

# Bael (*Aegle marmelos*): A Nutrient-Rich Functional Fruit with Potential to Combat Global Hunger and Malnutrition

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## ABSTRACT

*Aegle marmelos* (L.) Corrêa, commonly known as bael or Bel, is a medicinal and fruit-bearing tree native to the Indian subcontinent and Southeast Asia. It occurs naturally or has become naturalized in countries such as India, Pakistan, Bangladesh, Sri Lanka, and Nepal. Historical references to the plant can be traced to the Atharva Veda, highlighting its long-standing significance in traditional Indian culture. Owing to its close association with Lord Shiva, it is believed that the species was revered even during the Harappan civilization. The fruit is known by several common names, including bael fruit, Indian bael, golden apple, elephant apple, Indian quince, and stone apple. *Aegle marmelos* holds an important place in traditional medicine and is considered a sacred plant in India. It was described in the classical Ayurvedic texts of Charaka and Sushruta, where different parts of the plant were recommended for various therapeutic purposes. In particular, the unripe fruit is regarded as more medicinally potent than the ripe fruit and is commercially available in dried, sliced form under the name Belgiri. The World Health Organization (WHO) has documented numerous traditional remedies involving *A. marmelos* in the management of a wide range of ailments. Owing to its medicinal value, the plant was also recognized in the British Pharmacopoeia and later incorporated into Indian pharmacopoeial literature. Today, *A. marmelos* continues to be valued as an important medicinal, nutritional, and culturally significant species with extensive applications in traditional and modern healthcare systems.

**Keywords:** *Aegle marmelos*, bael, Pharmacopoea, Morphology, Medicinal Significance of Bel Patra.

## Introduction

*Aegle marmelos* (L.) Corrêa, commonly known as bael or Bengal quince, is a medicinally and economically important species belonging to the family Rutaceae. It is native to the Indian subcontinent and is widely distributed throughout South and Southeast Asia. The plant has been revered in traditional Indian systems of medicine for centuries and holds significant religious importance owing to its association with Lord Shiva. Various parts of the plant, including the fruits, leaves, roots, bark, and seeds, have been extensively utilized in Ayurveda for the treatment of gastrointestinal disorders, diabetes, inflammation, and infectious diseases [1]. Morphologically, *A. marmelos* is a deciduous shrub or a small- to medium-sized tree that can attain a height of up to 13 m. It possesses a relatively open and irregular crown with slender, drooping branches (Figure 1). The bark is pale brown to greyish in colour and exhibits a characteristic taste that is initially sweet but subsequently produces mild irritation in the throat. The leaves are alternate and trifoliate, with young leaves appearing pale green to pinkish and covered with fine hairs, whereas mature leaves are dark

green, glabrous, and aromatic [2]. The flowers are fragrant, bisexual, and pale green to yellowish in colour. They are arranged in short, drooping, unbranched clusters arising from the leaf axils and terminal twigs. The ovary is bright green and surrounded by an inconspicuous disc. The flowers generally consist of four to five overlapping petals in the bud stage and numerous stamens bearing short filaments and pale brown anthers. The style is short, and the calyx is flattened with four or five small teeth. Flowering usually coincides with the emergence of young leaves [3]. Owing to its distinctive morphology, nutritional value, and broad spectrum of pharmacological properties, *A. marmelos* has attracted considerable attention in phytochemical and pharmaceutical research.

## Fruits

The fruit of *Aegle marmelos* (L.) Corrêa is globose to slightly pyriform in shape and is characterized by a hard, woody pericarp.

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The outer shell is smooth and exhibits a green to grey coloration during maturation, eventually turning yellow upon ripening. The fruit encloses an aromatic orange-yellow pulp with a fibrous texture. The pulp possesses a pleasant fragrance and has been reported to exhibit an aroma resembling roses and a taste comparable to marmalade [4]. Numerous seeds are embedded within a mucilaginous matrix and are covered with fine hairs. Owing to its unique organoleptic characteristics and rich nutritional composition, the bael fruit has gained considerable importance as a functional food and a source of medicinally valuable constituents.

