



## Review Article

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### AEGLE MARMELOS (BAEL PATRA): AN AYURVEDIC PLANT WITH ETHNOMEDICINAL VALUE

Shailja Choudhary<sup>1</sup>, Gitika Chaudhary<sup>2</sup>, Hemlata Kaurav<sup>3\*</sup>

<sup>1</sup> Research Executive, Shuddhi Ayurveda, Jeena Sikho Lifecare Pvt. Ltd. Zirakpur, Punjab, India

<sup>2</sup> Head of the Department, Research and Development Department, Shuddhi Ayurveda, Jeena Sikho Lifecare Pvt. Ltd. Zirakpur, Punjab, India

<sup>3</sup> Research Associate, Shuddhi Ayurveda, Jeena Sikho Lifecare Pvt. Ltd. Zirakpur, Punjab, India

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\*Corresponding author

E-mail: kaurav.hem.88@gmail.com

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#### ABSTRACT

*Aegle marmelos* is considered as the most sacred or holy plant which is grown by the sides of Hindu temples. This plant is dedicated to Lord Shiva and is also believed that Lord Shiva resides under the Bael tree. Besides this, the plant is associated with a great medicinal value whose medicinal description is also mentioned in the ancient treatise like Vedas, Puranas, Charaka Samhita and Brihat Samhita and has also been portrayed in the paintings of Ajanta caves. Every part of the Bael plant is used to treat various diseases. In Ayurveda, the plant is used in Panchang form to treat diarrhea, dysentery and ulcer. In folklore, the plant parts are used to treat diabetes, skin diseases and typhoid, wound healing, ulcer, stomachache, jaundice, high BP, malaria, cancer and other diseases. The fruit of the plant is edible and carries great medicinal value because of the presence of vitamins, minerals and various antioxidants. The pulp of the fruit is aromatic, sweet, pale orange and resinous. The unripe fruit pulp of the plant is used to prepare murabba, pudding and juice. The plant is associated with ethnomedicinal uses and possesses various therapeutic and pharmacological properties including antioxidant, anti-diabetic, anti-histamine, radio protective, antiulcer, anticancer, cardio-protective, antidiarrheal, antibacterial, antimicrobial, hepatoprotective, anti-inflammatory and antiviral. In this review article, attempts have been made to summarize the phytochemistry, ethnomedicinal, Ayurvedic and pharmacological view of the Bael plant.

**Keywords:** Bael, *Aegle marmelos*, Ayurveda, Folk view, Pharmacological activities

#### INTRODUCTION

*Aegle marmelos* is commonly known as Bael, bilva golden apple, Indian quince and stone apple<sup>1</sup>. *A. marmelos* (Bael tree) (Figure 1) belongs to the citrus family Rutaceae<sup>2</sup>. It is the most significant underutilized medicinal, Indigenous fruit crop of India. This plant is of high economic value and is known in India since 800 B.C. as per historical reports. In 1629 A.D., the Chinese Buddhist pilgrim, Hiuen Tsiang also noticed the presence of the Bael tree during his visit to India<sup>3</sup>. As per Hindu culture, the plant is considered as a sacred tree that is grown by the sides of Hindu temples as the plant is dedicated to Lord Shiva. The trifoliate leaves of the plant are used in the prayers of Lord Shiva and Parvati, hence the plant is also known by the name of Shivaduma. It is also believed that Lord Shiva resides under the Bael tree. Besides this, the plant carries great medicinal value and its medicinal description is also mentioned in the Vedas (Yajurveda), Puranas and has also been portrayed in the paintings of Ajanta Caves<sup>4</sup>. The Bael fruits were known since the Ramayana period and the tree was reported to be found in the Panchvati and Chitrakuta hills. The medicinal properties of the fruit of the Bael tree are also described in the ancient treatise Brihat Samhita and Charaka Samhita<sup>5</sup>. As per ancient beliefs, the Bael tree acts as an indicator plant to trace the underground water. All the parts of the plant i.e. root, leaf, trunk, seed and fruits carry various medicinal properties and are used to treat variety of diseases. The fruit of this plant is edible and is mostly used for medicinal purposes as it is a rich source of vitamins, minerals and antioxidants<sup>6</sup>. It also acts as a Climate Purifier that absorbs the poisonous gases from the atmosphere and making them inactive or neutral<sup>7</sup>. The plant is associated with various bioactive compounds. The main active

phytochemical constituents isolated from the fruit part of the plant include marmelosin (helps in curing stomach diseases), psoralen, luvangetin, tannins and marmin<sup>8,9</sup>. In Ayurveda, all the parts are used in the form of 'Panchang' to cure diseases like diarrhea, dysentery and ulcer. The plant is also used to cure diseases like asthma, fractures, anemia and swollen joints, wound healing, diabetes, high BP, jaundice, diarrhea, brain typhoid troubles during pregnancy, stomachache, cancer, malaria and gastroduodenal disorders<sup>10-13</sup>. Besides this, the plant extracts are associated with pharmacological properties like anti-diabetic, antiulcer, antioxidant, anti-hyperlipidaemic, anticancer, antipyretic, radio-protective, analgesic, anti-inflammatory and anti-spermatogenic<sup>14-18</sup>. The vernacular names and taxonomical classification of the Bael plant are shown in Table 1 and 2.

