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Review Article

***Aegle marmelos*: A medicinal wild aromatic tree**

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Abstract

Plant as sources of medicinal compounds has continued to play a major role in the maintenance of human health since ancient times. Uttarakhand state is famous for its rich medicinal plants resources. Every aromatic plant has a medicinal value but not every medicinal plant is aromatic. *Aegle marmelos* is one of the most important medicinal plants of India. Despite of the sacred tree *A. marmelos* has numerous therapeutic properties. From traditional to modern use this medicinal tree owes its own space in medicinal system. Diabetes, liver toxicity, fungal infection, microbial infection, inflammation, pyrexia and to relieve pain are some of the uses of different parts of the magical tree. The present article aims at reviewing the most remarkable reports on pharmacology, phytochemistry and biological activities of *Aegle marmelos*.

Keywords: *Aegle marmelos*, Medicinal plants, Pharmacology, Biological activities.

INTRODUCTION

India has great wealth of medicinal plants and their traditional uses. Plants are used medicinally in different countries and are a source of many potent and powerful drugs (Srivastava et al., 1996). Plant as sources of medicinal compounds has continued to play a major role in the maintenance of human health since ancient times. Uttarakhand state is famous for its rich medicinal plants resources. The climatic, topographic and soil diversity of this state has resulted in the occurrence of several valuable and economically important medicinal herbs of great therapeutic potential. Uttarakhand supports a large number of medicinal plants curing a wide range of disorders, which are extensively used by the pharmaceutical industry for preparation of drugs used in Indian System of Medicine (Alam et al., 2005).

Aromatic plants are a special kind of plants used for their aroma and flavour. Aromatic plants are from a numerically large group of economically important plants. There is an increasing demand for essential oils, aroma chemicals drugs and pharmaceuticals in the world market since two decades. Aromatic compounds are present in plants i.e. in root, wood, bark, foliage, flower, fruit, seed etc. Every aromatic plant has a medicinal value but not every medicinal plant is aromatic.

Aegle marmelos commonly known as Bael tree, belonging to the family Rutaceae is indigenous to Indian subcontinent, mainly found in tropical and subtropical regions. *A. marmelos* is one of the most important medicinal plants of India, Burma and Ceylon (Srivastva et al., 2008). It is found as a wild plant in central and south India and cultivated in north India. *Aegle* is a small genus of three species distributed in tropical Asia and Africa. The bael is one of the sacred trees of the Hindus. Leaves are offered in prayers to Shiva and Parvathi since ancient times (Rajasekaran, 2008). Bael is a deciduous sacred tree, associated with Gods having useful medicinal properties, especially as a cooling agent. This tree is popular in Shiva and Vishnu temples and it can be grown in every house. Its leaves are trifoliolate symbolizing the Thrimurthies-Brahma, Vishnu, Shiva, with spear shaped leaflets resembling Thrisoolam the weapon of Lord Shiva. Many legends, stories and myths are associated with this tree (Nadkarni, 1954) **Figure 1**.

PLANT PROFILE

Scientific Classification (5)

- Kingdom- Plantae
- Order- Sapindales

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Figure 1. *Aegle marmelos* fruit and triplet leaves.

- Family- Rutaceae
- Subfamily- Aurantioideae
- Genus- *Aegle*
- Species- *Aegle Marmelos*
- Botanical name- *Aegle marmelos*

Vernacular names (6)

- English: Bengal quince, Beal fruit, Golden apple, Indian quince, Stone apple.
- Tamil: Aluvigam, Iyalbudi, Kuvilam, Mavilangai, Vilwam, Villuvam.
- Telugu: Bilvamu, Maluramu, Maredu, Sailushamu, Sandiliyamu, Sripalamu.
- Hindi: Bel, Bili, Sirphal, and Bela,
- Sanskrit: Adhararutha, Asholam, Atimangaliya, Bilva.
- Bengal: Bael, Bel,
- Gujarat: Billi,
- Kannada: Bela, Bilva
- Malayalam: Koovalam, Vilwam.

