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**Review**

# A Review on Phytochemical And Pharmacological activity of *Aegle Marmelos*

**Rohan Kanaujiya[1*], Farha Naaz[2]**

*Maya College of Pharmacy, Dehradun School of Pharmacy, Maya Devi University, Dehradun, Uttarakhand, India.*

*Author for Correspondence: Rohan Kanaujiya
Email: rohankanojia1810@gmail.com

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## Abstract

*Aegle marmelos* (L.) Corrêa, commonly known as Bael or Bengal quince, is a significant medicinal plant in traditional systems of medicine such as Ayurveda and Unani. It is valued for its broad spectrum of therapeutic properties, which are attributed to its diverse array of bioactive phytochemicals. Phytochemical analyses have revealed the presence of alkaloids, flavonoids, tannins, saponins, coumarins, and essential oils in various parts of the plant, including the fruit, leaves, bark, and roots. Key constituents like marmelosin, aegeline, skimmianine, and rutin are linked to the plant's medicinal efficacy. Pharmacological studies have demonstrated that *Aegle marmelos* possesses a wide range of biological activities, including antimicrobial, antidiabetic, anti-inflammatory, antioxidant, hepatoprotective, gastroprotective, and anticancer properties. The plant has shown promising potential in the management of chronic diseases such as diabetes mellitus and gastrointestinal disorders. This review highlights the therapeutic importance of *Aegle marmelos*, emphasizing its phytochemical diversity and pharmacological relevance, thereby underscoring its value as a source of natural bioactive compounds for future drug development.

**Keywords:** Aegle marmelos, Pharmacological, Phytochemistry, Traditional medicinal plant

## INTRODUCTION

The medicinal plant performs an essential role in the lives of underprivileged populations worldwide [1], likewise for primary medical care. Approximately 80 percent of countries worldwide rely on these conventional treatments, which frequently involve plant extracts [2]. India has one of the most expanded plant-origin medical traditions in the world. In India, rural communities know around 25,000 potent plant-based remedies employed in traditional medicine. Plants, especially those with ethno pharmacological uses, have been the primary sources

of medicine for early drug discovery [3]. Anciently most medications have been developed via natural ingredients or ingredients derived from natural compounds [4,5].
However, a significant amount of basic and applied research is required to validate and use plants in phytopharmaceutical chemistry, and the potential use of higher plants as a source of new medications is still underutilized, with this resource ranking on par with conventional pharmaceutical products in terms of importance [6]. Only a small portion of the approximated 250,000–500,000 plant genera have been thoroughly explored in terms of their pharmacological qualities, and only a small portion have been investigated phytochemically [7]. By supporting the conscious exploration of biodiversity as a source of bioactive molecules and their application in the production of new therapeutic medications, it also aims to encourage the developing and disseminating of this plant-based medicine. The main aim of this review is to know the phytochemical parameters, Traditional uses, and innovative applications of *A. marmelos* Linn.

**Fig 1: Aegle marmelos fruit**

**Taxonomical Classification**

- English: Bael Tree, Bael Fruit, Bengal quince, Elephant Apple, Golden Apple, Holy Fruit, Indian Bael, Indian Quince, Stone Apple, Wood Apple
- French: Bel Indien, Cognassier du Bengale, Oranger du Malabar
- Bengali: Bel
- Central Khmer: Bnau
- German: Baelbaum, Belbaum, Schleimapfelbaum
- Gujarati: Bili
- Hindi: Bel
- Indonesian: Maja Batuh
- Javanese: Modjo
- Lao: Toum
- Malay: Bilak
- Malayalam: Vilvam
- Portuguese: Marmelos
- Tamil: Vilvam
- Thai: Matum
- Vietnamese: Trai mam

