Himalayan Journal
of Agriculture
ISSN Print : 2709-3603 | ISSN Online : 2709-3611
OPEN ACCESS

Medicinal Properties of Super Fruit Aegle Marmelos

Arun Kumar Srivastava[1*] and Vinay Kumar Singh[2]
[1]Department of Zoology, M. G. P.G. College, Gorakhpur- 273001, U.P. India
[2]Department of Zoology and Environmental Science, DDU Gorakhpur University, Gorakhpur - 273009 U. P. India

Article History	
Received:	2023-01-22
Revised:	2023-02-03
Accepted:	2023-03-14
Published:	2023-04-10

Corresponding Author*
Arun Kumar Srivastava

DOI: 10.47310/hja.2023.v04i01.019

How to Cite the Article:
Srivastava, Arun Kumar and Vinay Kumar Singh. "Medicinal properties of super fruit Aegle Marmelos." *Himalayan Journal of Agriculture*, vol. 04, no. 01, 2023, pp. 01-07.

Copyright @ 2023: This is an open-access article distributed under the terms of the Creative Commons Attribution license which permits unrestricted use, distribution and reproduction in any medium for non commercial use (NonCommercial, or CC-BY-NC. ND) provided the original author and source are credited.

Abstract: Medicinal plants are potential source of phytochemicals valuable for novel drug discovery. These herbs are used in traditional Chinese, Ayurveda, Siddha, Unani and Tibetan medicines. Ancient literature such as Rigveda, Yajurveda, Atharvaveda, Charak Samhita and Sushrut Samhita also describe the use of herbs for the treatment of various health problems. Aegle marmelos is commonly known as wooden apple belongs to the Rutaceae family. The important phytochemicals isolated from various parts of the plant are alkaloids, cardiac glycoside, saponin, steroids, coumarines terpenoids, phenylpropenoids, tannins, polysaccharides and flavonoids. These phytochemical components are well known for their pharmacological and biological activity against certain chronic disease like cancer, cardiovascular disease, immunosuppressive disease and gastrointestinal disorder. Bael pulp is a rich source of glucose, sugar and fiber. In the traditional medicine system, the pulp of bael is used as an energy drink with milk. Other nutritive elements of bael are-protein, fat, minerals, fibers, carbohydrates, calcium, phosphate, potassium, iron, vitamins A, vitamin B1, nicotinic acid, riboflavin, vitamin C.

Keywords: Alkaloids, Saponin, Aegelin, Marmelosin, Carotenoids, Coumarin

INTRODUCTION

Medicinal plants are potential source of phytochemicals extremely useful for novel drug discovery [1]. Phytochemicals such as carotenoids, terpenoids, flavonoids, polyphenols, alkaloids, tannins, saponins, pigments, enzymes, minerals and vitamins, possess different kind of remedial effects [2]. In the remote times, medicinal plants were used for regulation and prevention of health complaint and are continued to play a decisive role in the maintenance of human as well as animal health [3]. Medicinal plants are the base of conventional system of medicine and herbal industry for the evolution of new drug and these herbs are used in traditional Chinese, Ayurveda, Siddha, Unani and Tibetan medicines [4]. Ancient literature such as Rigveda, Yajurveda, Atharvaveda, Charak Samhita and Sushrut Samhita also describe the use of herbs for the therapy of various health problems [5]. Aegle marmelos is commonly known as wooden apple belongs to the Rutaceae family and the tree is examining under the category of "aromatic" species [6]. The Aegle marmelos is a small genus of three species disseminate in tropical Asia and Africa and the tree of A. marmelos originates from Eastern ghats and central India and found mainly in foothills of Himalayas, Uttar Pradesh, Madhya Pradesh, Rajasthan, Chhattisgarh and Bihar (The wealth of India, n.d.). Bael is a deciduous sacred tree, related with Gods having practical properties, especially as a healing agentn [7]. Rakesh [8], written in his article that this tree is popular in 'Shiva' and 'Vishnu' temples and Its leaves are trifoliate symbolizing the 'Thrimurthies'- Brahma, Vishnu, Shiva, with spear shaped leaflets resembling "Thrisoolam" the weapon of Lord Shiva and A. marmelos is also known as bael, wooden apple, belo and bilwa. (The wealth of India, n.d.) reported that the important phytochemicals segregated from various parts of the plant are alkaloids, cardiac glycoside, saponin, steroids, coumarins terpenoids, phenylpropanoids, tannins, polysaccharides and flavonoids and these phytochemical components are well known for their therapeutic and biological activity against certain chronic disease like cancer, cardiovascular disease, immunosuppressive disease and gastrointestinal disorder. The Fruits are yellowish green, with small dots and the pulp of dried fruits retains it yellow and there are innumerable seeds, embedded in the pulp and cotton-like hairs on their outer surface (The wealth of India, n.d.). Lambole *et al.* [9], updated that the fruit, round, pyriform, oval, or oblong, 5-20 cm in diameter, may have a thin, hard, woody shell or a more or less soft rind, gray-green until the fruit is fully ripe, when it ripe turns yellowish.

