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Review Article

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BAEL (AEGLE MARMELOS) AN INCREDIBLE HERB OF INDIA: A REVIEW

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ABSTRACT

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Researchers have been attempting to recognize and validate plant-derived substances for the cure of various diseases that promote compounds for health and nutrition for the past few years. According to study of the literature, entire scrap of the plant such as roots, barks, leaves, fruits, seeds, and flowers, are used to treat various diseases. Nowadays, various products from various parts of the plant are prepared. Purpose of the present analysis is to compose the general chemical profile, both medicinal and economic value, improved items such as juice, jam, and toffee, and other benefits of *Aegle marmelos*. Phytochemical studies disclose the presence of alkaloids, tannins, flavonoids, coumarins, and essential oils that contribute to its various pharmacological activities. This plant is having excellent potential to treat the disease like diabetes, cholesterol, peptic ulcer, inflammation, diarrhoea, and dysentery, anticancer, cardio protective, antibacterial, antifungal, radio protective, antipyretic, analgesic, constipation, respiratory infection, antioxidant, hepatoprotective, wound healing, and many more.

This review aims to summarize the botanical description, traditional uses, phytochemical constituents, pharmacological activities, and chemical composition of *Aegle marmelos*, providing an updated overview of its medicinal importance and prospects for drug development.

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KEYWORDS

Keywords: Bael, antimicrobial activity, aromatic, traditional medicine

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INTRODUCTION

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Aegle marmelos (Bael) is an Indian herbal plant of the Rutaceae family, also known as golden apple, Bengal quince, or bilva. It holds religious importance in Hinduism, being sacred to lord shiva. The plant belongs to the class Magnoliopsida and grows mainly in dry forests across India and other Asian countries such as Vietnam, Malaysia, China. Bael is a subtropical species found throughout most Indian states, especially in central and southern regions. Is a medicinal tree widely used in historical Indian medicine for its therapeutic properties. The ripe fruit is aromatic, astringent, cardioprotective, and acts as a laxative, while the unripe fruit is beneficial for digestive issues like diarrhoea and dysentery. Bael is also valued for treating ulcers due to its mucilage content and has long been used in Ayurvedic medicine. It contains active ingredients like aegline, marmesin, marmin, and marmelosin, known for various health benefits including safeguard against heart disease.

According to WHO, 80% of people globally depend on traditional medicine, mainly plant-boosting, and anticancer effects, Key plant constituents include alkaloids, terpenes, flavonoids, lignans, steroids, saponins, and phenol. India is rich in medicinal plant, many of which are mentioned in ancient texts like the Rigved and Charak Samhita. Aegle marmelos is an important medicinal tree endemic to India and neighbouring regions. Every part of the Bael tree-stem, bark, root, leaves, and fruit-has remedial uses. Plant has an essential role in human life since ancient times, providing food, shelter, and medicine. Traditional systems like Ayurveda and ancient texts such as Rigved, Atharvaveda, and Charak Samhita highlight their medicinal importance. Over 25% of modern medicines are derived from plants, which contain various pharmacologically active compounds used to treat numerous diseases. India, rich in plant diversity, has long used herbal medicine for its safety and effectiveness. Aegle marmelos, a member of the Rutaceae family, is a well-known medicinal plant widely used in traditional Indian medicine. It possesses multiple therapeutic properties, including antibacterial, antifungal, antidiabetic, antioxidant, hepatoprotective, and anti-inflammatory activities. Bael is also of cultural and nutritional importance.

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MATERIALS AND METHODS

BAEL LEAVES

Bael (Aegle marmelos), commonly known as Bilva quince, wood apple, or bilva, is a sacred and medicinal plant belonging to the family Rutaceae. It is indigenous to the Indian subcontinent and widely distributed throughout tropical and subtropical regions of Southeast Asia. The tree is medium-sized, deciduous, and known for its aromatic leaves, fragrant flowers, and hard-shelled fruits. All parts of the Bael tree-including the leaves, fruits, bark, and roots- possess significant medicinal properties and have been utilized in Ayurvedic, Unani, and Siddha systems of medicine since ancient times.

