

THE BAEL LEGACY: EXPLORING THE THERAPEUTIC WONDERS OF AEGLE MARMELOS

Prathmesh Wagh^{*1}, Rahul Jagdale², Kavita Handge³, Aditi Kute³, Sneha Kurhade⁴,
Vivek Bhoir⁵, Kiran Dhokale⁶, Vishal Gupta⁷, Shraddha Wagh and Prasad Satalkar

India.

Article Received on
24 May 2024,

Revised on 13 June 2024,
Accepted on 03 July 2024

DOI: 10.20959/wjpr202414-33199



***Corresponding Author**
Prathmesh Wagh
India.

ABSTRACT

The most revered or holy plant that grows around Hindu temples is known to be Aegle marmelos. It is also thought that Lord Shiva resides beneath the Bael tree, and this plant is dedicated to him. In addition, the plant is associated with a noteworthy medicinal efficacy that has been documented in ancient books such as the Vedas, Puranas, Charaka Samhita, Brihat Samhita, and has also been shown in the paintings of the Ajanta caves. The Bael plant is used to treat a wide range of illnesses. The herb is used in Panchang form in Ayurveda to treat ulcers, dysentery, and diarrhea. Folklore claims that the plant's components can treat a variety of illnesses, including cancer, high blood pressure, diabetes, skin conditions, typhoid, ulcers,

stomachaches, jaundice, and wound healing. The plant's fruit is edible and has a great medicinal value because it contains several antioxidants, vitamins, and minerals. The fruit's pulp is resinous, light orange, sweet, and aromatic. The plant's unripe fruit pulp is used to make pudding, juice, and murabba. A variety of therapeutic and pharmacological properties, such as antioxidant, anti-diabetic, antihistamine, radioprotective, antiulcer, anticancer, cardio-protective, antibacterial, antimicrobial, hepatoprotective, anti-inflammatory, and antiviral qualities, are linked to the ethnomedicinal uses of the plant. An attempt has been made to describe the pharmacological, ethnomedicinal, Ayurvedic, and phytochemical characteristics of the Bael plant in this review paper.

KEYWORDS: Aegle marmelos, Pharmacological activities, Phytochemical constituents, Indian Beal.

INTRODUCTION

An extensive list of over 21,000 plant species that are used medicinally around the globe has been collected by the World Health Organization. India uses over 2500 plant species from more than 1000 taxa in its ancient medicinal system¹. India is the second-most valuable and most prolific exporter of medicinal plants in the world.^[1] India is home to one of the 12 main biodiversity centers in the world, with 16 agroclimatic zones.^[2,3] Fifteen thousand of the about forty-five thousand plant species are flowering species, while seven thousand have been identified as therapeutic plants.^[4] There are over 400 families in the world of flowers, and at least 315 of them are represented in India. Though the usage of plant-based drugs has been known to us for a long time, there hasn't been much attention paid to modifying these inexpensive remedies to fit modern demands. Only forty plant species are now used by pharmaceutical firms (11 foreign and 29 local). In contrast, just 42 plant species—out of a wide genetic base of over 1300 plant species known for their aromatic qualities—are used in the fragrance chemical business. Out of the 42 plant species, 20 are native, while the other species are imported. Tandon and Thayil claim that India's medical history, one of the oldest continuous traditions in the world, is in danger of being extinct. *Aegle marmelos* (Linn.) Correa ex Roxb., also known as Bael, is an underappreciated Indian plant with great therapeutic potential. It belongs to the Rutaceae family of citrus fruits.^[7] It has several names in different languages.^[5,6] In Urdu, Bel, Bel Kham; in Assamese and Marathi, Bel, Bilivaphal; in Malayalam, Marredy; in Oriya, Vilvama, Vilva marum; in Telugu, Bilva, Bilva pandu; in Hindi, Bel, Beli, Belgiri; in Sanskrit, Bilva, Shivadruma, Shivaphala, Vilva; in English, Bael, Bengal quince, Golden apple. Bael is mentioned in the old medical literature and has been known in India from ancient times¹³. It also has a great deal of mythological significance.^[8] As with many traditional treatments, every part of the plant—fruit, seed, bark, leaf, and root—is essential. Due to its therapeutic properties, it is one of the most prized medicinal plants in India. It has several applications in day-to-day living. The products that come from Bael are different. Nutritious and medical items are becoming more and more popular in both the Indian and international markets. Since bael is currently unproductive, India has a large area of waste land that may be exploited for its cultivation. It may be profitably produced on waste and unproductive ground for farmers' benefit.^[9] As a "Sink" for chemical pollutants, the Bael plant absorbs hazardous gases from the surrounding air and transforms them into inert or neutral compounds.^[10] It is a member of the group of plant species called "Climate Purifiers," which release more oxygen into the atmosphere when exposed to sunlight than other plant species do. The tree is also classified as a "fragrant" species due to its volatile