They also communicated that it is dotted with aromatic minute oil glands and inside, there is a hard central core and 8 to 20 faintly defined triangular segments, with thin, dark-orange walls, filled with aromatic, pale orange, pasty, sweet, resinous, more or less astringent pulp [9]. Fruits contain 61.5g water, 1.8g protein, 0.39g fat, 1.7g minerals, 31.8g carbohydrates, 55mg carotene, 0.13mg thiamine, 1.19mg riboflavin, 1.1mg niacin and 8mg per 100g of edible portion vitamin C [10]. Rakulini and Kalaichelvi [11], updated that bael fruit is highly alimentative with the richest source of riboflavin and physicochemical studies prove that bael fruit is rich in nutritional value and this is being used from several years ago. Bael pulp is a rich source of glucose, sugar and fibre and in the ancestral medicine system, the pulp of bael is used as a power drink with milk [12]. They also reported that drink is very useful to eliminate the hair from the stomach and other nutritive elements of bael are-protein, fat, minerals, fibers, carbohydrates, calcium, phosphate, potassium, iron, vitamins A, vitamin B1, nicotinic acid, riboflavin, vitamin C [12]. The different parts of the plant extract possess pharmacological activities like anticonvulsant, antioxidant, antihyperglycemic, anxiolytic, antidepressant, antihistaminic, antimicrobial, hepato protective, analgesic, immuno modulatory, cardio protective and antithyroid activity [6]. The present review article is focused to explore the different pharmacological activity of A. marmelos significant position in the modern drug industries due to the synergistic action with fewer side effects in the combination of herbal compounds.

Scientific Position

- Kingdom: Plantae
- Order: Sapindales
- Family: Rutaceae
- Subfamily: Aurantioideae
- Genus: Aegle
- Species: A. marmelos
- Nomenclature : Aegle marmelos (L.) Corr. Serr

Chemical Composition

Swarnkar [6], updated that Aegle marmelos having number of varieties of compound like alkaloids, cardiac glycoside, saponin, steroids, coumarines (marmelosin, marmesin, marmin, imperatorin, scopoletin), terpenoids, phenylpropenoids, tannins, polysaccharides and flavonoids. Kumari [13], reported that Aegle marmelos leaves contain γ-sitosterol, aegelin, lupeol, rutin, marmesinin, β-sitosterol, flavone, glycoside and phenylethyl cinnamamides. Shahidine, an alkaloid having oxazoline core has been isolated as a major ingredient from the fresh leaves of Aegle marmelos. Anupama [14], reported new alkaloids from the leaves of A. marmelos halfordino, ethylcinnamamide and marmeline, phenylethyl cinnamides, anhydromarmeline, aegelinosides A and B. Neeraj [15], reported that α-Phellandrene which is terpenoid was found to be the familiar constituent of the essential oil from leaves, twigs and fruits. They also reported that Limonene (82.4%) was main constituent from bael leaves which are characteristic marker for identification of A. marmelos oil samples. Prathapan [16], reported that Rutin flavon, flavon glycosides and flavon-3-ols are the major flavonoids of A. marmelos leaves and gets its medicinal values on basis of the various bioactive conjugates present in it like alkaloids, coumarins, polysaccharides, essential oils etc. Mali [10], updated that other sustaining constituents present in Bael fruits are water, sugar, protein, fiber, fat, calcium, phosphorus, potassium, Iron and vitamins. They also reported that the major alkaloids present in Bael are aegelin, aegelinine, fragine, o-methyl halforodinine, oiso pentanyl halfordinol, ethyl cinnamide, ethyl cinnamide. Choudhary [17], reported that the essential oil of the leaves contains d-limonene, 56% a-dphellandrene, cineol, citronellal, citral; 17% pcyrnene, 5% cumin aldehyde and the gum in wild fruits especially when they are unripe. Sawale [18], reported that the coumarins present in Bael fruit include marmelosin, marmesin, imperatorin, marmin, alloimperatorin, methyl ether xanthotoxol, scoparone, scopoletin, umbeliferone, marmelide and marmenol. They also updated that Marmelosin a resinous substance is likely the therapeutically active principle of Bael fruits. Ascorbic acid, sitosterol, crude fibres, α-amyrin, crude proteins are another minor constituent. The numerous polysaccharides present in Bael are Galactose, arabinose, uronic acid and carotenoids are principal pigment responsible for imparting pale-yellow colour to fruit [11].

Antimicrobial Activity

Rahman [19], disclosed that the essential oil isolated from the leaves of A. marmelos tree have antifungal activity against animal and human fungi like Trichophyton mentagrophytes, Trichophyton rubrum, Microsporum gypseum, Microsporum audounii, Microsporum cookie, Epidermophyton floccosum, Aspergillus niger, Aspergillus flavus and Histoplasma capsulatum. Pramila [20], investigated that antimicrobial activity of the plant was tested by agar wall diffusion method. The aqueous, petroleum ether and ethanol extract of the leaves adapted antimicrobial activity against Escherichia coli, Streptococcus pneumonia. Lamia [21], reported that an oil of plant extract is proved antifungal against various fungi like Trichophyton mentagrophytes, Trichophyton rubrum, Microsporum gypseum, Microsporum audouinii, Microsporum cookie, Epidermophyton floccosum, Aspergillus niger, Aspergillus flavus and Histoplasma capsulatum. They also reported that this plant extract showed influence against human coxsackieviruses B1-B6. [22], tested antibacterial activity of the plant parts such as leaves, fruits and barks of A. marmelos by disc diffusion method against Bacillus subtilis, Staphylococcus aureus, Klebsiella pneumoniae, Proteus mirabilis, Escherichia coli, Salmonella paratyphi A and Salmonella paratyphi B and found that among chloroform, methanol extract and water-methanol extract showed significantly high diversion against the bacteria.