Botanical Description

A. marmelos is a slow-growing, medium sized tree, up to 12 to 15 m tall with short trunk, thick, soft, flaking bark, and spreading, sometimes spiny branches, the lower ones drooping. Young suckers bear many stiff, straight spines. A clear, gummy sap, resembling gum Arabic, exudes from wounded branches and hangs down in long strands, becoming gradually solid. It is sweet at first taste and then irritating to the throat. The deciduous, alternate leaves, borne singly or in 2's or 3's, are composed of 3 to 5 oval, pointed, shallowly toothed leaflets, 4 to 10 cm long, 2 to 5 cm wide, the terminal one with a long petiole. New foliage is glossy

and pinkish-maroon. Mature leaves emit a disagreeable odor when bruised. Fragrant flowers, in clusters of 4 to 7 along the young branch-lets, have 4 recurved, fleshy petals, green outside, yellowish inside, and 50 or more greenish-yellow stamens. The fruit, round, pyriform, oval, or oblong, 5 to 20 cm in diameter, may have a thin, hard, woody shell or a more or less soft rind, gray-green until the fruit is fully ripe, when it turns yellowish. It is dotted with aromatic, minute oil glands. Inside, there is a hard central core and 8 to 20 faintly defined triangular segments, with thin, dark-orange walls, filled with aromatic, pale orange, pasty, sweet, resinous, more or less astringent, pulp. Embedded in the pulp are 10 to 15 seeds, flattened-oblong, about 1 cm long, bearing woolly hairs and each enclosed in a sac of adhesive, transparent mucilage that solidifies on drying. Bael has enormous traditional uses against various diseases and many bioactive compounds have been isolated from this plant also (Maity et al., 2009).

Distribution

'It is believed that the *A. marmelos* is originated from the Eastern Ghats and Central India. Bael trees are indigenous to India and are found growing in abundance in the Himalayan regions, Bengal, Central and South India, as well as in Srilanka, Burma, Thailand, Bangladesh, Nepal, Vietnam, Laos, Cambodia, and Pakistan (Lambole et al., 2010). 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 (Nagar et al., 2017). As per historical studies, the Bael plant occurs in India since 800 B.C. In India, the plant is distributed in Uttarakhand, Jharkhand, Deccan Plateau, Uttar Pradesh, Bihar, Chhattisgarh and Madhya Pradesh and along the foothills of Himalayas and east coast (Sharma, 2007).

TRADITIONAL USES OF AEGLE MARMELLOS

Ayurvedic view

The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangements of 4

x4 with three replications. The treatments consisted of four levels of nitrogen and phosphorus (0/0, 23/10, 46/20, and 69/30 kg ha⁻¹) and four levels of farmyard manure (FYM) (0, 5, 10 and 15t ha⁻¹) 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 medicinal properties of the plant are briefly described in Charaka Samhita (Das & Das, 1995). The juice prepared from the pulp part of fruit produces a soothing effect in the recovered patients of bacillary dysentery (Karunanayake et al., 1984). 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 (Sukhdev, 2006). 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 (Bhardwaj & Nandal, 2015).

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. *Aegle marmelos* is associated with multiple medicinal properties. Presently, the Bael plant has become popular because of its medicinal use in both human and animal diseases. Scientific literature has also proved that A. marmelos extracts manifested various biological activities including anti-obesity, analgesic, antiulcer, antimicrobial, anti-inflammatory, antioxidant, hypoglycemic and hypolipidemic, immunomodulatory, dioprotective, hepatoprotective and antitumor properties. Unripe fruit alcoholic extract have found to produce cardioprotective effect in isoproterenol induced myocardial infarction due to the presence of a potent compound known as auraptin (Rajadurai & Prince, 2005). Extensive experimental and clinical studies prove that *Aegle marmelos* possesses antidiarrhoeal, antimicrobial, antiviral, radioprotective, anticancer, chemopreventive, antipyretic, ulcer healing,

antigenotoxic, diuretic, antifertility and anti-inflammatory properties, which help it to play role in prevention and treatment of many disease.

