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A versatile tree of India: Uses and properties of Bael

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Abstract
The Bael tree, scientifically named *Aegle marmelos* (L.) Correa, stands out as one of the most cherished and valuable medicinal plants found across the Indian subcontinent. For centuries, it has held a position of deep respect and essential utility within traditional healing systems such as Ayurveda, Siddha, and Unani, where it is often treated as a natural cure-all for a wide variety of human ailments. This review brings together detailed information from thirty-five different scientific studies to create a complete picture of what makes this plant so special, covering its physical traits, the nutrients it contains, its complex chemical makeup, and its powerful healing abilities.

Every part of the Bael tree-including its leaves, the hard-shelled fruit, the bark, and the roots-is like a natural factory producing a rich variety of bioactive compounds. These include distinct chemical groups such as alkaloids, coumarins, flavonoids, tannins, and terpenoids, which work together to provide the plant's strong therapeutic effects. Modern laboratory research has started to confirm what traditional healers have known for a long time: that Bael possesses remarkable medical properties. Studies have proven its ability to lower blood sugar levels (antidiabetic), fight off harmful bacteria and viruses (antimicrobial), reduce swelling and pain (anti-inflammatory), and protect vital organs like the liver from damage (hepatoprotective). It also acts as a powerful antioxidant, helping to clean the body of harmful free radicals, and has even shown promise in fighting cancer cells.

One of the most unique and practically useful aspects of the Bael tree is the dual nature of its fruit. The medical application changes entirely depending on whether the fruit is ripe or unripe. The unripe or half-ripe fruit is famously used as a strong astringent to halt chronic diarrhea and dysentery, whereas the fully ripe fruit acts in the opposite way, serving as a gentle, natural laxative to relieve constipation. Despite its long history of successful use in folk medicine, the Bael tree has not yet been fully integrated into the modern pharmaceutical industry. This is largely due to a lack of standardized production methods and a need for more rigorous testing on humans. This paper carefully examines current scientific knowledge, points out where we still need more answers regarding how these plant chemicals work, and strongly suggests that future research should focus on large-scale clinical trials. Such research is essential to transform this ancient herbal remedy into a reliable, modern treatment for chronic diseases.

Keywords: *Aegle marmelos*, Bael, phytochemistry, ethnomedicine, pharmacological activity, antioxidant, antidiabetic, gastroprotective, antimicrobial, nutraceuticals

Introduction

Botanical Background and Significance

The Bael tree, scientifically designated as *Aegle marmelos* (L.) Correa, is a distinct and ecologically significant member of the Rutaceae family, which also encompasses citrus fruits [1]. While it is most ubiquitously known as "Bael" or "Bilva" within the Indian subcontinent, it has acquired various global monikers such as the Bengal Quince, Golden Apple, or Stone Apple, names that reflect the characteristic hard, woody shell of its fruit [2]. This subtropical deciduous tree is not merely a botanical specimen but is revered as a "panacea" in traditional Indian systems of medicine-a solitary biological resource capable of remediating a vast spectrum of human ailments [3]. The medicinal efficacy of *Aegle marmelos* is deeply historical; it has been documented for thousands of years in ancient Vedic scriptures, including the Rigveda and Yajurveda. These texts describe the plant as a potent restorative agent, effective against conditions ranging from fundamental digestive dysfunctions to complex respiratory and systemic infections [4].

Cultural and Spiritual Heritage

Beyond its botanical and therapeutic identity, *Aegle marmelos* occupies a sanctified position within the cultural and spiritual tapestry of India, particularly within Hinduism [5]. The tree is dedicated to Lord Shiva, and its unique trifoliate leaves (leaves composed of three leaflets) are

interpreted as symbolic of the Trishul (trident), the deity's divine weapon [6]. Consequently, these leaves, known as Tripatra, are indispensable offerings in religious rituals and worship. This profound religious association has yielded significant conservation benefits; due to its sacred status, the tree is frequently cultivated and vigorously protected in temple gardens, sacred groves, and homesteads, ensuring the preservation of its germplasm for centuries. In the holistic framework of Ayurveda, Bael is highly valued for its capacity to equilibrate the body's humors ("Tridosha"), specifically serving as a cooling agent to alleviate "pitta" (metabolic heat) imbalances. Traditional practitioners exhibit a comprehensive utilization strategy, employing the roots, bark, leaves, flowers, and fruits to formulate specific therapeutic interventions for diverse physiological disorders [7].

