replaces elements such as aluminum manganese, cadmium which are dangerous to people and the environment, and are expensive. Seed oil is also used for biodiesel production and as lubricants. seeds are rich source of bioactive proteins, including lectins which have insecticidal activity against *Aedes aegypti* (vector of dengue, chikungunya and yellow fever) and *Anagasta kuehniella* (pest of stored products).

[19,46,109,131,144,145,146, 147]

Gum (exudates)

When the tree is wounded the bark exudes a gum which is initially white in colour but changes to reddish brown or brownish black on exposure.

Used for dental caries, and as astringent and rubefacient; Gum, mixed with sesame oil is used to relieve headaches, fevers, intestinal complaints, dysentery, asthma; Used as abortifacient, rubefacient and to treat syphilis and rheumatism.

[8, 23,25,121,136]

Gum used in leather tanning and calico printing.

[22]

Flowers

Moringa flowers contain sucrose, D-glucose nine amino acids, alkaloid, wax, and are rich in calcium, potassium and a few flavonoids [12,98]. Consumption of flower juice improves the quality and flow of milk in feeding-mothers [99]. *Moringa* Flower contains pterogosperrin, an antibiotic that is highly effective in the treatment of cholera [100]. They are also a rich source of quercetin, a reputed flavonoid with hepatoprotective activity [98,101]. The flowers are used as a tonic and diuretic and are a fine source of pollen for honeybees [22,102]. The flowers have the ability to cure muscle diseases, inflammations, tumours, and enlarged-spleen and also decrease cholesterol, phospholipid and triglyceride [35,103,104]. In a study by Anwar et al., (2007) [12] the consumption of *Moringa* flower extracts reduced the lipids in liver heart and aorta and also the augmented faecal cholesterol in hypercholesteromic rabbits. *Moringa* tea has both nutritional and medicinal benefits. In some countries *Moringa* flower tea is preferred as a powerful cold remedy, or to treat a sore throat. In Puerto Rico the flowers are made into an infusion and used as an eye wash. The flowers may act as abortifacient and must not be used in pregnancy. Excess eating of flowers generates laxative effect on the body.

Fruits

The fruits are rich in minerals, protein, thiamine, riboflavin, vitamin A and C. They are eaten as a nutritious vegetable either cooked or pickled [2]. The raw pods act as a de-wormer and cures liver and spleen problems and joint-pains. Due to high protein and fibre content they can play a useful part in treating malnutrition and diarrhoea. The pods possess antihypertensive property which can be attributed to the presence of Thiocarbamate and isothiocyanate glycoside present in them [62]. It is also reported that *Moringa* fruits have the ability to reduce the serum cholesterol, phospholipid, triglycerides, low density lipoprotein (LDL), very low density lipoprotein (VLDL), and cholesterol- phospholipid ratio. Similar to flowers, the fruits also possess the ability to increase the fecal cholesterol and reduce the lipid contents of liver and heart in hypercholesteromic rabbit [104].

Seeds

Moringa seeds are considered to be antipyretic and also reported to have some antimicrobial activity [38]. The seeds can be consumed fresh, roasted, or pressed into sweet oil, commercially branded as 'ben-oil'. Due to their antibiotic

and anti-inflammatory properties they are used to treat boils, arthritis, rheumatism, gout, cramp and sexually transmitted diseases. [2] The seeds are roasted, crushed, mixed with coconut oil and applied to the affected area. Seed oil also has the same effect as seed powder. Sutherland et al., (1990) [105] reported that *Moringa* seeds inhibits the replication of bacteriophages. Roasted seeds and oil are diuretic and can also be used as a relaxant for epilepsy. The seeds contain the potent antibiotic and fungicide 'pterygospermin' and are effective against skin-infections caused by *Staphylococcus aureus* and *Pseudomonas aeruginosa*. The seeds are also used as a sexual virility drug for treating erectile dysfunction in men and also in women for prolonging sexual activity. Ben-oil is used for treatment of scurvy, hysteria, prostate and stomach disorders.

