IJP (2016), Vol. 3, Issue 3 **(Review Article)**

Received on 07 February 2016; received in revised form, 09 March 2016; accepted, 25 March 2016; published 31 March 2016

PHYTOCHEMISTRY, MEDICINAL WEALTH AND NUTRITIONAL STRENGTH OF *MORINGA OLEIFERA* LAM. (MORINGACEAE)

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Keywords:

Moringa oleifera, Medicinal properties, Nutritional benefits

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ABSTRACT: *Moringa oleifera* Lam. is the most imperative and legendary species of family Moringaceae. It is called as Soanjna in the local language (Punjabi). It has noteworthy medicinal and nutritional significance for both humans as well as for animals. Traditionally it is recommended to treat many ailments and to contest malnutrition mostly in tropics. It has scores of pharmacological activities such as anticancer, antioxidant, antispasmodics, anti-inflammatory, antimicrobial, anti-asthmatic, antidiabetic, antiarthritis, antiurolithiatic, hepatoprotective, nephro-protective, cardioprotective, antipyretic and antiulcer, *etc*. Its non-food benefits such as purification of water, as biodiesel oil and bio-enhancing activity are also valuable. The present review on the phytochemistry, pharmacology and nutritional strength of *Moringa oleifera* is an effort to give an updated literature appraisal of its properties.

INTRODUCTION: World population does not compromise on health issues, and perfect health is one of the primary needs of human being. Nature fulfills all the vital requirements of a human being either in healthy or diseased condition but just need to explore it in time. Medicinal plants are being utilized by human since ancient times to get rid off from different diseases. *Moringa oleifera* Lim. is one of the precious gifts of nature to man. It is the member of family Moringaceae, commonly known as 'Soanjana,' horseradish (portray of its root taste) or drumstick tree (illustrating the shape of pods).

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.IJP.3(3).115-30

Article can be accessed online on: www.ijpjournal.com

DOI link: http://dx.doi.org/10.13040/IJPSR.0975-8232.IJP.3(3).115-30

In Senegal, it is commonly known as "Nebeday" most probably meaning is "never die" because it can survive even in a prolonged period of scanty rainfall (drought) condition and can grow from seed or cutting as well as it has the power to rejuvenate itself. It is also called "Miracle tree" or "wonder tree" [1]. In the Philippines, it is most commonly called as "mother's best friend" and "malunggay" because mothers give its cooked leaves to their babies for nutritional purpose [2]. It is mostly present in tropics but a native of the Western and sub-Himalayan tracts of Pakistan, Bangladesh, Afghanistan, Asia Minor, Africa and India [3, 4]. It has valuable medicinal and nutritional value and is considered as an essential member of nature's pharmacy. Ancient king and queen used *M. oleifera* in their diet for mental alertness and healthy skin since 150 BC [5]. It is also present in the list of neutraceuticals [6]. Its young leaves, pods, flower, as well as roots, are edible mostly in Asia [7].

Taxonomic Classification:

Kingdom: Plantae,
Sub kingdom: Tracheobionta,
Super Division: Spermatophyta,
Division: Magnoliophyta,
Class: Magnoliopsida,
Subclass: Dilleniidae,
Order: Capparales,
Family: Moringaceae,
Genus: Moringa
Species: oleifera [8].

Synonyms: Latin; *Moringa oleifera*, Sanskrit; Subhanjana, Hindi; Saguna, Sainjna, Gujarati; Suragavo, Tamil; Morigkai, Telugu; Mulaga, Munaga, Malayalam; Murinna, Sigru, Punjabi; Sainjna, Soanjna, Unani; Sahajan, Ayurvedic; Akshiva, Haritashaaka, Raktaka, Tikshnagandhaa, Arabian; Rawag, French; Moringe à graine ailée, Morungue, Spanish; Ángela, Ben, Moringa, Portuguese; Moringa, Moringueiro, Chinese; La ken, English; Drumstick tree, Horseradish tree, Ben tree [8].

Plant Description: *Moringa oleifera* is small to medium-sized, fast-growing, evergreen tree with 7-12 m height as well as with 20-40cm diameter at chest height and sheds its leaves annually (deciduous) [9].

Stem: It has a short erectile stem with 1.5-3 m height, but extensive branching can lessen stem height. Mostly stem has widespread delicate branches without any pattern, but most upper branches are in the form of an umbrella.

Leaves: It has pinnate compound leaves (twice or thrice pinnate); consist of leaflets of about 1-2cm long. These leaflets are in obovate or elliptic form and arrange themselves in two opposite pairs around costa or pinnae stalk and form a pinna. Four to six pairs of pinnae are present on 20 to 50cm long rachis with long petioles. Pinnae and petiole have glands at their bases.

Flowers: A flower with five reflexed, slender-spatulated petals having five stamens and staminodes with five linear-tapered downward bent petals. As a whole flower is a white colored and yellow base, sweet-scented with 2.5 cm diameter and 10-25 cm long axillary and downward hanged panicles.

Fruits: Fruit is also known as pods which are 25-45 cm long, 2 cm wide, fragile, drooped and dark green but when it matured it become pointed at the apex, tapered at the base, nine ribbed, brown in color and woody in texture [10].

Seeds: Seeds consist of kernel and partially permeable hull (kernel to hull ratio; 75**:** 25) round shaped with 0.3gm weight and three papery wings. Approximately a pod has 12-35 seeds, and 15000-25000 seeds are formed by a tree in a year [11].

Nutritional Value: Malnutrition is basic problem in infants and nursing mothers. *Moringa oleifera* has acquired a significant place in different tropics to combat malnutrition, and it has been given a specific name “natural nutrition for the tropics” by three private organizations; Trees for Life, Church World Service and Educational Concerns for Hunger Organization, because in tropics most of the time in a year there is drought, and a no of trees lose their nutritional contents, but *M. oleifera* has the ability to tolerate droughts. Therefore, people use it for food purpose mostly in dry season [12]. Analysis of *Moringa* pods, fresh (raw) leaves and dried leaf powder has shown them to contain the following per 100g of edible portion **Table 1**. [2]

It has been observed that pods and leaves provide the best quality nutrition to pregnant and breastfeeding women, give energy to mother as well as provide required nutrients to the fetus. "It is revealed that one 100g portion of leaves could provide a woman with over a third of her daily need of calcium and give her important quantities of iron, protein, copper, sulfur, and B-vitamins" [2]. From the above table we can easily evaluate that a number of diseases can be treated easily by leaf powder such as scurvy (caused by lack of vitamin C), night blindness (caused by lack of vitamin A), kwashiorkor (caused by lack of protein), anemia (caused by lack of iron), *etc*.