#### Botanical description of *A. marmelos*

*Aegle marmelos* is a spinous, slow-growing, medium sized tree belonging to the family Rutaceae. The plant grows up to the height of 12-15 m and 90-120 cm in girth. The trunk is short, thick, soft, flaking bark with spreading spiny branches. Spikes present are long, sharp and axial<sup>24</sup>.

#### Leaves

The leaves of *A. marmelos* are alternate, trifoliate, aromatic, deciduous borne as single or compound and comprises of 3 to 5 oval, pointed shallowly, thin toothed leaflets with length 4-10 cm and 2-5 cm in width, terminal one have long petiole while the lateral one is without a petiole. Leaves are composed of 3 to 5 leaflets. Leaf petiole is long and glabrous. Mature leaves possess a disagreeable odor when bruised<sup>25,26</sup>.

**Table 1: Vernacular names of Bael Patra**

Hindi	Bel, Beli, Belgiri, Baelpatri, sirphal, kooralam
Sanskrit	Bilva, Shividruma, Shivaphala, Vilva
English	Golden apple, Bael fruit, Indian Bael, Holy fruit, Indian quince, elephant apple, stone apple
Urdu	Bel, Bel kham
Himachal Pradesh	Bil
Bengal	Bael
Karnataka	Bilpatra, kumbala, malura
Andhra Pradesh	Maredu
Kerala	Kuvalum
Assamese, Marathi	Bel
Gujrati	Bilivaohal, Bili
Malayalam	Marredy
Oriya	Belo
Tamil	Vilva marum
Telugu	Bilva pandu
Burmese	Opesheet, ohshit
French	Bel indien, cognassier du, Bengale, oranger du Malabar
German	Belbaum, Schleimapfelbaum, Baelbaum
Portuguese	Marmelo <sup>19-23</sup>

**Table 2: Taxonomical Classification of *Aegle marmelos***

Taxonomical Rank	Taxon
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Sapindales
Family	Rutaceae
Sub-family	Aurantioideae
Genus	<i>Aegle</i>
Species	<i>A. marmelos</i>
Common name	Bael Patra, Bael

**Figure 1: *Aegle marmelos* (Bael tree)****Flower**

Flowers are fragrant, 2 cm wide, erect, stalked, sweet-scented and formed a cluster of about 4 to 7 flowers, 4 to 5 recurved fleshy petals, yellowish from inside and greenish from outside with 50 or more greenish stamens. The calyx is shallow with five short broad teeth, capitate stigma ovary is oblong-ovoid and has slightly tapering thick short style<sup>27</sup>.

**Fruit**

Fruits are round, aromatic, pale orange, fibrous oval, oblong-pyriform up to 5-20 cm in diameter and contain a hard, smooth-woody shell i.e. pericarp. In the early stages, the crust is gray-green which turns orange or yellowish when matured and becomes very hard and orange-red when dried. The hard central core with 8 to 20 indistinctly apparent triangular segments with thin dark orange walls is present inside the fruit. The pulp of the fruit is resinous, sweet, aromatic, pale-orange and astringent. Due to the slow ripening, the fruit can take 1 year for full ripening<sup>28</sup>.

**Seed**

Seeds are hairy, flattened-oblong shape, that varies from 10-50, embedded in the pulp of a fruit and germinate within 2-3 months. The seed encases in a sack of sticky transparent mucilage that solidifies after drying. Most of the seeds get aborted during the development process. The testa is white<sup>29,30</sup>.

**Geographical distribution of *A. marmelos***

It is believed that the *A. marmelos* is originated from the Eastern Ghats and Central India. It is a native species of the Indian sub-continent and Southeast Asia and is grown in tropical and subtropical regions. The plant is grown in lower regions of the Himalayas up to an altitude of 500 meters and is grown best in dry, mixed deciduous, dry dipterocarp forests and soil of India. It was reported that the plant requires well-drained soil of pH 5-8 but from various studies and grower reports, it was found that the plant can also survive in stony, alkaline, stony and shallow soil<sup>31</sup>. It is mainly found in Northern India. The plant is distributed throughout Myanmar, Bangladesh, Thailand, Burma, Ceylon, Indo-China, Sri Lanka, Vietnam, Pakistan, the Philippines, Cambodia, Malaysia, Java, Egypt, Surinam, Trinidad, Florida and Indian Peninsula<sup>32</sup>. As per historical studies, the Bael plant occurs in India since 800 B.C. In India, the plant is distributed in Uttaranchal, Jharkhand, Deccan Plateau, Uttar Pradesh, Bihar, Chhattisgarh and Madhya Pradesh and along the foothills of Himalayas and east coast<sup>33</sup>. The plant is famous for its fruit species in India and Sri Lanka and can grow in very tough soil where other plants cannot survive<sup>34</sup>.