Anticonvulsant Activity

[23], reported that the aqueous leaves extract of A. marmelos possess anticonvulsant activity against

Pentylenetetrazole induced seizures in mice. They concluded that anticonvulsant activity of aqueous leaves extract of A. marmelos was due to presence of Lupeollinoleate, Skimmianine, Eugenol which was recognize by Liquid chromatography. Lomate [24], updated that ethanolic extract of leaves of A. marmelos reveals anticonvulsant activity due to presence of flavonoid and it interfere with GABA mechanism to exert their anticonvulsant activity. Pramila [20], also described in his review that the aqueous leaves extract of A. marmelos possess anticonvulsant activity against Pentylenetetrazole induced seizures in mice due to presence of Lupeollinoleate, Skimmianine, Eugenol which was identified by Liquid chromatography mass spectrometry.

Antihistaminic Activity

Swarnkar [6], updated in his review article that skimmianine, zeorin and Aegeline markedly inhibited the histamine release from rat leukemia cell line (RBL-2H3 cell) induced by DPN 24-BSA, thapsigargin and ionomycin. [25], reported that Marmin potently suppressed histamine release from RBL-2H3 cells induced by DNP24-BSA, a specific antigen for monoclonal IgE antibody.

Anxiolytic and Antidepressant

[26], investigated the methanolic leaves extract of A. marmelos which possess anxiolytic and antidepressant activity and it enhances anxiolytic and antidepressant activity of imipramine and fluoxetine.

Antioxidant Activity

Seal *et al*. [28] reported that antioxidants are having free radicals scavenging activity and capability of protecting the cells in oxidative stress and it is due to the presence of flavones, isoflavones, flavonoids, anthocyanin, coumarin, lignans, catechins and isocatechins. A. marmelos is extensively reported to possess antioxidant activity against a variety of free radicals [27], Ethanolic leaves extract of A. marmelos possess antioxidant activity due to present of flavonoids, alkaloids and terpenoids [28]. [29], studied that antioxidant activity of leaf extract of A. marmelos was due to presence of high levels of Total Phenolic Content (TPC) and Total Flavonoid Content (TFC) in the extract. [2], also updated that ethanolic leaves extract of Aegle marmelos possess antioxidant activity due to presence of flavonoids, alkaloids and terpenoids.

Hepatoprotective Activity

It was reported that leaves, seed and pulp of fruit of A. marmelos shows hepatoprotective activity Rahman [19], reported that the methanolic leaves extract of Aegle marmelos possess hepatoprotective activity against paracetamol induced hepatotoxicity in rats. Bhawani and Shanmugam also reported that alcoholic extract of Aegle marmelos @100 mg/kg b.w. produced hepatoprotective activity against Staphylococcus aureus intoxicated rats. Singanan [30], worked on Aegle marmelos leaf extract on alcohol induced liver injury in albino rats and presented data of excellent hepatoprotective effects and concluded that aqueous extarct of bael fruit pulp and seeds are effective in the treatment and prevention of CCI4 induced hepatic toxicity. Vaishnav [31], updated in some study on animals with four group, administrated 30% ethyl alcohol for 40 days with control group of Aegle marmelos leaves and concluded that the Aegle marmelos leaves have excellent hepatoprotective effect.

Analgesic Activity

Shankarananth [32], reported that the methanolic leaves extract of A. marmelos at the dose of 200 and 300 mg/kg showed significant analgesic activity on acetic acid induced writhing and tail flick test in mice.

Antifungal Activity

A, [33], reported that essential oil from Aegle marmelos leaves may interfere with the Ca2+ -dipicolonic acid metabolism pathway and possibly inhibit the spore formation at concentration of 500 ppm. Balakumar [34], reported that ethanolic, methanolic and water leaves extract of A. marmelos possesses antifungal activity against dermatophyte fungi. Patel [35], updated in his review article that anti-fungal activity of essential oils isolated from the leaves of Bael using spore germination assay and found that the oil exhibited variable efficacy against different fungal isolates and 100% inhibition of spore germination of all the fungi tested was observed at 500ppm.They proposed that essential oil from bael leaves may interfere with the Ca2+-dipicolonic acid metabolism pathway and possibly inhibit the spore formation [35]. M, [36], also demonstrated the antifungal activity of ethanolic root extract against Aspergillus fumiganus and Trichphyton mentagrophytes.

Neuroprotective Activity

Swarnkar [6], updated in his review article that ethanolic leaves extract of A. marmelos exhibited neuroprotective effect against streptozocine induced cognitive impairment in male rats and the extract also showed acetylcholinesterase (AChE) inhibitory activity in the brain. They investigated that the inhibition of AChE improves the symptoms of cognitive deficit by elevating the levels of acetylcholine [6].