Due to its enormous nutritional value, it has been evaluated that leaves can increase milk production in cows. It is studied that there is an increase in weight and milk by 30% with the only the addition of 40-50% of leaves in the feed of beef cattle [13]. It has been observed that the addition of leaves in the feed of broiler chickens can cause acceleration in food digestion and tissue growth [14]. Addition of

leaves in fish feed also enhances fish growth in a better way than normal feed [15]. All parts of *Moringa oleifera* have nutritional contents especially leaves, roots, and seeds both for man and livestock because all these parts of the tree are the rich source of amino acids and minerals. A study was performed on leaves, roots, and seeds to assess essential and nonessential amino acid and to know nutritional strength of this plant given in **Table 2**. It has been evaluated that seeds, roots, and leaves of *Moringa oleifera* accelerate the quality of diet both in human as well as in animals [16].

TABLE 1: INGREDIENTS IN EDIBLE PORTION OF *MORINGA OLEIFERA* (100g)

Ingredients	Pods	Leaves	Leaf powder
Moisture (%)	86.9	75.0	7.5
Calories	26.0	92.0	205.0
Protein (g)	2.5	6.7	27.1
Fat (g)	0.1	1.7	2.3
Carbohydrate (g)	3.7	13.4	38.2
Fiber (g)	4.8	0.9	19.2
Minerals (g)	2.0	2.3	-
Ca (mg)	30.0	440.0	2.003
Mg (mg)	24.0	24.0	368.0
P (mg)	110.0	70.0	204.0
K (mg)	259.0	259.0	1.324
Cu (mg)	3.1	1.1	0..57
Fe (mg)	5.3	7.0	28.2
S (mg)	137.0	137.0	870.0
Oxalic acid (mg)	10.0	101.0	1.6%
Vitamin A-B carotene (mg)	0.11	6.8	16.3
Vitamin B-choline (mg)	423.0	423.0	-
Vitamin B1 -thiamin (mg)	0.05	0.21	2.64
Vitamin B2 -riboflavin (mg)	0.07	0.05	20.5
Vitamin B3 -nicotinic acid (mg)	0.2	0.8	8.2
Vitamin C -ascorbic acid (mg)	120.0	220.0	17.3
Vitamin E –tocopherol acetate (mg)	-	-	113.0
Arginine (g/16g N)	3.6	6.0	1.33%
Histidine (g/16g N)	1.1	2.1	0.61%
Lysine (g/16g N)	1.5	4.3	1.32%
Tryptophan (g/16g N)	0.8	1.9	0.43%
Phenylanaline (g/16g N)	4.3	6.4	1.39%
Methionine (g/16g N)	1.4	2.0	0.35%
Threonine (g/16g N)	3.9	4.9	1.19%
Leucine (g/16g N)	6.5	9.3	1.95%
Isoleucine (g/16g N)	4.4	6.3	0.83%
Valine (g/16g N)	5.4	7.1	1.06%

TABLE 2: ESSENTIAL AND NON ESSENTIAL AMINO ACID IN *MORINGA OLEIFERA*

Amino acid	Root	Seed	Leaf
Glycine	4.60	5.00	5.15
Alanine	3.36	3.23	3.43
Serine	3.61	4.25	4.20
Valine	3.03	3.09	3.36
Threonine	3.94	3.22	4.38
Isoleucine	1.84	4.35	2.33
Aspartate	6.01	6.14	6.86
Lycine	3.62	3.24	3.60
Glutamate	13.52	14.76	15.14
Methionine	0.76	0.97	0.95
Phenylalanine	3.98	4.53	4.26
Histidine	1.91	2.01	1.90
Arginine	1.74	8.06	1.88
Leucine	5.02	5027	5.22
Tyrosine	2.43	2.33	2.20
Cysteine	2.42	2.02	2.05

Phytoconstituents:

Leaves: Mustard oil glycosides such as, niazicin A, niazicin B, niazimin A1and niazimin B3, as well as benzaldehyde glycoside, has been found in leaves [17, 18]. Some important and valuable flavonoids and phenolic acid contents were investigated in leaves such as rutin, naringin, caffeic acid, (-) epicatechin, benzoic acid, o-coumaric acid [19]. A phytochemical study was conducted on leaves, and it was revealed that five flavonol glycosides such as kaempferide 3-*O*- (2″,3″-diacetylglucoside), kaempferide 3-*O*-(2″-*O*-galloylrhamnoside), kaempferide 3-*O*-(2″-*O*-galloylrutinoside)-7-*O*-α-rhamnoside, kaempferol 3-*O*-[β-glucosyl-(1 → 2)]- [α-rhamnosyl - (1 → 6)]-β-glucoside – 7 – *O* -α-rhamnoside and kaempferol 3-*O*-[α-rhamnosyl-(1 → 2)]-[α-rhamnosyl- (1 → 4)] -β-glucoside-7-*O*-α-rhamnoside along with benzoic acid 4-*O*-β-glucoside, benzoic acid 4-*O*-α-rhamnosyl-(1 → 2)-β-glucoside and benzaldehyde 4-*O*-β-glucoside are present [20]. Quercetin-3-O-glucoside, kaempferol-3-O-glucoside was found in the crude extract of leaves, but the aqueous fraction of leaves has vicenin-2 [21]. Gallic tannins, catechol tannins, steroids and triterpenoids, saponins, anthraquinones, alkaloids and reducing sugars were present in leaves extract [22]. Total phenols, tannins, saponins, phytate were also detected in leaves [9]. Detection of novel bioactive nitrile glycosides aziridine and niazirin in pods by reverse phase HPLC technique has been done [23].

