

The Bael (*Aegle marmelos* L. Corr.): Health Benefits and its Varietal Wealth

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ABSTRACT

Indian medicinal plants are considered a vast source of several pharmacologically active principles and compounds and that are commonly used in home remedies against multiple ailments. Amongst those plants, bael has enormous traditional uses against various ailments and many bioactive compounds have been isolated from this plant. The leaves, bark, roots, fruits and seeds are an integral part of Indian traditional system of medicine 'Ayurveda' and various folk medicine to treat myriad ailments. Compounds like skimmianine, aegelin, lupeol, cineole, citral, citronellal, cuminaldehyde (4-isopropylbenzaldehyde), eugenol, marmesinin, marmelosin, luvangetin, auraptin, psoralen, marmelide, fagarine, marmin

and tanin have been proved to be biologically active against antiulcer, antidiabetic, antihyperlipidaemic, antioxidant, anticancer, antimicrobial, radioprotective, anti-inflammatory, antipyretic, analgesic and antispermatogenic (Takase *et al.* 1994). Previously, bael fruits are generally named after the locality were, they are easily available. So far reports on the available cultivars are mainly from the states of Uttar Pradesh, Uttarakhand, Bihar and West Bengal. Around twelve cultivars, viz., Basti No.1, Gonda No.1, 2 and 3, Kagzi Etawah, Sewan Large, Deoria Large, Chakaiya, Lamba and Baghel has been reported. A number of cultivars have been selected recently which are the best among the others with regards to yield and fruit quality. Narendra Bael-5 and 9, Pant Sujata, CISH-2 are popular among the farmers of Uttar Pradesh. New varieties like Goma Yashi and Goma Neelkanth are early maturing variety for the health, nutritional and economic security of farmers of dry tracts of the country.

Keywords Bael, Health benefits, Varieties, Medicinal properties.

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INTRODUCTION

Over the last few years, researchers have aimed at identifying and validating plant-derived substances for the treatment of various ailments. Interestingly, it is estimated that more than 25% of modern medicines are directly or indirectly derived from plants (Cragg *et al.* 1997). In this context, it is worth mentioning that

Indian medicinal plants are considered a vast source of several pharmacologically active principles and compounds and that are commonly used in home remedies against multiple ailments (Biswas *et al.* 2002). Among the various plants bael (*Aegle marmelos* (L.) Corr.) is another Indian plant, which has enormous traditional uses against various diseases and many bioactive compounds have been isolated. Bael belongs to the family Rutaceae. Native to India and found throughout Southeast Asia and nick named as Amrit Phal, Holy fruit, Shree Phal, Golden apple, Indian quince, Bengal quince, Stone apple. It has been grown in India for more than 4,000 years and is extremely appreciated for its identified therapeutic features. It is a deciduous and subtropical plant which can grow up to an altitude of 1200 m. It is an integral part of Ayurvedic practice and is also utilized to deal with numerous health benefits. Fruit contains a number of substances that can help to treat certain health conditions. The fruit is typically eaten fresh, dried or in juice form. The fruit pulp contains 60.7 % moisture, 0.46 % acidity, 8.36 % total sugars, 6.21 % reducing sugars, 2.04 % non-reducing sugars and 0.21 % tannins. The pectin content is 2.52 %, which is quite high. Fruit is a very good source of protein (5.12 %) and total mineral content (2.663 %). The important mineral content in fruits are phosphorus (0.137 %), potassium (0.746 %), calcium (0.188 %), magnesium (0.127 %) and iron (0.007 %). Fruits are also rich in riboflavin, vitamin A, carbohydrates (Gopalan *et al.* 1985). The leaves, bark, roots, fruits and seeds are used extensively in the Indian traditional system of medicine the Ayurveda and in various folk medicine to treat myriad ailments. Extensive chemical investigations on various parts of the tree have been carried out and more than 100 compounds have been isolated (Gupta and Tondon, 2004). Many of these compounds including skimmianine, aegelin, lupeol, cineole, citral, citronellal, cuminaldehyde (4-isopropylbenzaldehyde), eugenol, marmesinin, marmelosin, luvangetin, auraptin, psoralen, marmelide, fagarine, marmin and tanin have been proved to be biologically active against various major and minor diseases including cancer, malaria and gastroduodenal disorders (Takase *et al.* 1994, Badam *et al.* 2002). Various crude extracts of this plant have shown activities including antiulcer, anti-diabetic, antihyperlipidaemic, antioxidant, anticancer, antimicrobial, radioprotective, anti-inflammatory,

