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PHYTOCHEMICAL AND PHARMACOLOGICAL PROPERTIES OF THE BAEL PLANT [*AEGLE MARMELOS* (L.) CORREA]: A REVIEW ON SACRED PLANT

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ABSTRACT

Beal (Aegle marmelos) of family Rutaceae is an important medicinal and holy plant, originated from Eastern Ghats and Central India, containing golden colored pear shaped fruit. The plant has compound trifoliate leaves with peculiar fragrance. The spherical or oval fragrant fruit has medicinal properties. It is a holy plant used in worship of lord Shiva in Hindu mythology. From the ancient time it is used in various systems as Ayurvedic, Chinese and Siddha systems or folk medicines. The plant has several medicinal properties viz. anti-diarrhoeal, anti-diabetic, anti-microbial, anti-cancer, chemo-preventive, anti-pyretic, anti-genotoxic, anti-fertility and anti-inflammatory. It contains many bioactive compounds and secondary metabolites that used to cure several diseases.

INTRODUCTION

Medicinal plants are used in traditional medicine system since ancient time. Plants synthesize hundreds of phytochemical with potential to recover from various diseases. In recent days the uses of plant based substances have tremendously increased to cure various diseases because of their medicinal properties which attract the indigenous communities (Cragg *et al.*, 1997). Plant based medicines are generally taken in consideration as they are pollution free, non-hazardous, eco-friendly, less toxic. Of 6000 plants mentioned in the traditional systems of medicine approximately 350 species used as natural antioxidants, food additives or sources of nutritional supplements (Kaur and Kapoor, 2000, Miliauskas *et al*, 2004, Rai *et al*, 1991, Nigam and Nambiar, 2015). Bael, Bilva or *Aegle marmelos* is such a plant which is used as spiritual, religious and medicinal plant. All the plant parts have been used for over 5000 years in India to treat various diseases. Bael has anti-diarrhoeal, anti-diabetic, anti-microbial, anti-viral, radio-protective, anti-cancer, chemo-preventive, anti-pyretic, ulcer healing, anti-genotoxic, diuretic,

anti-fertility and anti-inflammatory properties, effective against several major diseases including cancer, diabetes and cardiovascular diseases.

In this review, information on the phytochemical and pharmacological activities of *Aegle marmelos* of Rutaceae (citrus family) has been collected. Bael is a golden colored pear shaped fruit resembles golden apple (generic name *Aegle*), its specific name *marmelos* is derived from marmelosin contained in the fruit (Dheeba *et al*, 2010). It is monotypic genus of Rutaceae (Parmar and Kaushal, 1982) which is widely used as medicinal and nutraceutical plant for diabetes and oedema (Jain, 1968). According to Charaka (1500 B.C.) no drug has been longer or better known or appreciated by the inhabitants of India than the bael. Leaf extract of bael is also reported to regenerate damaged pancreatic S-cells in diabetic rats. It is as effective as insulin in the restoration of blood glucose and body weight to normal levels.

Leaves have various therapeutic effects of which anti-diabetic activity is important. The improving mechanism of hypoglycemic action of leaves is not clear. It may be the result of improvement in the functional status of beta cells or reversing the histological and ultra-structural changes in the pancreas and liver of rats with *streptozotocin*-induced diabetes (Das *et al*, 1996). To study the mechanism, Skimmianine and Anhydroaegeline can be used as markers to standardize the plant material with respect to its potential anti diabetic activity.

The leaves contain many bioactive compounds. The leaves of bael can be used as a food additive due to their typical flavor and nutrient contents. The compounds obtained from leaves have antimicrobial, antioxidant therapeutic potential and play an important role in drug development, food storage, health supplement and spa. Bael may be useful in the alleviation of damages caused due to aging and may thus increase life expectancy. As the nutraceutical information of bael is developing continuously, it suggests further pre-clinical and clinical studies to explore its utility and efficacy in treatment of chronic diseases.

Key words: Bael, antioxidant, anti-diabetic activity.