Seeds: A study was conducted on seed oil and some fatty acids were found as given in **Table 3**. [24]

TABLE 3: FATTY ACID PRESENTS IN SEEDS OF *MORINGA OLEIFERA*

Fatty acid	Systemic names
Palmitic	Hexadecanoic
Palmitoleic	9-Hexadecenoic
Stearic	Octadecanoic
Oleic	9-Octadecenoic
10-Octadecenoic	10-Octadecenoic
Linoleic	9,12-Octadecadienoic
Behenic	Docosanoic
Lignoceric	Tetracosanoi

Another study was conducted on seed oil, and this study explored valuable sterols such as Δ5-avenasterol, 28-isoavenasterol, Δ7,14-stigmastanol, stigmasterol, clerosterol, stigmastanol, β-sitosterol, 24-Methylenecholesterol, campesterol, Campestanol, Δ**7**-campestanol, Δ**7**- avenasterol [25]. total phenols, saponins, phytates, cyanogenic glucoside, Glucosinolate, were also found in seeds kernel [9]. 4(a-L-rhanmosyloxy) phenylacetonitrile, 4-hydroxyphenyl acetonitrile, and 4-hydroxy phenyl-acetamide were found in seeds [26]. 4(a-L-Rhamnosyloxy) benzyl isothiocyanate also found in seeds and suggested as antimicrobial agent [27]. O-ethyl-4-(alpha-L-rhamnosyloxy) benzyl carbamate together with seven known compounds, 4(alpha-L-rhamnosyloxy)-benzyl isothiocyanate, niazimicin, niazirin, beta-sitosterol, glycerol-1-(9-octadecanoate), 3-O-(6'-O-oleoyl-beta-D-glucopyranosyl)-beta-sitosterol and beta-sitosterol-3-O-beta-D-glucopyranoside has been recognized in seeds by1H, 13C-NMR and mass spectroscopy [28].

Flowers: The methanol extract of flowers was assessed for phytochemical screening and a number of compounds **Table 4** were found by Gas Chromatography - Mass Spectrometry (GC-MS) technique. Identification of these compounds provides the relation of *Moringa oleifera* usage in folklore medicines [29].

Pods: By 2DNMR and spectral studies have shown the presence of niazidin possessing an *O*-nitrile thiocarbamate group, along with thiocarbamate, carbamate, and isothiocyanate glycosides in ethanolic extract of fresh pods. Fatty acid esters, long-chain hydrocarbons, carbamic acid, isocyanates, isothiocyanates, phenolic esters, nitriles, nitrile ester, polysulfide sulfinate, and a benzyl thiocarbamate, along with elemental sulfur (S_8) has also been found in the same extract by Gas Chromatography - Mass Spectrometry (GC-MS) technique [30]. By reverse phase HPLC there was the detection of novel bioactive nitrile glycosides niaziridin and niazirin in pods [23]. Niazirin was also investigated by HPLC and structure elucidation was done by ^{1}H, ^{13}C-NMR and ESI-MS (electrospray ionization-mass spectroscopy) data [31]. Isothiocyanate, niazicin A, niazinin A, niazirin were found in pods extract through 1D-and 2D-NMR and mass spectrometry [32]. Niazirdin which is best bio-enhancer especially accelerate bio-availability of antibiotics has been isolated and characterized [33].

Gum: O-(β-D-glucopyranosyl uronic acid)(1→6)-β-D-galactopyranosyl(1→6)-D-galactose known as aldotriouronic acid has been found in gum by acid hydrolysis [8].

TABLE 4: COMPOUNDS ISOLATED FROM *MORINGA OLEIFERA* FLOWERS

Names	Molecular formulas	Names	Molecular formulas
(4-Hydroxyphenyl) Acetonitrile	C_8H_7NO	(2E)-3,7,11,15-Tetramethyl -2-hexadecen-1-ol	$C_{20}H_{40}O$
4-Hydroxy-3,5,6-trimethyl -4-[(1E)-3-oxo-1-butenyl] -2-cyclohexen-1-one	$C_{13}H_{18}O_3$	3,5-Dihydroxy-6-methyl-2,3-dihydro-4H-pyran-4-one	$C_6H_8O_4$
Malonic acid, di(10 chlorodecyl) ester	$C_{23}H_{42}C_{l2}O_4$	(2E)-3,7,11,15-Tetramethyl -2-hexadecen-1-ol	$C_{20}H_{40}O$
Quinic acid	$C7H_{12}O_6$	Melamine	$C_3H_6N_6$
Methyl palmitate	$C_{17}H_{34}O_2$	Ethyl palmitate	$C_{18}H_{36}O_2$
Palmitic acid	$C_{16}H_{32}O_2$	cis-9-Hexadecenal	$C_{16}H_{30}O$
Methyl cis-7-Octadecenoate	$C_{19}H_{36}O_2$	12-Oleanen-3-yl acetate, (3alpha)	$C_{32}H_{52}O_2$
Methyl linoleate	$C_{19}H_{34}O_2$	Ethyl Oleate	$C_{20}H_{38}O_2$
Ethyl stearate	$C_{20}H_{40}O_2$	n-Tetracosane	$C_{24}H_{50}$
Ethyl docosanoate	$C_{24}H_{48}O_2$	n-Tetratriacontane	$C_{34}H_70$
9-Octadecenamide	$C_{18}H_{35}NO$	n-Hexatriacontane	$C_{36}H_{74}$
alpha.-Tocopherol- beta-D-mannoside	$C_{35}H_{60}O_7$	Ergost-5-en-3 beta-ol	$C_{28}H_{48}O$
Stigmasterol	$C_{29}H_{48}O$	Gamma-Sitosterol	$C_{29}H_{50}O$

Stem: 4-hydroxy mellein, vanillin, octacosanoic acid, β-sitosterol, and β-sitosterone has been identified in stem [8].

Medicinal Uses:

Regulation of Thyroid Hormone: Aqueous leaf extract of *Moringa oleifera* has a significant effect on the control of thyroid hormone. This effect was studied in adult Swiss rats. It was observed that aqueous leaf extract of *Moringa oleifera* causes the reduction in serum tri-iodothyronine (T3) and increase in serum thyroxin (T4) concentration. It was suggested that *Moringa oleifera* cause inhibition of peripheral conversion of T4 to T3. So *Moringa oleifera* leaf extract can be used for the management of hyperthyroidism [34].