### Phytochemistry

*Aegle marmelos* is a rich reservoir of biologically active secondary metabolites, including coumarins, alkaloids, flavonoids, terpenoids, and volatile oils, which are responsible for its diverse pharmacological activities. Several furocoumarins, such as xanthoxol and the methyl ester of alloimperatorin, have been isolated from different parts of the plant. In addition, flavonoids including rutin and marmesin have been identified and are known to contribute significantly to the antioxidant potential of the plant. The essential oil fraction contains numerous volatile constituents that impart characteristic aroma and therapeutic properties [5]. Among the alkaloidal constituents,  $\alpha$ -fagarine (allocryptopine), *O*-isopentenylhalfordinol, and *O*-methylhalfordinol have been reported. The leaves are particularly rich in aegeline[N-(2-hydroxy-2-(4-methoxyphenyl)ethyl)-3-phenyl-2-propenamide], an amide alkaloid that has attracted considerable attention due to its potential pharmacological applications. Furthermore, aeglemarmelosine has been isolated as an orange-colored viscous oil. Collectively, these phytoconstituents contribute to the broad spectrum of biological activities associated with *A. marmelos*, including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, gastroprotective, and anticancer properties. The diverse chemical composition of the plant substantiates its extensive use in traditional medicine and highlights its potential as a promising source for the development of novel therapeutic agents.



Figure 1: Morphology of the bel tree

### Geographical Distribution and Historical Significance

*Aegle marmelos* (L.) Corrêa, commonly known as bael, Bengal quince, or wood apple, belongs to the family Rutaceae. The name "Bilva" is derived from Sanskrit and refers to the bael tree, while "Patra" denotes its leaves. The species is indigenous to the Indian subcontinent and has a wide geographical distribution extending across South and Southeast Asia. It is commonly found in India, Pakistan, southern Nepal, Sri Lanka, Bangladesh, Myanmar, Vietnam, Laos, Thailand, and Cambodia. The plant has also been introduced and cultivated in several regions of Africa owing to its nutritional and medicinal importance.

Historically, *A. marmelos* has occupied a prominent place in traditional systems of medicine and cultural practices throughout Asia. In Hinduism, the bael tree is regarded as sacred, and its trifoliate leaves are traditionally offered to Lord Shiva during religious ceremonies. Similarly, the tree holds significance in Jainism, where it is associated with Parshvanatha, the twenty-third Tirthankara, who is believed to have attained spiritual enlightenment under this tree [6].

Owing to its religious and cultural importance, the species has been preserved and cultivated around temples and residential areas for centuries. Beyond its cultural significance, *A. marmelos* has been extensively utilized in Ayurvedic, Siddha, and Unani systems of medicine for the treatment of various ailments. Historical records and traditional literature describe the use of different plant parts, including leaves, fruits, roots, bark, and seeds, for managing gastrointestinal disorders, diabetes, inflammation, and infectious diseases. The longstanding ethnomedicinal applications and widespread distribution of *A. marmelos* have contributed to increasing scientific interest in its phytochemical composition and therapeutic potential.