**Phytochemical constituents of *A. marmelos***

The chemical constituents isolated from the different parts of the plant are described below. The chemical structures of some major phytochemicals are shown in Figure 2.

**Fruit**

The fruit part contains bioactive compounds, carbohydrates, minerals, vitamins, coumarins, phenolic acids alkaloids, flavonoids, organic acids, volatile compounds and fatty acids. *Aegle marmelos* plant is a rich source of various nutrients including carbohydrates (31.80 g/100 g) fibers (2.90 g/100 g), minerals (1.70 g/100 g), fats (0.39 g/100 g) and vitamins such as Vitamin A (0.05 mg/100 g), vitamin B2 (1.20 mg/100 g), Vitamin C (8.0 mg/100 g), riboflavin (0.03 mg/100 g), thiamine (0.13 mg/100 g) and beta-carotene (55.0 mg/100 g)<sup>35</sup>.

### Coumarins

Coumarins extracted from the fruit part of the plant include 6-(2-hydroxy-3-hydroxymethyl-3-butenyl)-7-hydroxycoumarin, 6-formylumbilliferone, 6-(4-acetoxy-3-methyl-2-butenyl)-7-hydroxyl coumarin, 8-hydroxysmyrindiol, 8-[(3-methyl-2-oxo-3-but-en-1-yl)oxy]-7H-furo[3,2-g]benzopyran-2-one, isofraxidin, isogosferol, alloimperatorin, decursinol, demethylsuberosin, marmelosin, isophellodenol C, psoralen, marmelonine, umbelliferone, scoparone, scopoletin, xanthotoxin, xanthoarnol and xanthotoxol<sup>36-41</sup>.

### Phenolic acids and Flavonoids

Phenolic acids and flavonoids extracted from the fruit part include ellagic acid, quercetin, chlorogenic acid, gallic acid, ferulic acid, and kaempferol and protocatechuic acid<sup>42</sup>.

### Alkaloids

Alkaloids isolated from the fruit part include aegelenine, aegelin, marmeline, marmesiline, O-(3,3-dimethylallyl) halofordinol and O-methylhalfordinol<sup>43</sup>.

### Volatile compounds

It includes 1,8-cineole, 3,5-octadiene-2-one, acetoin, (E)-2-octenal,  $\epsilon$ -6,10-dimethyl-5,9-undecadien-2-one, (E, E)-2-4-hepaoenoal, carvone, citral, caryl acetate, citronellal, caryophyllene oxide, dehydro-p-cymene, eugenol, hexanal, hexadecane, beta-ionone, humulene oxide, linalool oxide, limonene, p-cymene, verbenone, trans-p-mentha-2,8-dienol, alpha-humulene, beta-cubebene, beta-phellandrene and isoamyl acetate<sup>44</sup>.

### Carbohydrates

Arabinose, fructose, galactose, sucrose and glucose

### Organic acids

Malic acid, tartaric acid and oxalic acid

### Vitamins

Riboflavin and ascorbic acid<sup>45</sup>

### Leaves

The chemical constituents extracted from the leaf part include coumarins (mermenol and praelein), O-(3,3-dimethylallyl) halofordinol, N-4-methoxystyryl cinnamide, N-2-methoxy-2-[4-(3',3'-dimethyl allyloxy) phenyl] ethyl cinnamide.

### Bark

Coumarins include aegelinol, mermesin, marmesin and umbelliferone and alkaloids include skimmianine, gamma-fagarine<sup>46-51</sup>.

### Root

The chemical constituent isolated from root parts include alkaloids which include disctamine, haplopine, tembamide, gamma-fagarine and tembamide and coumarins include aegelinol, marmesin, marmin, scopoletin, umbelliferone, xanthotoxin<sup>52-54</sup>.