Roots

Moringa roots and root bark possess several compounds with proven anti-spasmodic activity [102,106]. *Moringa* root extracts is generally applied externally to cure inflammatory swellings. It contains an antibiotic, pterogosperrin that is effective in the treatment of cholera [2,22,100]. *Moringa* roots have shown hepaprotective activity and the juice from the root bark relieves earaches and toothaches [98]. They have also been reported as anti-inflammatory agent, stimulant in paralytic conditions, and as a cardiac/ circulatory tonic. It is also evidenced that roots are used in treating rheumatism, inflammations, articular pains lower back or kidney pain, and constipation [98,107]. An alkaloid 'spirachin' (a nerve paralytant) has also been found in the roots.

Table 6: *Moringa oleifera* tissue culture reports

Explant	Plant growth hormone used (mg/l)	Response	Reference(s)
A) Axillary nodes and single shoots from nodes. B) Immature Seed.	BA (1.0 mg/l) + GA ₃ (1.0 mg/l)	Immature seeds were the most responsive tissue source. The success rate was 73%. Average regeneration rate was 4.7 shoots per culture.	[148]
Nodal section bearing one or two axillary buds	BA (1.0 mg/l)	100% shoot production	[149]
Regenerated shoots from nodal sections	MS medium (devoid of hormones)	100% rooting (no. of root 4.0)	[149]
Stem nodes	BA (1.0 mg/l)	100% shoot induction with 1.5 shoots per explant	[150]
Leaf	2,4-D (0.1mg/l)	Induced highest frequencies of callus growth index (7.8)	[150]
Stem	BA (1.0 -4.0 mg/l) BA at 2.0 mg/l concentration was found to be optimal	Multiple shoot induction. 100% shoot formation with the highest average number of 10.8 shoots per explant.	[151]
Shoots	2,4-D (0.5mg/l)	Callus production	[151]
Friable callus	• BA (0 – 2.0 mg/l) • NAA (0.5 mg/l) • NAA (1.0 mg/l)	• No shoots or roots produced • Shoots and roots development • Root production	[151]
Nodal sections of young, aseptically-grown seedlings	BA (2.5 μM)	Shoot induction; 4.6 axillary shoots per explant	[152]
In vitro developed shoots	NAA (0.25 μM)	Optimal rooting; 6.8 roots per shoot	[152]
Cotyledon explants	BA (2.5 mg /l)+ 2,4-D (1.0 mg /l)+ TDZ(2.5 mg /l)	Significant increase in callus formation	[153]
Nodal section of young aseptically grown seedling	Benzyladenine (4.44μM)	Shoot induction; 9.0±1.0 shoots per explant	[154]
In vitro developed shoots	IAA (2.85 μM) + IBA (4.92 μM)	100% rooting; 15 ± 1.3 roots per shoot	[154]
Leaf	2,4-D (11.31 μM)	Calli formation in 91.8% explants	[155]
Zygotic embryo	NAA (10.75 μM)	Organogenic callus was established in 95.8% explants	[155]
Calli	2,4-D (4.52 μM) + BA (11.09μM)	The induced calli were maintained for somatic embryo induction	[155]
Shoots raised from induced somatic embryos	NAA (10.75 μM)	Rooting in 78.4 % shoots	[155]
Shoots and roots of two week old <i>in vitro</i> seedlings	2,4-D (0.5 mg/l)	Shoot and root-derived callus	[156]

Stem (bark)

The stem bark is used for cardiac and circulatory disorders, as a tonic and for inflammation. The bark is an appetizer and is digestive in function [8,77]. In Senegal and India, roots are crushed and mixed with salt to formulate a poultice for treating articular pains and rheumatism. The poultice is also used to relieve lower back or kidney pain. The bark exudates (gum) possess astringent, diuretic and abortifacient property and are also used for treatment of asthma.