antipyretic, analgesic and antispermatogenic effects on various animal models (Badam *et al.* 2002, Jagetia *et al.* 2005). Various value-added products viz., ready to serve (RTS) drink, nectar, squash, syrup, jam, slab, toffee, preserve, candy and powder which can attract both national and international markets. Besides its nutritional and medicinal properties bael plant has environmental importance which is of great concern due to global warming. These trees are the member of plant species group known as 'Climate Purifiers', which emit greater percentage of oxygen in sunlight as compared to other plants. It acts as a 'Sink' for chemical pollutants as it absorbs poisonous gases from the atmosphere and make them inert or neutral. Flowers and volatile vapours neutralize the bad smell of petrified organic matter or decaying refuse and thus save human life from bacterial attack by making them inert and deodorizing the bad odor of air (Dhankhar *et al.* 2011).

Biological activities of purified bael compounds identified from different parts of the bael tree

Several compounds such as skimmianine, aegelin, lupeol, cineole, citral, citronellal, cuminaldehyde, eugenol and marmesinin have been purified from bael leaves (Jagetia *et al.* 2005, Capasso *et al.* 2000). Skimmianine, an alkaloid, is also found in the immature bark of the tree. It has shown anticancer activity in human ovarian cancer cell line (Jagetia *et al.*, 2005). In various experimental animal models, skimmianine has shown sedative, hypnotic, analgesic, anticonvulsive, antipyretic, hypothermic and antidiuretic effects (Rastogi and Mehrotra 1991).

Fruits

The bioactive compounds isolated from bael fruits are marmelosin, luvangetin, auraptin, psoralen, marmelide and tannin (Badam *et al.* 2002, Rastogi and Mehrotra 1998). Marmelosin has shown antihelmintic as well as antibacterial activities (Ghosh and Playford 2003, Shoba and Thomas 2001). Luvangetin, a pyranocoumarin isolated from the seeds of bael fruit protects against multiple models of gastric ulceration in rodents (Shoba and Thomas 2001). Auraptin inhibits (IC₅₀ = 0.6 µg/ml) the chronotropic effects on cardiac tissue and thus may be useful in treatment

of hypertension (Rastogi and Mehrotra 1998). Psoralen shows various activities such as antispasmodic (Hansel *et al.* 1994), artemicide (LD50 = 5.93 µg/ml) and cytotoxic (Saqib *et al.* 1990). Marmelide is very effective against viruses and is found to influence the early stages of replicative cycle such as adsorption, penetration, Tannin, present in the unripe fruit of this plant, has astringent property and is an excellent remedy for diarrhoea (Shoba and Thomas 2001) Bael the richest source of Vitamin B₂ (Riboflavin) needed for growth and overall good health. It helps in breakdown of carbohydrates, proteins and fats to produce energy and it allows oxygen to be used by the body. It protects glutathione, which is an important antioxidant in the eye. Taking riboflavin can also reduce homocysteine levels in the blood by 26 to 40 %. High homocysteine levels contribute to arterial damage and blood clots in your blood vessels. Fruit contains allo-imperatorin, marmelosin which are potential multi-potent antioxidant, anti-inflammatory and anticancer property.

Roots and root bark

Among the important bioactive compounds isolated from bark are fagarine and marmin (Takase *et al.* 1994, Duke *et al.* 1992). Fagarine is present in the mature bark and possesses abortifacient activity (Duke *et al.*, 1992). Marmin, is found in the immature bark of the tree. It shows antiulcer activity in experimental ulcer models. Oral administration of marmin at a dose of 10-50 mg/kg in rats has inhibited the occurrence of ethanol induced gastric haemorrhagic lesions in a dose dependent manner with ED50 of 17.2 µg/kg. Intragastric administration of marmin at a dose of 25 mg/kg body weight also significantly inhibited gastric motility (Takase *et al.* 1994).

Medicinal benefits of bael

Diarrhoea and dysentery

Generally dried fruit pulp and its powder are used for the treatment of diarrhoea. The dried powder is also used as an important remedy for chronic dysentery conditions characterized by alternate diarrhoea and constipation (Sharma *et al.* 2007).

Antidiabetic activity

The fruit extract at a dose of 250 mg/kg exhibited to be more effective than glibenclamide, a well-known hypoglycemic drug (Kamalakkannan and Prince 2003). The antidiabetic mode of action is of extract can significantly lower the levels of blood glucose and glycosylated hemoglobin and increased the plasma insulin as well as liver glycogen in diabetic (Kamalakkannan *et al.* 2003). This antidiabetic effect is probably due to the presence of coumarins in the fruit extract, which potentiate the insulin secretion from existing beta cells of the Islets of Langerhans (Kamalakkannan and Prince 2005). The aqueous extract of bael seeds reduced the blood glucose level in normal as well as in severe diabetic (Swanker *et al.* 2005).

