A Review: Medicinal Properties and Health Benefits of Bael (*Aegle marmelos*)

Abstract

In ancient India, the *eagle marmelos,* also known as bael, was associated with folklore. In traditional medical systems such as Ayurveda, every component of the tree, including the root, bark, fruit, leaf, and flower, has therapeutic value for treating various maladies. Current studies have found valuable bioactive substances that support Bael's pharmacological functioning. Bael fruits are rich source in vitamins, minerals and many types of nutrients. Bael fruit has been a major topic for studies in recent years mainly due to its high nutritional (carbohydrates, proteins, minerals, and vitamins) value and presence of various phytochemicals, which attributed to its high medicinal value. These phytochemicals include various compounds, e.g., alkaloids, flavonoids, and phenolic acids (protocatechuic acid, gallic, and ellagic acid). Due to its possible application as an anticancer agent in the treatment of many cancer types and other fatal diseases, this plant is now gaining attention. In this article, we describe the botanical properties of Bael, its traditional use, its phytochemicals, and its pharmaceutical applications in brief.

Keywords: *Aegles marmelos,* Health benefits, Morphological uses, Medicinal values

1. INTRODUCTION

The Rutaceae family includes the subtropical fruit Aegle marmelos, sometimes referred to as Bael (Sharma *et al.,* 2007). *Aagle marmelos (L.)* Correa has served as an economically viable culinary and medicinal herb for over 5000 years, making it a highly significant indigenous plant to the Indian subcontinent. The pulp of the bael fruit is used to make desserts like murabba, puddings, and juice. The fruits are useful for dietetic purposes. Although it is indigenous to northern India, it is widely cultivated in Thailand, Bangladesh, Pakistan, Sri Lanka, and Burma, among other places of India (Brijesh *et al.,* 2009). Bael fruit is one of several plants that have had extensive therapeutic applications in Indian medicine since antiquity. In India, A. marmelos is planted as a temple garden plant, and its leaves are used in prayers to Lord Shiva (Sharma *et al.,* 2007). Part of tree, including the root, bark, leaf, flower, and fruit, can be used in several fields. The wild form of fruit is smaller in size than the cultivated variant and is also less popular

for commercial use (Sharma *et al.,* 2007). Bael is known by various names in different languages, including Bilva, Shivaphala in Sanskrit, Belo in Oriya, Bel in Assamese and Marathi, and Vilva marum in Tamil in India, Be Li in Sinhalese, Matoom in Thai, and Bela in Spanish (Lim, 2015).Numerous studies and applications have demonstrated *Aegle marmelos's* natural healing ability (Manandhar et al., 2018). The fruit of *Aegle marmelos* is a natural source of useful nutrients and antioxidants.

1.1 Family

The Rutaceae phylogeny that was most recently reported shows that 135 genera, or 87.7% of the family's identified genera, are Haplophylloideae, Amyridoideae, Aurantioideae, Cneoroideae, Rutoideae, and Zanthoxyloideae. The Rutaceae family produces physiologically potent essential oils, which are well-known and present in many of the family's members and ornamental and culinary plants, including orange, lemon, lime, grapes, and satinwood (Appelhans *et al.*, 2021). Numerous plant compounds, such as coumarins, flavonoids, terpenoids, and alkaloids, have been discovered in several investigations (Ahmad *et al.*, 2021). High concentrations of coumarins, such as marmelosin and luvangetin, which have antihelminthic, antiulcer, antibacterial, and antispasmodic properties, are found in Rutaceae family plants.

1.2 Area and Distribution

It is prevalent throughout South and Southeast Asia, including India, China, Nepal, Myanmar, Pakistan, Bangladesh, Nepal, Vietnam, Laos, Cambodia, Thailand, Indonesia, Malaysia, Tibet, Sri Lanka, Java, the Philippines, and Fiji. (Saroj *et al.,* 2006). This subtropical plant can grow up to 1200 meters above sea level and can withstand temperatures as low as -7°C. Bael trees can be found in India's Indo-Gangetic Plains, Sub-Himalayan tracts, North-Eastern area, and dry and deciduous forests of the central and southern peninsula (Singh *et al.* 2011a). Commercial cultivation of the high-yielding variety Goma Yashi has lately acquired pace in Rajasthan, Uttar Pradesh, Madhya Pradesh, Punjab, Tamil Nadu, and Gujarat states in the form of orchard or border plantation. Trees thrive in soils that are unsuitable for other crops, such as those with stones and limestone, swampy conditions, and extreme pH levels ranging from 5 to 10 (Saroj *et al*. 2006, Singh *et al.* 2016); (Roy *et al.*, 1979).

1.3 Botanical description

The *Aegle marmelos* tree is a medium sized, aromatic, slender medicinal tree that grows slowly, reaching a height of roughly 762 cm and a diameter of 90–120 cm (Jagtap *et al.*, 2004), whereas the bael tree has somewhat prickly stem branches (Bhar *et al.*, 2019).

Table 1.1: Botanical description of *Aegles marmelos*.

Parts of a plant	Botanical description	References	
Bark	The bark of bael tree observed to be thick in nature. And when the bark thrashed slightly, a sticky gum secretion ooze out that tastes sweet initially and then later on turns out to be unpleasant which gets thick and dangle down in long stands when it comes in the contact with air and thus solidifies.	(Bhar *et al.*, 2019); (Kaur and Kalia, 2017); (Aung *et al.*, 2021).	
Leaves	It has alternate leaves with serrated leaflets, trifoliate leaves have 3–5 leaflets each leaflet, each measuring 4–10 cm in length and 2.5–5 cm in width. The color of the blossoms is greenish-white. With time, the leaves turns into dark green colour	(Maity *et al.*, 2009).	