**Geographical Management**

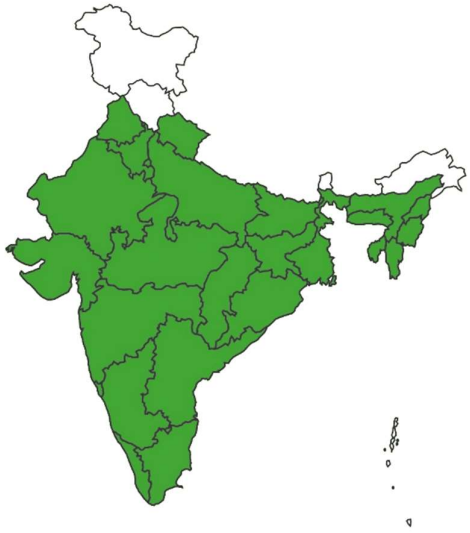

**Fig 2: Distribution of *Aegle marmelos***

The native distribution for Aegle marmelos is from eastern Pakistan through the sub-Himalayan tract to Bangladesh and south towards the Western Ghats (Hassan ud Din and Ghazanfar 1980, Board of Trustees, RBG Kew 2019, USDA, Agricultural Research Service, National Plant Germplasm System 2019). While some sources state that the species was introduced to Myanmar and the Andaman and Nicobar Islands (Board of Trustees, RBG Kew 2019), it is included as part of the respective native floras according to Kress et al. (2003) and Pandey and Dilwaker (2008); as such, its origin in these areas requires verification. The species occurs at altitudes between 0–1,200 m asl (Tropical Plants Database, Ken Fern 2019). Country Occurrence: Native, Extant (resident): Bangladesh; India (Andhra Pradesh, Assam, Bihar, Chattisgarh, Gujarat, Himachal Pradesh, Jammu-Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttaranchal, West Bengal); Nepal; Pakistan Extant & Introduced (resident): Bhutan; Cambodia; China; Cuba; Indonesia (Lesser Sunda Is., Sulawesi); Lao People's Democratic Republic; Malaysia; Micronesia, Federated States of ; Sri Lanka; Thailand; Trinidad and Tobago; Viet Nam.

**Phytochemical Screening**

*Aegle marmelos* has been widely utilized in traditional medicinal systems. It has been reported to contain numerous photochemical compounds such as polyphenol/phenolic compounds, carotenoids, alkaloids, pectin, flavonoids, tannins, coumarins, and terpenoids

**Alkaloids:** The alkaloids comprise the largest single class of secondary plant substances. New alkaloids from the leaves of A. marmelos were reported viz., O-3,3-(dimethylallyl)halfordinol (1), N-2-ethoxy-2-(4-methoxyphenyl) ethylcinnamamide (3), N-2- methoxy-2-[4-(3',3'-dimethylallyloxy)phenyl] ethylcinnamamide (4), N-2-methoxy-2-(4-methoxyphenyl) ethylcinnamamide (5) and marmeline (6).5 Govindachari and Premila6 reported four alkaloids, N-2-[4-(3',3'- dimethylallyloxy)phenyl] ethylcinnamide, N-2-hydroxy-2-[4-(3',3'-dimethylallyloxy)phenyl] ethylcinnamide or marmeline (6), N-4- methoxystyryl cinnamide and N-2-hydroxy-2-(4-hydroxyphenyl) ethylcinnamide (7) and aegeline (2) from dry leaves of A. marmelos. Aegeline was initially believed to be a sterol but after a critical study it was found to be a neutral nitrogenous compound. Recently, series of phenylethyl cinnamides, which included new compounds named anhydromarmeline (8), aegelinosides A (9) and B (10) were isolated from Aegle marmelos leaves as α- glucosidase inhibitors7.

Phenylpropanoids: These are naturally occurring phenolic compounds, which have an aromatic ring to which three-carbon side chain is attached. Among the phenylpropanoids are included hydroxycoumarins, phenylpropenes and lignans. The most widespread plant coumarin is the parent compound, coumarin itself, which occurs in over twenty-seven plant families. Marmesin (11) was established as a new compound from leaves, which is also a constituent of heartwood and root.8,9,1 Aegelenine, a minor base of the leaves, which was initially claimed to be a new compound, was found to be in identical to halfordinol, the basic constituent of Halfordia scleroxyla.11,12 Fresh leaves yield in distillation yellowish-green oil with a peculiar aromatic odour, marmelosin13 reported marmesinine, sitosterol, -D-glucoside and rutin in the leaves. Ali et al.15 isolated

Marmenol, a new 7-geranyloxycoumarin [7-(2,6-dihydroxy-7- methoxy-7-methyl-3-octaenyloxy)coumarin] from the leaves of methanolic extract of A. marmelos.