Antioxidant activity

Oxidative stress is produced during normal metabolic processes in the body as well as induced by a variety of environmental and chemical factors, which cause generation of various reactive free radicals and subsequent damage to macromolecules like DNA, proteins and lipids. The antioxidative phytochemicals such as flavonoids, alkaloids, sterols, tannins, phlobatannins and flavonoid glycosides present in the leaf extract of bael possess this free radical scavenging activity (Jagetia *et al.* 2003, Rajadurai and Prince 2005).

Anticancer activity

The hydroalcoholic extract of bael leaves has shown anticancer effect in the animal model of Ehrlich ascites carcinoma (Jagetia *et al.* 2005). Administration of the extract (400 mg/kg) has shown the greatest antitumor effect. The plant extract exhibits cytotoxicity against tumor cell lines in brine shrimp lethality assay and methyl thiazolyl tetrazolium (MTT) based assay (Costa *et al.* 2005). Studies showed that Indian bael extract possess significant antiproliferative effect. It inhibits in vitro proliferation of human tumor cell lines (Lampronti *et al.* 2003).

Leucoderma, constipation, eye infection and ear problem

Psoralen present in the pulp of bael increases tol-

Table 1. Biological activity of chemical constituents isolated from bael.

Plant parts	Compounds isolated	Biological activity	References
Leaves and	Alkaloids	Antifungal, anticancer	Gurjar <i>et al.</i> (2015)
	Eugenola and Cuminaldehyde	Antibacterial	
Fruits	Geraniol	Antihelmintic	
	Terpionoids	Nematicidal	
	Marmelosin	Laxative, diuretic, antioxidant, anti-inflammatory, Antimicrobial, hepatoprotective and anticancer	
	Lectin	Anti-invasive	
	Quercetin and Flavonoids	Anticancer	
	Tannins	Anticancer, antibacterial,	
	Marmesin	Cytotoxic, antiulcer, antipyretic	
	Galactose, arabinose, uronic acid L-Rhamnose carotenoids	Nutritive	
	Seeds	Proteins	Natural sweetener, nutraceutical
		Aegeline	Nutraceutical, antioxidant
Limonene		Cytotoxic	
Flavonoid		Anticonvulsant	
Psoralen		Antifungal	
Marmelide		Antifertility	
7-geranyloxy coumarin		Antimicrobial	
Aegelin		Antipyretic, antibacterial	
Aegelenine		Antibacterial, antioxidant	
Armeline		Antifungal, antidiarrheal	
Dictamine, fragrine	Cytotoxic		

erance of sunlight which aids in the maintenance of normal skin color and thus, it is employed in the treatment of leucoderma (Gupta *et al.*, 2006). Sharma *et al.* (2010) reported that the leaves are considered an effective treatment for ophthalmia and various eye inflammations as conjunctivitis. The riped bael fruit act as good laxative. It promotes peristaltic movements and thus helpful in the removal of fecal matter. The root of this tree possesses astringent activity and is used as a home remedy for curing ear problems. The astringent extract of the roots combined with the antiseptic properties of neem helps in curing ear infection, chronic inflammation and pus discharge. The juice of leaves processed in oil is also used as ear drops to treat ear infection (Rusia and Srivastava 1988).

Table 2. Commercial herbal and medicinal products of bael found in modern market. Source: Gurjar *et al.* (2015)

Products	Company Name
Chyawanprash	Himalaya
Aegle Marmelos Capsules	La-Medicca (India) Pvt. Limited
Leucare capsules	Leucare capsules
Entrostat syrup	Ambika medico
Kof-Rid syrup	Ambika medico
Pregeight	Sydlar remedies Pvt Ltd
Ojamin (Anti-diabetic drugs)	Tates remedies
Manasamithravatakram	Oushadhi
Pushyanugam gulika	Oushadhi
Vilwadi gulika	Oushadhi
Glucomap	Maharishi ayurveda
Ulco bliss tablets	Bliss ayurveda
Capsule bilv giri	Ayurvedic sanjivani
R-Qunol syrup	Vatsal ayurvedic products (P) ltd
Bael candy	Patanjali
Bael murabba	Patanjali
Baek bar (burfi)	Khandelwal food products

Peptic ulcer

Ulcer develops when there is imbalance between the defensive and aggressive factors on the mucosa resulting from either potentiation of aggressive factors and/or lowering of mucosal protection (Biswas *et al.*, 2002; Wallace and Granger 1996). Bael fruit and leaf infusion has been used for the treatment of peptic ulcer. One of the important advantages of this fruit is that it forms a mucilaginous layer on the gastric mucosa and thus prevents interaction of acid with mucosal layer (Goel *et al.* 2000).