	on maturation		
Flowers	The bale flower is bisexual and hypogynous in nature. May and June are the months when flowers appear. Some lateral panicles, which are supported by leaf axil, hold the greenish-white bael flowers jointly. The hue of the flowers is grewish white in colour. It has an actinomorphic, bisexual, ebracteate, hypogynous stalk with a strong fragrance. In lateral panicles, 10 flowers are seen in leaf axil	(Axay *et al.*, 2012).	 (Chandrasekara *et al.*, 2018)
Fruit	The fruit of A. marmelos is mostly yellowish green in color, with a hard, woody exocarp. Its diameter ranges from approx. 5 to 7 cm, and its approximate weight is 77.2 g, volume is 73 mL, and are spherical	(Sonawane *et al.*, 2020)	

	or oval in shape. (sphericity is 93.72 ± 2.78%.)		
Pulp	The pulp is fragrant, golden, silky, sweet, and resinous. The pulp of the fruit, which has a pale orange color, is pasty, sweet, resinous, and very aromatic. There are a few to fifteen seeds embedded in the pulp. May and June are the months when fruiting happens	(Bhar *et al.*, 2019); (Patel *et al.*, 2012)	
Seed	The seeds are flat, oblong-shaped, and around one centimeter long. Their structures are similar to those of woolly hair. Each seed is surrounded by a sac of sticky, transparent mucus that solidifies when it dries.	(Roy *et al.*, 2011b); (Sharma, 2007); (Palatty *et al.*, 2013)	

2. NUTRITIVE VALUE OF BAEL (*Aegle marmelos Linn.*)

Numerous bioactive compounds have been isolated from the Indian medicinal plant known as bael, which has been used traditionally to treat a variety of illnesses (Badam *et al.*, 2002; Gupta and Tandon, 2004). Bael, which is incredibly rich in vitamins like A, B group, and C, has been

shown to function as an antioxidant, reducing rancidity and color loss (Bhardwaj, 2015). Alkaloids (aegeline, fragrine, aegelenine), coumarins (Marmin, Marmelide, Psoralen, Imperatonin), terpenoids (cineol, Caryophyllene), etc. are found to be present in A. marmelos (Ali and Pervez, 2004; Gautam and Ramanathan, 2021). According to (Sampathkumar *et al.*, 2012), unripe fruit has greater medical benefits than ripe fruit. Fruit juice contains the following: phosphorus (52 mg), potassium (610 mg), calcium (80 mg), fiber (2.9%), protein (1.6%), moisture (61.0%), and carotene (55 mg) (Anurag *et al.*, 2014; Horwitz, 2005). Fruit pulp and leaves have extremely low fat contents, with 0.28% and 0.07%, respectively (Dar *et al.*, 2015). 34.4% oil, 8.8% stearic acid, 8.1% linolenic acid, 16.6% palmitic acid, and 30.5% oleic acid are found in Aegles marmelos seeds (Kumar *et al.*, 2012). The seed oil is utilized in compressors, cosmetics, and aromatherapy (Bajaniya *et al.*, 2015). Oil from A. marmelo can be used as an anti-inflammatory, antiseptic, antioxidant, antibacterial, astringent, disinfectant, carminative, and cytophylactic in medicine.

Table 1.2: Nutritive values of *Aegles marmelos.(fruits)*

Components	**Value (%)**	**Components**	**Value (%)**
Mineral	1.5	Vitamin B1	0.01
Fiber	2.2	Nicotinic acid	0.9
Fat	0.2	Vitamin A (IU)	186
Protein	1.8	Iron 0.3	0.3
Phosphorus	0.05	Calorific value	129
Carbohydrate	30.6	Riboflavin	1.2
Calcium	0.09	Vitamin C	0.01
Water (moisture)	64.2	Potassium 0.6	0.6

(Source: Shankar, 1967 & Neeraj *et al.*, 2017)

3. CONVENTIONAL APPLICATIONS OF BAEL

Bael has been used extensively in traditional medicine and Ayurveda. It has been discovered that every part of the bael tree has the ability to treat a variety of illnesses (Patel *et al.*, 2012). The following discusses a few uses as well as the chemical components found in the various portions of *Aegles marmelos Linn.*

Tabel 1.3: Chemical components along with their uses in Bael (*Aegles marmelos)*

Parts	**Chemical constituents**	**Uses**	**References**
Leaves	Rutin, Flavone, Cineol Glycoside, O-Halfordiol, Marmeline, Lupeol, Citronellal, Tannins, Marmesinin, Aeglin, Phenylethyl Cinnamamides, Citral, Skimmianine, Eugenol, and Isopentenyl alpha and beta sitosterol and Cuminaldehyde.	• Fever, nausea, vomiting, swellings, diarrhea, dyspepsia, seminal weakness, and intermittent fever are the conditions for which the leaves are most beneficial. • It is also used to treat cholera, bronchitis, beriberi, sore throat, stomach issues, wound healing, Jaundice, Asthama and stomach ulcers.	(Bhar *et al.,* 2019); (Atul *et al.,* 2012); (Sampath *et al.,* 2012); (Fawzi *et al.,* 2018)
Bark	Marmin, Coumarins and Fagarine	• Traditionally, the inhabitants cure fever and cough with a bark decoction. • It is one of the components that makes up chyavanprash. • While bark decoction, leaf extract with honey, and bael extract are used to cure fever, febrifuge, and intermittent fever, root bark may also be utilized	(Prakash,2006); (Lock and Guar, 2001); (Sharma *et al*., 2010); (Yadav *et al.,* 2015); (Kakiuchi *et al.,* 1991)

		as a fish poison and fever therapy.	
Fruit	Tannin, gallic acids, Psoralen, Aurapten, Marmelide, Luvangetin, and Marmelosin ~-tocopherol, γ-tocopherol, δ-tocopherol, Cobalamins, β-tocopherol, Vanillic acid, Malic acid, Propionic acid, Succinic acid, 2,3-dihydroxy benzoic acid, Chlorogenic Acid, pcoumaric acid, lactic acid,	• It is used as an astringent, for stomach problems, diarrhea, gonorrhea, epilepsy, ulcers, anti-diabetic, anti-cancer, antioxidant, and antimicrobial purposes. • The fruit consumption lowers the blood sugar and boosts the secretion of insulin • Pulp of a fruit is very helpful in urino-genital disorders when mixed with milk and sugar	(KimHJ et al., 2021); (Anurag *et al.*,2014)); (Sampath *et al.*, 2012); (Hazra *et al.*, 2020)
Flower	xanthotoxol, imperatorin, alloimperatorin, β-sitosterol	• Flowers can be distilled to create a local anesthetic, antidiabetic, diaphoretic, and anti-dysenteric drug. • It is used as an intestinal and stomach tonic. • It helps with epilepsy and can be taken as an expectorant as well.	(Gautam *et al.*, 2014); (Mani *et al.*, 2017)