blooms and fumes, which cover up the unpleasant smell of decaying animals or petrified organic materials and shield humans from bacterial infections by making the bacteria inert and removing the unpleasant stench from the air.^[11] This assessment covers the tree's general and chemical characteristics as well as its commercial value for use in medicine and other fields.

Plant Description

Known by the popular name "Bale fruit tree," Bael (*Aegle Marmelos* (Linn)) is a modestly big, slender, fragrant tree that grows wild in the deciduous woods of India. It is a member of the Rutaceae family. It is found on Andaman Island as well as in the western Himalayas, where it reaches an elevation of 1200 meters. The tree is 90 to 120 cm in diameter and 6.0 to 7.5 meters in height.^[12] The Hindu community usually considers this tree sacred since, during devotion, its leaves are offered to Lord Shiva. The tree is a distinct form of Lord Kailashnath in Hindu mythology.^[13] The leaves, fruit, stem, and roots of this tree are used in traditional medicine to cure a wide range of human ailments at every stage of development.



Aegle Marmelos Leaves (Indian Beal)



Aegle Marmelos Fruit (Indian Beal)

Taxonomical classification**Kingdom** :- Plantae**Division**:-Magnoliophyta**Class**:- Magnoliopsida**Order**:-Sapindales**Family**:-Rutaceae**Sub-family**:-Aurantioideae**Genus** :-Aegle**Species** :-A.marmelos**Common name**:- Bael Patra, Bael^[18]**Vernacular Names****Hindi** Bel, Beli, Belgiri, Baelputri, sirphal, kooralam**Sanskrit** Bilva, Shivadruma, Shivaphala, Vilva**English** Golden apple, Bael fruit, Indian Bael, Holy fruit, Indian quince, elephant apple, stone apple**Urdu** Bel, Bel kham**Himachal Pradesh** Bil Bengal Bael**Karnataka** Bilpatra, kumbala, malura**Andhra Pradesh** Maredu**Kerala** Kuvalum Assamese,**Marathi** Bel**Gujrati** Bilivaohal, Bili**Malayalam** Marredy Oriya Belo**Tamil** Vilva marum**Telugu** Bilva pandu Burmese Opesheet, ohshit**French** Bel indien, cognassier du, Bengale, oranger du Malabar**German** Belbaum, Schleimappelbaum, Baelbaum**Portuguese** Marmelo^[19]**Botanical description of A marmelos****Leaves**

A. marmelos has deciduous, aromatic, switching trifoliate leaves. They have three to five oval, pointy, shallowly toothed leaflets and may be solitary or complex. The leaflets are 2.5–5

cm broad and 4–10 cm long. The lateral leaflets lack a petiole, whereas the terminal leaflet possesses a lengthy one. 3–5 leaflets are present in each leaf. The petiole of a leaf is long and hairless. A disagreeable odor is released by damaged adult leaves.^[14,15]



Leaves

Flower

A cluster of four to seven fragrant, 2 cm wide, upright, stalked, and sweetly scented flowers with four to five recurved fleshy petals that are yellowish on the inside and greenish on the exterior and at least fifty greenish stamens are present. The capitate stigma ovary is oblong-ovoid with a slightly tapering thick short style, and the calyx is shallow with five short, wide teeth.^[16]



Flower

Fruit

Fruits have a firm, smoothwoody shell called the pericarp and are pyriform, spherical, fragrant, light orange, fibrous oval, oblong, and up to 20 cm in diameter. The crust is graygreen in the early stages, maturing to an orange or yellowish color, then drying to a very hard, orange-red texture. Within the fruit is a firm core with eight to twenty faintly visible triangular segments surrounded by thin walls of dark orange color. The fruit's flesh is

astrigent, sweet, fragrant, resinous, and light orange in color. The fruit might take up to a year to fully mature due to its sluggish ripening process.^[17]



Fruit

Phytochemical constituents of *A. marmelos*

Below is a list of the chemical components that were isolated from different parts of the plant. The molecular makeup of some important phytochemicals.