Antitumor and Anticancer Activity: Seeds of *Moringa oleifera* have antitumor activity due to the presence of 4(α-L-rhamnosyloxy) benzyl isothiocyanate, niazimicin, 3-o-(6'-O-oleooyl-β-D-glucopyranosyl)-β-sitosterol, and β-sitosterole-3-O-β-D-glucopyranoside. These compounds block EBV-EA induction and can be used to treat chemical carcinogenesis [28]. *Moringa oleifera* aqueous seed extract and CMOL (coagulant *Moringa oleifera* lectin) have been reported to possess cytotoxic activity against human peripheral blood mononuclear cell. Seed extract, CMOL, and WSMOL (water-soluble *Moringa oleifera* lectin) showed the moderate cytotoxic effect on NCI-H292, HT-29 AND HEp-2 cancer cell lines [35]. Sreelatha *et al.*, reported that leaf extract has significant anti-proliferative activity and potent ability to induce apoptosis. It was experimented by taking human tumor (KB) cell line and observed that leaf extract of *Moringa oleifera* has phenolic compounds such as quercitin and kaempferol. So, leaf extract of *Moringa oleifera* has cancer chemoprotective activity and can be used to treat cancer [36].

It has been found that aqueous, and ethanolic *Moringa oleifera* leaf extract has anti-proliferating activity against colon cancer cell lines; HCT15, SW48 AND SW480 [37]. It was assessed in a previous report that leaf extract of *Moringa oleifera* possesses significant cytotoxic effect on human multiple myeloma cell lines [38]. Ethanolic leaf extract of *Moringa oleifera* has anticancer activity against leukemia and hepatocarcinoma cell by inhibition of radical formation. It means that it possesses antioxidant activity due to the presence of phenolic compounds and flavonoids [39]. Phenolic compounds present in the leaf extract causes the inhibition of hydrogen peroxide-mediated DNA damage in human tumor KB cell [40]. Inhibitory effect of an extract of *Moringa oleifera* leaves on cultured human pancreatic cancer cells (Panc-1, p34, and COLO-357) at 0.1-2.0mg/ml for 72 h has

been assessed, and it was found that IC_{50} for Panc-1, p34, and COLO-357 was 1.1mg/ml, 1.5mg/ml, and 1.8mg/ml respectively. It was also examined that this extract induced apoptosis in Panc-1 cells up to 30% at 0.75 mg/ml.

This extract additionally possessed dose-dependent amelioration of activity of nuclear factor kappa B (NF-kB; a pro-inflammatory transcription factor and promote resistance to apoptosis in chemotherapy) at 0.25 mg/ml to 1.5 mg/ml in Panc-1 cells when exposed for 24hrs. More important synergistic effect of cisplatin and this extract has been observed on Panc-1 cells [41]. Tiloke and his colleagues reported anti-proliferating activity of leaves studying in cancerous A549 lung cells. It was examined that leaves extract causes acceleration in DNA fragmentation and oxidative stress by reactive oxygen species as well as induces apoptosis [42]. Aqueous leaf extract showed dose-dependent cytotoxic effect against HeLa cell line in a recent study [43].

Inbathamizh and Padmini investigated that flowers of *Moringa oleifera* possess anticancer compounds which have growth inhibitory effect on PC3 cell lines (classical in vitro androgen-independent models of prostate cancer with high metastatic potential [44]. Hydroethanolic extract of *Moringa oleifera* pod and saponins; isolated from seeds, tested for their chemoprotective activity. It was found that carcinogenic property of many chemical agents like PAH 7, 12-dimethyl-benz[a]anthracene (DMBA) can be prevented in male mice by pretreatment with hydroethanolic extract of *Moringa oleifera* pod (200 and 400 mg/kg body weight; p.o) and its isolated saponins for 21 days before DMBA single dose because DMBA cause soft tissue(liver, kidney) cancer by oxidative stress and *Moringa oleifera* exhibited good anti-oxidant activity, so soft tissue (liver, kidney) can be well protected [45]. Pod extract showed a chemopreventive effect on colon carcinogenesis model induced by azoxymethane and dextran sodium sulfate [46]. Roots extract cytotoxic effect against epithelial ovarian cancer Swiss-strain adult female mice studied by [47].

Anti-inflammatory Activity: The aqueous root extract of *Moringa oleifera* can be used for the treatment of rheumatic and articular pain. It was assessed that aqueous root extract causes a decrease in carrageenan-induced edema in rats at 750 mg/kg [48]. The same effect was observed at 600 mg/kg in rats. So root extract can be used for the treatment of acute and chronic inflammatory condition [49]. Fruit of *Moringa oleifera* has been reported for its anti-inflammatory activity. Because fruit contains phenolic glycosides; 4-[(20-O-acetyl-a-L-rhamno-syloxy)benzyl]isothiocyanate (1), 4-[(30-O-acetyl - a - L - rhamnosyloxy) benzyl] isothiocyanate and S – methyl - N-{4-[(α-L-rhamnosyloxy)benzyl]}-thiocarbamate which show inhibition of nitric oxide (NO; one of the inflammatory mediator) in the lipopolysaccharide-induced murine macrophage RAW264.7cell line.

Aqueous and ethanolic extract of the fruit (pod) has experimented for its anti-inflammatory activity against carrageenin-induced paw edema in Albino mice. It was observed that both extract at a dose of 1000 mg/kg body weight show diminution in edema in mice but ethanolic extract has greater anti-inflammatory activity than aqueous extract. It was thought that in the pod the presence of 4-Hydroxymellein, β-sitosterol, and vanillin is the primary cause of anti-inflammatory action [50, 51]. Aqueous and ethanolic extract of leaves showed significant anti-inflammatory activity in albino rats edema induced by carrageenan [52]. Extract ameliorated inflammation within 3hrs of carrageenan injection [53].