### Traditional and modern view of *Aegle marmelos* plant

#### Ayurvedic View

*A. marmelos* plant is acknowledged as the most significant plant in the Ayurvedic medicinal system. It balances the Kapha (water and earth component) and Vata (space and air component) dosha. The fruit of this plant is medicinally used in the Ayurvedic, Siddha and Unani medicinal system and is considered an excellent remedy for diarrhea<sup>55</sup>. The medicinal properties of the plant are briefly described in Charaka Samhita<sup>56</sup>. All the parts of the plant i.e. trunk, leaf, seed and fruit are used to treat various types of diseases<sup>57</sup>. The leaves of the plant carry expectorant, astringent and febrifuge properties that help in treating bleeding disorders, edema, hemorrhoids and bowel complaints. In Ayurveda, the roots of the plant are commonly used as an important ingredient in the Ayurvedic drug named 'Dashamoola' which is used to cure dysentery, colitis, diarrhea, flatulence, loss of appetite and fever since ancient times. The fruits of the plant are used in making Chyavanprash. The unripe fruit in Ayurveda is used as a tonic for the heart and brain and is used to treat chronic diarrhea and dysentery<sup>58</sup>. The tree barks and roots of the plant relieve urinary problems and palpitation of the heart<sup>59</sup>. The juice of *A. marmelos* helps in improving digestion, scurvy and strengthens stomach actions<sup>60</sup>. In Ayurveda, the plant is used to cure indigestion, intermittent fever, typhoid, cholera, heart palpitation, heart, stomach and intestinal disorders because of the presence of carminative and digestive properties. The unripe fruit is associated with more medicinal value as compared to ripe fruit. The leaves, fruits and bark of this plant have been reported to have anti-diabetic property<sup>61</sup>. The Rasapanchak (properties) of the plant is shown in Table 3.

#### Actions and Properties of *A. marmelos* plant

Kapha vata shamaka: It balances the Kapha and Vata dosha.

Shothahara: The leaves of the plant are used to cure edema.

Vedanasthapan: The plant is associated with analgesic property which helps in reducing pain.

Naaditanu: The roots of the plants are used to treat neurological disorders.

Deepan: The unripe fruit of the plant acts as an appetizer.

Krimighna: The plant is associated with an anti-helminthic property.

Mridurechan: The ripe fruit of the plant acts as a mild laxative.

Yakritdutejak: The leaf decoction of the plant helps in enhancing metabolism.

Pittasarak: It stimulates the digestive juices.

Hridya: It is used as a cardio-protective agent.

Raktastambhak: It is used to cure the bleeding disorder.

Mutra: It is used to treat the micturition problem.

Garbhashaya shotha: It improves uterine health.

Jwarghna: It helps in treating chronic disorders and acts as an antipyretic agent.

Anidra: It helps in treating insomnia.

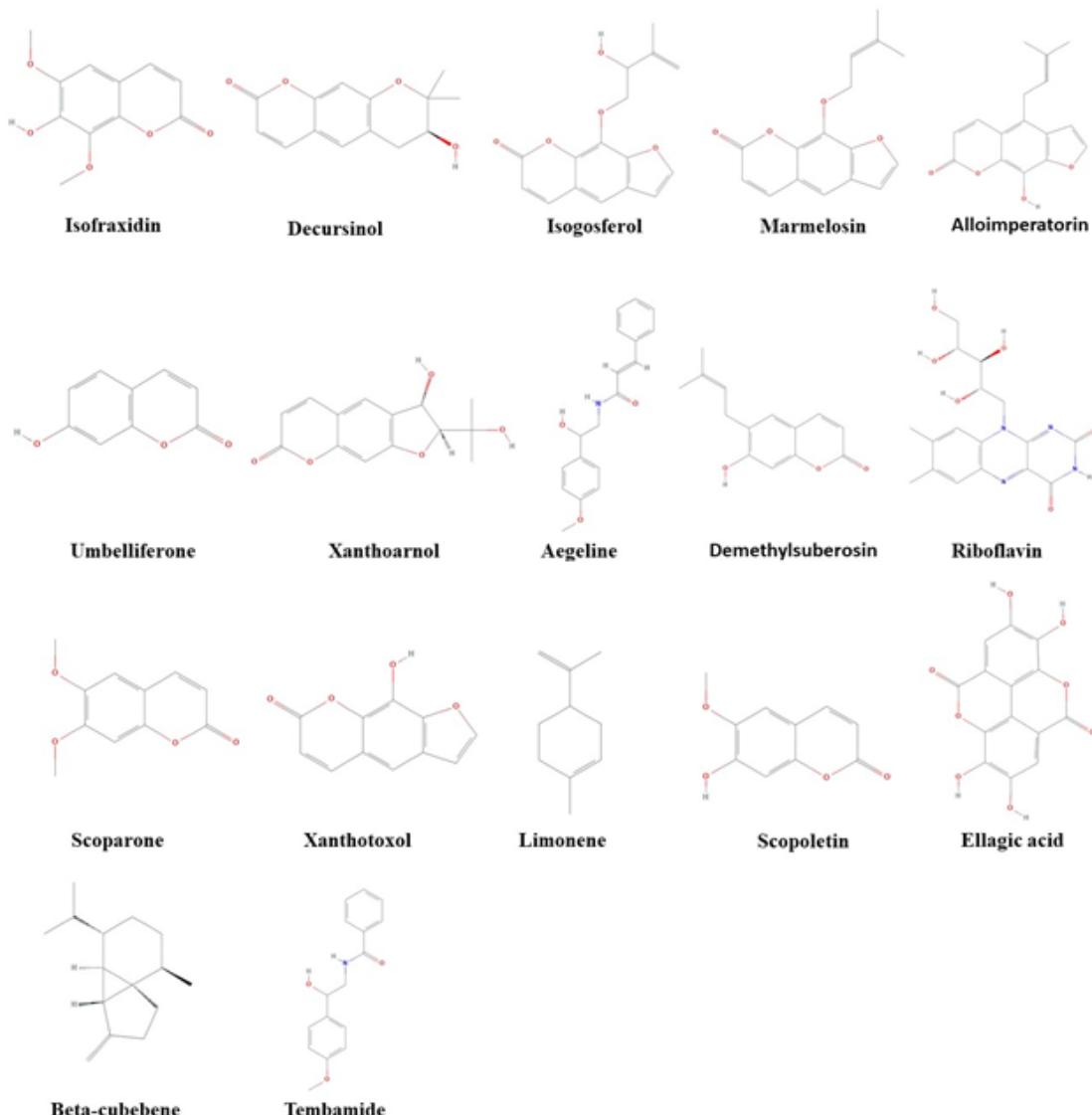
Atisaar and Pravahika: It is used to treat diarrhea and dysentery disorders.