Root	Marmesin, Marmelosin, Caryophyllene, α-zingiberene, β-funebrene, Betulinic acid, and Cis-piperitol O-(3,3-dimethylallyl) halofordinol, O-methylhalfordinine, and Aegeline	• Bael roots are said to be useful in managing fevers, preventing heart palpitations, and addressing urinary issues. • They are supposed to help with stomach pain as well. • The root of dashamula has therapeutic qualities that include treating fever, diarrhea, and flatulence.	(Monika *et al.*, 2023; (Shailja *et al.*, 2021) Owk & Lagudu, 2020)
Seed	Scopoletin, Dictamine, Umbelliferone, Cineol, Sitosterol, α-amyrin, Citral, D-limonene, Marmelosin, Aegeline, Limonene, Citronellal, Psoralen, Skimmianine, Marmel ide, Marmenol, A-D-phellandrene, 7-geranyloxy coumarin Cumin aldehyde, P-Cyrene.	• Seed oil contains antibacterial qualities and stops the growth of several pathogens, including Escherichia coli, Staphylococcus aureus, and Vibrio cholera	(Kandoliya *et al.*, 2015); (G. N. Sharma *et al.*, 2011); (Banerji *et al.*, 1949)

4. MEDICINAL PROPERTIES OF BAEL (*Aegles marmelos*)

Several studies have found that *Aegles marmelos*have many health benefits and medicinal values. The fruit can treat numerous health problems related to digestion, respiration, depression, skin related disorders and many other problems. Some of the medicinal effects has been discussed in this review.

4.1 Diabetes

- The hypoglycemic effect of bael leaf aqueous extract has been reported by (Upadhya *et al.*, 2004). This is corroborated by analysis based on plasma urea, glutathione-S-transferase, and glucose, as well as levels of malondialdehyde (MDA) and glutathione (GSH), checked for erythrocytes in diabetic rats induced with alloxan (Upadhya *et al.*, 2004).
- Bael's dietary fiber and amino acid content help with sugar absorption to a moderate extent (Bhardwaj, 2014). At a dosage of 250 mg/kg, it has been proven to be superior to the antidiabetic medication glibenclamide (Kamalakkannan, 2003).

4.2 Anti-cancer activity

- Leukemic K562, T-lymphoid Jurhat, Beta-lymphoid Raji, and Erythro leukemic HEL20 were among the human cancer cell lines whose in vitro proliferation was suppressed by bael. Although A. marmelos extract is antiproliferative, it only affects MCF-7 and MDA-MB-231 breast cancer cell lines at high concentrations (56–58) (Yogita *et al.*, 2023).
- Fruit extract from *A. marmelos* significantly decreased the tumor yield as well as the tumor burden (Group IV-3.7, 2.6; Group V-4.6, 2.3), indicating the fruit extract's potential as a chemopreventive strategy against DMBA-induced skin tumorigenesis in mice (Agrawal *et al.*, 2010).
- The Bael fruit extract contains the phytochemicals marmesin and marmelosin, which interact with HSULF-2 at its active site, possibly blocking it and producing anticancer action (Hemakumar *et al.*, 2023).

4.3 Anti-ulcer activity

The *H. pylori* bacteria is the cause of peptic ulcers. Further research is necessary to ascertain A. *marmelos's* impact on *Helicobacter pylori* because there is little to no literature on the subject. If it effectively lowers AMR, it will be a fantastic natural medication that treats abscesses without causing any side effects. (Kumar, 2020).

4.4 Anti-inflammatory activity

Tiwari *et al.* 202, found that the increased extract of *A. marmelos* fruit exhibited strong anti-inflammatory and anti-diabetic properties due to the presence of marmelosin and marmesin. *A. marmelos* fruit demonstrated anti-inflammatory, antioxidant, and mast cell stabilizing capabilities with significantly higher SOD and lower MDA levels as well as defense against mast cell degranulation (Behera *et al.,* 2011).

4.5 Anti-depressant activity

Depression is one among the mood-related disorders. Synthetic medications have been discovered to be successful in treating depression, but they also have certain negative side effects. Natural antidepressants, on the other hand, have fewer adverse effects (Newhouse, 1986; Zang, 2004). Using the tail suspension test and the elevated plus maze test, researchers have documented the antidepressant action of bael in mice treated with anxiolytic medications. After taking into account a number of characteristics, it was determined that bael had increased the antidepressant activity of fluoxetine and imipramine (Kothari *et al.,* 2010).The antidepressant efficacy of bael is derived from its agonistic action on the serotonin receptor (Kumar *et al.,* 2015).

4.6 Anthelmintic activity

For bael's anthelmintic action, the Indian earthworm model is employed. Earthworms are given distilled water to rinse them, and then they are given aqueous dry bael fruit extract at various concentrations of 1, 2, 10, and 20 mg/mL. Comparing the 1 mg/mL concentration group to the vehicle control group, a difference in paralysis and death time is seen. (Waghmare *et al.,* 2011).

4.7 Cytoprotective effect

- The integrity of the plasma membrane and the control of the antioxidant enzyme system are indicative of Bael's cytoprotective effects. (Nugroho *et al.,* 2010). Bael may

effectively shield red blood cells from oxidants, suggesting that it possesses cytoprotective qualities. Bael's cytoprotective impact is demonstrated by the stabilization of the plasma membrane and the modification of the antioxidant enzyme system (Vinodhini and Narayanan, 2002).

4.8 Anti-stress activity

Research indicates that immobilization stress can cause oxidative harm to the liver, kidney, and plasma. The amount of glucose has grown and non-enzymatic antioxidants are being depleted as plasma corticosterone levels rise. Bael extract can raise glucose levels, decrease non-enzymatic antioxidants, and raise plasma cortisol. Fruit contains vitamins C and E, which can help to alleviate stress (Saravanan *et al.,* 2014).