Radioprotective activity

A large number of cancer patients are regularly being

Table 3. Improved bael varieties developed in India.

Varieties	Institutes
Narendra Bael-5, Narendra Bael-7, Narendra Bael-9, Narendra Bael-16 and Narendra Bael-17	ND University of Agriculture and Technology, Kumargunj, Faizabad, UP
Pant Aparna, Pant Sujata, Pant Urvashi and Pant Shivani	GB Pant University of Agriculture and Technology, Pantnagar Uttarakhand.
CISH-1 and CISH-2	Central Institute of Sub-Tropical Horticulture, Lucknow, UP
Goma Yashi, Thar Divya and Thar Neelkanth	Central Horticulture Experiment Station (ICAR-CIAH) Vejalpur, Panchmahals (Godhra), Gujarat

Table 4. Description of some improved varieties of bael (Source: Singh *et al.* 2011; Singh *et al.* 2016).

NB 5	Early maturity, fruit size is medium, round in shape having smooth surface at maturity, average fruit weight 900-1000g, less seed and mucilage, moderately fibrous and have softlesh with excellent taste. TSS 25-27 °Brix
NB 6	Fruit size is medium, round with smooth surface, and have thin rind, few seeds, soft flesh, low mucilage and mild acidic.
NB-7	Tree are tall with medium canopy spread. Fruits are round and sunken at both the ends and weight more than 1.5 kg More vegetative growth in southern India.
NB-9	Tree are of medium height and produce average fruit weight of 1-1.5 kg containing more pulp and less mucilage. TSS 35-40 °Brix.
NB 16	Fruits are elliptical round, pulp yellow, Average fruit weight 1.3 kg, TSS 31%, medium seed and low fiber content.
NB 17	Fruits oblong, big sized, fruit quality excellent, seed content less.
Pant Shivani	Mid-season cultivar with ovoid oblong shape, size 2 kg, color lemon yellow on ripening fiber and mucilage content medium, rind medium thick, pulp light yellow with very good taste and pleasant flavor.
Pant Aparna	Late cultivar with small fruit size (0.6 - 0.8 kg), globose shape, and seed, mucilage, fibre and acidity are low. Its flesh is yellow, sweet, tasty and having good flavour. Mucilage, seed and fiber content are low.
Pant Urvashi	Mid-season variety. Trees are tall, vigorous, dense, upright growing, precocious and heavy bearer. Fruit is ovoid- oblong with average weight of 1.6 kg. Fruits are lemon yellow color and pulp is yellow. TSS 33%, acidity 1.15%. It is found to be best on yield and yield characteristics.
Pant Sujata	Early variety, trees are medium-dwarf with drooping and sereading foliage, dense, precocious and heavy brearer. Fruit are globose shaped drepessed at the both ends with average weight of 1.14kg. Fruit and pulp light yellow. Flavour is plesent and taste is good very good. TSS 30%, Acidity 0.75%. Mucilage, seed and fiber content are low.
CISH-1	Selection from open pollinated seedling. Mid-season variety and matures in April-May. Precocious and prolific bearer. Fruits oval-oblong, fruit colour truns lemon-yellow on ripening, average fruit weight 1.0kg, thin shelled, pulp dark yellow, pleasant flavour and less mucilage. Good taste and aroma , 65.57 % pulp, TSS 38.0°B and 20.54 % tatal sugar. Suitable for canning of slices. Yield 50-80 kg /tree.
CISH-2	Selection from open pollinated seedling. Tree dwarf and moderately spreading, Few thrones, sparse foliage, precocious and good yielder. Fruits oblong-oval, average fruit weight 1.80-2.70 kg. Thin shelled, pulp orange yellow, low seed and fiber content. Good taste, pleasant aroma, Pulp 61.32 %, TSS 31.9 °Brix, total carotenoids 0.99 mg/100g pulp, total sugars 16.33 % and 2.45 % tannin content. Yield 60-90 kg/tree.
Thar Divya	Early maturing variety for the health, nutritional and economic security of farmers of dry tracts of the country.
Yashi Goma	Produces very good quality fruit with weight of 1-2kg, fruits are ovate in shape, greenish yellow. Flesh color is straw. Fruit shell weight is 180gm. TSS 38 °Brix, shell thickness: < 2mm, low mucilage. Total number of seed: < 125 (low). Maturity: 280 Days after fruit setting.
Thar Neelkhanth	Vigorous and lustrous growth with dense canopy. Drought hardy and prolific bearer with average yield of 75.67 kg/ tree. High pulp content (71.30%) with less acidity (41.20%). Less number of seeds and mucilage, TSS and acid ratio (142.07). It is highly suitable to grow under fragile agroclimatic conditions.