Anti-Ulcer Activity

Ramakrishna [37], reported that methanolic extract of unripe fruit of Aegle marmelos reduced gastric ulceration and prevent the oxidative stress caused by Helicobacter Pylori-Lipopolysaccharide in rats. Gastro protective effect of extract was due to the presence of luvangetin which lowers oxidative stress in the gastro duodenal mucosa. Swarnkar [6], studied that ripe fruit of A. marmelos protect gastric mucosa in NSAID induced ulceration in rats by its antisecretory and cytoprotective property. Methanolic and aqueous fruit seed extract of A. marmelos exhibited antiulcer activity due to presence of quercetin compound [38]. [38], reported that oral; administration of pyranocoumarin isolated from the seeds of Aegle marmelos Correa, showed significant protection against pylorus-ligated and aspirin-induced gastric ulcers in rats and cold restraint stress-induced gastric ulcers in rats and

guinea pigs. Maity [22], reported that pre-treatment of rats with unripe bael fruit extract produce a significant inhibition of absolute ethanol induced gastric mucosal damage.

Antiviral Activity

The ethanolic Bael fruit extract have shown antiviral activity against virus of Ranikhet disease (The wealth of India, n.d.), Santhi [39], Maity [22], also reported that bael fruit contain marmilide which is the most effective viricidal agent which interferes with early events of replicating cycle. Remya [40], updated in his short communication that anti-cancer activity research proved that extracts from Aegle marmelos are able to inhibit the in vitro proliferation of human tumor cells, erythroleukemic HEL, melanoma colo38, MDAMB- 231 and breast cancer MCF7 cell lines. Mahato [41], reported in his book chapter that the ethanolic leaf extract of A. marmelos showed greater antiproliferative activity against colon, breast carcinoma and leukaemia cell line. They also noted that anticancer activity was due to leaves and fruit of bael which contain lupeol, eugenol, citral and marmelin skimmianine. It has been reported that ethanolic leaves extract of A. marmelos showed antiproliferative activity against ascites tumor in swiss albino mice [42]. Akhouri [43], reported that the hydromethanolic A. marmelos bark extract has antitumor and antioxidant potential against 7, 12- Dimethyl Benzene Anthracene (DMBA) induced skin papillomagenesis in swiss albino mice. Sharma [44], studied on ethnolic extract of dried fruit pulp of Aegle marmelos against various intestinal pathogens i.e. Shigella boydii, S. sonnei & S. Flexneri and proposed that certain phytochemicals including Phenols, Tannins and Flavonoids were effective against all. Nag [45], also experimented Aegle Marmelos on certain pathogenic bacteria like Salmonella typhi, Pseudomonas aeruginosa, Aeromonas hydrophyla & Vibrio sp. and concluded its positive bactericidal effects.

Immunomodulatory Activity

It was observed that methanolic leaves extract of A. marmelos stimulate cell mediated and antibody mediated immune responses in rats [46]. They also reported that low dose of methanolic extract of Aegle marmelos was found to be most effective in cell mediated immune response, whereas, high dose was best effective in humoral immunity [46].

Antithyroid Activity

A. marmelos leaves extract decreased thyroid hormone level [47]. They noted that it was due to presence of scopoletin which have more dominant therapeutic activity than propylthiouracil drug. Jagetia [48], reported that aqueous leaves extract of A. marmelos exhibited cardioprotective effect against isoproterenol induced myocardial infarction in rats the cardio protective activity is due to the presence of aurapten as potent compound. Bael fruit is the most effective remedy for prevention of diarrhea [49]. It has been reported that antidiarrhoeal activity was due to presence of tannins and flavonoids that inhibit intestinal motility [50]. Panda [51], isolated Scopoletin (7-hydroxy-6- methoxy coumarin) from Aegle marmelos leaves and evaluate for its potential to regulate hyperthyroidism. It was observed that scopoletin (at 1.00 mg / kg, p.o. for 7 days) to levothyroxine treated animals, decreased serum thyroid hormones level. It was also proved that the scopoletin have superior therapeutic activity than the standard antithyroid drug, propylthiouracil [51].

Antidiabetic Activity

Anusha [52], evaluated the aqueous extract of Aegle marmelos leaves for hypoglycemic and antioxidant effect by using alloxon induced diabetes in male albino rats and proposed AML may be useful in the long-term management of diabetes. Kamalakkannan and Prince also reported the anti-hyperlipidaemic activity of aqueous extract of Aegle marmelos fruits was by using the streptozotocin induced diabetic wistar rats. Sharma [47], discussed in his review article that alcoholic extract of Aegle Marmelos, Momordica Charantia and Eugenia Jambolana against Streptozotocine induced diabetic rats and confirmed their protective activity against laboratory induced cell necrosis. Thakur [53], reported that leaf extract of Aegle Marmelos on Alloxane induced diabetes and noted that used extract was enough capable to reduce oxidative stress by scavenging lipid peroxidation and enhancing certain Anti-oxidant levels which causes lowering of elevated blood glucose level. Beside of all above cited work, Sharma [44], had presented a tremendous result of Aegle Marmelos and documented its hypoglycemic action along with other pharmacological actions on molecular level. Anupama [14], studied that bilwa shows the antidiabetic property and it was reported in alloxan diabetic rats. They noted that the methanolic extract of leaves of bilwa reduces the blood sugar level. Patel [35], reported that leaf extract has been used in ayurvedic system of medicine for diabetes which enhances the ability to utilize the external glucose load in the body by stimulation of glucose uptake like insulin. Chauhan [54], evaluated in vivo in animal models for antidiabetic activity of different organic extracts and fresh juice of Aegle marmelos. They noted that antidiabetic potential of the leaves and callus of Aegle marmelos in streptozotocin induced diabetic rabbits and concluded that all the extracts reduced the blood sugar level in streptozotozin diabetic rabbits, however, among the various extracts, the methanol extracts of the leaf and callus brought about the maximum antidiabetic effect [55]. Swarnkar [6], also reported that the ethanolic extract of Aegle marmelos leaves possess antihyperglycemic activity when administered orally at 250 and 500 mg/kg to diabetic rats. They noticed that decrease in glucose absorption and inhibition of both α amylase and intestinal disaccharidase enzyme activity were observed due to inhibition of carbohydrate digestion and absorption and improvement of insulin action to uptake glucose in peripheral tissue.