4.9 Anti- Thyroid activity

- Aloe vera, Bacopa monnieri (200 mg/kg), and Aegle marmelos (1.00 g/kg) have all been researched for hyper thyroidism. Scopoletin (7-hydroxy-6-methoxy coumarin) is a compound found in bael leaves. Leaf extracts containing 125 mg/kg of scopoletin have been shown to exhibit effective anti-thyroid activity (Kar *et al.,* 2002).
- Animals treated with thyroxine are given 1 mg/kg for 7 days, which lowers the level of thyroid hormones in the serum. The antithyroid medication propylthiouracil functions similarly to bael extract (Behera *et al.,* 2012).

4.10 Insecticidalactivity

- Bael extract and Andrographis paniculata have demonstrated a noteworthy effect as a possible repellant, ovicidal, and oviposition deterrent against Culex htritaenio rhynchus (Elango *et al.,* 2010).
- Acetone extract of bael at a dosage of 250 ppm has demonstrated 100% efficacy (Patil *et al.,* 2010). Methanolic bael leaf extract has the ability to moderately inhibit Aedes aegypti and Anopheles stephensi mosquito larvae (Elango *et al.,* 2010).

4.11 Anti-oxidant activity

- It was found that marmelosin had superior antioxidant qualities to regular gallic acid (Pynam *et al.,* 2018).
- Bael has been found to have antioxidant properties because of phytochemicals such flavonoids and phenolic acids (Kumar *et al.,* 2015). Different substituents are present in the aromatic ring of phenolic acid, and as a result, different phenolic acids have varying antioxidant activity (Rice-Evans *et al.,* 1996).
- The radical scavenging activity of the hydroalcoholic extract of bael is demonstrated against 2,2'-azino-bis(3 ethylbenzothiazoline-6-sulphonic acid) and DPPH radicals. Bael extract can stop the oxidation caused by the 2, 2'-azobis (2-amidinopropane) dihydrochloride radical that occurs in biomolecules such as plasmid DNA, bovine serum albumin, and lipids (Nallamuthu *et al.,* 2014).

4.12 Anti-ocularhypertensionactivity

Bael leaf chloroform extract, at doses of 150 and 300 mg/kg body weight, has been used to treat cataracts by lowering osmotic stress, suppressing lens aldose reductase (AR), and raising glutathione, catalase, and superoxide dismutase (Panaskar *et al.,* 2013; Sankeshi *et al.,* 2013).

4.13 Anti-asthmatic activity

The primary cause of phelgm and asthma is histamine release. Phlegm in cold and asthma cases can be effectively reduced by using bael leaf decoction. Research using the ileum of guinea pigs reveals that histamine has an opposing influence on contraction (Arul *et al.,* 2004; Laphookhieo *et al.,* 2011). Bael leaves contain aegeline, which inhibits mast cell histamine release (Sankari *et al.,* 2010). Because leaves of *A. marmelos* successfully lower histamine production, they are beneficial for asthma management.

4.14 Wound healing activity

The wound healing process involves three distinct stages: inflammation, cell proliferation, and collagen lattice formation contraction. Basic wound symptoms including reddening, pain, and edema also occur during inflammation. It has been discovered that reactive oxygen species emission serves as a defense mechanism (Ilango and chitra, 2010).

Methanolic A. marmelos seed extract ointment was shown to have the ability to completely heal wounds in an experiment conducted on Wistar albino rats (Pattanayak and Sunita, 2008). A. marmelos functions similarly to the medication nitrofurazone in terms of wound healing (Veerappan *et al.,* 2007). As they can boost antioxidant activity, the phytochemicals included in A. marmelos are particularly beneficial for wound healing (Badam, 2002).

4.15 Cardioprotective effect

- It has been discovered that bael fruit protects against cardiovascular illnesses. Lipid peroxidation can be reduced by the bioactive compound marmesinin, also known as linear furanocoumarin, which is found in bael. Serum LDH and CK levels are elevated in isoprenaline-induced myocardial rats, but they are lowered when bael leaf extract (200 mg/kg) is administered. In addition, it is discovered that a few other biochemical parameters rise (Prince, 2005).
- Using various dilutions of bael extract, the cardiotonic activity of bael has been tested on a frog heart assembly that has been extracted. Digoxin is outperformed by bael extract (Dama *et al.,* 2010).

4.16 Anti-microbial activity

- According to reports, *A. marmelos* possesses antibacterial, anticancer, antiviral, anti-inflammatory, and antifungal properties that enable it to provide protection against a broad range of pathogenic organisms (Sharma *et al.,* 2007). The inhibition rate of A. marmelos extract varies according on concentration; for example, a 0.05% extract dose can prevent 100% of fungus, whereas a 0.04% dose may prevent 90% of them and a 0.03% dose can prevent 75% of them (Rana *et al.*, 1997).
- The quinine component was found in the ethyl acetate extract of *A. marmelos* leaf, and it had good antibacterial action against both gram-positive and gram-negative bacteria (Rejiniemon *et al.,* 2014).

4.17 DiarrohoeaandDysentery

- Bael fruit, particularly unripe or half-ripe fruit, can be used to treat chronic diarrhea. The ideal powder for this purpose is dried bael fruit. Unripe fruits can be roasted, then combined with jaggery to be consumed (Veer and Singh, 2019).

- The pulp of unripe fruit may be active against enterotoxins. Moreover, it can stop the production of colonies from the intestinal epithelium (Choudhary *et al.,* 2017).
- The astringent qualities of the tannin in bael make it a miraculous cure for diarrhea (Pathirana *et al.,* 2020; Seemaisamy *et al.,* 2019).
- Current investigations have concentrated on enhancing the effectiveness of *A. marmelos*-derived medications for dysentery and diarrhea. It has been noted that bael root extract containing chloroform has the same antibacterial properties as ciprofloxacin, but without any negative side effects (Rahman, 2014).