PHYTOCHEMICAL INVESTIGATION

A. marmelos has been reported to contains bioactive compounds like carbohydrates, minerals, vitamins, coumarins, phenolic acids alkaloids, flavonoids, organic acids, volatile compounds and fatty acids. Chemical constituents like marmenol, marmin, marmelosin, marmelide, psoralen, alloimperatorin, rutaretin, scopoletin, α -phellandrene, betulinic acid, marmesin, imperatorin, ellagic acid, quercetin, chlorogenic acid, gallic acid, ferulic acid have been isolated from different parts of the plant (Shoeb et al., 1973). The chemical constituents extracted from the leaf part include coumarins (mermenol and praeltin), O-(3,3-dimethylallyl) halofordinol, N-4-methoxystyryl cinnamide, N-2-methoxy-2-[4-(3',3'-dimethyl allyloxy) phenyl] ethyl cinnamide. The chemical constituent isolated from root parts include alkaloids which include discitamine, haplopine, tembamide, gamma-fagarine and tembamide and coumarins include

aegelinol, marmesin, marmin, scopoletin, umbelliferone, xanthotoxin (Farooq, 2005). from the fruit part of the plant include 6-(2-hydroxy-3-hydroxymethyl-3-butenyl)-7-hydroxycoumarin, 6-formylumbelliferone, 6-(4-acetoxy-3-methyl-2-butenyl)-7-hydroxyl coumarin, 8-hydroxysmyrindiol, 8-[(3-methyl-2-oxo-3-buten-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 (Sharma & Sharma, 1981), (Sharma, 1981), (Pynam & Dharmesh, 2018). Seed oil composed of palmitic, stearic, oleic, linoleic and linolenic acid (eep & Seema, 2011). Apart from these, seed oil has been found to contain 12.5% of an unusual fatty acids, ricinoleic acid along with other normal fatty acids (Katagi, 2011). Structure of some of the important extracted chemical constituents of *aegle marmelos* is shown in **figure 2**.

Analysis of Essential Oil

All the parts of *aegle marmelos* (roots, stem, leaves and fruit) produces a wide variety of metabolites including alkaloids, terpenoids, coumarins and sterols. The essential oil of *aegle marmelos* shows the presence of various chemical constituents having therapeutic properties (Bhandari & Gupta, 1974), (Garg et al., 1995), (Raju et al., 1999). Bael oil exhibited strong fungitoxicity against several pathogens and the main components encountered were found to be 1,8-cineole and β -caryophyllene (M.S. Karawya & Mirhom, 1987). Natural bicyclic sesquiterpenes as β -caryophyllene, γ -muurolene and monocyclic ones as α -humulene and ar-curcumene