Cardioprotective Activity

The leaf extract of bilwa has preventing effect in isoprenaline induced myocardial infarction in rats [56], [57], reported that bilwa aact as a cardiac depressant and also in palpitation. They also suggested that fresh fruit

juice of bilwa with different dilution were used for cardiotonic activity. Aqueous and alcoholic extract of the leaf are reported to possess cardio-tonic effect, like digitalis, on amphibian and mammalian hearts (The wealth of India, n.d.).

Anticancer Activity

Cancer is the most concerned deadly disease in the whole universe. It will increase to 3-fold and scientists have predicted that in such crisis situation, anything that can heal or soothe this disease will the boon for us. Aegle marmelos can be an effective weapon to boost our healing process in fighting cancer disease and Studies showed that plant extract can control the increase of leukemic K 562, Tlymphoid Jurkat, B-lymphoid Raji, erythroleukemia HEL, melanoma Colo38 and breast cancer cell lines MCF 7 and MDA-MB-231 [20]. [58], reported that the anticancer potential of folk medicine used in Bangladeshi and used extracts of Aegle marmelos for cytotoxic action using brine shrimp lethality assay; sea urchin eggs assay and MTT assay using tumor cell lines and the extract of Aegle marmelos was found to exhibited toxicity on all used assays. Rahman [19], investigated the anticancer effect of hydroalcoholic extract of bael leaves in the animal model of Ehrlich ascites carcinoma and proposed that induction of apoptosis may be due the presence of skimmianine in extract also noted that the cancer is 2nd main cause of death in both men and women in developed and developing countries. Akhouri [43], reported that the fruit extract of bilwa is used to improve the immune system that will finally increase the anticancer activity of a body. [49], experimented that the phytochemicals such as lupeol, eugenol, citral, cineole and d-limonene present in A. marmelos possess antineoplastic effects. [59], updated that it can even prevent cell proliferation. Constituents such as 1-hydroxy-5, 7-dimethoxy-2-naphthalene-carboxaldehyde (Marmelin) present in the plant can prevent the growth of epithelial cancer cell. Furthermore, phytochemicals present in the plant such as lupeol, eugenol, citral, cineole and d-limonene present can show antineoplastic effects [59].

Radioprotective Activity

Jagetia and Baliga reported that radioprotective effect of Aegle marmelos extract by exposing different doses of gamma-radiation in mice and found that oral administration of extract resulted in an increase in radiation tolerance by 1.6 Gy. Jagetia [48], studied effects of plant extract on the peripheral blood and small intestine of Swiss albino mice. They exposed the animals to gamma radiation and data were collected against radiation-induced changes in the peripheral blood, spleen colony forming units and intestinal mucosa, reported that Aegle marmelos extract significantly reduces the deleterious effect of radiation in intestine and bone marrow of mouse [48], Jagetia [48], updated that hydroalcoholic fruit extract of A. marmelos produced radioprotective effect against gamma radiations in mice and it was due to phenolics and flavonoids present in fruits of A. marmelos.

Antispermatogenic Activity

[60], reported that anti-spermatogenic activity of ethanolic extract of Aegle marmelos leaves in rats. [61], updated the effect of ethanol extracts of leaves of A. marmelos for them in vitro effect on sperm motility and was suggested that the extracts had a considerable effect on the motility of sperm. Chauhan [54], also reported that an increase in concentration of the extracts decreased the motility of sperms. They described that leaf, seed and fruit of Bael plant may interfere with male fertility in a reversible manner. In Aegle marmelos bark, two chemical compounds such as marmin and fagarine are present which is claimed to be responsible for the reduction of male fertility [38], tested methanolic extract of Aegle marmelos and found that it reduces reproductive organ weight and serum testosterone levels. They also noted that it can even reduce sperm density, motility, viability and sperm acrosomal integrity. Changes of elongated spermatids, nuclear chromatin condensation and degeneration were seen and significance histopathological changes such as necrosis are seen along with testicular cytotoxicity. But interestingly, on withdrawal it restores the morphological changes (J, n.d.). Chauhan [54], reported that the effects of Aegle marmelos on the testicular reproductive system, a 50% ethanolic extract of Aegle marmelos leaves was fed orally to male albino rats at the dose levels of 200 and 300 mg/kg body wt./day for 60 days. Recovery was assessed for an additional 120 days. They noticed that the motility and sperm concentration were significantly reduced along with complete inhibition of fertility at a dose of 300 mg/kg. The level of serum testosterone also declined and spermatogenesis was impaired and the number of normal tubules and the height of epithelial cells of the caput and cauda were reduced significantly [54]. (J, n.d.) reported in his thesis that the cross-sectional surface area of Sertoli cells and mature Leydig cells was reduced along with a dose dependent reduction of preleptotene and pachytene spermatocytes. Thus, the antifertility effects of Aegle marmelos seemed to be mediated by disturbances in structure and function in testicular somatic cells including Leydig and Sertoli cells resulting in an alteration in physio morphological events of spermatogenesis. However, complete recovery was observed after a 120-day withdrawal (J, n.d.).