5. CONCLUSION AND FUTURE ASPECTS

These studies have demonstrated the therapeutic potential of A. marmelos and the presence of components that may be utilized to create novel drugs for the treatment, mitigation, or prevention of diabetes, cancer, and other pathogenic diseases. Bael's non-toxic behavior has been confirmed by clinical research, ensuring that the pharmacological application is completely safe and devoid of any negative consequences. Many allopathic medicines' actions can be carried out by various A. marmelos components and extracts. As it has no side effects, this lowers the cost of medications while reducing the probability of developing new diseases. This is a significant benefit over allopathic medications and is also practically feasible economically.

Since A. marmelos contains powerful phytochemicals that are responsible for a variety of therapeutic effects, further study and research are needed to understand the molecular functions of these constituents in order to develop more effective medical treatments. Even though bael has been used extensively in traditional medicine from ancient times, it is now necessary to learn more about the bioactive components in the fruit and encourage its use globally in order to fully utilize its remarkable health advantages.

6. REFERENCES

1. A. Kar, S. Panda, S. Bharti, (2002) . Relative efficacy of three medicinal plant extracts in the alteration of thyroid hormone concentrations in male mice, J. Ethnopharmacol. 81. 281–285, https://doi.org/10.1016/S0378-8741(02)00048-X.

2. A. Mani, A. Singh, N. Jain, S. Misra, (2017). Flowering, fruiting and physio-chemical characteristics of bael (aegle marmelos correa.) grown in northern districts of West Bengal, Curr. J. Appl. Sci. Technol. 23 1–8, https://doi.org/10.9734/ cjast/2017/36310.
3. A. Waghmare, M. Kanyalkar, M. Joshi, S. Srivastava, (2011). In-vitro metabolic inhibition and antifertility effect facilitated by membrane alteration: search for novel antifertility agent using nifedipine analogues, Eur. J. Med. Chem. 46 3581–3589, https://doi.org/10.1016/j.ejmech.2011.05.022.
4. A.R. Patel, D. Garach, M. Chakraborty, J. Kamath, (2012) . Aegle marmelos (Linn.): a therapeutic boon for human health, Int. J. Res. Ayurveda Pharm. 159–163
5. Agrawal, A., Verma, P., & Goyal, P. K. (2010). Chemomodulatory effects of Aegle marmelos against DMBA-induced skin tumorigenesis in Swiss albino mice. Asian Pacific Journal of Cancer Prevention : APJCP, 11(5), 1311–1314.
6. Ahmad W, Amir M, Ahmad A. (2021). Aegle marmelos leaf extract phytochemical analysis, cytotoxicity, in vitro antioxidant and antidiabetic activities. Plants 10(12), 2573.
7. Ali MS, Pervez MK. (2004). Marmenol: a 7-geranyloxycoumarin from the leaves of Aegle marmelos corr. Nat. Prod. Res. 18(2), 141–146 .
8. Anoma Chandrasekara, Jurata Daugelaite, Fereidoon Shahidi. (2018). DNA scission and LDL cholesterol oxidation inhibition and antioxidant activities of Bael (Aegle marmelos) flower extracts, Journal of Traditional and Complementary Medicine,Volume 8, Issue 3,Pages 428-435,ISSN 2225-4110, https://doi.org/10.1016/j.jtcme.2017.08.010.
9. Appelhans MS, Bayly MJ, Heslewood MM, (2021). A new subfamily classification of the Citrus family (Rutaceae) based on six nuclear and plastid markers. Taxon 70(5), 1035–1061.
10. Aung HT, Zar T, Sein MM, Komori Y, Vidari G, Takaya Y. (2021)..Constituents of Aegle marmelos from Myanmar. J. Asian Nat. Prod. Res. 23(9), 844–850 .
11. Axay, P., Dipak, G., Manodeep, C., & Jagdish, K. (2012). Aegle Marmelos (Linn.): A Therapeutic Boon for Human Health. IJRAP, 3(2). www.ijrap.net
12. Badam L, Bedekar S, Sonavane KB, Joshi SP. (2002).In vitro antiviral activity of bael (Aegle marmelos Corr) upon human coxsackieviruses B1-B6. Journal of Communication Disorders.;34:88-89.

13. Bajaniya VK, Kandoliya UK, Bodar NH, Bhadja NV, Golakiya BA. (2015) Fatty acid profile and phytochemical characterization of bael seed (Aegle marmelos L.) oil. International Journal of Current Microbiology and Applied Sciences.;4(2):97-102
14. Behera J, Mohanty B, Ramani Yr, Rath B, Pradhan S. (2012). Effect of aqueous extract of Aegle marmelos unripe fruit on inflammatory bowel disease. Indian J. Pharmacol. 44(5), 614.
15. Bhar K, Mondal S, Suresh P. (2019). An eye-catching review of Aegle marmelos L. (golden apple). Pharmacognosy Journal.;11:207-224
16. C. Prakash Kala. (2006). Ethnobotany and Ethnoconservation of Aegle Marmelos, L.) Correa.
17. Choudhary Y, Saxena A, Kumar Y, Kumar S, Pratap V. (2017)..Phytochemistry, pharmacological and traditional uses of Aegle marmelos. Pharm. Biosci. Journal. 20, 27–33 Compl. Alternative Med. 9 (2009) 47, https://doi.org/10.1186/1472-6882-9-47.
18. G. Elango, A.A. Rahuman, A.A. Zahir, C. Kamaraj, A. Bagavan, G. Rajakumar, C. Jayaseelan, T. Santhoshkumar, S. Marimuthu (2010) . Evaluation of repellent properties of botanical extracts against Culex tritaeniorhynchus Giles (Diptera: Culicidae), Parasitol. Res. 107 .577–584, https://doi.org/10.1007/s00436-010-1897 8.
19. G.Y. Dama, H.L. Tare, M.S. Gore, V.S. Shende, S.R. Deore, J.S. Bidkar, P.V. Gorde, (2010) .Comparative cardiotonic activity of Aegle marmelos juice with digoxin on isolated frog heart, Int. J. Drug Dev. Res. 2.806–809.
20. Gautam M, Ramanathan M.(2021). Ameliorative potential of flavonoids of Aegle marmelos in vincristine-induced neuropathic pain and associated excitotoxicity. Nutr. Neurosci. 24(4), 296–306 .
21. Gupta AK, Tandon N. (2004). Reviews on Indian medicinal plants. Indian Council of Medical Research, New Delhi, India 1, 312.
22. Hazra, S. K., Sarkar, T., Salauddin, M., Sheikh, H. I., Pati, S., & Chakraborty, R. (2020). Characterization of phytochemicals, minerals and in vitro medicinal activities of Bael (Aegle marmelos L.) pulp and differently dried edible leathers. Heliyon, 6(10), e05382.
23. Hemakumar, C., Ravindranath, B. S., Ravishankar, G. A., Ramirez, D. C., & Kiran, S. V. (2023). Marmesin and Marmelosin Interact with the Heparan Sulfatase-2 Active Site: Potential Mechanism for Phytochemicals from Bael Fruit Extract as Antitumor Therapeutics.