Other promising uses**Biosorption and water purification**

The contamination of soil and water resources with environmentally harmful chemicals is an alarming issue, for the survival of all living organisms including humans. The progressing industrialization and urbanization has exposed the natural environment to increasing levels of toxic elements, such as heavy metals. Biosorption is the removal of toxic heavy metals from wastewater to enhance its quality from initial metal concentrations of 1–100 mg l⁻¹, to final concentrations of < 0.01–0.1 mg l⁻¹ [108-110]. The seed cake may be used for water purification purposes because it contains effective water purifying components [57]. Powdered seeds of *Moringa* contain cationic polyelectrolytes which act as a natural flocculent to clarify even the most turbid water. The seed-powder joins with the solids in the water, settles down and also removes 90–99% of bacteria contained in water [2,111]. Water purification begins with flocculation, sedimentation, antibiotics and even reduction of *Schistosoma* cercariae titer. This simple technique replaces chemicals such as aluminum sulphate, which are dangerous to people and the environment, and are expensive. *M. oleifera* has several advantages over commonly used coagulants which includes low operational cost, biodegradable sludge production, lower sludge volume, and unchanged pH of water.

Plant growth enhancer

Several lab-experimentation has shown that *Moringa* spray has marked beneficial effects on crops plants. The effects of sprays accelerated the growth of young plants that became firmer, more resistant to pests and disease, longer life-span, heavier roots, stems and leaves and large fruits with increased yield (20–35%). *Moringa* fermented leaf juice was also tested for its growth promoting attributes in *Brassica oleracea* and the results were promising [17]. There are prospects of widespread introduction and utilization of drumstick fermented leaf juice (DFLJ) by the Agriculture sector. It also implies that it may be worthwhile for small margin farmers to take up the production of drumstick fermented leaf juice for healthy cultivation and merge into the Organic Integrated Nutritional Management (OINM) programme in India and other countries. This practice would not only alleviate plant macro and micro-nutrient deficiencies but also enrichment of soil for several crops. Introducing DFLJ as an organic nutritional source for different crops will ensure sustainable agriculture and the farmers may stop the use of expensive inorganic fertilizer.

Biopesticide

Biopesticides, being a promising alternative to conventional pesticides are eco-friendly, cost-effective and are ineffective to non-target organisms as birds, insects, and mammals. When used in Integrated Pest Management (IPM) programs, biopesticides can significantly reduce the use of conventional pesticides without affecting the crop yield. *Moringa* seed oil has the potential to be deployed as a biopesticide [23]. The aqueous *Moringa* seed extract (AMSE) and leaf extracts have been reported to exhibit as insect repellent and fungicidal properties [112].

Biodiesel

Biodiesel is an alternative to petroleum-based conventional diesel fuel and is defined as the mono-alkyl esters of vegetable oils and animal fats. Biodiesel has been prepared from numerous vegetable oils, such as cottonseed, canola (rapeseed), palm, soybean, peanut and sunflower oils. The greatest potential for *M. oleifera* is currently thought to be in its cultivation for the production of biodiesel [19]. A yield of about 20 metric tonnes of pods / hectare / year is achievable for this species. This could provide 3000 and 4000 liters of biodiesel / hectare / annum. After acid pre-treatment to reduce the acid value of the *M. oleifera* oil, biodiesel is obtained by a transesterification procedure with methanol and an alkali catalyst at 60 °C. The methyl esters (biodiesel) obtained from *Moringa* seed oil exhibit a high cetane number of approximately 67, one of the highest found for a biodiesel fuel. Overall, *M. oleifera* oil appears to be promising input for biodiesel [146,147].