BOTANICAL DESCRIPTION

Bael (*Aegle marmelos*) is a slow-growing and medium sized tree. It is up to 12-15 m tall with short trunk. The stem has thick, soft, flaking bark and spreading, spiny branches, lower ones drooping. Young suckers bear many stiff and straight spines. A clear, gummy sap exudes from wounded branches. Leaves (4-10 cm long, 2-5 cm wide) are alternate, trifoliate and aromatic. Leaves are with ovate or ovate-lanceolate leaflets, crenate, laterals sub-sessile and the terminal long petiole (1-2.5 inch long). When leaves are young and immature they are glossy and pinkish-maroon in colour. After maturation colour changes from green to shiny colour and emit a

disagreeable odor. One young branchlet contains fragrant flowers that are greenish white, found in clusters of 4 to 7 on axillary panicles. Flower has four recurved fleshy petals; green outside and yellowish inside, 50 or more greenish-yellow stamens are found within them. In India flowering occurs in April and May. After it the new leaves appear and fruits ripen in 10 to 11 months from bloom (Orwa *et al*, 2009, Bramhachari and Reddy, 2010). Fruit is globose or round or pyriform or oval to oblong upto 5-20 cm. It is woody berry with golden yellow rind when ripe. The fruit may have a thin, hard, woody shell or more or less soft rind. The fruit is gray-green until fully ripe. Inside the fruit have a hard central core and 8 to 20 faintly defined triangular segments, dark-orange walls. It is filled with aromatic, pale-orange, pasty, sweet, resinous, more or less astringent pulp. Sometimes the skin of the fruit is so hard it must be cracked open with a hammer. The fruit contains numerous densely covered seeds with fibrous hairs that are embedded in a thick, gluey, unpleasant aromatic pulp. It is eaten fresh or dried. The juice is used as a drink similar to lemonade and it is also used in making Sharbat. Each seed enclosed in a sack of adhesive, transparent mucilage that solidifies on drying (Lambole *et al*, 2010, Kurian, 1992. The fruit has aromatic, minute oil glands (Fig. 1A-D).

ORIGIN AND DISTRIBUTION

It is grown all over the country especially in the premises of temples and houses. The *A. marmelos* has its origin from Eastern Ghats and Central India. It has a native range from India and exotic range from Bangladesh, Egypt, Malaysia, Myanmar, Pakistan, Sri Lanka and Thailand. The plant grows wildly in dry forests on hills and plains of central and southern India and Burma, Pakistan and Bangladesh. In India, it is found growing wildly in Sub-Himalayan tracts from Jhelum eastwards to West Bengal, in central and south India. It grows along foothills of Himalayas, Bihar, Chhattisgarh, Uttaranchal, Jharkhand, Gujarat, Madhya Pradesh and Rajasthan. It is also grown at some places in Surinam and Trinidad (Sharma and Dubey, 2005, Sukhdev, 1975). The bael plant is tolerant of water logging, drought, and temperature fluctuations (from 7°C to 48°C). A pronounced dry season is required to give fruit in early summer. In northern India bael plant grows up to an altitude of 1,200 m where the temperature rises to 48ºC or more in the shade in summer and falls to -6.67ºC in the winter and prolonged droughts occur. Where there is no long, dry season plant will not fruit. In India, it grows where other fruit trees cannot survive (Daniel, 2006). Bael is a subtropical species. It is grown best on rich well drained soil. Swampy, alkaline or stony soils are best for their growth and the optimum pH ranges from 5-8 for them.