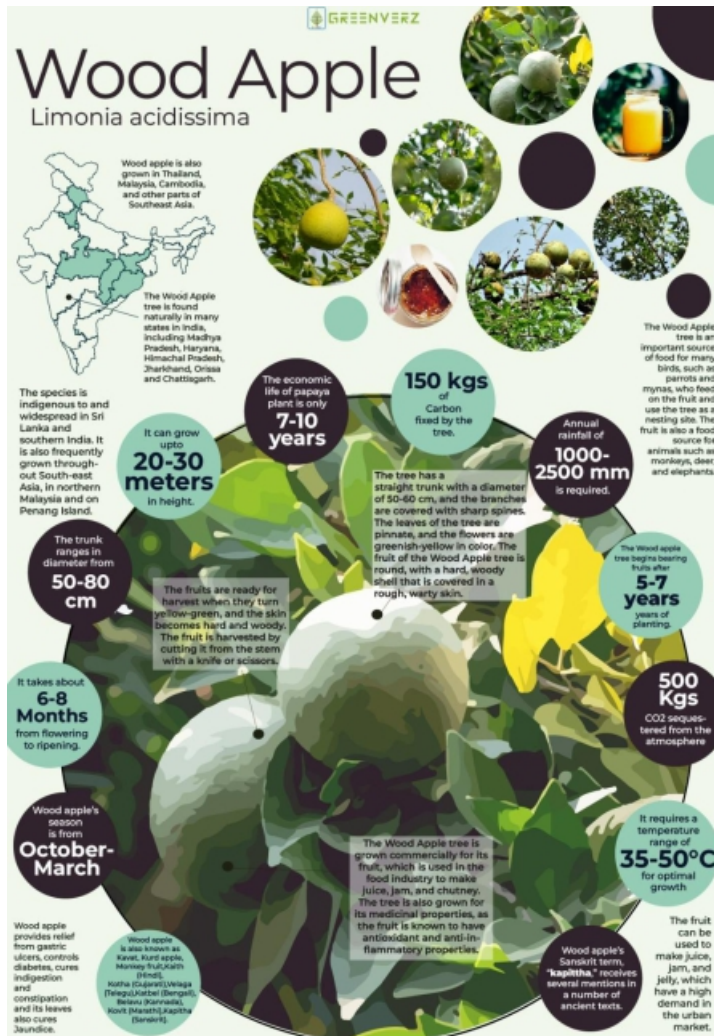


Figure 2: Geographical distribution of bel

### Historical and Cultural Significance

*Aegle marmelos* (L.) Corrêa, commonly known as bael or wood apple, has been valued for centuries owing to its nutritional, medicinal, and cultural significance. The species bears globose fruits enclosed within a hard woody shell, containing aromatic pulp with a characteristic sweet to mildly acidic flavor. Owing to its diverse uses, bael has occupied a prominent place in Indian traditions since ancient times. References to bael are found in ancient Indian scriptures, including the Vedas and Puranas, where the plant is associated with prosperity and divinity. The earliest mention of its sacred status appears in the *Sri Sukta* of the *Rigveda*, in which the tree is revered as the abode of Goddess Lakshmi, the deity of wealth and prosperity.

Bael is indigenous to India and is distributed throughout the country, occurring naturally in dry deciduous forests and plains of northern, central, eastern, and southern regions [7]. Historically, the species was extensively cultivated in the vicinity of Shiva temples, and natural populations have been reported from forested regions, including the Bahraich forests of northern India. Owing to its adaptability and economic importance, bael is now cultivated in several tropical and subtropical regions worldwide.

Since the Vedic period, bael fruits and their processed products have been utilized in traditional diets and indigenous healthcare systems. The fruit is consumed fresh or processed into beverages, preserves, candies, and other value-added products. Various parts of the plant, including the fruits, leaves, roots, and bark, have been employed in Ayurveda and other traditional systems of medicine for the management of gastrointestinal disorders, diabetes, inflammation, and stress-related conditions. Modern pharmacological studies have further demonstrated antioxidant, anti-inflammatory, antidiabetic, antimicrobial, and neuroprotective properties of the plant, thereby supporting many of its traditional uses. The longstanding ethnomedicinal relevance and cultural importance of *A. marmelos* have contributed to its recognition as a valuable medicinal and functional food species.

### Taxonomy of Bel Patra [8]

Botanical name	<i>Aegle marmelos</i>
Common Name	Wood Apple
Plant height	12 inch
Plant spread	6 inch
Flower colour	Yellowish green
Sunlight	More than 6 hours of sunlight
Watering	Pour 4 cups of water only when topsoil (1-2 inches) in the pot feels dry to the touch.
Temperature	20 to 35 degrees Celsius
Vastu direction	North-south direction, and centre
Fertilizer	Apply any fertiliser once a month (Oct-Jan).

### Medicinal Significance of *Aegle marmelos*

*Aegle marmelos* (L.) Corrêa is a versatile medicinal plant that has been extensively utilized in Ayurveda, Siddha, and other traditional systems of medicine owing to its broad therapeutic potential [9]. Different parts of the plant, including the fruits, leaves, roots, bark, and seeds, have been traditionally employed for the treatment and management of numerous ailments. The fruit is rich in essential nutrients and phytoconstituents, which contribute to its medicinal and nutritional value. In Ayurvedic medicine, *A. marmelos* is believed to help maintain the balance of the three doshas—Vata, Pitta, and Kapha—and is therefore regarded as an important Rasayana plant. The fruits are a rich source of carbohydrates, dietary fibre, vitamins A, C, and B-complex vitamins, including thiamine (B1), riboflavin (B2), pyridoxine (B6), and cobalamin (B12), along with minerals such as calcium and potassium. These nutrients play a crucial role in maintaining normal physiological functions and overall health. Traditionally, bael has been used to manage gastrointestinal disorders, particularly diarrhoea, dysentery, constipation, and peptic ulcers. Various formulations prepared from the leaves, fruits, and roots have also been employed in the treatment of respiratory ailments, fever, inflammation, and microbial infections. Ethnomedicinal reports indicate that mixtures containing raw bael fruit along with turmeric and clarified butter (ghee) have been applied externally for the management of fractures and wound healing in certain indigenous communities.

Contemporary pharmacological investigations have demonstrated that *A. marmelos* possesses antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, cardioprotective, gastroprotective, and neuroprotective activities. Several studies have suggested its potential role in mitigating metabolic disorders, including diabetes mellitus, hypertension, hyperlipidemia, and cardiovascular diseases. These therapeutic effects are primarily attributed to the presence of bioactive constituents such as alkaloids, coumarins, flavonoids, tannins, phenolic compounds, and essential oils. The increasing scientific evidence supporting the traditional uses of *A. marmelos* highlights its importance as a promising source of nutraceuticals and phytopharmaceuticals [10]. Consequently, the plant has attracted considerable interest for the development of novel therapeutic agents and functional foods aimed at promoting human health and preventing chronic diseases.