Fruit

Bioactive substances, carbohydrates, minerals, vitamins, coumarins, phenolic acids, alkaloids, flavonoids, organic acids, volatile compounds, and fatty acids make up the fruit component. Carbohydrates (31.80 g/100 g), fibers (2.90 g/100 g), minerals (1.70 g/100 g), fats (0.39 g/100 g), and vitamins (0.05 mg/100 g), vitamin B2 (1.20 mg/100 g), vitamin C (8.0 mg/100 g), riboflavin (0.03 mg/100 g), thiamine (0.13 mg/100 g), and beta-carotene (55.0 mg/100 g)³⁵ are among the many nutrients found in the *Aegle marmelos* plant.

Coumarins

6-(2-hydroxy-3-hydroxymethyl-3-butenyl)-7-hydroxycoumarin, 6-formylumbelliferone, and 6-(4-acetoxy-3-methyl-2-butenyl) are among the coumarins that have been isolated from the plant's fruit. 8-hydroxysmyrindiol, -7-hydroxyl coumarin, Eight-[(3-methyl-2-oxo-3-buten-1-yl)oxy]-7H-furo[3,2-g] psoralen, marmelonine, umbelliferone, scoparone, scopoletin, xanthotoxin, xanthoarnol, and xanthotoxol, with benzopyran-2-one, isofraxidin, isogosferol, alloimperatorin, decursinol, demethylsuberosin, marmelosin, isophellodenol C, and psoralen.
[20–25]

Phenolic acids and Flavonoids

Ellagic acid, quercetin, chlorogenic acid, gallic acid, ferulic acid, kaempferol, and protocatechuic acid are among the phenolic acids and flavonoids that are isolated from the fruit portion.^[26]

Alkaloids

Aegelenine, aegelin, marmeline, marmesiline, O-(3, 3-dimethylallyl) halofordinol, and O-methylhalofordinol are among the alkaloids that have been identified from the fruit portion.^[27]

Leaves

Coumarins (mermenol and praeltin), O-(3, 3-dimethylallyl) halofordinol, N-4-methoxystyryl cinnamide, and N-2-methoxy-2-[4-(3', 3'-dimethyl allyloxy) phenyl] ethyl cinnamide are among the chemical components that were isolated from the leaf portion.

Bark

Alkaloids include skimmianine and gammafagarine, while coumarins include aegelinol, mermesin, marmesin, and umbelliferone.^[28–33]

Root

Alkaloids such as discamine, haplopin, tembamide, gamma-fagarine, and tembamide, and coumarins such as aegelinol, marmesin, marmin, scopoletin, umbelliferone, and xanthotoxin are among the chemical constituents that were identified from root portions.^[34–36]

Ayurvedic View

It is well acknowledged that the most important plant in the Ayurvedic treatment method is *A. marmelos*. It equalizes the doshas of Vata (space and air) and Kapha (water and earth). The pharmaceutical systems of Siddha, Unani, and Ayurveda use the fruit of this plant for its therapeutic qualities. It is well known to be a very successful diarrhea therapy. The Charaka Samhita provides a short overview of the plant's medicinal properties.^[37] The stem, leaf, seed, and fruit of the plant are all used to treat different kinds of illnesses.^[38] The plant's leaves have expectorant, astringent, and febrifuge properties that help cure digestive problems, edema, hemorrhoids, and bleeding diseases. The plant's roots are often employed as a key component of "Dashamoola," a traditional Ayurvedic medicine used to treat fever, colitis, diarrhea, flatulence, dysentery, and lack of appetite. The plant's fruits are used to make

Chyavanprash. In Ayurveda, the unripe fruit is utilized as a heart and brain tonic and to treat dysentery and chronic diarrhea.^[39] Urinary tract diseases and heart palpitations are alleviated by the plant's roots and tree bark.^[40] The juice of *A. marmelos* improves stomach functions and helps with scurvy and digestive relief.^[41] Because of the plant's carminative and digestive properties, Ayurveda uses it to treat heart palpitations, indigestion, intermittent fever, typhoid, cholera, and stomach and intestinal illnesses. Compared to ripe fruit, unripe fruit is associated with greater therapeutic benefits.