Geographical Distribution and Ecology

Aegle marmelos is indigenous to the northern regions of India, yet it possesses a wide ecological amplitude that has facilitated its propagation far beyond its native range [8]. Currently, it is widely distributed, both in wild and cultivated forms, across the Indian peninsula and has naturalized in neighboring Southeast Asian nations, including Sri Lanka, Pakistan, Bangladesh, Myanmar, and Thailand. A defining characteristic of the species is its remarkable environmental resilience. It thrives across a spectrum of ecological zones, from arid, dry forests to humid subtropical climates, and is capable of growing at altitudes up to 1,200 meters. The tree exhibits extraordinary tolerance to temperature extremes, surviving shade temperatures as high as $48.9^{\circ}C$ during Indian summers while withstanding winter lows of $6^{\circ}C$. Furthermore, *Aegle marmelos* displays significant edaphic versatility; while it prefers rich, well-drained soil, it is uniquely capable of flourishing in marginal terrains where other fruit crops fail, including alkaline, stony, and swampy soils with pH levels ranging from 5 to 8.

Modern Relevance and Potential

In the contemporary era, there has been a paradigmatic shift in global healthcare preferences towards natural and preventative medicine. As concerns regarding the adverse effects and economic burden of synthetic pharmaceuticals rise, there is an escalating demand for herbal therapeutics. This trend has catalyzed rigorous scientific inquiry into *Aegle marmelos*, with researchers working to validate traditional claims through modern pharmacological assays. Despite its dense nutritional profile-rich in vitamins, minerals, and fiber-and its proven medicinal benefits, Bael remains categorized as an "underutilized fruit" in the global commercial market. However, the processed food sector is beginning to recognize its potential, utilizing the fruit for functional food products like squashes, jams, and powders. The convergence of its traditional utility with modern nutraceutical demand underscores the urgent need to transition *Aegle marmelos* from a folk remedy to a standardized therapeutic agent [9].

Botanical description

Scientific Name and Family

The tree is scientifically classified as *Aegle marmelos* (L.) Correa. It belongs to the Rutaceae family, which is the same botanical family that includes citrus fruits like lemons and oranges. Because of this familial relationship, the plant shares certain characteristics with citrus species, particularly the presence of aromatic essential oils in its leaves and the glandular texture of its fruit rind [10].

Biological Source

From a medicinal perspective, the biological source of *Aegle marmelos* is extensive because nearly every part of the tree possesses therapeutic value. The primary biological source for digestive remedies is the unripe or half-ripe fruit, which is harvested before it fully ripens to maximize its astringent properties [11]. However, the biological source also includes the fresh or dried leaves, the root bark, the stem bark, and the flowers. Each of these parts is collected at specific times of the year to ensure the highest concentration of active ingredients; for instance, the roots are often a key ingredient in the renowned Ayurvedic formulation known as "Dashmula" [12].

Fig 1: Bael Tree

Botanical Features (Morphology)

Aegle marmelos is a slow-growing, medium-sized deciduous tree that typically reaches a height of 12 to 15 meters in its mature state [13]. The tree is characterized by a short, thick trunk covered in soft, flaking bark that is greyish or pale brown in color. A distinguishing feature of the tree is its armature; the branches are armed with straight, sharp, axillary spines that can grow up to 2.5 centimeters long, serving as a natural defense against herbivores [14].

The leaves are alternate and compound, specifically described as "trifoliate," meaning they consist of three distinct leaflets. These leaflets are oval or lance-shaped, pale green, and emit a sweet, aromatic fragrance when crushed due to their volatile oil content. The flowers, which typically bloom between May and June, are greenish-white, bisexual, and sweet-scented, appearing in clusters along the branches. The fruit is botanically classified as a berry (amphisarca); it varies in shape from round to pear-shaped and possesses a hard, woody shell that turns from grey-green to yellow upon ripening [15]. Inside, the fruit contains a soft, yellow, mucilaginous pulp and numerous seeds covered in a woolly mucous sac [16].

Chemical Constituents

The Bael tree is a rich reservoir of diverse bioactive chemicals distributed across its various parts:

- **Leaves:** The leaves are exceptionally rich in alkaloids, including Aegeline, Skimmianine, and Fagarine. They also contain sterols like β-sitosterol and γ-sitosterol, as well as essential oils containing Cineol and Citral, which provide antimicrobial properties [17].
- **Fruit:** The fruit pulp contains high concentrations of Marmelosin (also known as imperatorin), which is considered the primary therapeutic principle responsible for the fruit's laxative and diuretic effects. It is also rich in tannins (up to 9% in unripe fruit), psoralen, marmelide, and phenolic acids, which contribute to its antioxidant and gastroprotective activities [18].

- **Bark and Roots:** These parts are sources of distinct coumarins such as Marmin and Umbelliferone, along with alkaloids like Fagarine [10]. The roots also contain Aurapten and Xanthotoxin, which are utilized in treating inflammation and intermittent fevers.

Geographical Area and Ecology

Aegle marmelos is indigenous to the Indian subcontinent, specifically originating from the northern regions, the Eastern Ghats, and central India [19]. However, its distribution is widespread; it is cultivated and found growing wild across the entire Indian peninsula and has naturalized in neighboring Southeast Asian countries, including Sri Lanka, Bangladesh, Pakistan, Myanmar, and Thailand.

