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Review Article

## *Aegle marmelos* (L.) (Bael): A Systematic Review

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### Abstract

*Aegle marmelos* is a plant in the Rutaceae family that is one of the most significant in the medicinal field due to its properties. Bilwa is used to treat a variety of medical problems. Since the time of the dinosaurs, this plant has existed. The plant contains a variety of pharmacological qualities, including wound healing, antipyretic potential, anti-diarrheal activity, Diuretic activity, Ulcer healing, and more. Antithyroid activity, Immunomodulatory activity, Antifungal activity, Antimicrobial activity, Antioxidant activity, Radioprotective effect, Contractile activity, Antiarthritis activity, Analgesic activity, Cytoprotective effect, Contractile activity, Alkaloids, Terpenoids, Vitamins, Coumarins, Tannins, Carbohydrates, Flavonoids, Fatty Acids, Essential Oils, and other miscellaneous chemicals are among the identified constituents. This study summarises information about the *A. marmelos*' morphology, distribution, phytochemistry, traditional uses, and biological activity.

**Keywords:** *Aegle marmelos*, Phytochemistry, morphology, pharmacological properties.

## Introduction

Plants are particularly significant to humans since they contain various active ingredients that are the precursor for the creation of many drugs<sup>1</sup>. For thousands of years, plants have been used in India as natural or herbal medicine. Plants used in Indian medicines are regarded as a rich source of numerous pharmacologically active principles and active ingredients, which are often employed in home treatments for a variety of diseases<sup>2</sup>. *Aegle marmelos* (L.) Correa (*A. marmelos*), often well-known for Bael and belongs to the Rutaceae family, has been widely employed in indigenous systems of Indian medicine due to its many therapeutic characteristics<sup>3</sup>. *A. marmelos* leaves are presented to Lord Shiva, whose devotion would be incomplete without them. Shivadurme, or Shiva's tree, is another name for it. Ancient Indian texts such as the Yajurveda and the Mahabharata<sup>4</sup>. Bael includes a variety of phytochemicals such as alkaloids, tannins, essential oils, gums, resins, coumarin, and polysaccharide, which makes it effective for a variety of diseases. When compared to other fruits, it has a substantially higher nutritional value. It is also quite important in terms of the environment.

## Synonyms<sup>5</sup>

Hindi (Bel, bael, sripal); Sanskrit (Bilva, sripthal, shivadruma, Shivapala); Telugu (Maredu); Bengali Cambodia (Phneou or pnoi); Vietnamese (Baunau); Malayan (M (Modjo). (Bel); Gujrati (Bil); Kannada (Bilpatra, kumbala, malura); Tamil (Kuvulum); Thai (Matum and mapin);

## Ecology<sup>6</sup>

Bael is of Indian origin and can be found in Bangladesh, Egypt, Malaysia, Myanmar, Pakistan, Sri Lanka, and Thailand. The tree fills wild in dry woodlands on the slopes and fields of focal and southern India, just as in Burma, Pakistan, and Bangladesh, just as in blended deciduous and dry timberlands.

## Botanical Description

It is a slow growing medium to small size tree that can reach a height of 25 to 30 feet. The stem is soft and dense, with a few spiky branches. Table 1 contains the whole botanical description of *A. marmelos*<sup>7</sup>.

**Table 1: Botanical Description of *Aegle marmelos* (L.)**

Plant Part	Morphological characteristics
<b>Bark</b>	The bark grey or brownish in colour, and it bears a number of long, straight spines. It includes gums, which form from wounded branches and harden over time. The easiest way to describe these gums is as a transparent, sticky sap. It tastes good at first, but it quickly gets irritating to the throat.
<b>Leaf</b>	It has trifoliolate leaves with a circular base and a pointed apex. The adult leaves are dark green, whilst the young leaves are pale green.
<b>Flower</b>	The flowers are bisexual and greenish or yellowish in colour. It is usually evident with fresh leaves.
<b>Fruit</b>	The bael fruit has a tough outer jacket with a diameter of around 5 to 12 cm. It is green while unripe and turns yellowish brown when ripe. Its interior includes up to 20 orange pulp.
<b>Seed</b>	They are small (almost 1 cm long), hard, hairs, flattened-oblong and each is surrounded by an adhesive sac.