**Terpenoids**: The essential oil of A. marmelos (L.) Correa leaves were studied very much extensively in India by various workers since 1950.Phellandrene was found to be the common constituent of the essential oil from leaves, twigs and fruits.[16,17] Phellandrene (56%) and p-cymene (17%) were reported from leaf oil.[18] Later, similar report was published on leaf essential oil by many workers. p-Menth-1-en-3,5-diol was isolated and characterized from A. marmelos leaves.[19] Limonene (12) (82.4%) was reported as the main constituent from A. marmelos leaves and it was shown that limonene is characteristic marker for identification of A. marmelos oil samples.[20] -Sitosterol from the leaves was identified[21]

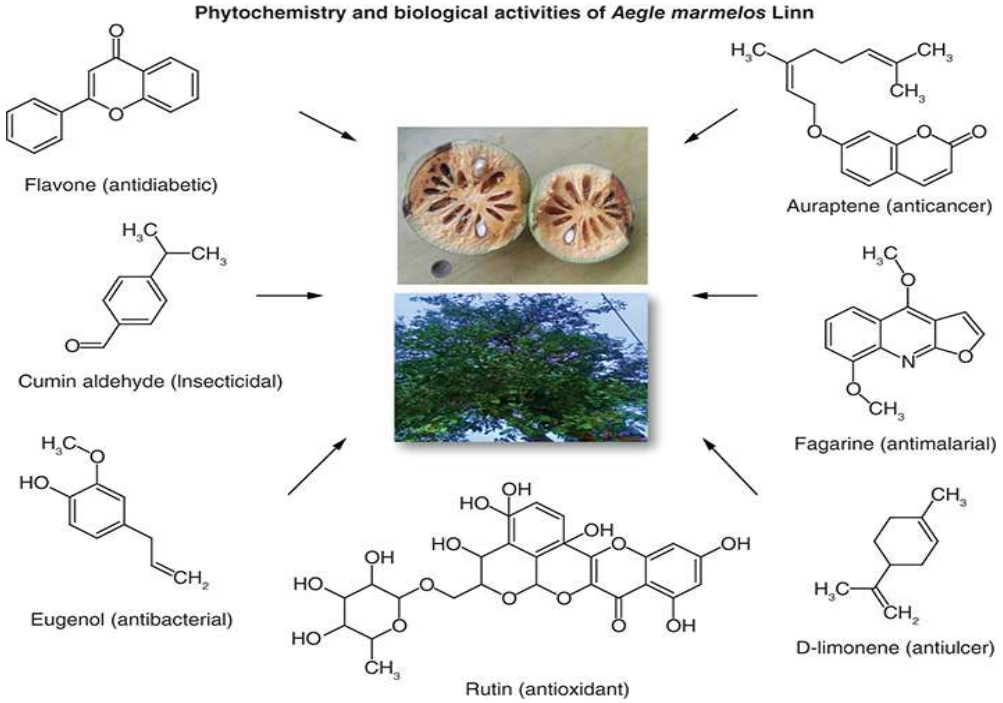


**Fig 3: Phytochemical Screening of *Aegle marmelos***

**Miscellaneous compounds**

Ali et al.15 reported praealtin D, trans-cinnamic acid, valencic acid, 4-methoxybenzoic acid, betulinic acid, N-p-cis-& trans- coumaroyltyramine, montanine, and rutaretin from the leaves of methanolic extract of Aegle marmelos. Rutin, flavan-3-ols, anthrocyanins, lecucanthrocyanins, flavone glycosides and tannins also have been reported from the leaves.[14,22,23]