The leaves are alternate, single, or compound, with one or sometimes two pairs of shortly stalked opposite leaflets. The leaves are trifoliate and aromatic, mostly when chopped. The leaves are alternate and deciduous, and borne as single or compound. In the compound leaves, the leaflet appears in 2-5 oval-ovate or ovate shaped, pointed leaflet. Among the various parts of the plant, the leaves hold special importance due to their rich phytochemical composition. Phytochemical analysis has revealed that Bael leaves contain alkaloids such as aegeline, flavonoids, phenols, tannins, saponins, and essential oils. These active constituents put-up to the plant's wide range of pharmacological activities, including antimicrobial, antioxidant, anti- inflammatory, hepatoprotective, antidiabetic, and restoration.

Conventional, Bael leaves have been used to treat ailments such as fever, asthma, diabetes, dysentery, and skin infections. The leaves are known to exhibit broad-spectrum antimicrobial activity opposed gram-positive and gram-negative bacteria, making them effective in managing skin disorders. Of jaundice, asthma, it is found to be very useful. Bael leaves are good aid in removing mucilage secretion from bronchial tubes. It is used as remedial measure in the treatment of beriberi. Furthermore, their antioxidant and anti-inflammatory properties help reduce oxidative stress and inflammation related with acne lesions. Due to these properties, Bael leaves are gaining attention in the development of herbal and cosmeceutical formulations such as creams, gels, and lotions aimed at promoting skin health.

BAEL FRUIT

Bael fruit is an indigenous fruit of India. It grows throughout the Indian Peninsula as well as in Sri lanka, Pakistan, Bangladesh, Burma, Thailand and most of the Southeastern Asian countries. There is no organized orcharding of this fruit in india. Its cultivation is restricted, and now it grows mainly wild or in spritual gardens. It has some demand from the endemic systems of medicine, such as the "Ayurvedic." it has the excellent flavour and nutritive and therapeutic

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values which lies an untapped potentiality for processing.

History — Bael fruit has been known in India from prehistoric times. Leaves of that tree are traditionally used as blessed offerings to “Lord Shiva.” In the epic times, such as those of the “Ramayana,” Bael fruit was realize, and bael trees were found growing in the Chitrakuta Hills and panchavati.

Chemistry and medicinal properties — Various chemical constituents have been secluded and identified from different parts of Bael fruit such as alkaloids, coumarins and steroids. The Bael fruit is highly nutritious. It accommodates 61.5 g water, 1.8 g protein, 0.39 g fat, 1.7 g minerals, 31.8 g carbohydrates, 55 mg carotene, 0.13 mg thiamine, 1.19 mg riboflavin, 1.1 mg niacin, and 8 mg per 100 gm of edible portion vitamin C, no other fruit has such a high include of riboflavin. Marmelosin (C_{16} H14O4) is most probably the healing active principle of Bael. fruits it was isolated as a colourless crystalline compound