Grahnai: It is used to cure irritable bowel syndrome (IBS).

Udarshool: It helps in relieving abdominal pain.

Vibandh: The ripe fruit of the plant helps in curing constipation.

Netrabhisbyand: The leaf decoction or leaf paste helps to cure cataract disease.

Figure 2: Chemical structures of some major phytochemicals of *Aegle marmelos* plant.Table 3: Rasapanchak (properties) of *A. marmelos* plant

Sanskrit / Hindi	Sanskrit / Hindi
Veerya / Potency	Ushna / Hot
Vipaka / Metabolic property	Katu / Bitter
Guna / Physical property	Laghу / light, Ruksha / dry
Rasa / Taste	Kashaya / astringent, Tikta / astringent

### Folk Uses

The *Aegle marmelos* (Bael) plant is considered as the most sacred plant which is dedicated to Lord Shiva as per Hindu religion. *Aegle marmelos* tree is also known as Shivaduma (the tree of Lord Shiva) and another form of Lord Kailashnath. It is believed that Lord Shiva lives under the Bael tree. It is also said that Goddess Laxmi resides in the leaves of Bael plant. The trifoliate leaves (bilva-patra) of the Bael plant is offered to Lord Shiva and the three leaflets are believed to be the symbol of three attributes or gunas namely Satwa (morality), rajas (superiority) and tamas (immorality), three Gods (Brahma, Vishnu and Mahesh) and three lives (past, present and future) respectively. The Bael plant is also mentioned in the Indian ancient scriptures such as Vedas (Yajurveda) and Purana (Mahabharata)<sup>62,63</sup>. The leaves of this plant are used for enchantments. The cutting of the Bael tree is

considered a sinful act as per Hindu culture. The plant is mostly cultivated around the Hindu temples as it holds extreme auspicious value. The *A. marmelos* plant carries great medicinal value and is used in the treatment of various diseases. In India<sup>64</sup>, Bangladesh<sup>65</sup> and Sri Lanka<sup>66</sup>, the plant is used in the treatment of diabetes. The juice prepared from the pulp part of fruit produces a soothing effect in the recovered patients of bacillary dysentery<sup>67</sup>. The oil prepared from the unripe fruit when soaked in gingelly oil for a week is useful in removing the peculiar burning sensation in the soles. The root, leaf and bark decoction of the plant is used to treat intermittent fever, heart and stomach disorders<sup>68</sup>. The leaves of the plant are said to be beneficial for the treatment of backache, cholera, asthma, ophthalmia, hypoglycemia, hearing loss, febrifuge, inflammation analgesia and hepatitis. The leaves are also used in veterinary medicine to cure the wound, killing worms and as fodder for sheep, goat and