**Pharmacological activities**

**Anticancer activity**

Bael and some of the Bael phytochemicals possess antineoplastic, radioprotective, chemoprotective and chemo preventive effects, properties efficacious in the treatment and prevention of cancer.[22] Preclinical studies have shown that Bael leaf extracts were effective in inhibiting the growth of leukemic K562, T-lymphoid Jurkat, B-lymphoid Raji, erythroleukemic HEL, melanoma Colo38, and breast cancer cell lines MCF7 and MDA-MB- 231.[23-24] The hydroalcoholic extract of the Bael leaves is also shown to possess antineoplastic effects on the Ehrlich ascites carcinoma in Swiss albino mice.[25] The ethanolic extract of the fruit is also shown to possess cytotoxic effect on SKBR3 (human breast adenocarcinoma cells) in vitro.[26] Studies have also shown that treatment with the Bael extract did not increase ERα mRNA levels in MCF7 cells and MDA-MB-231. However, when added in combination with the decoy molecule, the extract and one of its phytochemicals, lupeol, stimulated the decoy effect of RA4 DNA sequence, increased ERa gene expression in MDA-MB-231 (ERα-negative breast cancer cells) and inhibited cell proliferation.[27]

**Fruit extract against DMBA induced breast cancer in rats**

Breast cancer is among most common form of cancer worldwide. It is also the major cause of death in female cancer patient around the world. Despite various therapeutic measures, it remains associated with high mortality rate. In Aegle marmelos (L.) Correa there are very limited reports regarding its anticancer activity. Vivek Akhouri et al.[28], aimed to study the anticancer activity of Aegle marmelos fruit extract on 7,12-dimethylbenz(a)anthracene (DMBA) induced breast cancer in rats. Female Charles Foster rats, 55–60 days old weighing around (150± 10 g) was used for the study and were induced DMBA (20 mg/mL dissolved in Olive oil) orally. After the development of breast tumours (about 0.5 cm), the rats were treated with Aegle marmelos ethanolic fruit pulp extract (200 mg/kg b.w./day) orally for 5 weeks and then volume of tumour was measured. Aegle marmelos treatment showed significantly reduced mammary tumour volume ($P< 0.05$), along with significant reduction ($P< 0.0001$) in the different serum biomarkers such as TNF-α level, serum malondialdehyde (MDA) level and glucose levels. Significant ($P< 0.0001$) improvement in both, the kidney and liver serum biomarker parameters were also observed after the treatment with Aegle marmelos ethanolic fruit pulp extract. From the entire study, taking everything into account it can be interpreted that Aegle marmelos ethanolic fruit pulp extract possesses anti-proliferative activity by suppressing the progression of breast tumours in rat model. The plant extract also possesses hepato-renal protective effect. Hence, it can be targeted as novel and safe anti-cancer drug against breast cancer. Costa-Lotufo et al.[29], studied the anticancer potential of 11 plants used in Bangladeshi folk medicine and found among all tested extracts, only the extracts of Oroxylum indicum, Moringa oleifera and Aegle marmelos showed potential anticancer cactivity. It was also reported that Aegle marmelos (L.) inhibits the proliferation of transplanted Ehrlich ascites carcinoma in mice.

The anticancer effect of hydroalcoholic extract of Aegle marmelos (AM) was studied in the Ehrlich ascites carcinoma bearing Swiss albino mice. The spatial effect of various AM administration schedules showed that six-day administration increased the survival of tumour bearing mice. The best antineoplastic action of AM was obtained when AM administered through intraperitoneal route than the oral route at equimolar dose. Dose of 400 mg/kg was considered as the best dose.[30] Lambertini et al.[31] studied the effects of extracts from Bangladeshi medicinal plants on in- vitro proliferation of human breast cancer cell lines and expression of estrogen receptor alpha gene, according to this study extract from Aegle marmelos is antiproliferative on both cell line MCF7 and MDA-MB-231cells, but at a higher concentration. Taxol is an important anticancer drug widely used in the clinic. An endophyte fungus Bartalinia robillardoides (strain AMB-9) was isolated from Bael, a medicinal plant. This endophytic fungus produced 187.6 µg/l of Taxol which suggests that the fungus can serve as a potential material for genetic engineering to improve the production of Taxol.[32]

**Radioprotective activity**

Nowadays radiotherapy is one of the most important therapies for curing cancer especially for those suffering from vital visceral malignancies. Although it is very useful all over the world, however it has some side effects. Radioprotective effect has been studied with the use of Bael fruit hydroalcoholic extract in mice that are exposed to several doses of gamma radiation. Swiss albino male mice were administered 5, 10, 15, 20 or 40 mg/kg of Aegle marmelos extract intraperitoneally daily for 5 days before exposure to 10 Gy 60Co gamma- radiations.