### Traditional utilization of *Aegle marmelos*

*A. marmelos* is extensively described in Vedic literature for the treatment of a variety of diseases.

It has long been used to cure a range of ailments<sup>8-14</sup>, which are summarised in Table 2.

**Table 2: Various parts of *Aegle marmelos* utilized**

Plant part	Traditional utilization
<b>Leaf</b>	Sore, spinal pain, eye grievances, stomach problems, retching, trims and wounds, ulcer, dropsy, beriberi, heart shortcoming, cholera, the runs, cardio tonic, glucose, creature wounds, neurological issues, hair tonic, intense bronchitis. In anesthetized felines, veterinary medicine for wounds, worm murdering, feed for sheep, goats, and steers, incitement of breath and withdrawal of denervosed nictitating film.
<b>Fruit</b>	Astringent, looseness of the bowels, gastric issues, blockage, purgative, tonic, stomach related, stomachic, diarrhea, mind and heart tonic, ulcer, antiviral, intestinal parasites, gonorrhoea, epilepsy.
<b>Root</b>	Dog chomp, gastrointestinal issues, heart sicknesses, discontinuous fevers, antiamoebic, hypoglycaemic, stiffness.
<b>Bark</b>	Stomach problem, discontinuous fevers, heart issue.
<b>Seed</b>	Febrifuge.
<b>Flower</b>	Expectorant, epilepsy.
<b>Whole plant</b>	Stomach torment, sore, astringent, spinal pain, canine nibble, bosom torment, cholera, blockage, seizures, cramp, diabetes, loose bowels, diarrhea, fever, eye grievances, gastric difficulty, stomach issues, jaundice, purgative, queasiness, night fever, heart issues, snakebite, stomach problem, heaving, tonic, cut and wounds.
<b>Root, Bark</b>	Fish poison.
<b>Seed mucilage</b>	Plaster for walls.
<b>Seed oil</b>	Laxative.
<b>Wood</b>	Globules utilized by the lower stations, and exceptional couches for rheumatoid patients
<b>Gum around seed</b>	To increase the adhesion strength of water paints.
<b>Unripe fruit rind, Bark</b>	Yellow dye
<b>Stem</b>	Oil and sugar mill pestles.

### Biophysical limits <sup>15</sup>

Bael is located at an elevation of 0-1200 meters; it requires an annual temperature range of 6 to 48 degrees Celsius and an annual rainfall range of 570 to 2000 millimetres. Furthermore, it demands well-drained soil and grows best in rocky soils and alkaline with pH levels ranging from 5 to 8.

### Taxonomy <sup>5, 16</sup>

Kingdom: Plantae  
Order: Sapindales  
Family: Rutaceae  
Sub family: Aurantioideae  
Genus: *Aegle*  
Species: *A. marmelos*

## Phytochemistry

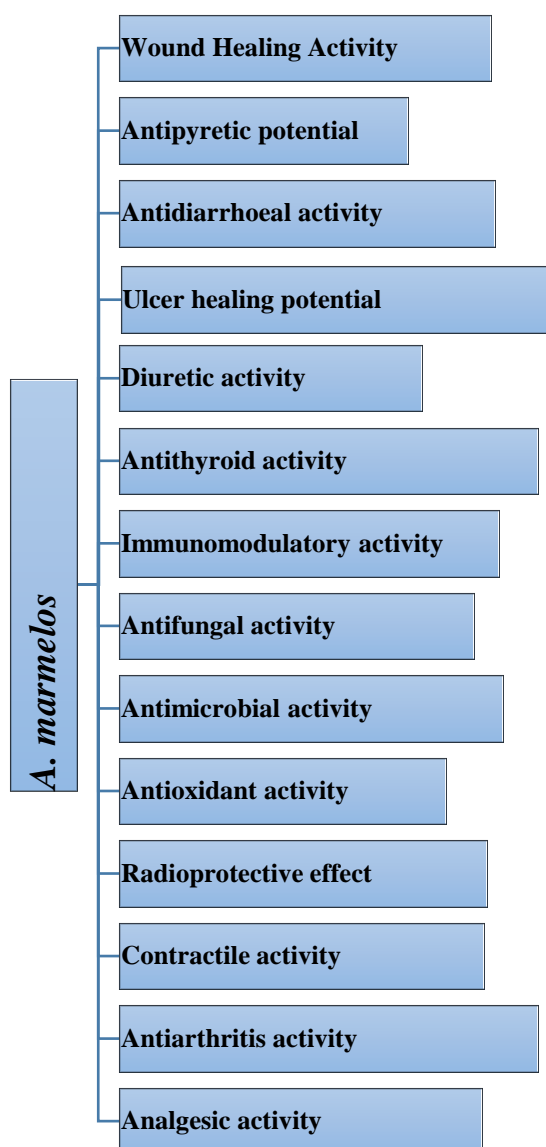
A few investigations have been led to discover dynamic compound fixings from different areas of the bael plant<sup>2, 7, 17-18</sup>. Table 5 lists the chemical compounds extracted from *A. marmelos*.