Ecologically, the tree is remarkably resilient. It thrives in dry, subtropical forests and is capable of growing at altitudes up to 1,200 meters. It exhibits extraordinary tolerance to temperature extremes, surviving scorching summers with shade temperatures as high as $48.9^{\circ}C$ and enduring cold winters with temperatures dipping to $6^{\circ}C$ [20]. Furthermore, it is edaphically versatile, meaning it can grow in marginal soil conditions where other fruit trees might fail, including alkaline, stony, and swampy soils with a pH ranging from 5 to 8 [21].

Traditional Uses

Leaf

- **Information:** The leaves of *Aegle marmelos* hold immense spiritual value in Indian culture. They are trifoliate (composed of three leaflets) and are revered as *Tripatra*, symbolizing the three eyes of Lord Shiva or the holy trinity [22]. They are aromatic due to the presence of essential oils and are traditionally offered in temples during prayers.
- **Medicinal Uses**
  - **Diabetes:** Leaf extracts are a staple in ethnomedicine for managing high blood sugar. Chewing fresh leaves or consuming leaf juice is a common practice to control diabetes [23].
  - **Respiratory & ENT:** They are used as an expectorant to treat asthma and bronchitis. Medicated oils prepared from the leaves are used to treat ear infections and deafness.
  - **Infections & Wounds:** A poultice made from fresh leaves is applied to wounds, cuts, and boils to promote healing. They are also used to treat conjunctivitis, jaundice, and leucorrhea.

Fig 2: Bael Leaf

Fruit

- **Information:** The fruit is the most versatile part of the tree, with its therapeutic application changing entirely based on its stage of maturity.
- **Medicinal Uses**
  - **Unripe Fruit:** It is one of the most effective natural remedies for chronic diarrhea and dysentery. The unripe pulp is dried and powdered or used in decoctions as a potent astringent and digestive aid [24].
  - **Ripe Fruit:** Unlike the unripe fruit, the ripe fruit serves as a natural laxative. The aromatic pulp, often consumed as a cooling drink ("sherbet"), is excellent for relieving constipation, treating dyspepsia, and soothing inflammation of the rectum [25]. It is also regarded as a tonic for the heart and brain.

Diagram

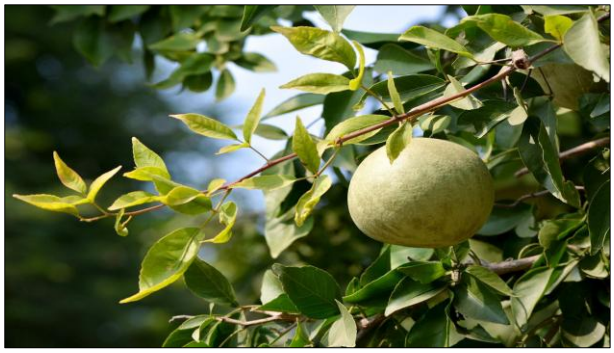

Fig 3: Bael Fruit

Flower

- **Information:** The flowers of the Bael tree are greenish-white and emit a sweet, pleasant fragrance. They typically bloom in the summer months (May-June) [26].
- **Medicinal Uses**
  - **Digestive Tonic:** A distillation or infusion of the flowers is traditionally used as a tonic for the stomach and intestines.
  - **Systemic Ailments:** They are employed in the treatment of epilepsy and are considered an expectorant, helping to clear mucus from the respiratory tract [27].
  - **Other Uses:** The flowers also possess antidiabetic and anti-dysenteric properties, and are sometimes used as a local anesthetic.

Diagram

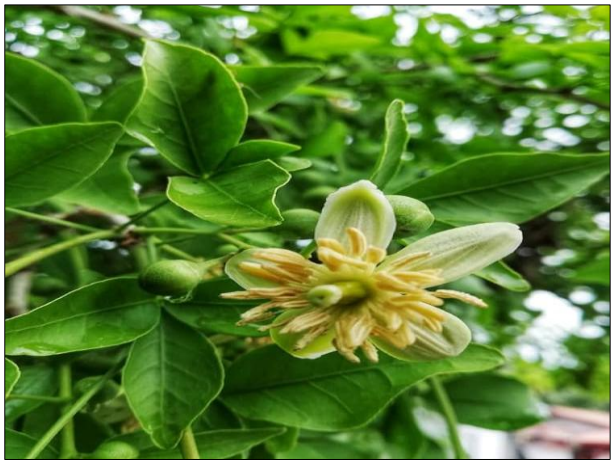

Fig 4: Bael Flower

Root

- **Information:** The root is a critical component of Ayurvedic pharmacology. It is one of the ten ingredients

in the famous "Dashmula" (ten roots) formulation, which is widely used for fatigue and pain.