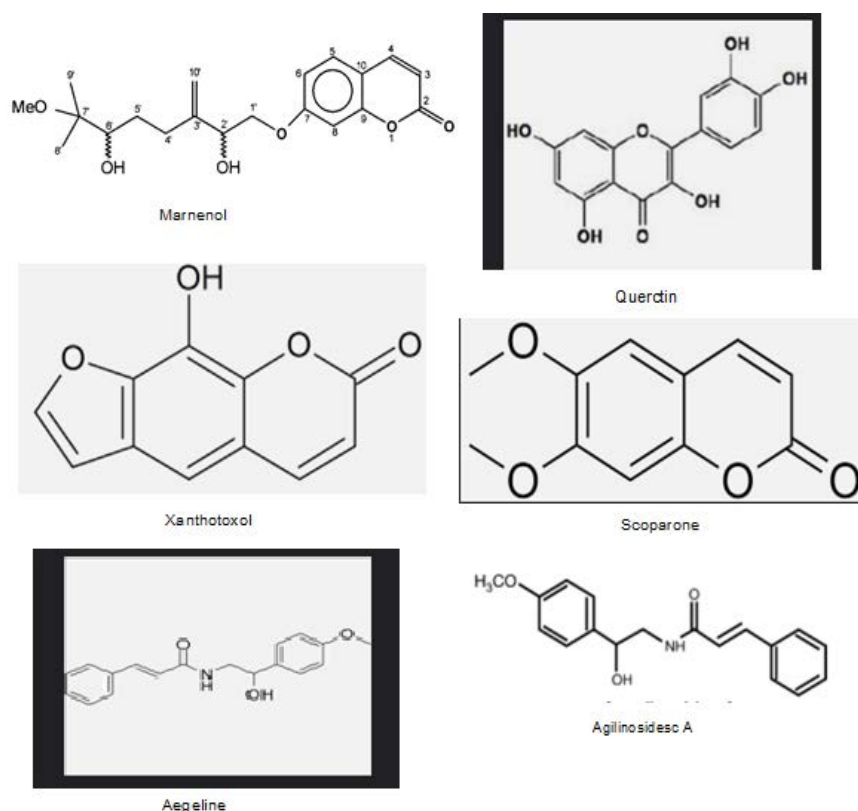


Figure 2. Chemical constituents of *Aegle marmelos*.

are abundantly found in essential oils and their potential anticancer activities, affecting growth and proliferation have been deeply studied (Quassinti, L et al. 2014). The essential oil of *aegle marmelos* revealed a sesquiterpene rich composition with large amount of β -caryophyllene, α -humulene, γ -muurolene and ar-curcumene indicating the presence of a different chemotype (Pant et al., 2019).

Nutritional Evaluation

The fruit of *A. marmelos* possess high nutritional value. The fruit is used to make juice, jam, sirup, jelly, toffee and other products. The pulp is reported to contain water, sugars, protein, fiber, fat, calcium, phosphorus, potassium, Iron, minerals and vitamins (Vitamin A, Vitamin B1, Vitamin C and Riboflavin). The leaves and the shoot of the plant are used as green vegetable in Indonesia (Sharma et al., 2007), (Rathore et al., 2009). Various studies have been done to know the proximate composition of the leaves, pulp of fruit and seed powder of *Aegle Marmelos*. A study was conducted to analyze values for proximate composition of *Aegle Marmelos* leaf, pulp and seed powder using standard methods found that bael leaf, pulp and seed powder are good source of protein, fat, minerals, crude fiber and energy, rich source of available carbohydrates, dietary fiber and also contain antinutrient content which help in controlling blood sugar (Morton, 1987).

Antioxidant Activity

The data on plant growth and yield-related traits were recorded from ten sample plants randomly selected from central rows in each plot, leaving aside, plants from the border rows and those at both edges of each row. The parameters considered for data collection were plant height, branch number, leaf area index, number of pods per plant, dry calyx yield, seed yield, thousand seed weight, harvest index, and above ground biomass *A. marmelos* is extensively reported to possess antioxidant activity against a variety of free radicals. Antioxidant activity of the fruit of *A. marmelos* was reported. Antioxidant activity and free radical scavenging activity of the ripe and unripe fruit of *Aegle marmelos* was compared. Results indicate that the enzymatic antioxidants increased in ripe fruit when compared to unripe fruit extract (except glutathione peroxidase). The percentage of free radical inhibition was also high in unripe fruit than that of the ripe fruit (S. Sharmila & Devi, 2011). Antioxidant effect of *Aegle marmelos* against experimental diabetes was examined in a study. *Aegle marmelos* extract effectively reduced the oxidative stress induced by alloxan and produced a reduction in blood sugar. Parameters like reduced glutathione, glutathione peroxidase, glutathione reductase, superoxide dismutase (SOD) and catalase have shown a dose related increase in their level/activity and a decrease in lipid peroxidation following the treatment with *Aegle marmelos*

leaf extract (Singh et al., 2000). In vitro antioxidant activity of the methanolic extract of *Aegle Marmelos* leaf was studied using standard methods like DPPH scavenging activity, H₂O₂ scavenging activity and ferrous reducing power. In vitro activity of Methanolic extract of *Aegle marmelos* showed that it has good antioxidant activity with the IC₅₀ value 23±0.08. It thus can be used as potential inhibitor of free radicals (Siddique et al., 2010).

Antimicrobial Activity

A. marmelos has been traditionally used for the treatment of various infectious diseases and been extensively reported to inhibit the broad range of pathogenic microorganisms. Many in vitro studies proved the antimicrobial potential of *A. marmelos* extracts towards the pathogenic microorganisms including bacteria and fungi. 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* (Sivaraj et al., 2011).