Modern View

Due to its better accessibility, lower cost, and less side effects, herbal medications are becoming more and more popular in today's society. Worldwide, the use of herbal treatments has grown. According to research reports, there was an annual growth in the sales of herbal items from 3% to 12% between 2000 and 2008. The industry for herbal medications is facing growing adulteration and replacement due to rising consumer demand, which is seen as a serious threat to product quality and the advancement of research on commercial natural products. The lack of authentic plant products, deforestation, the extinction of many species of herbal plants, errors in species identification, etc. are the main causes of adulteration. Additionally, a few of herbal merchants have developed novel techniques for high-quality adulteration that are only detectable by microscopic inspection and chemical analysis.^[42] The acceptance of herbal medications is based on two weaknesses: low quality medicine and a lack of standardization, which lowers the product's commercial worth. Thus, it is necessary to set up a Herbal Authentication System (HAS), which might serve as a regulator and improve the standard of the herbal trade.^[43] *Aegle marmelos*, a herbaceous plant, has several medicinal properties. The historical consequences of the plant's devastation and overuse are evident. The plant is linked to the names of the trees of Lord Shiva and Goddess Laxmi to protect it from overuse and eventual destruction. The Bael plant is becoming more and more well-known these days due to its medicinal efficacy in treating both human and animal illnesses. Owing to the *A. marmelos* plant's immense economic value, those who had previously used the plant's products wisely turned into violent and destructive collectors. The government of India's National Medicinal Plants Board has prioritized the *A. marmelos* plant among its 32 medicinal plants in order to save it from extinction. Numerous projects for the plant's sustainable use and conservation have also received government approval.^[44]

Pharmacological Effect

Antioxidant activity

By using the DPPH radical scavenging method, nitric oxide scavenging assay, reducing power assay, H₂O₂ radical scavenging assay, ABTS radical scavenging assay, and superoxide radical scavenging assay, the antioxidant activity of the methanolic and ethanolic extract of the fruit pulp of *A. marmelos* plant was evaluated in a rat model.^[45] The plant's methanolic and ethanolic extracts, which had strong antioxidant activity, were shown to block free radicals. Unripe fruit has a higher level of inhibitory action than ripe fruit.^[46]

Antispermato-genic activity

Because it inhibits spermatogenesis and reduces sperm motility in rats, the leaf extract has anti-spermato-genic activity.^[47] In Bangladesh, leaves were employed to regulate fertility.^[48–49]

Anticancer activity

Using the MTT assay technique, the lethality of brine shrimp assay, and the sea urchin egg assay, the anticancer activity of the plant extract was evaluated against tumor cell lines. Against every test that was utilized, the plant extract shown harmful effects.^[50] Additionally, Jagetia G.C. et al. observed that the hydroalcoholic extract of the leaves showed anticancer effects in Ehrlich ascites carcinoma and suggested that the plant extract's skimmianine content may be the cause of the induction of apoptosis.^[51]

Wound healing activity

Male Wistar rats were used as test subjects for the Methanolic extract of the seed ointment and Bael plant injection in relation to an excision wound model. On days 0, 4, 8, 12, 16, and 20 after the wound had first healed, the ointment was administered and the healing process was monitored.^[52] Comparing the results to the control group, they revealed a greater rate of contracting wounds and a quicker pace of healing. The healing effect of the plant extract was shown by the increase in tensile strength in the incision model.^[53]

Anti-hyperlipidemia activity

At dosages of 125 and 250 mg/kg, the hyperlipidaemic activity of the aqueous extracts of the fruits and seeds was evaluated using an albino rat model. The tissue lipid profile and serum are considerably reduced when the aqueous extract is taken orally.^[54]

Antidepressant and anxiolytic activity

Using a mouse model, the Bael plant's methanolic extract of leaves exhibited anxiolytic and antidepressant properties.^[59]

Anti-arthritis activity

In Wistar albino rats with collagen-induced arthritis, the Bael plant's methanolic extract of the leaves exhibited anti-arthritis efficacy. After the experimental rat model was treated with the plant's methanolic extract, there was a noticeable decrease in the radiological and histological changes.^[55]