cattle<sup>69,70</sup>. The wood of the plant in polish form is used in agricultural implements, constructing carts and building houses. From ancient times, the ripe fruit of the plant is used as a dietary source in the Indian subcontinent<sup>71</sup>. In India, the semi-ripe fruits are used in the preparation of jams by adding sugar, citric acid and are also used as a preservative<sup>72</sup>. The pulp of the fruit is used in making murabba and syrups, in a jelly form which is eaten with Indian bread and is also used in manufacturing wrapping paper<sup>73</sup>. In Thailand, the fruits of the plant in dried form are packed as a teabag. The fruit is also preserved in syrup form that is used as an ingredient in the preparation of cakes and dessert. The roots of the plant are effective against urinary troubles, abdominal pain, fever, cardiac malfunction, melancholia and hypochondriasis. The mature fruit of the plant in fresh form is used as an astringent, febrifuge, appetizer, tonic, digestive and laxative agent and is used to treat epilepsy, constipation, gastric troubles, ulcer, intestinal parasites, gonorrhea and stomachache<sup>74,75</sup>. In Burma, the fruit of the Bael plant is used in making paints. In Bangladesh, the fruit of the Bael plant is used as an anti-proliferative agent and also helps in fertility control<sup>76</sup>. The fruit of the plant in powder form is used to cure cancer. The formulation prepared from the combination of all the parts of the plant i.e. root, bark, leaf and the flower is believed to be effective against various mental disorders. The immature fruit pulp of the plant when mixed with boiled rice water is used to cure vomiting in pregnancy which is taken twice a day. The immature fruit pulp is also helpful in treating urinogenital diseases when mixed with sugar and milk. The leaf extract of the Bael plant is used to get rid of intestinal worms. The fresh leaves of the plant in paste form are used to cure abscesses. Leaves poultice is used in the treatment of eye disorders. The polyherbal formulation made by mixing the Bael root extracts, *Allium cepa* Linn. and *Curcuma domestica* in equal amounts helps in treating earache and ear secretions. In children, the Bael tea is used to cure flatulence, cough, chronic intestinal diseases and gastrointestinal disorders. Because of the presence of detergent property, the pulp of the fruit of the Bael plant is used in washing clothes. The flower of the plant is associated with expectorant and wound healing properties and is used to cure epilepsy disorder. The gums around the seed are used to improve the adhesive strength of water paints. The shell of hard fruit is used as a pillbox, snuffboxes and sometimes decorated with gold and silver<sup>77</sup>.

### **Modern View**

In the modern world, people are taking more interest in herbal medicines because of their lesser side effects, easy availability and cheaper prices. The consumption of herbal medicines has increased world widely. Reported studies have revealed an increased growth in the sale of herbal products from the year 2000 to 2008 that is reached from 3% to 12% per year. With the increasing demand of the people, adulteration and substitution also rise in the herbal drug industry which is considered as a major threat to the quality and in the research areas on commercial natural products. The main reason for the adulteration is the non-availability of the original plant product, deforestation, extinction of many herbal plant species, confusion in the species identification, etc. Also, many herbal dealers have developed new methods of high-quality adulteration that can only be identified by using chemical analysis and microscopic examination<sup>78</sup>. The poor quality of the drug and lack of standardization are the two weaknesses that lay behind the acceptance of herbal products which results in the decreased market value of the product. So, there is a need to develop an Herbal Authentication System (HAS) which can serve as a regulator and helps in improving the quality of herbal trade<sup>79</sup>. The herbal plant named *Aegle marmelos* is associated with multiple medicinal properties. The destruction and over-exploitation of the plant have their historical concerns.

To protect the plant from over-exploitation, it is attached with the name of the tree of Lord Shiva and Goddess Laxmi to prevent it from destruction. Presently, the Bael plant has become popular because of its medicinal use in both human and animal diseases. Due to the high economic value of the *A. marmelos* plant, people who once used the plant products judiciously became ruthless and destructive collectors. To prevent the plant from destruction, the National Medicinal Plants Board of the Government of India has placed the *A. marmelos* plant on the priority list of 32 medicinal plants and many projects have been sanctioned by the government for the conservation and sustainable utilization of the plant<sup>80</sup>.

### **Reported therapeutic and Pharmacological properties**

The various therapeutic and pharmacological properties of the *A. marmelos* plant are proved by various clinical and experimental studies. Some of the reported studies of the plant are briefly discussed below. Table 4 represents the summary of pharmacological activities of the *A. marmelos* plant.

#### **Antioxidant activity**

The Methanolic and ethanolic extract of the fruit pulp of *A. marmelos* plant was tested for antioxidant activity in a rat model by DPPH radical scavenging method, nitric oxide scavenging assay, reducing power assay, H<sub>2</sub>O<sub>2</sub> radical scavenging assay, ABTS radical scavenging assay and superoxide radical scavenging assay<sup>81</sup>. The free radical inhibition was observed by the Methanolic and ethanolic extract of the plant that showed good antioxidant activity of the plant. The inhibitory activity of the unripe fruit is more than the mature fruit<sup>82</sup>.

#### **Antimicrobial activity**

The petroleum ether, ethanol and aqueous extract of the leaves of the *A. marmelos* plant were tested for antimicrobial activity using the agar well diffusion method. It was found that the extracts showed effective results against *E. coli*, *Streptococcus pneumonia*, *Salmonella typhi*, *Proteus vulgaris* and *Klebsiella pneumonia*. It was also observed that petroleum ether and aqueous extract showed antimicrobial activity against *Fusarium oxysporum* while ethanolic extract showed activity against *Penicillium chrysogenum*<sup>83</sup>.