Fig.1: Bael leaves



Fig.2: Bael fruits

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RESULTS

PHYTOCHEMICAL CONSTITUENTS

Bael is announced to have number of coumarins, alkaloids, steroids, and essential oils. Bael fruits are rich in nutrients and bioactive substances with a high moisture content. Bioactive compounds contain fat, carb, protein, vitamin b1, b2, b3, c, and amino acids such as threonine, lysine, isoleucine, valine, fat, leucine, methionine, fibres, and minerals. The phytochemistry of Bael plant has been extensively studied, and the plant contain variety of biologically active compounds. Bael fruit is rich in vitamins A, B2, and C, as well as minerals like phosphorous, calcium.[9] It contains carbohydrates, fibres, amino acids, and fat. Fruits in addition contain xanthotoxin, imperatorin and marmelline. It also contains polysaccharides like galactose arabinose, uranic acid and L-rahaminose, which may obtain after hydrolysis. Scientist has long known importance of plant and chemicals which produce in overcoming disease. Over 25% of all prescribed drugs still uses plants as their principal ingredients. Different types of carotenoids have found in Aegle Marmelos, which are responsible for the imparting yellow pale colour to fruit. Root and fruits contain coumarins such as scoparone, scopoletin, umbellliferone, marmesin and skimming. Marmelosin, skimmianine and umbelliferone are the therapeutically active principal of Bael plant. Minor phytochemical constituents such as tannins, ascorbic acid, sitosterol, crude fibres, carotenoids, and crude proteins. Apart from these chemical constituents more than 100 compounds have been isolated these are skimminine, aegelin, lupeol, cineole, citral, citronellal, cuminaldehyde, eugenol, marmesinin, marmelosine, fagarine, marmin, and tannins these are biologically active against major and minor diseases.

- Rich in nutrient, high moisture content
- Contains fat, carbohydrates, fibres, protein, amino acids and vitamins (B1, B2, C, A)
- Amino acids – Methionine, isoleucine, leucine, threonine, lysine, valine.
- Minerals – phosphorous, calcium.
- Seeds – highest colorifie value (244 Kcal), highest fat (control) content.

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- Fruit pulp – 139 Kcal, high mineral contents, second highest protein.

- Leaves – lowest protein, highest vitamin etc.

- Leaves and fruit pulp – lowest fat content.

Ø Table: list of phytoconstituents isolated from various parts of Aegle marmelos

Sr. no	PART	PHYTOCONSTITUENTS
1	Leaf	Skimmianine, Aegeline, Lupeol, Cineol, Citral, Eugenol.
2	Bark	Skinnianine, Fagarine, Marmin
3	Fruit	Marmelosin, Luvangetin, Psoralen, Tannin, Marmelide.

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Aegle marmelos contains groups like alkaloids, cardiac glycosides, phytosterol, hormones, coumarins, terpenoids, phenylpropenoids, tannins, flavonoids, and polysaccharides. They are ? - sitosterol, aegelin, lupeol, sophorin marmesinin, ß - sitosterol, 2-phenyl-4H-chromen-4- one, glycoside and phenylethyl cinnamides in the leaves of Aegle marmelos. Shahidine, an alkaloid with an oxazoline place, secluded from the fresh leaves of Aegle marmelos which is determine constituent. Which is display against a few gram – positive bacteria.

- **Alkaloids**

Leaves mainly contain rutacine, ?- sitisterol, aegelemine and aegeline, marmeline, dictamine, cinnamide and different derivatives of cinnamide.

- **Coumarins**

Marmin, umbelliferon, skimmianine, psoralen, xanthotoxol were identified from the bark leaves, fruit and root of plant.

- **Seed oil**

Seed oil is bitter and contains 15.6 % palmitic acid, 8.3% steric acid, 28.7% linoleic, and 7.6 % linolenic acid while seed residue contains about 70 % protein. [4]