- **Medicinal Uses**
  - **Fevers & Pain:** The root bark is used to treat intermittent fevers and is effective in managing palpitations and melancholia.
  - **Antidote:** Traditionally, it has been used as an antidote for dog bites and snakebites.
  - **Chronic Conditions:** It is prescribed for gastric troubles, rheumatism, and to check vomiting. [28]

Diagram

Fig 5: Bael Root

Bark

- **Information:** The stem bark of *Aegle marmelos* is thick, soft, and flaking. Like the root, it is harvested for decoctions.
- **Medicinal Uses**
  - **Malaria:** A decoction of the stem bark is traditionally used as a remedy for malaria and other intermittent fevers.
  - **Toxicity:** It acts as a fish poison but is therapeutically used in humans to treat melancholia and heart disorders.
  - **General Health:** It shares many properties with the root, being used for gastric troubles and hypochondriasis [29].

Diagram

Fig 6: Bark of Bael tree

Nutritional Composition

The fruit pulp of *Aegle marmelos* is nutritionally dense, serving as a significant source of energy and essential nutrients despite its high moisture content (approximately 61%). The composition varies slightly depending on the cultivar, geographical origin, and ripening stage, but it generally boasts a robust profile of macronutrients and micronutrients that supports its traditional use as a restorative tonic [30].

Macronutrients

- **Carbohydrates:** The fruit is a powerhouse of energy, with carbohydrate content estimated between 30.5% and 34.35%. These include a mix of reducing and non-reducing sugars such as glucose and fructose, which provide immediate energy, alongside complex polysaccharides.
- **Proteins:** While fruits are typically low in protein, Bael contains a moderate amount, ranging from 1.6% to 3.64% in standard cultivars. However, certain high-yielding varieties have been reported to contain protein levels as high as 8.8%. The protein is considered high quality, containing essential amino acids like valine, threonine, and lysine. [31]
- **Fats:** The fruit is naturally low in fat, with content ranging from a negligible 0.2% to roughly 0.43% [5, 29]. The small quantity of lipid present is composed primarily of unsaturated fatty acids, which are beneficial for maintaining cardiovascular health [3].

Micronutrients (Vitamins and Minerals)

- **Vitamins:** Bael fruit is exceptionally rich in vitamins, surpassing many common fruits like apples and guavas in specific nutrient densities. It is an outstanding source of Riboflavin (Vitamin B2), containing approximately 1190 to 1200 µg per 100g of pulp, which is critical for cellular metabolism. It also provides significant amounts of Vitamin C (Ascorbic Acid), ranging from 8 mg to 60 mg per 100g, which confers strong antioxidant properties. Additionally, it contains Vitamin A (approx. 55 µg/100g) for ocular health, Thiamine (Vitamin B1) (0.13 mg/100g), and Niacin (Vitamin B3) (1.1 mg/100g).
- **Minerals:** The mineral profile of the fruit is equally impressive, characterized by high levels of Potassium (600-610 mg/100g), which is essential for hypertension management and nerve function. It is also a rich source of Calcium (80-85 mg/100g) and Phosphorus (50-52 mg/100g), supporting skeletal health. Trace elements such as Iron (0.3-0.6 mg/100g) and Copper are also present, facilitating oxygen transport and enzymatic reactions. [32]

Dietary Fiber

The fruit is an excellent source of dietary fiber, containing between 2.9% and 4.8% total fiber. This includes pectin, cellulose, and hemicellulose. The high fiber content, combined with the fruit's natural mucilage, is responsible for its ability to regulate bowel movements, acting as a laxative when ripe and a soothing agent for the intestines [33].

Phytochemicals in Bael

Aegle marmelos is a botanical reservoir of diverse bioactive compounds, which are distributed throughout the plant's various tissues. These phytochemicals are the functional drivers behind its extensive medicinal properties [34].

Alkaloids
- **Compounds:** The plant is a prolific source of alkaloids, including Aegeline, Marmeline, Fagarine, and Skimmianine.
- **Distribution:** These nitrogenous compounds are predominantly found in the leaves and bark.
- **Significance:** Aegeline, an alkaloid-amide specifically found in the leaves, has been extensively studied for its metabolic effects and its role in inhibiting histamine release. Skimmianine contributes to the plant's sedative and anticancer potential [35].

Coumarins
- **Compounds:** Bael is particularly renowned for its rich coumarin content. Key compounds include Marmelosin (also known as imperatorin), Marmesin, Umbelliferone, Psoralen, Marmelide, Imperatorin, and Marmin.
- **Distribution:** These are abundant in the fruit pulp, roots, and bark.
- **Significance:** Marmelosin is often cited as the active therapeutic principle responsible for the fruit's laxative and diuretic effects. Umbelliferone and Psoralen are known for their photosensitizing and antioxidant activities.