#### **Antifungal activity**

The ethanolic extract of the root showed antifungal activity against *A. fumigatus* and *T. mentagrophytes*<sup>84</sup>. The essential oil isolated from the leaves of the Bael plant showed antifungal activity against *Trichophyton mentagrophytes*, *T. rubrum*, *Microsporum gypseum*, *Histoplasma capsulatum*, *A. flavus*, *M. cookie* and *Aspergillus niger*<sup>85</sup>.

#### **Anti-diabetic activity**

All extracts of *A. marmelos* leaves was investigated for hypoglycemic activity against various animal models. The aqueous and alcoholic extract of the fruit part showed hyperglycemia activity against rabbits at the dosage of 500 mg/kg body weight<sup>86,87</sup>. The fruit extract of the plant showed protective effects on pancreatic tissues in diabetic rats<sup>88</sup>.

#### **Anti-proliferative activity**

The ethanolic extracts of the plant were reported to show anti-proliferative effects against various human tumor cell lines. The cells are allowed to grow for 24 hours in a carbon dioxide incubator. The plant extract was added further after the complete growth of the cells and incubated for 48 hours. It was observed that the extract inhibits the *in vitro* proliferation of human tumor cell lines including the leukemic K562, T-lymphoid jurkat, B-lymphoid Raji, erythroleukemic HEL, melanoma Colo 38 and breast cancer MCF and MDA-MB-231 cell lines.<sup>89</sup>

### Cytoprotective activity

To identify the Cytoprotective activity of the *A. marmelos* plant, the study was carried in *Cyprinus carpio* or freshwater fish. The experimental fish was provided with the sun-lethal concentration of metal ion for 1, 8, 16 and 32 days. Later, these fishes were fed with crude powder of the *A. marmelos* plant at a dosage of 500 mg/kg. Results showed the stabilization of plasma membrane and modulation of antioxidant enzymes system, thus showed cardioprotective activity<sup>90</sup>.

### Hepatoprotective activity

The alcoholic extract of the leaves of the *A. marmelos* plant was tested for the hepatoprotective activity against the albino rat model. Rats were injected (intra peritoneal route) with bacterial suspension at a dosage of 5\*106 CFU/0.1 ml. Later, the animal model was treated with the alcoholic extract of the plant for 15 days. After that, the albino rat fasted for 12 hours and mild chloroform anesthesia was given to the model. 30% ethyl alcohol extract was administered to albino rats regularly for 40 days and then fed with the leaf powder of the plant for the next 21 days. The hepatoprotective effect of the *A. marmelos* leaf was observed in the experimental model<sup>91</sup>.

### Antifertility activity

The Methanolic extract of the leaves of *A. marmelos* plant was investigated for antifertility activity in the male rat model. It was found that the Methanolic extract at the dosage of 200, 400 and 600 mg/kg showed an abnormal reduction in the sperm count with the decrease in the motility of sperm and also affects the sexual behavior and epididymal sperm concentration<sup>92</sup>.

### Anticancer activity

The plant extract was tested for the anticancer activity against tumor cell lines by using sea urchin egg assay, brine shrimp lethality assay and MTT assay method. The plant extract showed toxic effects against all the used assays<sup>93</sup>. Jagetia G.C. et al also reported that the hydro alcoholic extract of the leaves exhibits anticancer effects in the *Ehrlich ascites carcinoma* and proposed that the induction of apoptosis may be due to the presence of skimmianine in the plant extract<sup>94</sup>.

### Analgesic activity

The Methanolic extract of the leaves of the Bael plant was tested for analgesic activity using writhing and tail immersion test in the mice model at a dosage of 200 mg/kg. Results showed a significant analgesic activity of the plant<sup>95</sup>.

### Antiviral activity

The hydro alcoholic extract of the fruit of the Bael plant showed significant antiviral activity when tested against Ranikhet disease virus<sup>96</sup>.

### Antilcer activity

The polyherbal formulation prepared from the leaf part of *A. marmelos*, rhizome of *Glycyrrhiza glabra* (200 mg), the root part of *Hemidesmus indicus* and fruit part of *Cuminum cyminum* was investigated for antilcer activity against ethanol-induced gastric ulcer model in Wistar rats. The oral administration of the polyherbal formulation at the dosage of 500 mg/kg produces moderate inhibition of gastric lesions in the rat model concerning the standard 20 mg/kg omeprazole administration. It was found that the polyherbal formulation can be useful to treat severe gastric ulcers and produces a non-toxic effect seven at high concentration<sup>97</sup>.