The antifungal activity of the leaves of *Aegle marmelos* was reported against clinical isolates of dermatophytes. *A. marmelos* leaf extracts and fractions were found to have fungicidal activity against *Trichophyton mentagrophytes*, *T. rubrum*, *Microsporum canis*, *M. gypseum*, *Epidermophyton floccosum* (Balakumar et al., 2011). The antifungal and antibacterial activity of the fruit of *A. marmelos* was reported. The antimicrobial activity was performed by tube dilution MIC method. The decoction of the fruit showed

activity against *Aspergillus niger*, *Aspergillus fumigatus*, *Candida albicans* and *Staphylococcus aureus* and the MIC results for the above respective organisms were 19.5 µg/ml, 39 µg/ml, 625 µg/ml and 1.25 mg/ml. The antibacterial activity of the leaves, fruits and barks of *Aegle marmelos* was reported. The antimicrobial activity of chloroform, methanol and water was performed by disc diffusion method. The antimicrobial activity was checked against *Bacillus subtilis*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Escherichia coli*, *Salmonella paratyphi A* and *Salmonella paratyphi B*. The methanol extract showed significantly high activity against above mentioned bacteria than that of the other extracts (Poonkothai & Saravanan, 2008). 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* (Jain, 1977).

Pharmacological Activities

A. marmelos is one of the most widely used medicinal and nutraceutical plant in the family Rutaceae. In recent history this plant is reported for various medicinal properties **Figure 3**. Some of the reported studies of the plant are briefly discussed below.

Antidiabetic activity

A. marmelos has been used to control diabetes in traditional medicinal system. Many in vivo scientific studies have been conducted in animal models to evaluate the ant-diabetic activity of different organic extracts and fresh juice of *A. marmelos*. The aqueous and alcoholic extract of the fruit part showed hyperglycemia activity against rabbits at the dosage of 500 mg/kg body weight (Anandharajan et al., 2006).

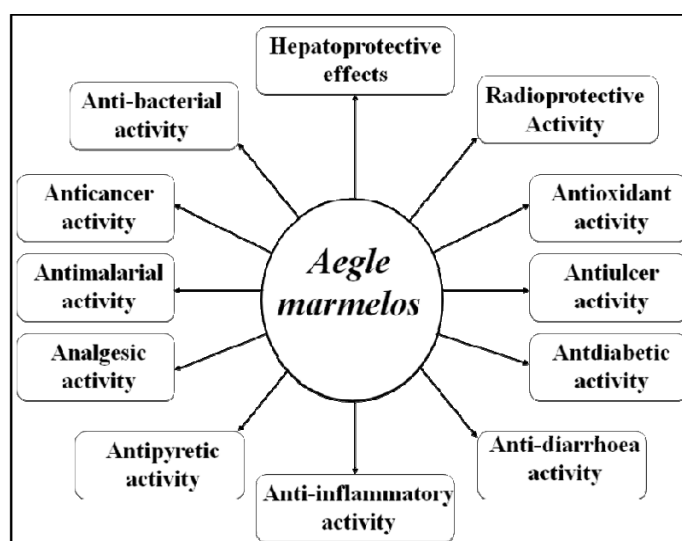


Figure 3. Medicinal properties of *Aegle marmelos*.

The fruit extract of the plant showed protective effects on pancreatic tissues in diabetic rats (Hema & Lalithakumari, 1988).

Antidiarrhoeal activity

In a *in vitro* and *in vivo* study antidiarrhoeal potential of chloroform extract of the root of *A. marmelos* it was found that the extract was comparable to that of ciprofloxacin and mostly active against the strains of *Vibrio cholerae*, followed by *Escherichia coli* and *Shigella spp* (Mazumder et al., 2006). Also it was found that methanol extract of the fruits of *A. marmelos* decreased the intestinal propulsion in rats (Gutiérrez et al., 2007). The unripe fruit pulp of *A. marmelos* affected the bacterial colonization to gut epithelium and production and action of certain enterotoxins. These suggest the varied possible modes of action of *A. marmelos* in infectious forms of diarrhoea thereby validating its mention in the ancient Indian texts and continued use by local communities for the treatment of diarrhoeal diseases (Dhuley, 2003).