VERNACULAR NAMES

Bael (*Aegle mamelos*) is known by different names in different languages *viz. Aegle mamelos* (L.) Corr. Serr. (Latin), baelputri, bela, sirphal, siri-phal (old hindi), kooralam (hindi), wood apple, stone apple, bael fruit, Indian bael, holy fruit, golden apple, elephant apple, Bengal quince, Indian quince (English), Mbau Nau, Trai Mam (Vietnamese); Bel, Gudu (Nepali); Toum Lao (Sino-Tibetan) Bnau Khmer Modjo (Javanese); Oranger du Malabar, cognassier du Bengale, belindien (French); Ohshit, opesheeet (Burmese); Mojo tree, majabatuh, maja) (Indonesian); bnau (Khmer); Pokok Maja Batu, bilak, bel, bila, majapahit (Malay); Mapin, Matum, Tum (Thai); Shreephal, Bilva, Bilwa (Sanskrit); Bel, Shreefal (Bengali); Kaveeth (Marathi); VilvaMaram, VilvaPazham (Tamil); Maredu (Telugu); Bel (Urdu); Billi (Gujarati); Belo (Orissa); German (Belbaum, Schleimapfelbaum, Baelbaum) and Portuguese (marmelos).

Fig 1. (A) Plant of *Aegle marmelos*, (B) leaves of plant, (C) trifoliate leaf, (D) leaves on branches

NUTRITIONAL VALUE

The fruit can be eaten fresh or dried. The leaves are eaten as salad in many Asian countries. The young shoots and leaves are used as vegetable in Thailand. They are also used as seasonal food in Indonesia. They are helpful in reduction of appetite (Rajasekaran and Meignanam, 2008). In Indonesia, pulp of fruit is used with palm sugar eaten in breakfast. In India, seeded pulp of bael beating with milk and sugar makes sherbet. It can also be used as a beverage made by combining fruit pulp with tamarind. Bael fruit jam is prepared by fruit pulp mixed with citric acid. Toffee is also prepared by combining the fruit pulp with sugar, glucose, skim milk powder and hydrogenated fat. The leaf powder has approximately 10.3g ash, 0.14µg zinc, 2.67µg iron and 1.73µg of chromium (Morton, 1987; Singh*et al*, 2012). Per 100 g of fresh bael fruit contains 54.96-61.5 g water, 1.8-2.62 g protein, 0.2-0.39 g fat, 28.11-31.8 g carbohydrate, 1.04-1.7 g ash, 55 mg carotene, 0.13 mg thiamine, 1.19 mg riboflavin, 1.1 mg niacin, 8-60 mg abscisic acid and 2.11 mg tartaric acid.

MEDICINAL USES

In Ayurvedic (like *dasamoola*) medicines all plant parts of Bael is used in various forms for curing diabetes, leprosy etc. Its bark is used to cure intestinal disorders and leaves are used to treat hypoglycemic patients due to an alkaloid rutacin present in it. Leaves and fruits are used to treat diarrhea and dysentery. Bael is a rich source of carbohydrate, protein, fat, fiber, minerals and vitamin B and C. Fruit pulp is used to cure mouth ulcers and it is also used in preparing the shampoo. It is used as cooling agent due to richest natural source of riboflavin (1191 units/ 100 g). The rind of bael fruit is used for tanning and dyeing. The aromatic wood is used to make pestles in oil and sugar mills or agricultural implements (Rajarajan, 1997).

BAELAND INDIAN MYTHOLOGY

In many legends, stories and myths the leaflets of this tree are given to devotees as prasadam in Shiva temples and as Tulsi in Vishnu temples. Leaves are offered to Shiva and Parvathi since ancient time (Rajasekaran and Meignanam, 2008). It is a religious tree worshiped in Shiva and Vishnu temples. It is considered as embodiment of Lord Shiva and religious tree in Hinduism with spiritual powers. Its trifoliate leaves symbolize the Thrimurthies (Brahma, Vishnu and Shiva). Its pear shaped leaflets resemble Thrisoola (weapon of Lord *Shiva*).

Baelis a medical plant, which is an ancient plant or treatise in Sanskrit, Charak Samhita, Ayurvedic and Siddha systems or folk medicines to treat variety of ailments. In Ayurveda, bael is termed as tridoshhar (remedy for three disturbances; bile, wind and phlegm). The tree is also worshiped to the Jains community. The 23rd Tirthankara, Bhagwan Parasnath ji enlightened under a Bael tree (Ariharan and Nagendra Prasad, 2013). In '*Baelsharbat*' fruit pulp mixed with sugar, water and tamarind juice which is used to cure stomach and intestinal disorders.