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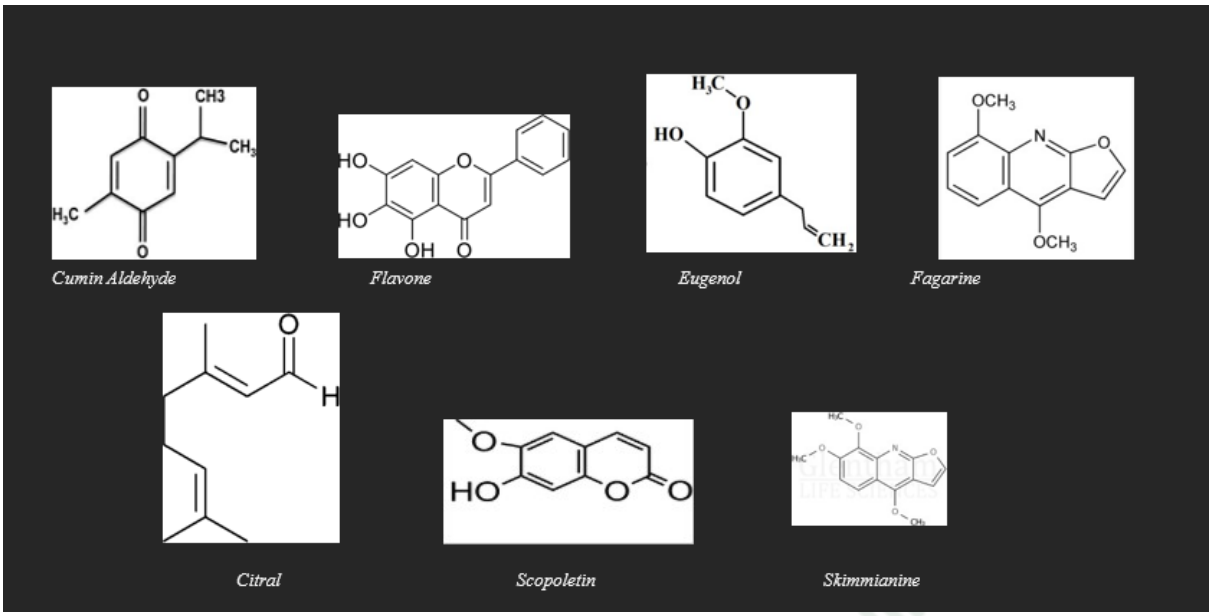


Fig.3: Structures of few important phytochemical constituent

PHARMACOLOGICAL ACTIVITIES OF BAEL

- **Antimicrobial Activity**

Scientists observed significant antimicrobial effect of ethnolic extract of dried fruit peste of Aegle marmelos against various intestinal pathogens i.e. shigella boydii, S.sonnei and S.flexneri and bacteria like E. coli salmonella typhi, Pseudomonas aeruginosa and proposed that certain phytochemicals including tannins, phenols, and flavonoids are affected against all. A. marmelos are traditionally used to reduse a wide variety of pathogenic microorganisms for the treatment of different infectious diseases. The antibacterial activity of leaves and fruit extract was evaluated by the reviewer.

- **Antioxidant Activity**

Antioxidants have the potential to defend cells from oxidative stress through scavenging free radicals. Flavones, isoflavones, flavonoids, anthocyanins, coumarins, lignans, catechins, and isocatechins are all antioxidants found in Bael plant. Antioxidant activity

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against variety of free radicals is well start in reliable A.marmelos. another reserch found antioxidant action A.leaf extract A.marmelos was responsible for the high levels of total phenolic content (TPC) and total flavonoid content (TFC) in the extract.

- **Antifungal Activity**

Antifungal activity of essential oil extracted from leaves of Bael leaves was evaluated by spore germination assay and was found to possess varying effectiveness against different fungal isolates by scientists and they reported antifungal activity of different extracts of Bael leaves. volatile oils from Aegle marmelos leaves can interfere with the metabolism pathway of Ca2+ dipicolonic acid and inhibit the development of spores at a concentration of 500 ppm. Extract of A. ethanolic, methanolic and water. leaves of Aegle marmelos has antifungal action against fungal dermatophytes.

- **Antihyperlipidemic Activity**

Aegle marmelos leaf extract pre –cleaning at 100 mg/kg and 200 mg/kg doses for 35 days significantly improved the activities to marker enzymes and decreased plasma lipids, lipoproteins,and lipid peroxides in rats treated with isoproterenol, indicating an antihyperlipidemic activity. The aegle marmelos fruit powder has been shown to lower both ester and cholesterol levels. Rats with streptozotocin-induced diabetes were given an aqueous extract of bael seeds and fruits separately at 250 mg/kg concentration, which help to reduce the lipid profile in both serum and tissue.