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 (Trivedi HP, 2011).

Anti inflammatory activity

Different organic extracts of the *A. marmelos* leaves possess highly significant acute and subacute anti-inflammatory activity (eep & Seema, 2011). In acute and chronic inflammatory animal models, *A. marmelos* showed significant anti-inflammatory activity and it can be a promising anti-inflammatory agent. These activities may be due to the presence of lupeol and skimmianine in the leaves because both the compounds have shown the same potentialities in pure form. Activation of histamine receptor is essential for allergic and asthmatic manifestation. The alcoholic extract of *A. marmelos* leaves antagonized the histamine induced contractions and demonstrated positive relaxant effect in isolated guinea pig ileum and tracheal chain, suggesting inhibition of H1 receptor activity this extract may underlie these effects (Benni et al., 2011).

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 (Duraisami et al., 2011).

Antifertility activity

A. marmelos leaf, seed and fruit is known to affect male fertility in reversible manner. *A. marmelos* bark extract is a rich source of marmin and fagarine known for reducing male fertility. Methanolic extract of *A. marmelos* causes a dose and duration dependent infertility via reducing reproductive organ weight and serum testosterone levels. It was also reported that reduction in sperm density, motility, viability and sperm acrosomal integrity. Exfoliation of elongated spermatids, nuclear chromatin condensation and degeneration were found in testes histopathological studies and presence of spaces within the germinal epithelium signifying testicular cytotoxicity and necrosis. Finally time dependent complete infertility was observed in that study. The authors also reported that after the withdrawal of treatment, complete restoration of the morphological as well as physiological parameters in extract treated rats (Agrawal et al., 2012) These findings suggest that *A. marmelos* extract is a strong candidate for male contraceptive via its ability to produce complete inhibition of pregnancy, rapid restoration of fertility after withdrawal from treatment (Chauhan & Agarwal, 2008).

Hepatoprotective Effect

The hepatoprotective effect of the leaves of *A. marmelos* and were reported in alcohol induced liver injury in Albino rats. Rats were administered with 30% ethyl alcohol for a period of 40 days. The induced rats were fed with leaves of *A. marmelos* for 21 days. The TBARS values of healthy, alcohol intoxicated and herbal drug treated animals were 123.35, 235.68 and 141.85 µg/g tissue respectively. This indicates the excellent hepatoprotective effect of the leaves of *A. marmelos* (Singanan & Singanan, 2007).

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 (Shankarananth et al., 2007).

TOXICOLOGY

Generally, *A. marmelos* considered safe and few studies have been carried out with respect to its toxicity. *A. marmelos* is widely used in traditional medicinal system and fruit is usually utilized as nutritional food. However *A. marmelos* is not recommended in pregnant or breastfeeding women

because the leaves of *A. marmelos* have been traditionally used to induce abortion and to sterilize women. 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 (Raja, S. B et al. 2009). Dried fruit pulp of *A. marmelos* was screened for its topological profile. Ethanolic extract of *A. marmelos* dried fruit pulp was screened for the acute oral toxicity test in Swiss albino mice at 550 and 1250 mg/kg body weight. At these concentrations test extract did not showed any sign of toxicity. No change in the behaviour and physiological activity was recorded in mice during the experiment (14 days). The results concluded that LD50 of the test extract is more than 1250 mg/kg body weight (Joshi et al., 2009).

CONCLUSION

It is quite evident from this review that *Aegle marmelos* contains a number of phytoconstituents which reveals its uses for various therapeutic purposes. The Plant or its individual parts can be used for the treatment of various disorders in human being such as, diabetes, liver toxicity, fungal infection, microbial infection, inflammation, pyrexia and to relieve pain. Based on its value in traditional medicine and promise from preclinical studies, bael fruit which is also of dietary use has emerged as fruit worth to be subjected to detail investigations for its myriad beneficial effects. 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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