Hepatoprotective activity

Tests were conducted to determine if the alcoholic extract of *A. marmelos* plant leaves had hepatoprotective effects on an albino rat model. A bacterial suspension containing 5×10^6 CFU/0.1 ml was administered intraperitoneally (I.P.) into rats. After that, the plant's alcoholic extract was given to the animal model for a period of 15 days. The albino rat was then given a moderate chloroform anesthetic and allowed to starve for a full twelve hours. After feeding the plant's powdered leaves to the albino rats for 21 days, the rats were given a 30% ethyl alcohol extract on a daily basis for 40 days. The experimental model demonstrated the hepatoprotective action of the *A. marmelos* leaf.^[55–58]

Cytoprotective activity

Freshwater fish, namely *Cyprinus carpio*, were used in the research to determine the cytoprotective activity of the *A. marmelos* plant. For 1, 8, 16, and 32 days, the experimental fish was exposed to the sun-lethal dose of metal ions. Following that, 500 mg/kg of crude *A. marmelos* plant powder was given to the fish. The results demonstrated the antioxidant enzyme system's regulation and the stability of the plasma membrane, indicating cardioprotective activity.^[60]

Antiulcer activity

Wistar rats were used as test subjects for the polyherbal formulation's antiulcer effectiveness. The formulation was made from the leaf part of *A. marmelos*, the 200 mg rhizome of *Glycyrrhiza glabra*, the root part of *Hemidesmus indicus*, and the fruit part of *Cuminum cyminum*. In comparison to the conventional 20 mg/kg omeprazole administration, the oral administration of the polyherbal formulation at a dose of 500 mg/kg results in a moderate suppression of gastric lesions in the rat model. It was discovered that the polyherbal

formulation had a non-toxic impact even at high concentrations and may be helpful in treating severe stomach ulcers.^[61]

Antipyretic and Analgesic activities

Bael extract has been shown to significantly suppress carrageenan-induced paw edema, cotton-pellet granuloma, and paw itching in mice and rats, indicating that it possesses antipyretic, anti-inflammatory, and analgesic properties.^[62] Additionally, it is utilized as a febrifuge for sporadic and nighttime fevers.^[63–65]

Antimicrobial activity

The antibacterial activity of petroleum ether, ethanol, and an aqueous extract of *A. marmelos* plant leaves was evaluated by means of the agar well diffusion technique. The findings indicated that the extracts were efficient against *Salmonella typhi*, *E. Coli*, *Klebsiella pneumonia*, *Proteus vulgaris*, and *Streptococcus pneumonia*. Additionally, it was shown that ethanolic extract had antibacterial action against *Penicillium chrysogenum*, whereas petroleum ether and aqueous extract showed antimicrobial activity against *Fusarium oxysporum*.^[66]

Respiratory infections

Relief from recurring colds and respiratory infections may be obtained from medicinal oil made from leaves. The leaf juice is combined with an equal amount of sesame oil, cooked, and then cooled. A small pinch of black pepper and half a teaspoon of black cumin are added, and the mixture is taken off the heat and kept in the refrigerator until used. Apply a dollop of this oil to the scalp and massage it in before taking a head bath. Regular usage strengthens the body's defenses against cough and colds. Giving leaf juice to treat asthmatic cough and respiratory spasms is a prevalent practice in South India. The leaf juice is served as a drink after being combined with some warm water and pepper.^[69–70]

Toxicity

To find out the plant's damaging effects, the full aqueous, methanolic, and alcoholic extract of the leaves was evaluated using an experimental rat model. At a dosage of 50 mg/kg body weight, the extracts administered intraperitoneally did not show any histological changes for 14 days.^[68] Using the Ames test, it was discovered that the plant's fruit aqueous extract was non-mutagenic against the *Salmonella typhimurium* strain TA 100.^[68]

CONCLUSION

Given the many uses and possibilities for bael, it is crucial to cultivate this plant extensively, especially on waste land and unproductive areas. This may help farmers who are landless and in poverty improve their financial situation. To fully realize this underutilized plant's potential, methodical, scientific study is also necessary. The authors believe that as Native Americans, we are most suited to harness the full potential of this plant, Panacea, for both environmental and human well-being since we have strong traditional knowledge combined with modern scientific approaches.

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