Oxidative Medicine and Cellular Longevity, 2023, 1–19. https://doi.org/10.1155/2023/9982194.

24. I. Nallamuthu, A. Tamatam, F. Khanum, (2014) . Effect of hydroalcoholic extract of Aegle marmelos fruit on radical scavenging activity and exercise-endurance capacity in mice, Pharm. Biol. 52 .551–559, https://doi.org/10.3109/ 13880209.2013.850518.
25. J. Behera, B. Mohanty, Y. Ramani, B. Rath, S. Pradhan, (2012) . Effect of aqueous extract of Aegle marmelos unripe fruit on inflammatory bowel disease, Indian J. Pharmacol. 44 .614–618, https://doi.org/10.4103/0253-7613.100389.
26. J. Sharma, R.M. Painuli, R.D. Gaur, (2010) . Plants used by the rural communities of district Shahjahanpur, Uttar Pradesh, Indian J. Tradit. Knowl. 9 .798–803.
27. J.M. Lock, R.D. Gaur, (2001).Flora of the district garhwal north-west himalaya (with ethnobotanical notes), Kew Bull. 56 .251, https://doi.org/10.2307/ 4119449.
28. Jagtap AG, Shirke SS, Phadke AS. (2004). Effect of a polyherbal formulation on experimental models of inflammatory bowel diseases. Journal of Ethnopharmacology;90:195-204
29. K. Ilango, V. Chitra, (2010). Wound healing and anti-oxidant activities of the fruit pulp of Limonia acidissima linn (Rutaceae) in rats, Trop. J. Pharmaceut. Res. 9.223–230, https://doi.org/10.4314/tjpr.v9i3.56281.
30. K.E. Newhouse, Goodman and Gilman's. (1986) . The Pharmacological Basis of Therapeutics, Yale J. of Biol. Med. 59 (1) 71–72.
31. K.P. Sampath, M. Umadevi, D. Bhowmik, D.M. Singh, A.S. Dutta, (2012). Recent trends in medicinal uses and health benefits of Indian traditional herbs Aegle marmelos, Pharma Innov. 1.57–65.
32. Kandoliya, U. K., Bhadja, N. V, Bajaniya, V. K., Bodar, N. H., & Golakiya, B. A. (2015). Fatty Acid Profile and Phytochemical Characterization of Bael Seed (Aegle marmelos L.) Oil Original Research Article Fatty Acid Profile and Phytochemical Characterization of Bael Seed (Aegle marmelos L.) Oil. In Int.J.Curr.Microbiol.App.Sci (Vol. 4, Issue 2). http://www.ijcmas.com
33. Kaur A, Kalia M. (2017). Physico chemical analysis of bael (Aegle marmelos) fruit pulp, seed and pericarp. Chem. Sci. Rev. Lett. 6(22), 1213–1218.

34. KimHJ, Seo YJ, Htwe KM, Yoon DK. (2021). Chemical Constituents from Aegle marmelos Fruits. Nat. Prod. Sci. 27(4), 240–244.
35. Kumar KS, Umadevi M, Bhowmik D, Singh DM, Dutta AS.(2012). Recent trends in medicinal uses and health benefits of Indian traditional herbs Aegle marmelos. The Pharma Innovation.;1(4):57-65
36. Kumar TM. (2020). Exploring antibacterial & antiulcer activity of Aegle marmelos linn: a review. Int. J. Pharm. Chem. Anal. 7(3), 107–112.
37. M. Fawzi Mahomoodally, A. Mollica, A. Stefanucci, M. Zakariyyah Aumeeruddy, R. Poorneeka, G. Zengin, (2018) . Volatile components, pharmacological profile, and computational studies of essential oil from Aegle marmelos (Bael) leaves: a functional approach, Ind. Crop. Prod. 126 .13–21, https://doi.org/ 10.1016/j.indcrop.2018.09.054.
38. M. Sankari, V. Chitra, P. Silambujanaki, D. Raju, (2010). Anticonvulsant activity of ethanolic extract of Aegle marmelos (leaves) in mice, Int. J. PharmTech Res. 2.640–643.
39. M. Saravanan, P. Pandikumar, S. Saravanan, E. Toppo, N. (2014). Pazhanivel, S. Ignacimuthu, Lipolytic and antiadipogenic effects of (3,3-dimethylallyl) halfordinol on 3T3-L1 adipocytes and high fat and fructose diet induced obese C57/BL6J mice, Eur. J. Pharmacol. 740 .714–721, https://doi.org/ 10.1016/j.ejphar.2014.06.004.
40. M. Yadav, Kapil, Laxmi Gupta, Kumar Shukla Abhishek, Deo & Yadav Kapil, Br & Laxmi, Narayan & Gupta, Abhishek & Kumar, (2015). OUTCOME OF BILWA (Aegle marmelos) PHALA MAJJA CHURNA ON INTESTINAL TRANSIT, Ayurpharm- Int. J. Ayurveda Allied Sci. 4.23–28.
41. M.K. Gautam, V. Purohit, M. Agarwal, A. Singh, R.K. Goel, (2014). In vivo healing potential of aegle marmelos in excision, incision, and dead space wound models, Sci. World J. 2014., https://doi.org/10.1155/2014/740107.
42. Maity, P., Hansda, D., Bandyopadhyay, U., & Mishra, D. K. (2009). Biological activities of crude extracts and chemical constituents of Bael, Aegle marmelos (L.) Corr. Indian Journal of Experimental Biology, 47(11), 849–861.
43. Manandhar B, Paudel KR, Sharma B, Karki R. (2018). Phytochemical profile and pharmacological activity of Aegle marmelos Linn. Journal of Integrative Medicine.;16:153-163