AGRO-TECHNOLOGY

Bael grows well in humid tropical and subtropical climate. It grows in wide range of soils i.e. from sandy loam to clay loam. Twelve varieties are cultivated for their fruits in Northern India. *Kacha, Ettawa, Seven Large, Mirsapuri* and *Deo Reo Large* are the varieties used especially for 'Sharbat'. The plant is commonly propagated by seeds but sometimes root cuttings are also used for the same. The pulp is removed, and then dried in sun and fresh seeds extracted from ripe fruits. To improve seed germination, seeds are first soaked in water for 6 hours and then sown on seed beds which are covered with rotten straw. Seeds germinate within 15-20 days. The flowers are aromatic and having pleasant odour. The fruits slowly develop into mature fruits. Fruiting in Bael is seen from October-March.

Bael tree generally bears 200-400 fruits, each weighing 1-2 kg. Roots are collected from mature trees at age of 10 years or more. Roots with its attached wood are marketed, for this purpose tree is cut down about 1m from the ground and then underground roots dug out carefully (Rajarajan, 1997).

PHYTOCHEMICAL AND THEIR BIOLOGICAL ACTIVITIES

Bael contains a number of chemical compounds such as coumarins, alkaloids, sterols and essential oils. Roots and fruits of bael contain coumarins such as scopoletin, scoparone, umbelliferone, marmesin and skimmin. Fruits of bael contain xanthotoxol, imperatorin and alloimperatorin. Fruit also contain alkaloids like aegeline and marmeline, b- sitosterol and its glycoside. Stem barks and roots contain a coumarin named as aegelinol. Bael roots contain xanthotoxin, psoralen, 6,7-dimethoxy coumarin, mermin, tembamide and skimmianine. Bael leaves contain the alkaloids- N-2-ethoxy-2 (4-methoxy phenyl) ethyl cinnamide, O-(3,3-dimethyl allyl)-halfordinol, N-2-methoxy-2-(4-3',3'-dimethyl allyloxy) phenyl] ethyl cinnamide, N-2-hydroxy-2-[4-(3',3'-dimethyl allyloxy) phenyl] ethyl cinnamide, N-4-methoxy sterylcinnamide, N- 2- [4-(3',3'-dimethyl allyloxy) phenyl] ethyl cinnamide and N-2-hydroxy-2-(4- hydroxy phenyl) ethyl cinnamide, Mermesinin, rutin and b-sitosterol - b-D-glucoside (Nigam and Nambiar, 2015).

Flavone, Lupeol, Eugenol, Marmeline, Citronellal, Cineol, citral, Glycoside, Skimmianine, Aeglin, Rutin, γ-sitosterol, β-sitosterol, O-isopentenyl, Halfordiol, Cumin aldehyde phenylethylcinnamamides, Eugenol and Marmesin in are found in the leaves of plant. In the fruit Aurapten, Psoralen, Marmelide, Marmelosin, Luvangetin and Tannin Bark of bael contains Fagarine and Marmin are found as good medicinal compound. The Seed is rich in Essential oil-D-limonene, A-D-phellandrene, Cineol, Citronellal, Citral, P-cyrnene, Cumin aldehyde (Hafiz Hasan, 2017).

The leaves of plant contained aegelin, lupeol, rutin, marmesinin, γ-sitosterol, β- sitosterol, flavone, glycoside, *O*-isopentenylhalfordiol, marmeline and phenylethylcinnamamides (Narayan and Yadav, 2009). The four alkaloids comprise the largest single class of secondary plant substances as from dry leaves (Govindachari and Premila, 1983; Brijesh *et al,* 2009). A series of phenylethylcinnamides new compounds named anhydromarmeline, aegelinosides A and B have been isolated from leaves of which α-glucosidase inhibitors are important in diabetes mellitus (Phuwapraisirisan *et al,* 2008; Sharma *et al,* 1981). In fresh leaves a rare alkaloid, shahidine is isolated which is moisture-sensitive, parent compound of aegeline and other amides. It showed activity against a few Gram-positive bacteria (Pattnaik *et al,* 1996).