After 30 days of post radiation, maximum protections are reported by highest number of survivors. Five consecutive dose of 15 mg/kg extract produces survival to 10 Gy radiation was observed.[33-35] Jagetia et al.[36], evaluated the radio protective effect of hydro alcoholic extract of Bael leaves in cultured human peripheral blood lymphocytes (HPBLs). The irradiation of HPBLs with different doses of gamma-radiation caused a dose-dependent increase in the frequency of lymphocytes bearing one, two and multiple micronuclei. Treatment of HPBLs with 5 µg/ml leaf extract significantly reduced the frequency of lymphocyte bearing one, two and multiple micronuclei when compared with the irradiated control. The mechanism of this type of radio protective activity of the leaf extract may be due to the scavenging of radiation –induced free radicals.

Jagetia et al.[37] also investigated the radioprotective activity of a leaf extract of Aegle marmelos (AM) in mice exposed to different doses of gamma-radiation. AM treatment reduced the symptoms of radiation- induced sickness and increased survival. The radioprotective action might be due to free- radical scavenging and arrest of lipid peroxidation accompanied by an elevation in glutathione.

**Chemo-preventive Activity**

The effect of hydroalcoholic (80% ethanol, 20% water) extract of leaves of Aegle marmelos on carcinogen-metabolizing phase-I and phase-II enzymes, antioxidant enzymes, glutathione content, lactate dehydrogenase and lipid peroxidation were studied. The changes in the levels of drug-metabolizing enzymes

and antioxidative profiles are strongly indicative of the chemo preventive potential of this plant, especially against chemical carcinogenesis.[38]

**Anti-arthritis activity**

Aegle marmelos leaves were found to be active against collagen induced arthritis in Wistar albino rats.[39] Radiological and histopathological changes were also significantly reduced in methanol extract treated rats.[40] Parichha S.[41], reported that Raw Bael fruit is used for treatment of arthritis and gout. Its pulp mixed with hot mustard oil can be applied on swollen joints for relief from these disorders.

**Cardioprotective activity**

Prince et al.[42], evaluated the preventive effects of an aqueous Aegle marmelos leaf extract (AMLEt) in isoprenaline (isoproterenol)- induced myocardial infarction in rats. Pretreatment with AMLEt decreased the activity of creatine kinase (CK) and lactate dehydrogenase (LDH) in serum and increased them in the heart, also AMLEt pretreatment increased the activity of $Na^+$ $K^+$ ATPase and decreased the activity of $Ca_2^+$ATPase in the heart and aorta simultaneously and the levels of cholesterol and triglycerides decreased whereas phospholipids increased in heart and aorta of AMLEt-pretreated rats. All the deranged biochemical parameters were restored with 200 mg kg-1 AMLEt. Hema et al.[43], studied the effect of the aqueous, alcoholic and petroleum ether extracts of A. marmelos for the hypoglycaemic and other pharmacological actions and observed that the aqueous extract acts as a cardiac stimulant, smooth-muscle relaxant and uterine stimulant while the alcoholic extract revealed cardiac depressant, smooth muscle relaxant and uterine relaxant properties.

**Anti-diabetic activity**

Leaf extract of the Bael plant is generally known for their antidiabetic activity. It has been found that Bael extract significantly reduces blood urea and cholesterol level in diabetic animals. It also decreases oxidative stress in diabetic animal. Leaf juice is directly employed in Unani system of medicine for antidiabetic activity.[44-47] Various studies as detailed below have signified its use as an antidiabetic agent. Ismail et al.[48], evaluated antidiabetic activity of Aegle marmelos leaf decoction and found that approximately five grams of leaf decoction administered orally once daily possess antidiabetic effect. It was further proved by another study that aqueous leaf extract of Aegle marmelos have anti hypoglycemic activity, the results of which have shown that aqueous extract of the Aegle marmelos leaves were found to inhibit primarily the uptake of glucose across rat inverted gut sacs.[49]Sabu et al.[50], used methanolic leaf extract of Aegle marmelos to evaluate antioxidant and antidiabetic activity of plant material. Alloxan was used in this study to induce oxidative effect on pancreatic beta cells and further effect on glucose level. They found a significant decrease in lipid peroxidation, conjugated diene and hydroperoxide levels in serum as well as in liver induced by alloxan. It was predicted from the results obtained that the methanolic leaf extract of Aegle marmelos have characteristics to be used as hypoglycemic and antioxidant agent. Similarly, Sharma et al.[51] also studied both hypoglycemic and hypolipidemic effect of Aegle marmelos (L.) leaf extract on streptozocin induced diabetic mice. Initially, diabetic condition was introduced in mice using streptozocin (60 mg kg-1 body weight).