- **Antidiabetic Activity**

The Bael extract has multifaceted antidiabetic effect because it may significantly lower hemoglobin glycosylated and blood glucose levels while it increases hepatic glycogen and plasma insulin stages in diabetic rats. The extract of bael leaves lowers blood glucose levels by increasing serun insulin levels. When its administered orally to rats with streptozotocin-induced diabetes, the aqueous extract of Bael fruit produced a hypoglycemic effect. The fruit extract contains coumarin which increases the insulin release from the island of langerhans’ already-existing beta cells, is most likely the cause of this antidiabetic action.

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♦ **Anti Diarrhoea and Dysentery**

Generally dried fruit peste and its powder are used for the therapy of diarrhoea. The dried powder is also used as an important remedy for chronic dysentery conditions characterized by alternate diarrhoea and constipation. It has been found that bael extract fundamentally reduces blood urea and cholesterol stages in diabetic animals. Also decreases oxidative stress. For analysing this, scientist studied on leaf extract of Aegle marmelos on alloxane induced diabetes and reported that used extract was enough capable to reduce oxidative stress by scavenging lipid peroxidation and enhancing certain antioxidant levels which causes lowering of elevated blood glucose level.

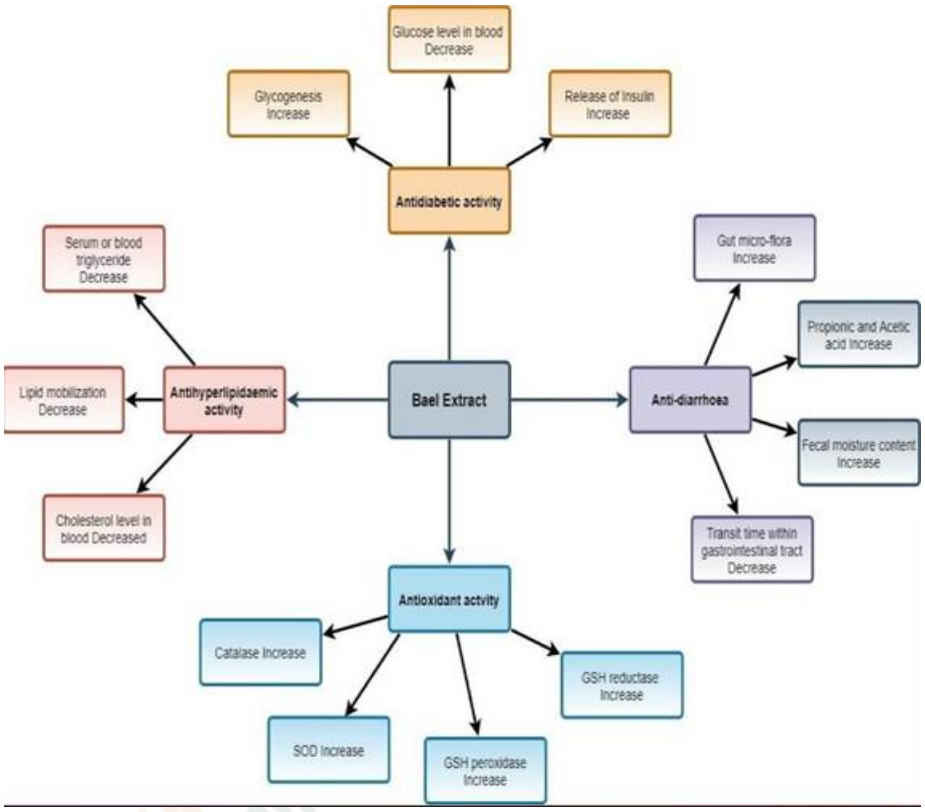
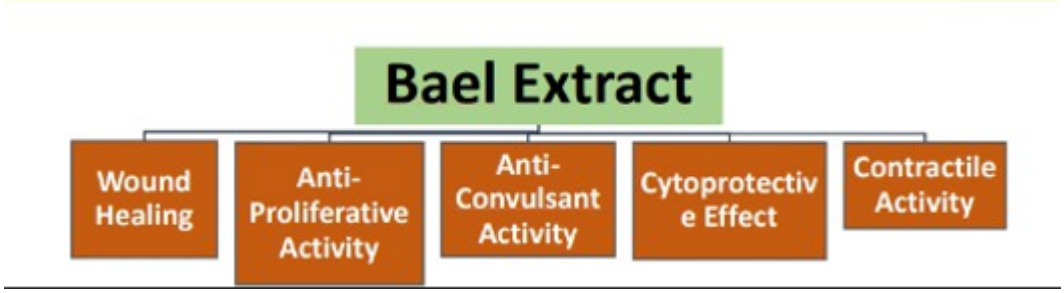