**Table 3: Plant Part Chemical Constituents**

Plant part	Chemical Constituents
<b>Leaf</b>	Skimmianine, Aeglin, Rutin, -sitosterole, -sitosterol, Flavone, Lupeol, Cineol, Citral, Glycoside, O-isopentenyl, Hallordiol, Mameline, Citronellal, Cuuminaldehyde phenylethyle cinnamamides, Eugenol,
<b>Fruit</b>	Psoralen, Marmelide, Tannin, Phenol, Marmelosin, Luvangetin, Aurapten, Tannin, Phenol, Tannin, Tannin, Tannin, Tannin, Tannin, Tannin,
<b>Bark</b>	Alkaloids, Fagarine, Marmin, Furoquinoline
<b>Seed</b>	D-limonene, A-D-phellandrene, Cineol, Citronellal, Citral, P-cyrnene, Cumin aldehyde are essential oils.
<b>Root</b>	Terpines, Halopine, Coumarins, and Alkaloid

## Pharmacological studies

*A. marmelos* is one of the most frequently utilised medicinal and nutritional plants in the Rutaceae family. This plant has recently been found to have a variety of therapeutic benefits shown in Figure 1.



**Figure 1: Pharmacological activities of *A. marmelos***

### Wound Healing Activity

The impact of skin and intraperitoneal organization of methanolic concentrates of *Aegle marmelos* balm and infusion on two sorts of twisted models in rodents, extraction and entry point, was explored. The infusion and salve of *Aegle marmelos* methanolic separate got critical reactions in both. As proven by an increment in elasticity in the entry point model, the concentrate helps in the mending cycle. The outcomes were likewise contrasted with those of the criticized drug nitrofurazone<sup>7, 19</sup>.

### Antipyretic potential

*A. marmelos*' antipyretic movement on Brewer's yeast actuated pyrexia in pale skinned person rodents. They show that at portions of 200 mg/kg body weight and 400 mg/kg body weight, the ethanolic extricate created a critical (P0.001) decrease in high internal heat level in a dose subordinate way. The concentrates' antipyretic viability was similar to that of paracetamol (100 mg/kg body weight)<sup>20</sup>.

### Antidiarrhoeal activity

The antidiarrheal activity of a chloroform extract of *A. marmelos* root. In an in vitro research, the extract was found to be equivalent to ciprofloxacin and mostly active against *Vibrio cholerae* bacteria, followed by *Escherichia coli* (*E. coli*) and *Shigella* spp<sup>21</sup>.

The antimalarial activity of alcoholic extracts of *A. marmelos* seeds and leaves was tested in vivo and in vitro against the *Plasmodium berghei* NK65 strain. The seeds were schizontocidal in both systems, while the leaves were solely schizontocidal in the in vitro system<sup>22</sup>.

### Ulcer healing

In albino rats, *A. marmelos* fruit pulp extract lowers mucosal thickness, superoxide dismutation, catalase activity, and glutathione levels considerably. Ulcer index, aspartate aminotransferase, alanine aminotransferase, and lipid peroxidation activity all increased significantly. These data suggest that an antioxidant mechanism may impact *A. marmelos*' gastroduodenal preventative and antiulcerogenic effects.<sup>23</sup>

### Diuretic activity

Several organic extracts and fractions of *A. marmelos* fruit were studied for their diuretic properties. The extracts were administered to the rats at dosages of 300, 400, and 500 mg/kg intraperitoneally. To examine the diuretic impact, they

analysed urine volume and salt content in urine. They observed that the ethanolic extract generated a significant increase in sodium excretion at the higher dosage (500 mg/kg). Petroleum ether, chloroform, and ethyl acetate fractions are also effective<sup>24</sup>.