44. Monika, S., Thirumal, M., & Kumar, P. (2023). Phytochemical and biological review of Aegle marmelos Linn. Future Science OA, 9(3). https://doi.org/10.2144/fsoa-2022-0068
45. Mrs. Yogita M Vispute1, Ms. Namrata Thosar2, Mr. Preet Chavarkar3. (2023). Bael Patra as Anti-Oxidant: A Review. International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538 Volume 11 Issue I Jan 2023- Available at www.ijraset.com
46. N. Kakiuchi, L.R.E. Senaratne, S.L. Huang, X.W. Yang, M. Hattori, U. Pilapitiya, T. Namba, (1991) . Effects of constituents of Bael (Aegle marmelos) on spontaneous beating and calcium-paradox of myocardial cells, Planta Med. 57 .43–47, https:// doi.org/10.1055/s-2006-960014.
47. N. Kamalakkannan, P.S.M. Prince, (2003). Hypoglycaemic effect of water extracts of Aegle marmelos fruits in streptozotocin diabetic rats, J. Ethnopharmacol. 87.207–210, https://doi.org/10.1016/S0378-8741(03)00148-X.
48. N.G. Dar, N. Saleem, U. Ali Soomro, W. Afzal, B. Naqvi, K. Jamil, (2015). Nutritional Exploration of Leaves, Seed and Fruit of Bael (Aegle Marmelos L.) Grown in Karachi Region.
49. N.P. Atul, V.D. Nilesh, A.R. Akkatai, S.K. Kamlakar, (2012). A review ON aegle marmelos: a potential medicinal tree, Int. Res. J. Pharm. 3.86–91.
50. Neeraj, Bisht, V., & Johar, V. (2017). Bael (Aegle marmelos) Extraordinary Species of India: A Review. Int. J. Curr. Microbiol. App. Sci., 6(3), 1870 1887.
51. Nugroho AE, S. Riyanto, M.A. Sukari and K. Maeyama, (2010). Effects of Skimmianine, a Quinoline Alkaloid of Aegle marmelos Correa Roots, on the Histamine Release from Rat Mast Cells.
52. Owk, A. K., & Lagudu, M. N. (2020). Aegle marmelos (Rutaceae): Evaluation of Root Phytochemical Constituents for Antimicrobial Activity. In Medicinal Plants: Biodiversity, Sustainable Utilization and Conservation (pp. 573–582). Springer Singapore. https://doi.org/10.1007/978-981-15-1636-8_34
53. PC, Sharma, Bhatia V, Bansal N, Sharma A. (2007). A review on Bael. Natural Product Radiance.;6(2):171-178

54. P.S.M. Prince, M. Rajadurai, (2005). Preventive effect of *Aegle marmelos* leaf extract on isoprenaline-induced myocardial infarction in rats: biochemical evidence, J. Pharm. Pharmacol. 57 .1353–1357, https://doi.org/10.1211/ jpp.57.10.0015.
55. Palatty, P. L., Shivashankara, A. R., Baliga, M. S., Jaiswal, A., Pankaj, P., & Joseph, N. (2013). The Indian Medicinal Plant Aegle marmelos in the Treatment of Diabetes Mellitus. In Bioactive Food as Dietary Interventions for Diabetes (pp. 519–536). Elsevier. https://doi.org/10.1016/B978-0-12-397153 1.00083-4
56. Pathirana CK, Madhujith T, Eeswara J. (2020). Bael (Aegle marmelos L. Corrˆ ea), a Medicinal Tree with Immense Economic Potentials. Adv. Agric. 2020, 1–13.
57. Pattanayak SP, Sunita P. (2008). Wound healing, anti-microbial and antioxidant potential of Dendrophthoe falcata (L.f) Ettingsh. Journal of Ethnopharmacology.;120:241-247
Prod. Resour. 6 (2007) 171–178.
58. Pynam H, Dharmesh SM. (2018). Antioxidant and anti-inflammatory properties of marmelosin from Bael (Aegle marmelos L.); Inhibition of TNF-α mediated inflammatory/tumor markers. Biomed. Pharmacother. 106, 98–108.
59. R. Vinodhini and M. Narayanan. (2009). Cytoprotective effect of Nelumbo nucifera and Aegle marmelos in common carp (Cyprinus carpio L.) exposed to heavy metals. Int J Integr Biol; 7: 124–129.
60. R.L. Bhardwaj, (2014). Role of bael fruit juice in nutritional security of Sirohi tribals, Benchmark Surv. Rep. Sirohi Tribals. 11–37.
61. R.L. Bhardwaj, U. Nandal, (2015). Nutritional and therapeutic potential of bael (Aegle marmelos Corr.) fruit juice: a review, Nutr. Food Sci. 45 .895–919, https:// doi.org/10.1108/NFS-05-2015-0058.
62. Rahman S, Parvin R. (2014). Therapeutic potential of Aegle marmelos (L.)-an overview. Asian Pacific Journal of Tropical Disease.;4:71-77
63. Rana BK, Singh UP, Taneja V. (1997). Antifungal activity and kinetics of inhibition by essential oil isolated from leaves of Aegle marmelos. Journal of Ethnopharmacology.;57:29-34
64. Rejiniemon TS, Arasu MV, Duraipandiyan V. (2014). In-vitro antimicrobial, antibiofilm, cytotoxic, antifeedant and larvicidal properties of novel quinone isolated from Aegle marmelos(Linn.) Correa. Ann. Clin. Microbiol. Antimicrob. 13(1), 1–9.