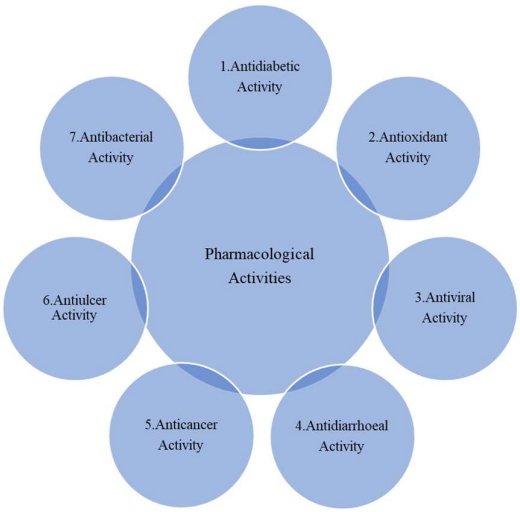


**Fig 4: Pharmacological Activity of *Aegle marmelos***

Different evolutionary parameters were evaluated such as glucose tolerance test, lipid profile, glycogen biosynthesis, glucose uptake, differential regulation of glucose homeostatic enzymes like glucose-6-phosphatase, hexokinase and insulin release in vitro, for demonstrating the hypoglycemic and hypolipidemic effect in animal. Diabetes and its related complications are closely related with oxidative stress of the body.[52] Diabetes is closely inter-linked with cardiovascular as well as renal disorder at advanced stage and creates fatal disease syndromes. Oral as well as intraperitoneal administrations of the aqueous extract of Bael fruit exhibited hypoglycemic effect against streptozotocin induced diabetic rats.[53] The fruit extract at a dose of 250 mg/kg exhibited to be more effective than glibenclamide, a well- known hypoglycemic drug.[54] This antidiabetic effect is probably due to the presence of Coumarins in the fruit extract, which potentiate the insulin secretion from existing beta cells of the isles of Langerhans.[53] In an uncontrolled clinical trial the administration of leaf extract for 15 days significantly reduced blood cholesterol levels with slight lowering of blood glucose in some patients with diabetes mellitus.[55] The plant also possesses various pharmacological activities such as Antioxidant, Antibacterial, Antifungal, Antidiarrheal, Antiproliferative, Cytoprotective, Hepatoprotective, Antifertility, Analgesic, Contractile, Antihyperlipidemic, Antiviral, Anti-ulcer, Immunomodulatory and Wound Healing properties.[56]

## CONCLUSION

*Aegle marmelos* is a rich source of diverse phytochemicals with significant pharmacological activities that validate its traditional use in various medicinal systems. The presence of alkaloids, flavonoids, coumarins, and essential oils contributes to its wide-ranging therapeutic effects, including antidiabetic, antimicrobial, anti-inflammatory, antioxidant, hepatoprotective, and anticancer properties. These findings underscore the plant's potential as a natural source for the development of novel therapeutic agents.

Despite the wealth of traditional knowledge and preclinical evidence, comprehensive clinical studies are still limited. Future research should focus on detailed mechanistic studies, standardization of extracts, identification of active constituents, and their molecular targets. Additionally, toxicological evaluations and well-designed clinical trials are essential to ensure the safety and efficacy of *Aegle marmelos*-based formulations. Advances in phytochemical profiling using modern analytical techniques and biotechnological approaches can further enhance the therapeutic applications of this plant. Overall, *Aegle marmelos* holds immense promise for integration into evidence-based modern medicine, provided that rigorous scientific validation supports its traditional claims.

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