Flavonoids
- **Compounds:** The plant contains potent antioxidant flavonoids such as Rutin, Quercetin, and Kaempferol.
- **Distribution:** These are found in high concentrations in the leaves and fruit.
- **Significance:** These compounds are crucial for the plant's antioxidant activity, helping to scavenge free radicals and mitigate oxidative stress [36].

Phenolic Acids
- **Compounds:** Significant phenolic acids identified include Gallic acid, Caffeic acid, Ferulic acid, Chlorogenic acid, and Protocatechuic acid.
- **Distribution:** These are primarily located in the fruit pulp.
- **Significance:** Phenolic acids contribute to the plant's anti-inflammatory and chemopreventive properties.

Tannins
- **Compounds:** The fruit is rich in tannins, with concentrations reaching up to 9% in the unripe state.
- **Distribution:** Highly concentrated in the unripe fruit and bark.
- **Significance:** Tannins are responsible for the strong astringent taste of the unripe fruit and are the primary agents behind its efficacy in treating diarrhea and dysentery [37].

Terpenoids
- **Compounds:** Major terpenoids include Lupeol, Cineol, Limonene, and β-sitosterol.
- **Distribution:** Found in the leaves, bark, and roots.
- **Significance:** Lupeol, a triterpenoid, has demonstrated significant antidiabetic and anticancer potential in preclinical studies [38].

Essential Oils
- **Compounds:** The volatile oils contain compounds like D-limonene, Citral, Eugenol, and Citronellal.
- **Distribution:** Present in the leaves, fruit rind, and seeds.
- **Significance:** Limonene is the primary constituent responsible for the characteristic aroma of the fruit and leaves, and it exhibits insecticidal and antimicrobial properties [31].

Medicinal Properties of Bael

The therapeutic versatility of *Aegle marmelos* is extensive, with different parts of the plant exhibiting distinct pharmacological activities that have been validated by modern science.

Digestive Health

The application of Bael in digestive healthcare is unique because its therapeutic effects vary significantly based on the fruit's maturity.
- **Antidiarrheal and Anti-dysenteric:** The unripe or half-ripe fruit is a potent remedy for chronic diarrhea and dysentery. This efficacy is largely attributed to its high tannin content, which acts as an astringent to reduce intestinal motility and fluid secretion. Ethanolic extracts of the unripe fruit have shown significant activity against enteric pathogens such as *Shigella* species and *Escherichia coli*, validating its traditional usage [35].
- **Gastroprotective (Anti-ulcer):** Bael exhibits strong anti-ulcer activity. The fruit pulp contains mucilage that forms a protective layer over the gastric mucosa, preventing damage from stomach acid and irritating drugs like aspirin [39]. Methanolic extracts and specific coumarins, such as Luvangetin, have been shown to reduce ulcer indices and gastric acidity in animal models, offering protection comparable to standard drugs [40].
- **Laxative:** In contrast to the unripe fruit, the ripe fruit acts as a natural laxative due to its high fiber and mucilage content. It helps in cleaning the intestines and removing old accumulated fecal matter, making it effective for treating habitual constipation [18].

Diabetes (Antidiabetic Activity)

Bael is extensively used in traditional medicine for managing diabetes, a use now supported by pharmacological studies.
1. **Mechanism:** Extracts from the leaves and fruit possess significant hypoglycemic (blood sugar-lowering) properties [5]. Bioactive compounds such as Aegeline and various coumarins stimulate insulin secretion from pancreatic beta-cells and improve insulin sensitivity in peripheral tissues [41].
2. **Enzyme Inhibition:** Methanolic extracts of the leaves have been found to inhibit carbohydrate-digesting enzymes like α-amylase and α-glucosidase, thereby reducing postprandial blood glucose spikes.
3. **Regeneration:** Treatment with Bael extract has been observed to aid in the regeneration of damaged pancreatic β-cells and can mitigate secondary complications such as diabetic nephropathy.

Antimicrobial Activity

Aegle marmelos acts as a broad-spectrum antimicrobial agent against a wide range of pathogens.
- **Antibacterial:** Extracts inhibit the growth of both Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*, *Salmonella typhi*, *Pseudomonas aeruginosa*, and *Escherichia coli*. This activity is linked to essential oils and phytochemicals like eugenol and cuminaldehyde.

- **Antifungal:** The plant exhibits antifungal efficacy against strains such as *Candida albicans*, *Aspergillus niger*, and *Fusarium* species by interfering with spore germination
- **Antiviral:** Bael has shown potential antiviral activity against the Ranikhet disease virus and has been investigated for efficacy against human coxsackieviruses B1-B6 [11].

Anti-inflammatory Activity

Chronic inflammation is a key driver of many diseases, and *Aegle marmelos* possesses potent anti-inflammatory properties [42].