### Habit, Habitat, and Traditional Uses of *Aegle marmelos*

*Aegle marmelos* (L.) Corrêa is a medium-sized, slow-growing, deciduous tree belonging to the family Rutaceae. The species is native to the Indian subcontinent and Southeast Asia and is widely cultivated in India, Sri Lanka, Thailand, Malaysia, and neighboring countries (Maity et al., 2009; Mc et al., 1959). In India, the plant is distributed throughout Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh, Jharkhand, Odisha, the Himalayan foothills, the Indo-Gangetic plains, and the Deccan Plateau. Phytogeographical studies suggest that the species originated in India, particularly in the Eastern Ghats and the central and northern regions of the country. It commonly occurs in dry, open forests, plains, and hilly areas at elevations ranging from sea level to approximately 1,200 m, under mean annual rainfall conditions of 570–2,000 mm. Owing to its drought tolerance and adaptability to diverse climatic conditions, *A. marmelos* has become an important fruit and medicinal tree in tropical and subtropical regions. The ethnomedicinal uses of *A. marmelos* have been extensively documented in India and Pakistan [11]. Different parts of the plant are employed in traditional medicine for the treatment of a wide variety of ailments, particularly those affecting the gastrointestinal system.

#### Ripe Fruit

The pulp of the ripe fruit is sweet, aromatic, cooling, and highly nutritious. Traditionally, it is consumed fresh and is considered a mild laxative. The ripe fruit has been used for the management of habitual constipation, chronic dysentery, dyspepsia, and bowel irregularities. It is also believed to promote digestion and has been employed in the treatment of inflammatory conditions of the gastrointestinal tract, liver disorders, and tuberculosis. The fresh juice possesses a characteristic bitter and pungent taste and is regarded as a digestive tonic.

#### Unripe Fruit

The unripe or half-ripe fruit is considered more therapeutically valuable than the ripe fruit due to its pronounced astringent properties. Decoctions and preparations derived from immature fruits have traditionally been used in the treatment of diarrhoea, dysentery, piles, and atonic conditions of the intestinal mucosa. Owing to its stomachic, digestive, demulcent, and restorative properties, the unripe fruit has been prescribed particularly for chronic diarrhoea and dysentery associated with debility, especially in children.

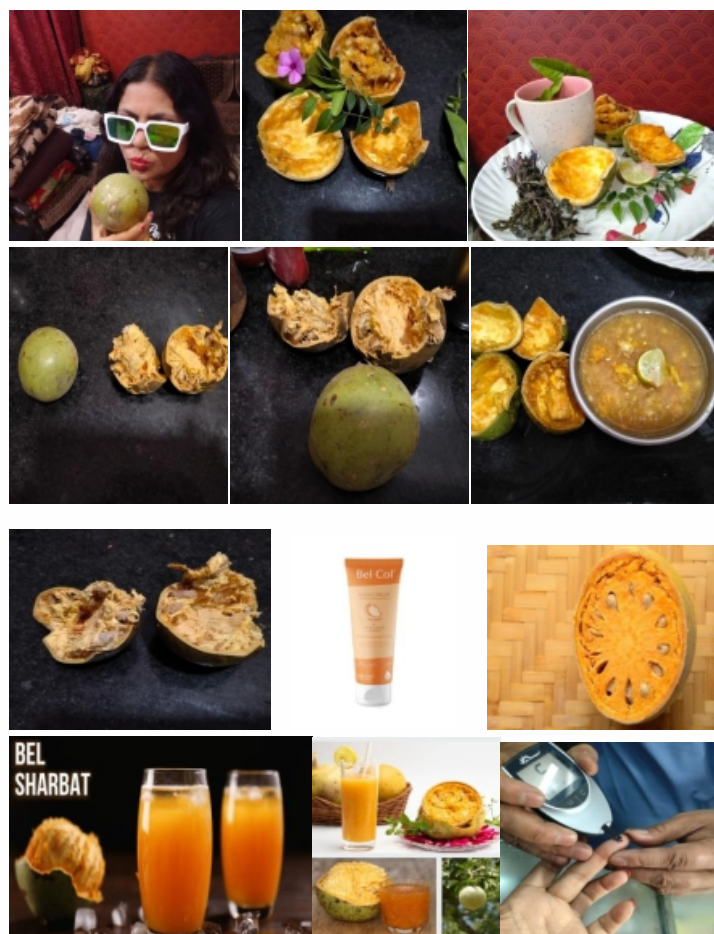
The mild astringent activity of the fruit makes it valuable during convalescence following gastrointestinal infections.