### Anti-arthritis activity

The Methanolic extract of the leaves of the Bael plant showed anti-arthritis activity against collagen-induced arthritis in Wistar albino rats. Significant reduction in the histopathological and radiological changes was observed in the experimental rat model after their treatment with Methanolic extract of the plant<sup>98</sup>.

### Contractile activity

The alcoholic extract of the leaves of the Bael plant was tested for the contractile activity against guinea pig isolated ileum and tracheal chain because of its use in treating asthma and related disorders. It was observed that the alcoholic extract at dosages of 1 mg/ml and 2 mg/ml showed significant relaxation of guinea pig ileum and tracheal chain because of the depression of H1 receptors<sup>99</sup>.

### Immunosuppressant activity

The Methanolic extract of the fruit was investigated for the immunosuppressant activity against Wistar albino rats using carbon clearance assay and neutrophil adhesion test. It was found that the extract at the dosage of 500 mg/kg showed immunomodulatory activity against the rat model by increasing the production of neutrophil adhesion and phagocytic index in carbon clearance assay<sup>100</sup>.

### Wound healing activity

The effect of Methanolic extract of the seed's ointment and injection of Bael plant was investigated against excision wound model in male Wistar rats. The ointment was applied over the wound till its complete healing and measured on 0, 4, 8, 12, 16 and 20 post wounding day<sup>101</sup>. Results showed a faster healing rate and showed a higher rate of contracting wounds when compared with the control sample. The increase in the tensile strength in the incision model showed the healing process of the plant extract<sup>102</sup>.

### Antimalarial activity

The root extract of the plant was tested against the *Plasmodium falciparum* parasite (K1, multidrug-resistant) using Trager and Jensen method<sup>103</sup>. The micro-culture radioisotope technique was used to assess the antimalarial activity of the plant. Results showed an effective antimalarial activity against the parasite<sup>104</sup>.

### Anti-stress and adaptogenic activity

The aqueous extract of the plant was studied for anti-stress and adaptogenic activity against albino rats of either sex using Swimming endurance or post-swimming motor function test, swimming endurance test and forced swim test. The extract when subjected to a forced swim model for adaptogenic activity, it failed to show an increase in serum cholesterol and serum triglyceride level but the increase was not sustained on subsequent groups. Also, the extract enhances the swimming endurance time and could also restrict the increase in the level of these markers during stress<sup>105</sup>.

### Anti-hyperlipidemia activity

The aqueous extracts of the seeds and fruits was tested for hyperlipidaemic activity against the albino rat model at the dosage of 125 and 250 mg/kg. The oral administration of the aqueous extract significantly decreases the tissue lipid profile and serum<sup>106</sup>.

### Radio-protective activity

The hydro alcoholic extract of the fruit of the Bael plant was evaluated for the radio-protective activity against Swiss albino mice model that was exposed to several doses of gamma radiation. The extract was administered through intra-peritoneal route for 5 days at the dosage of 5, 10, 15, 20 and 40 mg/kg before exposure to 10 Gy 60 Co gamma-radiations. The maximum

protection was reported after the 30 days of post-radiation and it was also observed that 15 mg/kg dosage of the extract produces the highest survival rate<sup>107</sup>.

#### **Antidepressant and anxiolytic activity**

The Methanolic extract of the leaves of Bael plant showed antidepressant and anxiolytic activity against the mice model<sup>108</sup>.

#### **Toxicity**

The total aqueous, Methanolic and alcoholic extract of the leaves of the plant was studied using an experimental rat model to detect the toxic effects of the plant. The intra peritoneal administration of the extracts showed no histopathological changes for 14 days at the dosage of 50 mg/kg body weight<sup>109</sup>. The aqueous extract of the fruit of the plant was reported to be non-mutagenic against *Salmonella typhimurium* strain TA 100 in the Ames assay<sup>110</sup>.

#### **CONCLUSION**

From the literature study, it is quite evident that *A. marmelos* plant is associated with great medicinal properties and is considered as the most significant medicinal herb. It is used in Ayurveda, Siddha and other medicinal systems to treat various types of diseases. As per ancient beliefs, the Bael tree acts as an indicator plant to trace the underground water. The fruit juice of the plant carries different medicinal properties that promote the good health of people and prevent the risk of diseases. The reported studies on the Bael plant revealed that the phytochemical constituents extracted from the Bael plant possess various therapeutic and pharmacological activities like antifungal, antioxidant, radio-protective, hepatoprotective, anti-diabetic, anti-stress, antiulcer, anticancer, anti-inflammatory, antimicrobial, wound healing and anti-asthmatic. The fruit of the plant is edible, highly nutritious and contains antioxidant properties. The plant is widely studied for its medicinal value still the plant requires more exploration in the research areas to identify its more Phytoconstituents to explore the unidentified therapeutic and pharmacological properties.

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