Biogas

Much research on *Moringa stenopetala* has been reported for the production of Biogas. Availability of water is a prerequisite for large scale biogas production from *M. stenopetala* seed cake powder. The pH of the system should be monitored very well in biogas production. The *Moringa* biogas plant can contribute to solve a waste problem for industries with organic wastes; can provide cheap energy to that industry; produces a digestate that can be an excellent fertilizer, and which can be sold e.g. to farmers. Replacing chemical fertilizers with this bio fertilizer will add important minerals to the soil, and thereby contribute to increase the fertility of farmed land. The biogas plant reduces the percentage of methane released to the atmosphere and shall replace the use of fossil fuels. Last but not the least a biogas plant can serve the food producing industry [16].

Moringa: Tissue culture

Although much research is going on with this "miracle tree" but its robust tissue culture protocol is yet to be discovered. The *in vitro* regeneration helps in rapid multiplication of the plant as compared to growing from seeds. The propagation of *Moringa* is found to be less due to its low seed germination, viability and lack of vegetative propagation methods. Most of the *in vitro* regenerations carried out so far were from stem and very few on leaves as explants [148-156]. An established *in vitro* regeneration protocol shall provide a useful means of mass clonal propagation in order to meet the growing requirement of pharmaceutical industries for the manufacture of plant based medicines. The Table 6 shows some tissue culture reports of *M. oleifera* using different explants and with varying success rates.

CONCLUSION

Moringa oleifera is a nature's gift to mankind as it is the most nutrient-rich and multipurpose plant discovered. Therefore, the production and consumption demand (agri-business) of this "green super food" has tremendously increased in the past 10 years. It has proved to be a wonder crop, in relation to health benefits and agroforestry. *M. oleifera* tree is extraordinary in that all parts of the tree are edible and is the most inexpensive and credible alternative to providing good nutrition, and a number of promising applications from biotechnological point of view. It provides a rich, rare and perfect combination of nutrients, amino acids, antioxidants, anti-aging and anti-inflammatory properties used for nutrition and healing. As the *Moringa* tree has spread from the Indian sub-continent throughout the tropical and sub-tropical world, it has adapted itself to local conditions, resulting in many variations. Thus, rigorous, localized studies are needed to test the leaves' nutritional content and effects in different areas. *Moringa* leaves have been used in the traditional medicine since centuries, in many cultures. Now they have also attracted the interest of the scientific community. However, most of the studies done so far are either nutritional analyses or laboratory studies with animals. There are few studies done so far on its direct effects on human beings. Considering the potentially enormous benefits to humanity, medically controlled studies with human subjects are crucial, to document the bio-availability and effectiveness of nutrients in *Moringa* leaves. *M. oleifera* is also a promising source of 2nd generation biodiesel and the foundation of a profitable business planning. The key challenge is to overcome the bottlenecks in the business planning. It can be possible through joint efforts by the private sector, smallholders, associations, larger companies and public institutions. The conservation of the *Moringa* is of immense concern from biodiversity, ethnobotanical, dietary and pharmacological perspective. The governments of all the developing countries should collectively take initiatives to uplift the rural standards by employing poor farmers under Operation Plant *Moringa* Tree (OPMT) and provide them with land and other resources. They should organize routine-workshops, assist them in harvesting and processing, and pay them according to their yield. This type of empowerment will trim down their poverty and make this 'miracle tree' to grow in every house and become a part of their routine diet.

Abbreviations

ADF: acid detergent fibre; AMSE: aqueous *Moringa* seed extract; BA: benzyladenine; CNS: central nervous system; 2,4-D: 2,4-dichlorophenoxyacetic acid; DFLJ: drumstick fermented leaf juice; GA₃: gibberellic acid; IAA: indole-3-acetic acid; IPM: integrated pest management; LDL: low density lipoprotein; NAA: naphthalene acetic acid; NDF: neutral detergent fibre; OPMT: operation plant *Moringa* tree; OINM: organic integrated nutritional management; TDZ: thidiazuron; VLDL: very low density lipoprotein WHO: world health organization.

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