#### Antithyroid activity

Thyroid hormone levels were lowered when the leaves of *A. marmelos* were extracted. It was due to the presence of scopoletin, which has a stronger therapeutic effect than the propylthiouracil drug.<sup>2</sup>

#### Immunomodulatory activity

It was discovered that methanolic leaves extract of *Aegle marmelos* stimulate cell mediated and antibody mediated immune responses in rats. However, a low dose of methanolic extract of *Aegle marmelos* was found to be most effective in cell mediated immune response, whereas a high dose was found to be most effective in humoral immunity<sup>25</sup>.

#### Antifungal activity

Essential oil from *Aegle marmelos* leaves may meddle with the Ca<sup>2+</sup>-dipicolonic corrosive metabolic pathway and maybe limit spore improvement, as per an examination. *A. marmelos* leaf removes in ethanol, methanol, and water showed antifungal adequacy against dermatophyte organism<sup>26</sup>.

#### Antimicrobial activity

It has been stated that *A. marmelos* has traditionally been used to treat a variety of infectious disorders by inhibiting a wide range of harmful microorganisms. The antibacterial activity of *A. marmelos* leaves and fruit extract was investigated. The use of leaf and fruit extracts against *Rouletella planticola* resulted in inhibition zones of 11 mm and 9 mm, respectively. The plant extract produced a maximum inhibition zone of (18mm) activity against the fungal strain *Penicillium chrysogenum* and a minimum inhibition zone of (7mm) activity against *Candida albicans*<sup>27</sup>.

#### Antioxidant activity

The DPPH radical scavenging method, the reducing power assay, the nitric oxide scavenging assay, the superoxide radical scavenging assay, the ABTS radical scavenging assay, and the H<sub>2</sub>O<sub>2</sub> radical scavenging assay were used to determine the antioxidant activity of *A. marmelos* fruit pulp methanolic and aqueous extract. The antioxidant activity of both the aqueous and alcoholic extracts was high. Unripe fruit likewise showed a greater free radical inhibition percentage than ripe fruit.<sup>28</sup>

#### Radioprotective effect

One of the most important cancer therapies, especially for those with critical visceral tumours, is radiotherapy. It has certain bad side effects, despite the fact that it is quite valuable all over the world. In mice exposed to various amounts of gamma radiation, the radioprotective effect of bael fruit hydroalcoholic extract was investigated. Before being subjected to 10 Gy 60Co gamma-rays, Swiss albino male mice were administered 5, 10, 15, 20, or 40 mg/kg *Aegle marmelos* extract intraperitoneally every day for 5 days. After 30 days of post-radiation therapy, the majority of survivors report maximum protection<sup>29</sup>.

#### Contractile activity

The contractile action of *Aegle marmelos* leaves alcoholic extract was discovered on guinea pig separated ileum and tracheal chain due to its traditional usage in treating asthma and associated disorders. The alcoholic extract of *A.*

*marmelos* leaves at low and high dosages of 1 mg/ml and 2 mg/ml caused the guinea pig ileum and tracheal chain to relax the most owing to H<sub>1</sub> receptor depression<sup>30</sup>.

#### Antiarthrititis activity

The leaves of *Aegle marmelos* were found to be anti-collagen in Wistar albino rats, causing arthritis<sup>31</sup>.

#### Analgesic activity

Writhing and tail immersion tests were used to investigate the antinociceptive effect of *A. marmelos* leaves methanol extract in mice. The greatest possible impact of methanolic extract (200 mg/kg p.o.) was statistically significant when compared to other dosages. It is concluded that the methanol extract of *A. marmelos* leaves has a potent analgesic effect<sup>32</sup>.

#### Cytoprotective effect

This effect has been found in the freshwater fish *Cyprinus carpio*. For 1, 8, 16, and 32 days, experimental fish were maintained at sublethal metal ion concentrations. After 32 days, the fish were fed *Aegle marmelos* crude powder (500 mg/kg diet). By stabilising the plasma membrane and regulating the antioxidant enzyme system, the therapy produced a cytoprotective effect.<sup>33</sup>

#### Anti-constipating effect

The majority of the available ripe fruits are thought to be a natural remedy for various types of laxatives. The fruits of *A. marmelos* are commonly used to cleanse and tone the gut. Consuming this fruit on a regular basis for two to three months helps in the evacuation of old accumulated faecal matter from the colon. It is commonly consumed in the form of 'sherbat,' which is formed from ripe fruit pulp<sup>34</sup>.