Phenylpropanoids are naturally occurring phenolic compounds as hydroxycoumarins, phenylpropenes and lignans. Coumarin is the most widespread parent compound. Marmesin found in leaves and constituent of heartwood and root (Kurian, 1992). Aegelenine is found in leaves (Chatterjee and Majumder, 1971, Chatterjee and Roy, 1957). Aegeline consumed as a dietary supplement (Lanjhiyana*et al*, 2012). Oil is yielded from fresh leaves by distillation which is yellowish-green with a peculiar aromatic odour. Marmenol, a new 7-geranyloxycoumarin was isolated from the leaves of methanolic extract of *A. marmelos* (Ali and Pervez, 2004). Terpenoids as α-Phellandrene (56%) and p-cymene (17%) were reported from leaf oil (Baslas and Deshpandey, 1951). α-Phellandrene was found to be the common constituent of the essential oil of leaves, twigs and fruits (Bauer *et al*, 1986; Karaway *et al*, 1980). Compound p-Menth-1-en-3,5-diol, limonene (82.4%) and γ-Sitosterol reported as the main constituent of leaves (Garg*et al*, 1995; Kaur *et al*, 2006; Chakravarti and Dasgupta, 1958). Tannins in leaves found as skimmianine (4,7,8-trimethoxyfuro-quinoline) (Daniel, 2006).

Flavonoids are mainly found as rutin, flavone, flavan-3-ols, flavone glycosides. It has been reported that bael contains highest alkaloids (1.08%), tannins (15.26%), flavonoid (0.98%) and saponins (2.62%) in leaves as compared with other plants (Dhandapani and Sabna, 2008). The GC-MS analysis has also been done in bael and it revealed many bioactive compounds like flavonoids, alcohols, aldehydes, aromatic compounds, fatty acid methyl esters, terpenoids, phenolics, and steroids that can be postulated for antibacterial activity (Mujeeb*et al*, 2014).

Seed oil is bitter in taste and contains palmitic acid (15.6%), stearic acid (8.3%), linoleic acid (28.7%) and linolenic acid (7.6%) while seed residue contains about 70% proteins (Sivaraj*et al*, 2011).Praealtin-D, betulinic acid, *N*-p-*cis*- & *trans*-coumaroyltyramine, montanine, *trans*-cinnamic acid, valencic acid, 4-methoxybenzoic acid and rutaretinyielded from the leaves of methanolic extract of plant (Ali and Pervez, 2004). Rutin, flavan-3-ols, anthrocyanins, lecucanthrocyanins, flavone glycosides and tannins isolated from the leaves (Sharma*et al*, 1981).

PHARMACOLOGICAL PROPERTIES

Root, bark, leaves and fruits of the plant are hypoglycemic, astringent, febrifuge, antidiarrhoeal and antivenin. Leaf is anti-inflammatory, expectorant, anti-catarrhal, anti-asthamatic, anti-ulcerous and ophthalmic. Unripe fruit is stomachic and demulcent. The mature fruit has cardiotonic, restorative, laxative, antitubercular, antigonorrhoeal, antidysenteric and antiscorbutic properties. Seed is anthelmintic and antimicrobial, flower is emetic (Ankita *et al*, 2018).

The fresh cut wood is gray-white, hard and strongly aromatic. The wood is not durable so used in carts, construction, carving, small-scale turnery, tool and knife handles, pestles and combs by taking a fine polish. The leaves and twigs are lopped for fodder. The gum enveloping the seeds is most abundant in wild unripe fruits. The gum is used as household glue as adhesive by jewelers or resorted as a soap-substitute. Gum is mixed with lime plaster for waterproofing walls; artists add it in watercolors or applied as a protective coating on paintings.