- **Mechanism:** Bioactive compounds such as lupeol, citral, and skimmianine inhibit the release of pro-inflammatory mediators like TNF-α, Interleukin-6 (IL-6), and Interleukin-1β (IL-1β).
- **Applications:** This activity has been validated in animal models of carrageenan-induced paw edema and cotton pellet granuloma, where Bael extracts significantly reduced swelling and pain, comparable to standard anti-inflammatory drugs like phenylbutazone.

Respiratory Health

In traditional ethnomedicine, Bael is highly regarded for treating respiratory disorders.

- **Expectorant:** The leaves are used to loosen and expel mucilage (phlegm) from the bronchial tubes, providing relief in conditions like asthma, bronchitis, and the common cold [9].
- **Anti-asthmatic:** The alkaloid Aegeline found in the leaves inhibits the release of histamine from mast cells, a key mechanism in preventing allergic reactions and constriction of the airways [43].
- **Infection Control:** The essential oil from the leaves is also useful in treating respiratory infections.

Immunity Health (Immunomodulatory Effect)

Aegle marmelos acts as a natural immunomodulator, enhancing the body's defense mechanisms.

- **Mechanism:** Extracts from the fruit and leaves boost both cellular and humoral immunity by stimulating the production of white blood cells, such as neutrophils and leukocytes.
- **Therapeutic Value:** This immune-boosting capability aids the body in combating infections and is also linked to the plant's antitumor potential, as a strengthened immune system is better equipped to detect and destroy abnormal cells [44].

Blood Purifier (Detoxification and Systemic Health)

While the specific term "blood purifier" is more traditional, modern science interprets this as the plant's ability to detoxify the system and protect vital organs.

- **Hepatoprotective (Liver Detox):** The liver is the primary organ for blood filtration. Bael extracts protect the liver from toxicity induced by chemicals like carbon tetrachloride (CCl_4) and alcohol. By restoring liver enzyme levels (SGOT, SGPT) and reducing lipid peroxidation, it effectively supports the body's natural detoxification processes [45].
- **Systemic Cleansing:** The fruit's ability to regulate lipid metabolism, lowering "bad" cholesterol (LDL) and triglycerides, further contributes to cleaning the circulatory system and maintaining cardiovascular health [46].

Conclusion

Aegle marmelos (Bael) stands out as a botanical treasure with immense therapeutic and nutritional potential, bridging the gap between ancient traditional systems and modern pharmacology. This comprehensive review has highlighted its complex phytochemical profile, which includes a rich array of alkaloids, coumarins, flavonoids, and terpenoids distributed across its leaves, fruit, bark, and roots. These bioactive constituents drive the plant's diverse pharmacological activities, ranging from potent antidiabetic and antimicrobial effects to significant anticancer and hepatoprotective capabilities.

The plant's deep-rooted traditional usage is now being substantially validated by modern science. The unique dual therapeutic role of the fruit-serving as an astringent for diarrhea when unripe and a laxative when ripe-validates its centuries-old status as a gastrointestinal panacea. Furthermore, its capacity to regulate blood glucose, scavenge free radicals, and modulate immune responses positions it as a valuable candidate for managing chronic lifestyle diseases such as diabetes and cardiovascular disorders.

However, the transition of *Aegle marmelos* from ethnomedicine to mainstream pharmaceutical application is currently hindered by specific challenges. While preclinical data is robust, there is a notable scarcity of large-scale, randomized human clinical trials to definitively establish dosage, safety profiles, and efficacy for chronic conditions. Additionally, the variability in phytochemical composition due to geographical and environmental factors necessitates the development of standardized extraction protocols. Addressing these gaps through rigorous scientific inquiry and standardization will not only preserve this ancient medicinal heritage but also integrate it effectively into modern healthcare systems for the benefit of global health.

References

1. Sarkar T, Salauddin M, Chakraborty R. In-depth pharmacological and nutritional properties of bael (*Aegle marmelos*): A critical review. J Agric Food Res 2020;2:100081. DOI: 10.1016/j.jafr.2020.100081
2. Ghorpade D, Rakde S, Chavan A, *et al*. DESIGNING AND ASSAYS OF POLYHEDRAL DUSTING POWDER WITH ANTIMICROBIAL PROPERTIES FOR MANAGING SKIN ITCHING. World J Pharm Res 2024;13(13):1362. DOI: 10.20959/wjpr202413-33088
3. Kakde RK, Kale NR, Sanap G. Review on Immunological Perspectives and Therapeutic Management Strategies for COVID-19. J Res Appl Sci Biotechnol 2024;3(5):246-257. DOI: 10.55544/jrasb.3.5.25
4. Sharma N, Radha, Kumar M, *et al*. *Aegle marmelos* (L.) Correa: An Underutilized Fruit with High Nutraceutical Values: A Review. Int J Mol Sci 2022;23(18). DOI: 10.3390/ijms231810889
5. Dar MA, Shrivastava S. World Journal of Pharmaceutical research FORMULATION. SJIF J 2021;2(5):1685-1703. DOI: 10.20959/wjpr20241-30762
6. Laddha SS, Sanap GS, Nagari AV, Road M. Emergency Contraceptive Pills - A Review. 2011;2(1):27-33.
7. Garg D, Sharma A, Kumar V. Bael (*Aegle marmelos*) an Astonishing Herb of India: a Review. Int J Pharm Sci Res 2022;13(11):4363.