cured all over the world with this treatment. The radio protective effect of hydroalcoholic extract of bael leaves has been evaluated in cultured human peripheral blood lymphocytes (HPBLs). The irradiation of HPBLs with different doses of gamma-radiation caused a dose dependent increase in the frequency of lymphocytes bearing one, two and multiple micronuclei. Treatment of HPBLs with 5 µg/ml leaf extract significantly reduced the frequency of lymphocytes bearing one, two and multiple micronuclei when compared with the irradiated control. The mechanism of this type of radioprotective activity of the leaf extract may be due to the scavenging of radiation-induced free radicals (Jagetia *et al.* 2003).

Antifungal and antibacterial

The germination of any spore (i.e. bacterial or fungal)

is related to Ca²⁺ – dipicolonate and/or free Ca²⁺ ions availability in the medium as well as within cytoplasm of microbes. The essential oil from the bael leaves may interfere with the Ca²⁺ – dipicolonic acid metabolism pathway and possibly inhibit spore germination. The essential oil isolated from the leaves of the bael tree has proved its antifungal activity against many animal and human fungi like *Trichophyton mentagrophytes*, *Trubrum*, *Microsporum gypseum*, *M. audouinii*, *M. cookei*, *Epidermophyton floccosum*, *Aspergillus niger*, *A. flavus* and *Histoplasma capsulatum* (Dubey and Mishra, 1990; Yadav and Dubey, 1994). The ethanolic extract of the root has shown activity against *Aspergillus fumigatus* and *Trichophyton mentagrophytes* (Pitre and Srivastava 1987). The essential oil obtained from the leaves exhibited activity against *Aeromonas sp.*, *Escherichia coli*, *Pseudomonas salanacearum*

and *Xanthomonas vesicatoria* (Khanna *et al.* 1991, Pandey *et al.* 1981). The ethanolic extract of the root has shown activity against *Vibrio cholerae*, *Salmonella typhimurium*, *Klebsiella pneumoniae*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis* and *Staphylococcus aureus* (Pitre and Srivastava 1987, Valsaraj *et al.* 1997).

4. Varietal wealth of bael

Previously, bael fruits are generally named after the locality were, they are easily available. So far reports on the available cultivars are mainly from the states of Uttar Pradesh, Uttarakhand, Bihar and West Bengal. Around twelve cultivars, viz., Basti No.1, Gonda No.1, 2 and 3, Kagzi Etawah, Sewan Large, Deoria Large, Chakaiya, Lamba and Baghel has been reported. Kagzi Etawah, Sewan Large, Deoria Large and Mirzapuri have been found to be superior and better than the other varieties in case of taste and qualities. Bael trees with desirable fruit characteristics have been collected and evaluated for their growth, flowering, fruiting and quality attributes and many promising varieties have been developed through selection at ICAR Institutes/ Regional Stations and State Agriculture Universities viz., Narendra Bael-5, Narendra Bael-7, Narendra Bael-9, Narendra Bael-16 and Narendra Bael-17, Pant Aparna, Pant Sujata, Pant Urvashi and Pant Shivani, CISH-1 and CISH-2, Goma Yashi, Thar Divya and Thar Neelkanth. Description of some improved varieties of bael have been presented on Table 4.

CONCLUSION

It is quite evident that bael is a good source of bioactive compounds which are very helpful to improve health conditions. Woefully, most of the compounds are yet to be evaluated for the investigation of new lead molecules. Moreover, mode of action of few bioactive compounds have been identified so far. Thus, comprehensive research is required to reveal the bioactivity of other compounds, mode of action, their therapeutic potential, level of toxicity, standardization, clinical trials and exploitation to combat various ailments. Consequently, bael may play a very important role in modern system of medicine in future. A number of cultivars have been selected recently which are the

best among the others with regards to yield and fruit quality. Narendra Bael-5 and 9, Pant Sujata, CISH-2 are popular among the farmers of Uttar Pradesh. New varieties like Goma Yashi and Goma Neelkanth are early maturing variety for the health, nutritional and economic security of farmers of dry tracts of the country. Sir George Watt, a renowned botanist and erstwhile Professor of Calcutta University, had written: "No drug has been longer and better known nor more appreciated by the inhabitants of India than the bael."

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