In pulp of wild fruits approx. 9% tannin is occurred as compared to cultivated types. The rind contains up to 20% tannin; unripe fruit used in tanning and yields a yellow dye for calico and silk fabrics. Tannin is also present in the leaves.The essential oil of the leaves contains d-limonene. The limonene-rich oil is distilled from the rind which is used for scenting hair oil.

The leaves are said to cause abortion and sterility in women shows poisonous property of plant. As a fish poison plant bark is used. Leaf extract has insecticidal activity against *Nilaparvata lugens* (brown plant hopper) on rice plant in Asia.

Decoction of the unripe fruit with fennel and ginger is prescribed in hemorrhoids. Psoralen in the pulp increases tolerance of sunlight and aids in the maintaining of normal skin color and employed in the treatment of leucoderma. Marmelosin derived from fruit pulp is laxative and diuretic but in large doses it lowers the rate of respiration, depresses heart action and causes sleepiness. The young fruits (tender) sliced, sun-dried and sold in local markets. They are much exported to Malaysia and Europe. In India, in summer days due to its astringic property the unripe wild fruits are prized by means of halting diarrhea and dysentery. The hard shell of fruits fashioned into pill- and snuff boxes or decorated with gold and silver. The tree can grow well in minimum of fertilizer and irrigation without any specific requirements. Plant may yield 200 to 800 fruits in a season depending upon cultivar and environmental conditions. The spacing in orchards is 6-9 m between plants (Lambole *et al*, 2010).

Baelextract effectively reduced the oxidative stress induced by alloxan and reduction in blood sugar. There was a significant decrease in lipid peroxidation, conjugated diene and hydroperoxide levels in serum as well as in liver induced by alloxan (Singh *et al*, 2000). In a study the hypoglycaemic and antioxidant activity of leaf extract by analyzing the glucose, urea and GST (glutathione-S-transferase) levels in plasma and GSH (glutathione) and MDA (malondialdehyde) levels in erythrocytes of alloxan induced diabetic rats (Upadhya *et al*, 2004). Leaf extract administration has been noticed in returning the diabetic male albino rats to normal level suggesting its antidiabetic potential. Eugenol and marmesinin may be responsible

antioxidant activity due to their independent activity against oxidative stress (Nagashima, 1989; Ogata *et al*, 2000).

In vitro antioxidant activity of the methanolic extract of leaf was studied using standard methods like DPPH scavenging activity, H_2O_2 scavenging activity, and ferrous reducing power and found that it has good antioxidant activity and potential inhibitor of free radicals (Siddique and Mujeeb, 2010). The leaves screened for phytochemicals, antioxidant (DPPH) and polyphenol content (Folin-ciocalteu assay) using a series of solvents found that methanol and water extract of leaves are rich in ascorbic acid, glutathione, flavonoids, saponins, reducing sugars, turpenoids and polyphenols.

Extract of leaves, root and stem bark of bael has greater amount of phenolic compounds which leads to more powerful radical scavenging effect as shown by methanolic extract of leaves (Bhalla *et al,* 2012). The leaf extract has anti-diabetic properties on liver of *Streptozotocin* diabetic rats and found effective as insulin in restoring of blood glucose and body weight to normal levels (Seema *et al,* 1996; Rao *et al,* 1995; Ponnachan *et al*, 1993).

In a study, antioxidant and anti-plasmodial activities of *Curcuma longa* and *Aegle marmelos* on malaria infected mice (*In vitro* and *In vivo)* were studied using DPPH free radical scavenging activity and reported that bael exhibited higher antioxidant activity and polyphenol content than *Curcuma longa* (Kettawan *et al*, 2012). Ethanol extract of bael has higher antioxidant activity values of 46.08%, 50.56% and 54.32% at of 5, 10 and 15mg/ml concentration respectively (Sathya *et al,* 2013). In Ayurvedic system it is for the treatment of diabetes mellitus (Saxena and Vikram, 2004). Aqueous leaf extract of bael have anti hypoglycemic activity or found to inhibit primarily the uptake of glucose across rat inverted gut sacs (Therasa *et al*, 2009).

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