65. Roy, S. K., Saran, S., & Kitinoja, L. (2011b). Bael (Aegle marmelos (L.) Corr. Serr.). In Postharvest Biology and Technology of Tropical and Subtropical Fruits (pp. 186–216e). Elsevier. https://doi.org/10.1533/9780857092762.186
66. S. Anurag, K.S. H, K. Pragati, U. Ashutosh, (2014) . Bael (Aegle marmelos Correa) products processing: a review, Afr. J. Food Sci. 8 .204–215, https://doi.org/ 10.5897/ajfs2013.1119.
67. S. Brijesh, P. Daswani, P. Tetali, N. Antia, T. Birdi, (2009). Studies on the antidiarrhoeal activity of Aegle marmelos unripe fruit: validating its traditional usage, BMC Compl. Alternative Med. 9 .47, https://doi.org/10.1186/1472-6882-9-47
68. S. Kothari, M. Minda, S.D. Tonpay, (2010). Anxiolytic and antidepressant activities of methanol extract of Aegle marmelos leaves in mice, Indian J. Physiol. Pharmacol. 54 .318–328.
69. S. Kumar, R.K. Mahaseth, M. Tiwari, R. Sehgal, P. Rajora, R. Mathur, (2015). Interaction of aqueous leaf extract of Aegle marmelos (L.) Corr. with cholinergic, serotonergic and adrenergic receptors: an ex vivo study, Indian J. Pharmacol. 47.109–113, https://doi.org/10.4103/0253-7613.150374.
70. S. Laphookhieo, C. Phungpanya, C. Tantapakul, S. Techa, S. Tha-In, W. Narmdorkmai, (2011). Chemical constituents from Aegle marmelos, J. Braz. Chem. Soc. 22.176–178, https://doi.org/10.1590/s0103-50532011000100024.
71. S. Upadhya, K.K. Shanbhag, G. Suneetha, M.B. Naidu, S. Upadhya, (2004). A study of hypoglycemic and antioxidant activity of Aegle marmelos in alloxan induced diabetic rats, Indian J. Physiol. Pharmacol. 48 .476–480.
72. S. V Patil, C.D. Patil, R.B. Salunkhe, B.K. Salunke, (2010). Larvicidal activities of six plants extracts against two mosquito species, Aedes aegypti and Anopheles stephensi, Trop. Biomed. 27.360–365.
73. S.N. Panaskar, M.M. Joglekar, S.S. Taklikar, V.S. Haldavnekar, A.U. Arvindekar, (2013). Aegle marmelos Correa leaf extract prevents secondary complications in streptozotocin-induced diabetic rats and demonstration of limonene as a potent antiglycating agent, J. Pharm. Pharmacol. 65.884–894, https://doi.org/ 10.1111/jphp.12044.
74. Saroj P L, Singh R S and Singh A K. (2006). Bael (Aegle marmelos), pp. 21–38. Aavances in Arid Horticulture, Vol 2.(Eds) P L Saroj and O P Awasthi.International Book Distributing Co., Lucknow.

75. Seemaisamy R, Faruck LH, Gattu S, et al. (2019). Anti Microbial and Anti Cancer activity of Aegle marmelos and Gas Chromatography Coupled Spectrometry Analysis of their Chemical Constituents. Int. J. Pharm. Sci. Res. 10(1), 373–380.
76. Shailja Choudhary. (2021): Aegle marmelos (bael patra): an ayurvedic plant with ethnomedicinal value, Int J Res Ayurveda Pharm; 12(3): 147-156.
77. Shankar, G., & Garg, K. L. (1967). In: Nutritional value of some important fruits
78. Sharma PC, Bhatia V, Bansal N, Sharma A. (2007). A review on Bael tree. Indian Journal of Natural Products and Resources.;6:171-178
79. Sharma Prabodh, B. V. (2007). A review on Bail Tree. Natural Product Radiance, 6(2), 171–178.
80. Sharma, G. N., Sati, N., Dubey, S. K., & Sanadya, J. (2011). Phytochemical Screening and Estimation of Total Phenolic Content in Aegle marmelos Seeds. In Article in International Journal of Pharmaceutical and Clinical Research (Vol. 3, Issue 2). www.ijpcr.com
81. Singh A K, Singh Sanjay and Saroj P L. (2016c). Cultivating climate resilient bael for future.Indian Horticulture 62(4): 43–5.
82. Singh A K, Singh Sanjay, Makwana P and Sharma S K. (2016a). Evaluation of bael germplasm under rainfed semi-arid environment of western India. International Journal of Noni Research 11(1&2): 11–19.
83. Sonawane A, Pathak SS, Pradhan RC. (2020). Physical, thermal, and mechanical properties of Bael fruit. Journal of Food Process Engineering.:43;e13393.
84. T.K. Lim, (2015). Edible Medicinal and Non Medicinal Plants, Springer Netherlands.
85. V. Arul, S. Miyazaki, R. Dhananjayan, (2004) . Mechanisms of the contractile effect of the alcoholic extract of Aegle marmelos Corr. on isolated Guinea pig ileum and tracheal chain, Phytomedicine 11 .679–683, https://doi.org/10.1016/ j.phymed.2002.12.001.
86. V. Sankeshi, P. Anil Kumar, R. Ravindar Naik, G. Sridhar, M. Praveen Kumar, V.V. Hara Gopal, T. Naga Raju, (2013). Inhibition of aldose reductase by Aegle marmelos and its protective role in diabetic cataract, J. Ethnopharmacol. 149.215–221, https://doi.org/10.1016/j.jep.2013.06.025.
87. Veer B, Singh R. (2019). Phytochemical Screening and Antioxidant Activities of Aegle marmelos Leaves. Anal. Chem. Lett. 9(4), 478–485.

88. Veerappan A, Miyazaki S, Kadarkaraisamy M, Ranganathan D. (2007). Acute and subacute toxicity studies of Aegle marmelos Corr., an Indian medicinal plant. Phytomedicine.;14:209-215
89. W. Horwitz, George W. Latimer, (2005). Official Methods of Analysis of AOAC International, eighteenth ed., AOAC International, Gaithersburg Md.
90. Z.J. Zhang, (2004). Therapeutic effects of herbal extracts and constituents in animal models of psychiatric disorders, Life Sci. 75 .1659–1699, https://doi.org/ 10.1016/j.lfs.2004.04.014.