#### Fruit Pulp

The pulp of the fruit has been traditionally employed in the treatment of aphthous ulcers, scurvy, and prolonged febrile conditions such as typhoid and hectic fever. In traditional medicine, fresh fruit pulp mixed with milk and cubeb powder has been administered as a diuretic and as an astringent for mucous membranes of the genitourinary tract. Such preparations have also been used as adjunctive remedies in the management of chronic gonorrhoea and related disorders. The extensive use of ripe and unripe fruits in indigenous medicine highlights the importance of *A. marmelos* as a valuable ethnopharmacological resource [7]. Many of these traditional applications have been supported by contemporary studies demonstrating antioxidant, anti-inflammatory, antimicrobial, antidiarrhoeal, and gastroprotective activities of the plant.



Figure 3: Trunks and leaves of Indian bael (*Aegle marmelos*) in India



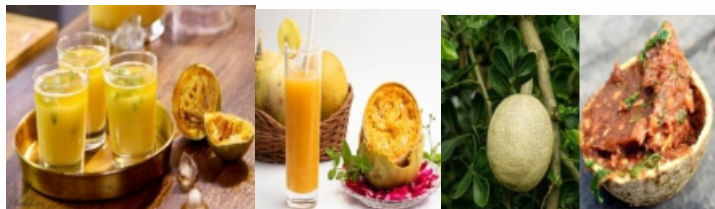


Figure 4: Bael Refresher and its Products

## Traditional Medicinal Uses, Culinary Applications, and Cultural Significance

### Traditional Medicinal Uses

*Aegle marmelos* (L.) Corrêa has been widely utilized in traditional systems of medicine, including Ayurveda, Siddha, and Unani, for centuries. Various plant parts, including the leaves, bark, roots, fruits, and seeds, are employed for the treatment of numerous ailments. Preparations derived from these parts have traditionally been used in the management of gastrointestinal disorders, respiratory diseases, fever, inflammation, diabetes, and microbial infections. The fruit is particularly valued for its antidiarrhoeal and digestive properties, whereas the leaves and roots are commonly incorporated into formulations intended for the treatment of metabolic and inflammatory disorders. The extensive ethnomedicinal use of *A. marmelos* has stimulated considerable scientific interest in elucidating its phytochemical constituents and pharmacological activities.

### Culinary Applications

The fruit of *A. marmelos* is highly nutritious and constitutes an important dietary component in several regions of South and Southeast Asia. Rich in vitamin C, carbohydrates, dietary fibre, and essential minerals, the fruit can be consumed fresh or processed into a variety of value-added products. The pulp is utilized in the preparation of beverages, nectar, jams, candies, toffees, fruit powders, and preserves [6]. A traditional refreshing drink known as *sharbat* or *belapana* is prepared by diluting and sweetening the fruit pulp, and it is particularly popular during the summer season. Owing to its pleasant flavor and nutritional composition, bael fruit is increasingly recognized as a functional food with potential health-promoting properties.

### Cultural Significance

Beyond its medicinal and nutritional importance, *A. marmelos* holds considerable religious and cultural significance in the Indian subcontinent. The trifoliate leaves of the plant are traditionally used in the worship of the Shiva lingam and constitute an integral component of Hindu religious rituals. Consequently, bael trees are commonly cultivated around temples and household gardens, reflecting their long-standing association with cultural and spiritual practices. The species also occupies an important place in ancient Indian literature and traditions, contributing to its conservation and widespread cultivation throughout the region.

### Conclusion

*Aegle marmelos* (L.) Corrêa is an important medicinal and fruit-bearing species that possesses considerable nutritional, therapeutic, cultural, and religious significance. Native to the Indian subcontinent, the plant has been extensively utilized in traditional systems of medicine and is valued for its diverse phytochemical constituents and broad spectrum of pharmacological activities.

In addition to its medicinal applications, bael occupies a unique position in Hindu culture and religious practices, where its leaves and fruits are traditionally associated with the worship of Lord Shiva. The widespread cultivation of bael around temples and home gardens has contributed to its conservation and continued importance in society. Owing to its ethnomedicinal relevance and increasing scientific validation of its therapeutic properties, *A. marmelos* continues to attract considerable attention as a promising source of nutraceuticals and phytopharmaceuticals, warranting further investigation for the development of novel therapeutic agents.

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