Hepatoprotective Activity: Seed extract of *Moringa oleifera* possesses hepatoprotective effect. Seed extract causes prevention from hepatotoxicity in arsenic-induced female rat of Wister strain by decreasing hepatic enzyme concentration (alanine transaminase, aspartate transaminase) [54]. Seed oil protected liver from toxicity induced by carbon tetrachloride (CCl_4), suggested due to antioxidant activity [55]. By decreasing the level of the hepatic enzyme (ALT, AST, and ALP) and by preventing the lowering of glutathione level, leaves of *Moringa oleifera* gave prevention to Sprague-Dawley rats from acetaminophen-induced hepatotoxicity [56, 57, 58, 59]. Hepatotoxicity induced by alcohol causes an increase in the levels of enzyme markers of tissues damage (ALT, AST, and ALP), lipid peroxidation and decreased serum vitamin C level, can be prevented by pretreatment with 100 and 200 mg/kg body weight of leaves extract and

can be treated by post-treatment with 200mg/kg body weight of leaves extract [60]. Hepatotoxicity induced by an antitubercular drug such as isoniazid (INH), rifampicin (RMP), and pyrazinamide (PZA) in rats can be prevented by prior oral administration of ethanolic extract of leaves [61]. High-fat diet causes fatty liver which leads to liver damage. This can be prevented by administration of leaf extract in mice [62].

Antimicrobial Activity: Crude seed extract of *Moringa oleifera* exhibited potent activity against *Shigella dysenteria, Bacillus cereus, E. coli* and *Salmonella typhi* due to the presence of 4-(β-D-glucopyranosyl-1→4-α-L-rhamnopyranose) benzyl thiocarbox-amide [63]. *Moringa oleifera* seed extract has anti-microbial activity against wound isolates of Multi-Drug Resistant-Methicillin Resistant *Staphylococcus aureus* (MDR-MRSA) and can reinstate the efficacy of β-lactam antibiotics against MRSA [64]. *In vitro* antibacterial activity of *Moringa oleifera* seeds has been conducted against *Mycobacterium phle* and *Bacillus subtil,* and it was found that minimum inhibitory concentrations (MIC) for these bacteria were 40µmol/liter, and 56µmol/liter found respectively, suggested due to the presence of 4(α-L-Rhamnosyloxy) benzyl isothiocyanate compound [27]. Chloroform extract of seeds has MIC 1.0 and >4.0mg/ml against *E. coli* and *Salmonella typhimurium* and showed 100% antifungal activity against *Mucor* and *Rhizopus* species at 0.5mg/ml concentration [65].

Cyanobacterium such as *Microcystis aeruginosa* causes contamination of water. It has been assessed that when crushed was added into contaminated water at 160 mg/l then there was complete eradication of cyanobacteria, suggesting its good cynobatericidal activity [66]. Aqueous seed extract showed superior *in-vitro* antibacterial activity than methanol or petroleum ether extract against gram positive bacteria [67]. By disc diffusion and MIC determination method *Moringa oleifera* leaves were tested *in vitro* in different forms such as leaf powder which was dissolved in DMSO (dimethyl sulfoxide), fresh leaf juice, cold water and ehanolic extract of fresh and dried leaves for evaluating its antibacterial activity against different human pathogenic Gram-positive (*Staphylococcus aureus, Bacillus cereus, Streptococcus-B- haemolytica, Bacillus subtilis, Sarcina lutea* and *Bacillus megaterium*) and gram-negative (*Shigella shinga, Pseudomonas aeruginosa, Shigella sonnei* and *Pseudomonas* spp.) bacteria. It was found from disc diffusion method powder (dissolved in DMSO) has greater antibacterial activity than fresh leaf juice, cold water, and ethanolic extract while fresh leaf juice and ethanol extract has greater antibacterial activity than cold water extract of leaves. From the MIC method it was assessed that all the different forms of leaves show activity against all above-mentioned bacteria, but ethanolic extract has no activity against *S. aureus* and *Streptococcus-B-hemolytic.* MIC values for powder, fresh juice, cold water and ethanolic extract were; 229 to 458µg /ml, 1.25 to 2.5µl/disc, 29.8-58.75 mg/ml, and 458 - 916µg/ml, respectively [68].

Active ingredients (phenolics, flavonoids, tannins, glycosides) having antibacterial activity in *Moringa oleifera* leaves is more soluble in organic solvents as compared to aqueous solvents because in disc diffusion method ethanolic extract of leaves has shown activity against *Salmonella typhii* and *Staphylococcus aureus* whereas the aqueous extract exhibited an inhibitory effect on *Staphylococcus aureus* only [69, 70]. Ethanolic leaf extract generated 8mm zone of inhibition at 100 mg/ml against *Salmonella typhi* in disc diffusion method suggesting due to alkaloids [71]. Ethanolic extract of leaves has MIC values in between 2.0 and >4.0mg/ml against *Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus,* and *Enterobacter aerogenes* extract of leaves showed in vitro weak antibacterial activity against *Escherichia coli* and *Enterobacter aerogene* while *Pseudomonas aerogenosa, Staphylococcus albus, Staphylococcus aureus* and, *Staphylococcus pyogenus* were resistant to extract, suggested due to very low concentration of active anti-bacterial agent such as pterygospermin [72].

Acetone extract of leaves inhibited the growth of Escherichia *coli, Enterobacter cloace, Proteus vulgaris, Staphylococcus aureus* and *Micrococcus kristinae* at 5mg/ml concentration [73]. Ethanolic extract of leaves produced a zone of inhibition 15mm, 18mm, 13mm, 14mm, 19mm and 16mm against *Bacillus cereus Bacillus subtilis Staphylococcus aureus Sarcina lutea Escherichia coli* and *Mycobacterium phlei* respectively [74]. Steam distillate of leaves also exhibited significant

antibacterial and antifungal activity [75]. Leaf extract showed good healing property against different bacteria with no side effect as compared to synthetic antibiotics [76].

Aglycon portion of Deoxy-niazimicin (N-benzyl, S-ethyl thioformate) present in bark extract of *Moringa oleifera* showed significant antibacterial activity against *Shigella boydii, Shigella dysenteriae, and Staphylococcus aureus* with the zone of inhibition in between 9-13mm. This compound also possessed moderate anti-fungal activity against *Candida albicans* and *Aspergillus flavus* [77]. Methanolic extract of stem bark showed antibacterial activity against *Escherichia coli* with MIC 64µg/ml [78]. Ethanolic extract of bark also showed antibacterial activity studied by Rastogi *et al.*, 2009. Purified dichloromethane extract of *Moringa oleifera* capsules studied for its antibacterial activity by agar-well diffusion method, and it was found that extract at 5-10% W/V concentration had significant activity against *Staphylococcus aureus, E. coli, Pseudomonas aeruginosa* and *Klebsiella pneumonia* [79].

