

Ethnological and Ethno-medicinal Importance of *Aegle marmelos* (L.) Corr (Bael) Among Indigenous People of India

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ABSTRACT

The Bael (*Aegle marmelos*) (L) Corr. Is an important Indian plant, conserved since centuries by tribal communities and in sacred groves, has enormous traditional uses as a food source and against various diseases. Focus on plant research has increased in recent times with an aim towards their edible, medicinal and amelioration properties in animal welfare globally and lots of evidence has collected to show immense potential of nutritional and medicinal plants used in various ethical societies. Over the last few years, researchers have aimed at identifying and validating plant derived substances for the treatment of various diseases and amelioration of toxicity. It has been proved that various parts of plants such as Leaves, fruits, seeds, provide health and nutrition, promoting compounds in the human diet and which has enormous traditional uses against various diseases, especially the ethnic communities of Jharkhand, who suffer from malnutrition and severe health issues. The present paper aims to compile ethnobotanical and ethnomedical values of *Aegle marmelos* generated through the research activity using modern scientific approaches and innovative scientific tools.

Keywords- *Aegle marmelos*, Ethnomedical, Ethnobotany, Biochemical, Nutritional, Medical uses.

INTRODUCTION

The indigenous and ethnic people of the world have learnt to live in most hostile environmental condition in this universe¹. The most interesting feature associated with these indigenous and ethnic has been found that, they live in localities which are

immensely rich in biodiversity. India is a country with large ethnic society and has immense wealth due to which it is rich in biodiversity. There are 45,000 species of wild plant out of which 9,500 species are ethno botanically important species. Of these 7,500 species are in medicinal use of indigenous health practices. The ethnic and

indigenous people have to depend upon several wild species for fruits, seeds, bulbs, roots and tubers which are used for edible purposes².

The ethnic community of India has played a vital role in preserving biodiversity of several virgin forests and have conserved several flora and fauna in sacred groves of tribal, otherwise these flora and fauna might have been disappeared from natural ecosystems. *A. marmelos* is one of such tree which has been conserved since ages^{1,3}.

Apart from being a medicinal plant, *Aegle marmelos* Correa is a sacred tree, dedicated to Lord Shiva. The offering of *bael* leaves is a compulsory ritual of the worship of Lord Shiva in the hills. This importance seems largely due to its medicinal properties. All parts of this tree, viz., root, leaf, trunk, fruit and seed, are used for curing one human ailment or another⁴.

More than 70% of the tribal communities remained intermingled with the nature and traditional knowledge for thousands of years and are the custodian of numerous indigenous plants that are used for the cure of several ailments⁵. One of the principal reasons for such a practice is the lack of modern medical facilities in the remote areas of the difficult terrains of the state.

There is a widespread belief that the green medicines are healthier and more harmless or safer than synthetic ones⁸. The present study, therefore, aims to document various indigenous uses of *Aegle marmelos* (L.) Correa, one of the most important medicinal plants of India, for its immense low cost medical importance and to emphasize its ethno conservation for the benefit of mankind. The fruit's medicinal value is very high when it is just beginning to ripen; therefore it is best eaten just as fresh as it ripens. The ripe fruit and unripe fruit, as well as the roots, leaves and branches have all been used in traditional

medicine. In Ayurveda, the ripe fruit has been used for chronic diarrhea and dysentery, as a tonic for the heart and brain, and as adjuvant treatment of dysentery. A decoction of the root has been used to treat melancholy, intermittent fevers and palpitation; the roots have mainly been used as an ingredient of the Ayurvedic medicine, dashmool. The leaves have been given as febrifuge and as a poultice for the treatment of eye disorders and ulcer and administration of fresh leaves have been used for weakness of the heart, dropsy and beriberi.

The word bilva (bel tree) is usually used as bilva-patra (leaf of bel). It is a sacred tree having sacrificial importance. The leaves of this sacred tree are generally trifoliolate. This trifoliolate leaf is symbolic of Trikal (Brahma, Vishnu and Mahesh), three eyes of Lord Shiva, Trishakti (Volition, action and knowledge), three lingas and three syllables of Omkar.

The bilva tree itself is so holy and auspicious that its worship or its significance is mentioned in many Puranas and other scriptures at various instances. Born from the breasts of Goddess Lakshmi, the Bilva tree is ever dear to Mahadeva. So I ask this tree to offer a Bilva leaf to Lord Shiva. To have Darshan of the Bilva tree, and to touch it, frees one from sin. The most terrible karma is destroyed when a Bilva leaf is offered to Lord Shiva. Sri Bilva Shtakam⁹. The proportion of Sattva component is more in bilva patra and hence it has more capacity to absorb and emit Sattvik frequencies. This has various effects. One of them is the reduction of raja-tama particles present in the atmosphere. A Sattvik leaf like bilva patra when brought in proximity of a person suffering from negative energy, distress than the black energy present within him is reduced¹⁰.

In a study in the Bundu block indicated that *A. marmelos* can be a good cash crop, indicating that the inhabitants

earn Rs.2991/annum selling ripe fruits and approximately 30 households are involved in this business¹¹.

Ethnic value of *A. marmelos*

In India there are 68 million people, belonging to 227 ethnic groups (573 tribal communities)¹², live close in the vicinity of the forests or villages and have been able to conserve biodiversity of their localities. The forest and trees/plants not only cater their daily needs of timber and fuel wood, but also their livelihood and traditional medicines.

There are 45,000 species of wild plants out of which 9500 species are ethnobotanically important and 7500 species are used as medicinal and herbal health practices. Many of these plants are conserved and worshipped in their natural habitat due to their magical- religious belief that they are habitat of God and Goddess³. Bael is one of them, worshipped as a symbol of Lord Shiva.