Fig.4: Pharmacological Activities of Bael

Uses of Bael

Bael is one of the most important medicinal herbs in India. In ethnomedicine, Aegle marmelo's antidiarrheal, astringet, antiinflammatory, and antipyratic and properties have been used to profit from its leaves, fruits, stems, and roots.



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Fig.7: Numerous biological uses of Bael extract

1) Wound Healing -

The ointment and injection made up from methanolic extract of Aegle marmelos which administered topically and intraperitoneal was studied respectively on two types of wound models i.e. the incision and excision wound models in rats. in excision model the Bael extract treated wound were found to epithelialize faster and rate of wound contraction was higher. And the incision wound models in rat. Both the ointment and injection produce a significant response.

2) Antiulcer activity-

For 21 days, an oral dose of 1gm/kg body weight of the Bael leaf aqueous extract was provided. After receiving extract treatment, observation showed a substantial decrease in the number of ulcer lesion, gastric juice volume, acidity (pH level is high) and hexosamine. An additional investigation on the extract of unripe Bael fruit demonstrates gastro-protective effect when applied to mucosal injury caused by ethanol.

3) Anticancer activity-

The effect of Bael fruit extract on breast cancer in rats generated by 7, 12-dimethylbenz(a)anthracene (DMBA). Treatment with bael extract resulted in the substantial reduction in the volume of breast toumer. The extract of Aegle marmelos was tested on sea urchin eggs, and shrimp by assay method upon tumour cell and they concluded that A. marmelos extract produces toxic effect on all used assays. In a rat, the alcoholic fruit pulp extract has anti-proliferative effect by inducing the progression of breast
cancers.

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DISCUSSION

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The biological actions of isolated compounds from A. marmelos that are being investigated using extracts can be connected to this review. This investigation concludes that A. marmelos has a promising future in treating and preventing different ailments, like cancer, infectious disorders, and diabetic conditions. Reviews on antimicrobial and antipyretic, inflammatory, antiulcer, and malaria treatment drugs are only a few topics covered in these reviews. For this reason, it is essential to develop clinical research on this medicinal plant and learn from traditional healers who have gathered knowledge through many generations of trial and error. The use of bael has gained popularity worldwide as its beneficial characteristics are being researched to develop new treatments.

CONCLUSION

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Aegle marmelos is a medically valuable plant with a wide range of therapeutic properties, including antimicrobial, antioxidant, antidiabetic, and anti-acne potential. Bael serves as a safe and effective alternative in traditional medicine. Bael extract shoes promising results against diseases and various pathogens in Ayurveda and other herbal systems. The reviewed literature indicates that its leaves, fruit, and roots contain various chemical constituents. Bael is multipurpose medicinal plant with significant nutritional, modern medicine, economic importance, makes it excellent natural resource for developing future herbal formulations.

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No Abbreviations

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CONFLICT OF INTERESTS

Certificate of Conflict of Interest:

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