Larvicidal Activity: Aqueous extract of *Moringa oleifera* seeds studied for its larvicidal activity against *Aedes aegypti* **(**causes a human viral disease called dengue). This extract demonstrated larvicidal activity with an IC_{50} value of 1260µg/ml and revealed larval mortality (99.2 ± 2.9%) within 24 h at 5200µg/ml [80].

Antioxidant Activity: Seeds of *Moringa oleifera* have antioxidant activity [54]. Oil of *Moringa oleifera* seeds has significant antioxidant activity due to 3,5,7,3',4',5'-hexa-hydroxyflavone. This activity was tested against rancidity in sunflower oil [81]. Due to the antioxidant activity of *Moringa oleifera*, seed powder can be used for the treatment of arsenic-induced toxicity in rats where it reduces arsenic-induced oxidative stress and shows free radical scavenging activity [82]. Leaves of *Moringa oleifera* have better antioxidant activity and give better prevention from lipid Per-oxidation, protein oxidation, and OH induced deoxyribose degradation in PUC18 plasmid DNA than fruit and seeds because leaves contain higher amount of gallic acid, chlorogenic acid, ellagic acid, ferulic acid, kaempferol, quercetin and vanillin than in fruit and seeds [83]. MOEF (*Moringa oleifera* ethyl acetate fraction) has greater *in-vitro* antioxidant activity, reducing power, DPPH(2,2-diphenyl-2-picrylhydrazyl) radical and superoxide anion radical scavenging activity, ferrous ion chelating capacity, lipid peroxide inhibition, and highest *in-vivo* antioxidant activity in rats taking CCl_4 than MOCF (crude extract), MODF (diethyl ether fraction), MOCF (chloroform fraction) due to higher polyphenolics and flavonoids amount [84].

Due to significant antioxidant activity, *Moringa oleifera* leaves prevent animals from diseases induced by oxidative stress and save diet from oxidative deterioration [85]. Ciprofloxacin produced oxidative stress in testis and semen of rats by escalating H_2O_2 and MDA (malondialdehyde) levels with lessening in GSH (glutathione), GST (glutathione-S-transferase), GPX (glutathione peroxidase), and SOD (superoxide dismutase) activities in semen. Elevation of GGT (gamma glutamyl transferase) and LDH (lactate dehydrogenase) activities have been observed in testis only. TSN (Testicular sperm number) and DSP (daily sperm production) were also declined. All these effects of ciprofloxacin can be restricted by giving ethanolic extract *Moringa oleifera* leaf, suggesting *Moringa oleifera* leaves have considerable anti-oxidant activity [86].

Due to antioxidant and free radical scavenging activity, *Moringa oleifera* leaves provided an antigenotoxic, antimutagenic, anticlastogenic and anticarcinogenic effect in mouse taking cyclo-phosphamide (CP). It was observed that CP has genotoxic, mutagenic and clastogenic effect due to hydroxyl radical which is given by its metabolites in the mouse. *Moringa oleifera* leaves extract has anti-oxidant and cause a scavenging effect on this hydroxyl radical and show chemo-protective effect [87] when given at doses of 250, 500, 1000 and 2000 mg/kg body weight for consecutive 7 days before CP was given [88]. Ethanolic extract of leaves showed greater in vitro anti-oxidant activity than *in vivo* antioxidant activity of ethanolic extract of leaves [89]. Acceleration of hepatic marker enzyme and lipid peroxidation induced by the antitubercular drug (isoniazid, rifampicin, and pyrazinamide) in rats can be prevented by prior administration of leaf extract of *Moringa oleifera* [90]. Oxidative stress caused by insulin resistance has an adverse effect on different body organs.

This effect can be prevented by giving an aqueous extract of leaves in rats [91]. The crude extract of *Moringa oleifera* bark possessed a significant amount of phenolic compounds so, it showed *in vitro* potent natural antioxidant activity by scavenging DPPH (2,2-diphenyl-2-picrylhydrazyl) and nitric oxide radical [92]. Pods contain a valuable amount of phenolic compounds, strong reducing power and free radical scavenging capacity [89]. *In vitro,* antioxidant activity of pods of *Moringa oleifera* has been compared with standard antioxidants such as BHA, α'-tocopherol, and ascorbic acid and it was found that pods show maximum free radical scavenging activity at the concentration of 2500ug/ml. Pods extract has concentration-dependent anti-oxidant activity [93].

Anti-hyperlipidemic Effect: Fruit of *Moringa oleifera* has ability to decline serum cholesterol, phospholipids, triglyceride, VLDL, LDL, cholesterol to phospholipids ratio, and atherogenic index but has significant activity to increase HDL ratio (HDL/HDL~total cholesterol) in hyperlipidemic rabbits as compared to control group, suggesting fruit has β-sitosterol, decrease reabsorption of cholesterol from endogenous sources, and increase its excretion into feces in neutral steroid form [94, 95].Leaves of *Moringa oleifera* were found to have a valuable anti-hypercholesterolemic effect on serum, liver, and cholesterol level by 14.35%, 6.40%, and 11.09% respectively in high-fat diet fed Wister rats [96]. Hypolipidemic effect of Moringa oleifera leaves investigated by using dehydrated drumstick leaf tablets {(DDL tablets), 8 tablets/ day(which is equivalent to 4.6 g DDL powder) for 50 days} in obese subjects having total serum cholesterol >180 mg/dl and/or serum triglycerides e" 140 mg/dl and it was found that the level of HDL is improved (6.25%), TG level is reduced by 1.65%, and LDL level is also decreased suggesting antihyperlipidemic effect of *Moringa oleifera* leaves due to the presence of high amount of β-carotene, and polyphenols [97].

Antiurolithiatic Property: Aqueous and alcoholic extracts of *Moringa oleifera* roots are reported to decrease and prevent urinary stone formation by diuresis and declining of urinary stone-forming components concentration (oxalate, calcium, and phosphate) in ethylene glycol induced lithiasis male albino rats so, have anti-urolithiasis activity [98, 99].