DOI: 10.13040/IJPSR.0975-8232.13(11).4363-72
8. Sanap GS, Mohanta GP. Design and evaluation of miconazole nitrate loaded nanostructured lipid carriers (NLC) for improving the antifungal therapy. J Appl Pharm Sci 2013;3(1):46-54. DOI: 10.7324/JAPS.2013.30109
9. Lokhande A, Kale N, Sanap G. A Review on Comorbidity of Diabetes Mellitus. Int J Multidiscip Res 2025;7(1):1-14. DOI: 10.36948/ijfmr.2025.v07i01.33304
10. Jain S, Kore DS, Luthra S, *et al*. Health Benefits and Therapeutic Potential of Bael (*Aegle marmelos* L.): A Comprehensive Review. J Adv Biol Biotechnol 2024;27(11):776-784. DOI: 10.9734/jabb/2024/v27i111661
11. Dhapse PD, Sawle N, Kale NR, Sanap G, Shivshankar M. PELLETS IN PHARMACEUTICALS: AN OVERVIEW OF PELLETIZATION TECHNIQUES AND EXCIPIENTS FOR OPTIMIZED DRUG DELIVERY. 2025;10(1):97-114.
12. Patel PK, Sahu J, Sahu L, Narendra K, Dubey PBK. *Aegle marmelos*: A review on its medicinal properties. Int J Pharm Phytopharm Res 2012;1(5):332-341.
13. Dorle MD, Bhivasane A, Sanap GS. Review: Cutaneous Mucormycosis. World J Pharm Res 2023;12(7):57-69. DOI: 10.20959/wjpr20237-27831
14. Swami NB, Sanap GS. Diabetic Retinopathy: a Sight-Threatening Complication of Diabetes Mellitus. World J Pharm Res 2024;13(1):349-376. DOI: 10.20959/wjpr20241-30684
15. Sanap GS, Sawant VA, Shende VS, *et al*. Anti-hyperglycemic and antioxidant activities of the Mehari choornam. Res J Pharm Technol 2010;3(2):402-405.
16. Sahoo L, Nayak Y, Mohanty SK. Exploring the phytochemical constituents of *Aegle marmelos* (bael) and their therapeutic potential against chronic diseases. Int J Basic Clin Pharmacol 2025;14(2):316-323. DOI: 10.18203/2319-2003.ijbcp20250495
17. Pawar S, Manikpuriya S, Sanap G. The Phytochemical and Pharmacological Screening of *Withania coagulans*. World J Biol Pharm Heal Sci 2023;16(3):109-117. DOI: 10.30574/wjbphs.2023.16.3.0501
18. Patil DR, Kale NR, Sanap G, *et al*. AI in Polycystic Ovary Syndrome: Revolutionizing Diagnosis and Management. Int J Multidiscip Eng Curr Res 2025;10(1):37-46.
19. Shaikh I, Farooqui M, Sanap G, Abed S. Study of Antimicrobial and Antifungal Activity of the Bis-Indole Derivatives of 2-Phenyl-1-H-Indole. 2018;3(4):34-37.
20. Sayyad S, Shelke P, Sanap G. Review Of Anti-Inflammatory Herbal Drugs And Their Impact On Health. Int J Pharm Sci 2024;2(1):165-179. DOI: 10.5281/zenodo.10499753
21. Baliga MS, Bhat HP, Joseph N, Fazal F. Phytochemistry and medicinal uses of the bael fruit (*Aegle marmelos* Correa): A concise review. Food Res Int 2011;44(7):1768-1775. DOI: 10.1016/j.foodres.2011.02.008
22. Raut PS, Gadekar NK, Mokale B, Sanap G. Review on *Momordica dioica*. World J Pharm Res 2023;12(5):2295. DOI: 10.20959/wjpr20235-27733
23. Sonawane VM, Hatwar P, Sanap G, *et al*. Protein Fiber in Drug Delivery System. World J Pharm Res 2023;12(22):786. DOI: 10.20959/wjpr202322-30680
24. Sanap GS, Mohanta GP. Development of miconazole nitrate controlled release formulations based on sln and NLC for topical delivery. Int J Pharm Pharm Sci 2014;6(4):393-399.
25. Wakodkar RR, Sanap G, Farooqui M, Kayande DD. A Facile Synthesis of 6-Amino-4-Aryl-3-Methyl-2,4-Dihydropyrano [2,3-C] Pyrazole-5-Carbonitriles in Aqueous Medium. J Ultra Chem 2018;14(02):50-56. DOI: 10.22147/juc/140201
26. Sanap G. A Review: Solid Lipid Nanoparticle A Potential Drug Delivery Carrier. Int J Chem Pharm Anal 2014;1(2):52-62.
27. Bodkhe MA, Mokle MB, Sanap G. Lumpy skin disease: An Overview. Int J Creat Res Thoughts 2023;11(3):174-183.
28. Gadekar NK, Raut PS, Mokale B, Sanap GS. Review: on *Cucumis callosus*. World J Pharm Res 2023;12(5):2109-2120. DOI: 10.20959/wjpr20235-27734
29. Hatwar P, Hudekar GG, Hudekar MS, Sanap GS. A Review on Hydrotropy: a Solubility Enhancing Technique. World J Pharm Res 2022;10(2):2320-2882. DOI: 10.20959/wjpr20235-27706
30. Sanap G, Dama G, Hande A, *et al*. Preparation of Transdermal Monolithic Systems of Indapamide by Solvent Casting Method and the Use of Vegetable Oils as Permeation Enhancer. 2008. DOI: 10.4103/0973-8258.41189
31. Shinde A, Kale A, Wagh S, *et al*. Formulation of essential oil based on solid perfume. World J Pharm Med Res 2024;10(7):191-196.
32. Thorat AN, Kathar NP, Sanap GS, Bodkhe MS. Review: Bilayer Tablet Is a New Approach. World J Pharm Pharm Sci 2023;12(5):1028-1047. DOI: 10.20959/wjpps20235-24788
33. Ghadge RN, Parhad MB, Sanap GS. Review: Niosomal Drug Delivery Systems. World J Pharm Res 2023;12(5):680-691. DOI: 10.20959/wjpr20235-27583
34. Dalvi K, Jadhav S, Sanap G, *et al*. Volatile Components of Essential Oils of Selected Plants: Comprehensive Review. World J Pharm Res 2015;11(4):448. DOI: 10.20959/wjpr20224-23472
35. Kalatre VD, Kale NR, Sanap G. A Review on Transdermal Drug Delivery System (TDDS). Int J Adv Res Sci Commun Technol 2024;226-232. DOI: 10.48175/ijarsct-18137
36. Kumbhakar A, Suleman S, Ahmed RZ, Kale N. Topical Fibronectin Improves Wound Healing in Postmastectomy Breast Cancer Radiation Therapy: A Review. Int J Sci Res Sci Technol 2024;11(2):469-482. DOI: 10.32628/ijsrst52411291
37. More VV, Jadhav V, Sanap GS. Review on Herbal Lipbam. World J Pharm Res 2023;12(5):1951-1964. DOI: 10.20959/wjpr20235-27705
38. Sanap GS, Mohanta GP, Kharche A, Khuspe P, Vidhate B. Novel Carriers in Topical Antifungal Therapy of Miconazole. World J Pharm Res 2016;5(3):553-569.
39. Sanap GS, Mohanta GP. Solid lipid nanoparticles (SLN)-based hydrogel formulation for topical delivery of miconazole nitrate. Int J Pharma Bio Sci 2013;4(2):21-33.
40. Dhamale P, Pardhe AT, Manikpuriya S, *et al*. Formulation and Evaluation of Herbal Cream Containing Extracts of *Hyptis suaveolens* and *Murraya koenigii*. World J Pharm Res 2023;12(9):1726. DOI: 10.20959/wjpr20239-28113