#### Anticancer activity

The effects of *Aegle marmelos* fruit extract on breast cancer in rats generated by 7, 12-dimethylbenz(a)anthracene (DMBA). The study employed female Charles Foster rats that were 55–60 days old and weighed approximately (150 10 g). They were stimulated orally with DMBA (20 mg/mL diluted in Olive oil). The rats were given *Aegle marmelos* ethanolic fruit pulp extract (200 mg/kg b.w./day) orally for 5 weeks after developing breast tumours (approximately 0.5 cm) and the amount of tumour was assessed. Treatment with *Aegle marmelos* resulted in a substantial reduction in breast tumour volume (P 0.05), as well as a substantial drop (P 0.0001) in serum biomarkers such as TNF-, serum malondialdehyde (MDA), and glucose levels. In a rat model, the ethanolic fruit pulp extract has anti-proliferative effect by slowing the progression of breast cancers.<sup>35</sup>

#### Transcriptome Analysis

The transcripts of *A. marmelos* were also annotated using information from other Rutaceae species, such as *Citrus clementina* and *Citrus sinensis*. 482 transcripts were classified as cytochrome p450s (CYPs), whereas 314 transcripts were classified as glucosyltransferases (GTs). The monoterpenoid biosynthesis pathway found the most prevalent in *A. marmelos* leaves. A total of 133,616 contigs were assembled into 46,335 unigenes with lengths ranging from 201 to 14,853 bp. There were 7002 transcription factors and 94,479 SSR markers in the study<sup>36</sup>.

#### Antidiabetic activity

The circulatory alterations in alloxan-induced diabetic rats treated with *Aegle marmelos* methanolic leaf extracts. The study included five treatment groups of methanolic leaf extracts: control, diseased, low dosage (100mg/kg), medium dose (250mg/kg), and high dose (500mg/kg). Very-Low-

Density Lipoprotein (VLDL), Serum Sialic Acid, Glutathione Peroxidase, Serum Catalase, Ascorbic acid, Sodium, Potassium, and Chloride levels were used to assess the cardiovascular effects. When compared to the sick treatment groups, the high dosage treatment group had significantly lower levels of Very Low-Density Lipoprotein (VLDL), Serum Sialic Acid, Glutathione Peroxidase, Serum Catalase, Ascorbic acid, Sodium, Potassium, and Chloride. When compared to the high dosage treatment group as well as the sick group, low and medium dosage treated animals exhibited no significant change in these cardiovascular parameters<sup>37</sup>.

## Food applications

The health advantages of bael are not confined to the edible section (fruit), but also include the non-edible portions (root, trunk, bark, leaf, blossom, and seed), which contain biologically active substances in equivalent amounts. With growing awareness of the importance of diet for human well-being among health-conscious consumers, interest in functional foods has grown. As a result, research into the functional attributes of various under utilised plants has been reaffirmed, and various sources have emerged as suitable food material for the processing industry. Several research publications gathered from diverse bibliometric sources showed that *A. marmelos* and its bioactive ingredients might play a key role in the prevention of oxidative stress-related chronic and degenerative disorders. The focus of this study is on contemporary scientific information on *A. marmelos* nutrition and bioactive profile, health benefits, clinical and nonclinical studies of various phytoconstituents, and *A. marmelos* potential in the food processing sector for diverse food items<sup>38</sup>.

## Conclusion

Several parts of *A. marmelos* have been classified as traditional healers, capable of curing a wide range of human ailments. There are several phytoconstituents in *A. marmelos* that are significant components in the plant's medicinal effectiveness. Almost every part of this plant is used to cure a variety of illnesses, including the leaf, fruit, seed, bark, and root. Given the Bael tree's great potential, it should either be cultivated or preserved in order to maximize its potential for exploitation and the discovery of new and effective herbal treatments. To produce goods for better economic and therapeutic usage, a comprehensive research and development effort should be undertaken.

## Disclosure Statement

There are no conflicts of interest.

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