Immunomodulatory Activity: Seeds of *Moringa oleifera* were found to cause dose-dependent inhibition of spleen weight with a decrease in circulatory leukocyte and splenocyte count in mice. In addition to this, delayed-type hypersensitivity and humoral antibody responses were suppressed in mice using SRBC antigen. Seeds also ameliorated macrophage phagocytic activity in mice [100]. Aqueous leaf extract of *Moringa oleifera* increased serum interleukin-2, total leukocyte, lymphocyte counts, and liver ameliorated glutathione concentration ($p<0.05$), while interleukin-6, tumor necrosis factor-α, erythrocyte parameters, neutronphils, and monocyte concentrations malondialdehyde and serum uric acid were reduced ($p<0.05$), suggested that it has significant immunomodulatory effect [101]. Methanolic extract of leaves at 250 and 750mg/kg, per oral, showed accelerating effect on cellular and humoral immune response by increasing the levels of serum immunoglobulin, circulating antibody titer, adhesion of neutrophils and phagocytic index [102]. Pre-treatment with ethanolic extract of leaves at 125, 250 and 500 mg/kg body weight orally for 15 days shielded mice from immunosuppression induced by cyclophosphamide [103].

Effect on Central Nervous System: *Moringa oleifera* leaf extract affects CNS in a multiple ways by giving neuronal safety, altering synaptic connectivity, up-regulation of both axonal and dendritic length and branching, and by promoting neuronal differentiation. All these effects cause the enhancement of primary hippocampal neuron growth [104]. Leaf extract also showed CNS inhibitory effect in Holtzman strain adult Albino rats having penicillin (PCN) induced convulsion, locomotor behavior, brain serotonin (5-HTT), dopamine (DA) and norepinephrine (NE) level when given at 100, 200, 300, 350, 400, 450 mg/kg; per oral. It was observed that leaf extract protects seizer, accelerates 5-HTT but ameliorates DA in the cerebral cortex (CC), midbrain (MB), caudate nucleus (CN) and cerebellum (CB) as well as decreases NE in CC only [105]. These types of monoamine modulatory properties had beneficial effects in Alzheimer's disease in rats because in this disease monoamines level become irregular 106. Methanolic extract showed CNS dose-dependent depressant effect in mice.

It was revealed that root extract accelerated hypnosis induced by pentobarbitone sodium, diazepam and meprobamate, as well as promoted analgesia induced by morphine and pethidine and convulsion produced by strychnine and leptazol, can be prevented by giving root extract [107].

Nephroprotective Effect: Aqueous-ethanolic extract of *Moringa oleifera* at 150 and 300mg/kg has been shown the decrease in serum urea and creatinine levels possibly by suppressing lipid per-oxidation in nephrotoxicity induced by gentamicin in rabbits [108].

Antiulcer Activity: Leaves of *Moringa oleifera* tested for its antiulcer activity. It has been observed that leaves modulate 5-HT secretion through EC cells via 5-HT3 receptors in GIT of Adult Holtzman strain albino rats so can be used for the treatment of ulcer [109]. Alkali preparation of roots and fresh leaf juice studied for their anti-ulcer activity. It was found that roots possessed better ulcer protective activity than a leaf in male albino rats with ulcer induced by aspirin. The anti-ulcer property was suggested due to alkaloidal contents and anti-histaminic activity of roots and leaf [110]. Indomethacin induced gastric ulceration ameliorated when leaf extract was given at 200, 300 and 400mg/kg of body weight in rats [111]. Anti-secretary effect of acetone and methanol extract of the leaves has been assessed in pylorus-ligated rats, and the same extract possessed cytoprotective effect in ethanol, indomethacin, stress-induced gastric ulcers and cysteamine-induced duodenal ulcers [112].

Wound Healing Activity: The bark of *Moringa oleifera* has been examined for its wound healing property. In Wister albino rats it was observed that bark causes fastening of epithelization, accelerate wound contraction, promote granulation breaking strength and hydroxyproline content in dead space of wound [113]. Aqueous extract of leaves showed significant *in vitro* wound healing ability by accelerating proliferation and viability as well as the migration of human dermal fibroblast (HDF) cells suggesting due to a bioactive compound known as Vicenin-2 [114]. Conditions of Excision, incision and dead space (granuloma**)** effectively treated by ethyl acetate extract of dried leaves. Aqueous leaf extract at 300mg/kg of body weight showed acceleration in wound closure rate, skin-breaking strength, granuloma breaking strength, hydroxyproline content, granuloma dry weight and decrease in scar area in albino rats, suggesting due to deposition of collagen [115]. Valuable amount of crude proteins, zinc and some anti-microbial component present in seeds extract caused acceleration in wound closure rate, skin-breaking strength, granuloma breaking strength, hydroxyl-proline content, granuloma dry weight and decrease in scar area in albino rats [116].

Antidiarrheal Activity: The methanolic root extract of *Moringa oleifera* has shown antidiarrheal activity against castor oil induced diarrhea in rats possibly by dwindling severity, the rate of diarrhea, intestinal fluid amassing, the quantity of intestinal contents, and intestinal passing at 200 (p<0.01) and 400 mg/kg (p<0.001). Root extract has better anti-diarrheal activity than atropine [117].

Effect on Reproduction System: Leaves of *Moringa oleifera* has revealed activity in male mice (Mus musculus) at 0.5, 5 and 50 mg/30 g BW daily for 21 days.It was found that *Moringa oleifera* leaves improved weights of testis (at medium and high doses); epididymis (at all doses); seminal vesicle (at the high dose) and also enlarged seminiferous tubule diameter (at all doses); augmented thickness of epididymal wall (at medium and high doses); higher score for lumen formation (at the high dose) and epididymal maturity (at all doses). It was also observed there is no effect on serum luteinizing hormone and follicle stimulating hormone in male mice [118].