41. Napagoda M, Witharana S. Nanotechnology in Drug Delivery. Nanotechnol Mod Med 2022;12(1):47-73. DOI: 10.1007/978-981-19-8050-3_3
42. Gadekar JK, Kakde AH, Shelke PA, Sanap GS, *et al*. Review on Therapeutic Role of *Azadirachta indica* Neem and Their Active Constituents in Disease Prevention and Treatment. World J Pharm Res 2023;12(5):2122. DOI: 10.20959/wjpr20235-27735
43. Sanap GS. Formulation and evaluation of mucoadhesive beads of glipizide using 2 3 factorial design. 2009;2(5):934-938.
44. Tripathi M, Prasad S. A review on therapeutic potential of *Amaranthus spinosus*. Int J Pharm Res Dev 2024;6(1):67-70. DOI: 10.33545/26646862.2024.v6.i1a.45
45. Murkute MPS, Kathar NP, Sanap GS. Nanotechnology: Its Application, Process Development And Nano-Technology Based Herbal Medicine. 2021;6(5):593-605. DOI: 10.35629/7781-0605593605
46. Phalphale SG, Daniel K. Nephroprotective, Hepatoprotective and Toxicological Studies of *Vigna mungo* Aqueous Extract. Int J Drug Deliv Technol 2025;15(3):1034-1039. DOI: 10.25258/ijddt.15.3.19