Antipyretic Activity

Anupama [14], described in his article that the use of modern medicine is not safe as herbal one. They reported that Bael shows anti-pyretic property and used in fever and pain. studied that the ethanolic extract, at dose of 200 mg/kg body weight and 400 mg/kg body weight, produced significant antipyretic effect of extracts was comparable to that of paracetamol (100 mg/kg body weight) and concluded that Bael shows antipyretic effect. Priya [62], reported that in albino rats where yeast induced pyrexia attacked rats were treated with Bael extracts and ethanolic extract and found that this antipyretic impact was similar to the impact of 100 mg/kg body weight of paracetamol.

CONCLUSION

It is quite evident from this review that Aegle marmelos contains a number of phytoconstituents which reveals its uses for various therapeutic purposes. The Plant or its individual parts can be used for the treatment of various disorders in human being such as, diabetes, liver toxicity, fungal infection, microbial infection, inflammation, pyrexia and to relieve pain. Still, so much work is required with the Aegle marmelos to investigate the mechanism of actions with other therapeutic activities. From above article it's clear that bilwa is one of the auspicious plants with its valuable properties. In today's world man went towards modern medicine to get instant relief from diseases, knowing the side effect of that medicine. The present review elaborates various therapeutic and innovative approaches to find out the perspective on globalization of the Bael tree. There is a need to develop, protect and promote traditional medicines for the betterment of the health care system.

REFERENCES

[1] Alam, S. *et al*. "Antidiabetic phytochemicals from medicinal plants: prospective candidates for new drug discovery and development." *Frontiers in Endocrinology*, vol. 13, 2022.

[2] Mujeeb, F. *et al*. "Phytochemical evaluation, antimicrobial activity and determination of bioactive components from leaves of Aegle marmelos." *BioMed Research International*, 2014, Article ID 497606.

[3] Sofowora, A. *et al*. "The Role and place of medicinal plants in the strategies for disease prevention." *African Journal of Traditional, Complementary and Alternative Medicines*, vol. 10, no. 5, 2013, pp. 210–229.

[4] Shakya, A.K. "Medicinal Plants: Future source of new drugs." *International Journal of Herbal Medicine*, vol. 4, no. 4, 2016, pp. 59–64.

[5] Surana, A. and R. Wagh. "Phytopharmacological Review of Hamelia patens." *International Journal for Pharmaceutical Research Scholars*, vol. 4, no. 2, 2015, pp. 290–295.

[6] Swarnkar, R. *et al*. "Pharmacological properties of Aegle marmelos: A Review." *International Journal of Current Microbiology and Applied Sciences*, vol. 8, no. 5, 2019, pp. 1600–1608.

[7] Anadani, S.V. *et al*. "Physico-chemical characteristics of bael (aegle marmelos) fruit and pulp." *Chemical Science Review and Letters*, vol. 10, no. 8, 2021, pp. 1282–1284.

[8] Rakesh, N. *et al*. "A Study on anti-bacterial activity of Aegle marmelos." *World Journal of Pharmaceutical Research*, vol. 9, 2019, pp. 1013–1021.

[9] Lambole, V.B. *et al*. "Phytopharmacological properties of aegle marmelos as a potential medicinal tree: An overview." *International Journal of Pharmaceutical Sciences Review and Research*, vol. 5, no. 2, 2010, pp. 67–72.

[10] Mali, S.S. *et al*. "A Systematic review on Aegle marmelos (Bael)." *Research Journal of Pharmacognosy and Phytochemistry*, vol. 12, no. 1, 2020, pp. 31–36.

[11] Rakulini, R. and K. Sounthararajan. "A Review of anti-diarrheal activity of Aegle marmelos." 2019.

[12] George, M. *et al*. "Phytochemical and pharmacological screening of in vivo anti-inflammatory activity of Aegle marmelos (L.) corr. Serr." *Journal of Chemical and Pharmaceutical Research*, vol. 8, no. 2, 2016, pp. 330–334.

[13] Kumari, R. "Preliminary study on the effect of aegle marmelos in hyperlipidemia." *International Journal of Scientific Study*, vol. 4, no. 2, 2016, pp. 60–61.

[14] Anupama, K. *et al*. "Bilwa (Aegle marmelos): A Review Article." *International Ayurvedic Medical Journal*, vol. 8, no. 2, 2020, pp. 2792–2796.

[15] Neeraj, V.B. and V. Johar. "Bael (Aegle marmelos) Extraordinary Species of India: A Review." *International Journal of Current Microbiology and Applied Sciences*, vol. 6, no. 3, 2017, pp. 1870–1887.

[16] Prathapan, A. *et al*. "Polyphenol Rich Fruit Pulp of Aegle marmelos (L.) Correa Exhibits Nutraceutical Properties to Down Regulate Diabetic Complications—An in Vitro Study." *Food Research International*, vol. 48, no. 2, 2012, pp. 690–695.

[17] Choudhary, M. and K. Grover. "Amla (Emblica officinalis L.) Oil." *Fruit Oils: Chemistry and Functionality*, 2019, pp. 875–882.

[18] Sawale, K.R. *et al*. "Bael (Aegle marmelos) a super fruit of an hour: A Review." *International Journal of Chemical Studies*, vol. 6, no. 3, 2018, pp. 1720–1723.