Antidiabetic Activity: Methanolic extract of *M. oleifera* has been investigated for its anti-diabetic activity. It was found that fruit has niazicin A, phenylacetonitrile, methyl N-{4-[(α-L-rhamno-pyranosyl) benzyl]} carbamate, and methyl N-{4-[(4'-O-acetyl -α -L -rhamnopyranosyl) benzyl]} carbamate. All these compounds have shown insulin secretagogue effect in rodent pancreatic β-cells at 100 ppm by unknown mechanism [119]. Fasting blood glucose (FBG) and oral glucose tolerance test (OGTT) revealed amelioration of blood glucose level in normal animals by 26.7 and 29.9% respectively 200mg/kg of leaves extract. There was a maximum decrease in blood glucose in the sub and mild diabetic condition 31.1 and 32.8%

respectively at 200 mg/kg. Decrease in FBG and postprandial glucose (PPG) values in severe diabetic condition 69.2 and 51.2% was observed after 21 days treatment with leaf extract [120]. Polyphenolics compound such as quercetin-3-glucoside and fiber contents in MO leaf powder were the major cause of glucose reduction in Wistar rats and Goto-Kakizaki (GK) rats, modelled Type 2 diabetes [121].

Cyclo-oxygenase (COX) Inhibitory Effect: Methanolic extract of *Moringa oleifera* has been assessed for its inhibitory effect on COX enzyme. Compounds such as 1-O-phenyl-α-L-rhamno-pyranoside and 4-[(β-D-glucopyranosyl)-(1→3)-(α-L-rhamnopyranosyl)] phenylacetonitrile at 83ppm have been shown inhibition of COX in rodents. Compound 6 exhibit greater specificity for COX -2 (46%) than COX-1 [120].

Anti-Asthmatic Activity: Powder of seed kernels of *Moringa oleifera* studied for its anti-asthmatic activity. It was observed that when powder was given in dose of 3g for 3 weeks then there was noteworthy progress in forced vital capacity, forced expiratory volume in one second, and peak expiratory flow rate values by 32.97 ± 6.03%, 30.05 ± 8.12%, and 32.09 ± 11.75%, respectively, in asthmatic subjects with no adverse effect, so seed powder can be used for the treatment of bronchial asthma [122]. It has been observed that the seed kernel at 100mg/kg and 200 mg/kg increased pre convulsion time in models exposed by acetylcholine or histamine.

It was suggested that bronchodilating property is due to its spasmolytic effect, anti-inflammatory effect, antimicrobial activity and dose-dependent inhibition of mast cell degranulation. Chemicals such as toluene diisocyanate - induced immune - mediated inflammatory responses in rats that leads to severity in asthma can be prevented by giving seed extract, suggesting due to its antioxidant activity [123,124,125].

Anti-implantation Activity: Roots of *Moringa oleifera* expressed significant anti-implantation activity in rats [126].

Antipyretic Activity: *Moringa oleifera* seeds have been studied for their anti-pyretic activity. It was found that ethanolic and ethyl acetate extract of seeds had considerable anti-pyretic activity in rats [115].

Cardiovascular Effect: Anti-oxidant, anti-lipid per-oxidation and myocardial preservative effect of leaves extract of *Moringa oleifera* kept heart protected from toxicity induced by isoproterenol in rats [127]. Phyto-chemical screening of ethanolic extract of leaves provided valuable compounds such as niazinin A, niazinin B, niazimicin, and niaziminin. All these compounds showed significant hypotensive and bradycardiac effects in anesthetized rats at 1-10 mg/kg owing to their depressant action [17, 18].

Antianthelmintic Activity: Extract of *Moringa oleifera* showed dose-dependent anti-anthelmintic activity against Indian earthworm *Pheritima posthuma* [128].

Protease Inhibitor Activity: *Moringa oleifera* whole plant was assessed for its protease inhibition activity, and it was found that mature leaves showed 77% and seed 63% of inhibition against trypsin activity. Barks, flowers, and roots, however, revealed very less amount of trypsin inhibitor activity [129].

Toxic Effect: Aqueous leaf extract of *Moringa oleifera* has no significant toxicity at higher dose except show a decrease in movements and dullness because of dose-dependent decline in food consumption in animals at 250 to 1500 mg/kg extract [130]. Seeds of *Moringa oleifera* at sublethal dose has shown to cause elevation of WBC count, MCV, MCH, plasma glucose, AST, ALP, and ALT but decrease plasma protein level in freshwater fish *Cyprinus carpio* [131].

Bioenhancing Activity: Niaziridin; a new nitrile glycoside present in pods. It is very useful for accelerating bioavailability and ameliorates toxicity, dose, dosage, cost, and particularly duration of therapy of different drugs especially antibiotics (rifampicin, tetracycline, ampicillin, quinolones, fluoroquinolones, isoniazid *etc*.), antifungal (clotrimazole, ketoconazole, miconazole and itraconazole, etc) and nutrients at 0.1µg/ml to 10µg/ml or in case of lyophilized fraction 0.1µg/ml to 100µg/ml. It was assessed niaziridin enhances bioavailability from 2 to 80 folds of above-mentioned drugs [132].

Purification of Water: Due to edible oil and water-soluble substances, *Moringa oleifera* seeds are used for cleaning of water and wastewater [133]. *Moringa oleifera* seeds have flocculating protein. Moringa is nontoxic, biodegradable, environmentally friendly, has less effect on pH and conductivity of water, a sludge formed after coagulation is not harmful. Not only in tropical developing countries but common *Moringa oleifera* is especially used for softening of hard water and use as alternative coagulant [134]. *Moringa oleifera* seeds have carbohydrate binding protein that is lectin CMOL (Coagulant *Moringa oleifera* lectin) and WSMOL (Water Soluble *Moringa oleifera* lectin) that have coagulant activity that is why *Moringa oleifera* seed powder can clean turbid water [135].

CONCLUSION: Looking upon wide prospects and potential of *Moringa oleifera* it is evident that the names "miracle tree" or "multipurpose tree" are quite fit for this tree. It should be cultivated on a large scale to obtain nutritional as well as health benefits. Different parts of the plant have widespread and imperative medicinal potential in diverse diseased conditions, but more research is required to see the sights and to evaluate the maximum wealth of this tree especially in developing countries.

ACKNOWLEDGEMENT: Nil

CONFLICT OF INTEREST: No conflict of interest between authors.

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How to cite this article:
Ahmad S, Akbar U, Asif H M, Khaliq FH and Khurshid U: Phytochemistery, Medicinal wealth and nutritional strength of *Moringa oleifera* Lam. (Moringaceae). Int J Pharmacognosy 2016; 3(3): 115-30. doi link: http://dx.doi.org/10.13040/IJPSR.0975-8232.IJP.3(3).115-30.