[19] Rahman, S. and R. Parvin. "Therapeutic potential of Aegle marmelos (L.)—An Overview." *Asian Pacific Journal of Tropical Disease*, vol. 4, no. 1, 2014, pp. 71–77.

[20] Pramila, G.J.D. "A Review on pharmacological properties of Aegle marmelos." *International Journal of Pharmaceutical Sciences Review and Research*, vol. 65, no. 2, 2020, pp. 40–43.

[21] Lamia, S.S. *et al*. "Phytochemistry and pharmacological properties of *Aegle marmelos* L. (Rutaceae): A Review." *Phytochemistry Reviews*, vol. 3, no. 3, 2018, pp. 45–54.

[22] Maity, P. *et al*. "Biological activities of crude extracts and chemical constituents of Bael, *Aegle marmelos* (L.) Corr." *Indian Journal of Experimental Biology*, vol. 47, 2009, pp. 849–861.

[23] Puthallath, R.E. *et al*. "Anticonvulsant activity of *Nigella sativa*, *Aegle marmelos* and *Benincasa hispida* in Pentylenetetrazole-Induced Seizure in Swiss Albino Mice." *Asian Journal of Medical Sciences*, vol. 7, no. 3, 2016, pp. 97–102.

[24] Lomate, K.A. *et al*. "A Review on phytochemical and pharmacological values of *Aegle marmelos*." *Journal of Drug Delivery and Therapeutics*, vol. 11, no. 2-S, 2021, pp. 162–166.

[25] Nugroho, A.E. *et al*. "Effects of marmin isolated from *Aegle marmelos* Correa on L-histidine decarboxylase enzyme in RBL-2H3 cells." *Thai Journal of Pharmaceutical Sciences*, vol. 35, no. 1, 2011, pp. 1–7.

[26] Kothari, S. *et al*. "Anxiolytic and antidepressant activities of methanol extract of *Aegle marmelos* Leaves in mice." *Indian Journal of Physiology and Pharmacology*, vol. 54, no. 4, 2010, pp. 318–328.

[27] Sekar, D.K. *et al*. "A Review on pharmacological and phytochemical properties of *Aegle marmelos* (L.) Corr. Serr. (Rutaceae)." *Asian Journal of Plant Science and Research*, vol. 1, no. 2, 2011, pp. 8–17.

[28] Karumaran, S. *et al*. "Antimicrobial and antioxidant activity of leaf extracts of *Aegle marmelos*." *Advances in Applied Science Research*, vol. 7, no. 3, 2016, pp. 205–208.

[29] Asghar, N. *et al*. "Phytochemical composition, antilipidemic and antihypercholesterolemic perspectives of bael leaf extracts." *Lipids in Health and Disease*, vol. 17, no. 1, 2018, pp. 1–9.

[30] Singanan, V. *et al*. "The hepatoprotective effect of bael leaves (*Aegle marmelos*) in Alcohol-Induced Liver Injury in Albino Rats." *International Journal of Science & Technology*, vol. 2, no. 2, 2007, pp. 83–92.

[31] Vaishnav, P.L. *et al*. "Evaluation of anticonvulsant activity of hydroalcohol extract of *Aegle marmelos* (Linn. Correa, Stem Bark)." *International Journal of Advanced Research*, vol. 3, no. 3, 2015, pp. 804–809.

[32] Shankarananth, V. *et al*. "Analgesic activity of methanol extract of *aegle marmelos* leaves." *Fitoterapia*, vol. 78, no. 3, 2007, pp. 258–259.

[33] A, R. "Studies in natural products chemistry." *Bioactive Natural Products*, vol. 32, 2005, p. 1269.

[34] Balakumar, S. *et al*. "Antifungal activity of *aegle marmelos* (L.) correa (rutaceae) leaf extract on dermatophytes." *Asian Pacific Journal of Tropical Biomedicine*, vol. 1, no. 4, 2011, pp. 309–312.

[35] Patel, P.K. *et al*. "Aegle marmelos: A review on its medicinal properties." *International Journal of Pharmaceutical and Phytopharmacological Research*, vol. 1, no. 5, 2012, pp. 332–341.

[36] M, A.K. and P. "Antifungal activity of medicinal plants collected from servarayan hills, eastern ghats, against dermatophytic fungi." *International Journal of Current Microbiology and Applied Sciences*, vol. 10, no. 8, 2021, pp. 305–311.

[37] Ramakrishna, Y.G. *et al*. "Aegle marmelos fruit extract attenuates *helicobacter pylori* lipopolysaccharide-induced oxidative stress in sprague dawley rats." *BMC Complementary and Alternative Medicine*, vol. 15, no. 1, 2015, pp. 1–10.

[38] Gupta, R. *et al*. "Phytochemical evaluation and antispermatogenic activity of *thevetia peruviana* methanol extract in male albino rats." *Human Fertility*, vol. 14, no. 1, 2011, pp. 53–59.

[39] Santhi, V.P. *et al*. "Edible fruit extracts and fruit juices as potential source of antiviral agents: A Review." *Journal of Food Measurement and Characterization*, vol. 15, no. 6, 2021, pp. 5181–5190.

[40] Remya, M. *et al*. "In Vitro effect of *Aegle marmelos* on human sperm motility." *Journal of Medicinal Plants Research*, vol. 3, no. 12, 2009, pp. 1137–1139.

[41] Mahato, H. and B. Kumar. *Medicinal Uses with Immense Economic Potential and Nutritional Properties of Aegle marmelos: A Concise Review.* Biocomposites; Books on Demand, 2022, p. 133.

[42] Chockalingam, V. *et al*. Gnanasambantham. "Antiproliferative and antioxidant activity of Aegle marmelos (Linn.) leaves in dalton's lymphoma ascites transplanted mice." *Indian Journal of Pharmacology,* vol. 44, no. 2, 2012, p. 225.

[43] Akhouri, V., M. Kumari and A. Kumar. "Therapeutic effect of aegle marmelos fruit extract against dmba induced breast cancer in rats." *Scientific Reports,* vol. 10, no. 1, 2020, p. 18016.

[44] Sharma, B. *et al*. "Hypoglycemic and Hypolipidemic Effect of Aegle marmelos (L.) Leaf Extract on Streptozotocin Induced Diabetic Mice." *International Journal of Pharmacology,* vol. 3, 2007, pp. 444–452.

[45] Nag, S. *et al*. "A study on antimicrobial activity and phytochemical screening of Methanolic extract from barks of Aegle marmelos (L.)." *European Journal of Biotechnology and Bioscience,* vol. 3, no. 4, 2015, pp. 28–32.

[46] Govinda, H.V. and S.M.B. Asdaq. "Immunomodulatory potential of methanol extract of Aegle marmelos in animals." *Indian Journal of Pharmaceutical Sciences,* vol. 73, no. 2, 2011, p. 235.

[47] Sharma, G.N. *et al. Medicinal Values of Bael (Aegle marmelos)(L.) Corr.: A Review. International Journal of Current Pharmaceutical Review and Research,* vol. 2, no. 1, 2011, pp. 12–22.

[48] Jagetia, G.C. *et al*. "Aegle marmelos (L.) correa inhibits the proliferation of transplanted ehrlich ascites carcinoma in mice." *Biological and Pharmaceutical Bulletin,* vol. 28, no. 1, 2005, pp. 58–64.

[49] Baliga, M.S. *et al*. "Phytochemistry and medicinal uses of the bael fruit (Aegle marmelos Correa): A concise review." *Food Research International,* vol. 44, no. 7, 2011, pp. 1768–1775.

[50] Brijesh, S. *et al*. "Studies on the antidiarrhoeal activity of aegle marmelos unripe fruit: Validating its traditional usage." *BMC Complementary and Alternative Medicine,* vol. 9, 2009, pp. 1–12.

[51] Panda, S. and A. Kar. "Evaluation of the Antithyroid, Antioxidative and Antihyperglycemic Activity of Scopoletin from Aegle marmelos Leaves in Hyperthyroid Rats." *Phytotherapy Research,* vol. 20, no. 12, 2006, pp. 1103–1105.

[52] Anusha, C. *et al*. "The effects of aqueous leaf extract of aegle marmelos on immobilization-induced stress in male albino wistar rats." *International Journal of Nutrition, Pharmacology, Neurological Diseases,* vol. 3, no. 1, 2013, pp. 11–16.

[53] Thakur, G. *et al*. "Some common antidiabetic plants of the indian subcontinent." *Food Reviews International,* vol. 26, no. 4, 2010, pp. 364–385.

[54] Chauhan, A. and M. Agarwal. "Reversible changes in the antifertility induced by aegle marmelos in male albino rats." *Systems Biology in Reproductive Medicine,* vol. 54, no. 6, 2008, pp. 240–246.

[55] Agarwal, P. *et al*. "Antimicrobial, antioxidant and antidiabetic activity of Aegle marmelos." *Unpublished manuscript.*

[56] Prince, P.S.M. and M. Rajadurai. "preventive effect of aegle marmelos leaf extract on isoprenaline-induced myocardial infarction in rats: Biochemical evidence." *Journal of Pharmacy and Pharmacology,* vol. 57, no. 10, 2005, pp. 1353–1357.

[57] Yekehtaz, H. *et al*. "Cardiovascular considerations in antidepressant therapy: An evidence-based review." *The Journal of Tehran University Heart Center,* vol. 8, no. 4, 2013, p. 169.

[58] Costa-Lotufo, L.V. *et al*. "Studies of the anticancer potential of plants used in bangladeshi folk medicine." *Journal of Ethnopharmacology,* vol. 99, no. 1, 2005, pp. 21–30.

[59] Prasathkumar, M. *et al*. "Therapeutic and pharmacological efficacy of selective indian medicinal plants: A Review." *Phytomedicine Plus,* vol. 1, no. 2, 2021, p. 100029.

[60] Sur, T.K. *et al*. "Effect of Aegle marmelos leaf on rat sperm motility: An in vitro study." *Indian Journal of Pharmacology,* vol. 34, no. 4, 2002, p. 276.

[61] Singh, A. and S.K. Singh. "Evaluation of antifertility potential of brahmi in male mouse." *Contraception,* vol. 79, no. 1, 2009, pp. 71–79.

[62] Priya, S. and S. Nethaji. "Antipyretic activity of ethanolic extract of leaf and bark of *diospyros virginiana* in yeast induced pyrexia." *International Journal of Pharmacy and Pharmaceutical Sciences,* vol. 7, 2014, pp. 502–504.