Many of these plants are conserved in sacred groves. It has been estimated that the total number of sacred groves in the country lies between 100,000 and 150,000¹⁴. These are mainly distributed in the states of Andhra Pradesh, Bihar, Jharkhand, Orissa, Maharashtra¹⁵. Sacred Groves is an age-old tradition where a patch of forest or water body is dedicated to local deities and none is allowed to cut plants or to kill animals or any form of life (Figure 1 & 2). The institution of sacred groves dates back to the pre-agrarian hunting-gathering phase of human civilization and is known to thrive in most parts of India. *A. marmelos* are an important plant of such sacred grove of Jharkhand⁶.

Besides conservation of biodiversity, the role of sacred groves is also important as a life support system. The sacred groves help tribal communities by providing edible fruits, leaves, fibers and medicinal plants. Also acts as an atmosphere purifier and

sinks, air pollutants and deodorizes bad air¹⁰. An example of sacred grove is shown in a sacred grove in Panchmarhi village, where Gonds worship *A. marmelos* apart from other sacred trees (Table.1).

Occurrence, botanical description

A. marmelos is one of the most important medicinal plants of India, Burma and Ceylon¹⁶. It is found as a wild plant found all over India and cultivated in north India. The *Aegle* is a small genus of three species distributed in tropical Asia and Africa. The *A. marmelos* belongs to the family Rutaceae and is known as Opesheet, Ohshit. It is termed differently in different languages as well as countries¹⁷.

A. marmelos are a subtropical species and grow best in rich, well-drained soil. It grows well in swamps, alkaline or stony soils having a pH range from 5 to 8¹⁷. In India flowering occurs in April and May and the fruit ripens in 10 to 11 months after (March to June) of the following year¹⁷. *A. marmelos* are 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. A clear, gummy sap, resembling gum Arabic, exudes from wounds branches.

The marmelos tree

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 pinkish-maroon and glossy. Damaged leaves emit a foul odor.

Flowers are fragrant, found in clusters of 4 to 7 along the young branchlets, have 4 fleshy petals, green outside, yellowish inside, and 50 or more greenish-yellow stamens. Fruit is round, pyriform, oval or oblong, 5 to 20cm in diameter, may have a thin, hard, woody shell, gray-green when immature but turns yellowish when

fully ripe. 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, astringent pulp 10 to 15 flattened-oblong seeds remain embedded in the pulp. The seeds are about 1 cm long, covered with woolly hairs and each enclosed in a sac of adhesive, transparent mucilage that solidifies on drying (Figure 3a & 3b).

The Ethnomedicinal importance of *A. marmelos*

This plant is used in traditional medicine treatments, such as intermittent fever, intestinal ailments, fertility control and treatment after childbirth and fish poison¹⁸. British pharmacopoeia has included *A. marmelos* fruit because of its effectiveness against diarrhoea and dysentery¹⁹. Moreover, Chopra (1982) has appropriately stated that “No drug has been longer and better known, nor more appreciated by the inhabitants of India than the Bael fruit”.

Leaves

Extracts of leaves are efficient to treat ulcers, abscess, backache, vomiting, cuts, weakness of heart, acute bronchitis, blood sugars, diarrhea, dropsy, beriberi, injuries caused by animals²⁰. Juice prepared from the leaf extract acts as a laxative agent and is helpful for treating ophthalmic infections and asthmatic complaints. Medicated oil prepared from the leaves of the plant not only helps to prevent cold, cough and other respiratory ailments, but is also a good hair tonic when mixed with cumin seeds and massaged on the scalp.

Leaves are also used as a veterinary medicine for wound and fodder for animals and stimulation of denervated nictitating membrane in anesthetized cats²¹. A brief outline of *A. marmelos* indicating the Ethnomedicinal importance of various parts of the plant is shown in Table 2.

Root bark

The root bark is used in remission of intermittent fevers, fish poison, remedy for heart palpitation and melancholia. Bark juice, mixed with cumin in milk, increases seminal fluid volume. Alcoholic root extracts cure hypoglycemia²². It is also used in dog bite, gastric troubles, heart disorders, anti-amoebic, rheumatism²³.

Flower

Extracts of distilled flower are used as a tonic for the stomach, intestine, anti-dysenteric, anti-diabetic, diaphoretic and local anesthetic²⁴. As an expectorant it is used to cure epilepsy.

Fruit

Eaten during diarrhea, dysentery and convalescence. It acts as a mild astringency. Dry powder mixed with mustard oil is used to treat burn cases²⁵.

Fruits are used in diarrhea, dysentery, gastric troubles, constipation, laxative, tonic, digestive, brain and heart tonic, ulcer, intestinal parasites, gonorrhoea, epilepsy²². Fresh fruit extracts lower blood pressure²⁶. Fine powder of unripe fruit can be an alternative medicine to cure intestinal parasites, like *Entamoeba histolytica*, *Ascaris lumbricoides*²⁷.

Phytochemical constituents isolated from *A. marmelos*

Various chemical constituents like alkaloids, coumarins and steroids have been isolated and identified from different parts of the tree. The biological activities of the phenolic compounds present in *A. marmelos* is shown in Figure.4, indicating the widespread therapeutic effect of the plant.

Coumarins

Farooq, (2005) reported presence of marmelosin, marmesin, imperatorin, marmin, alloimperatorin, methyl ether, xanthotoxol, scopoletin, scoparone,

umbelliferone, psoralen and marmelid. Marmenol, a 7-geranyloxy coumarin [7-(2,6-dihydroxy-7-methoxy-7-methyl-3-octaenyl) Coumarins]³¹.

Alkaloids

Manandhar *et al.* (1978) identified the presence of aeglin, aegelenine, dictamine, fragrine (C₁₃H₁₁O₃N)³², O-methylhalfordinine, isopentenylhalfordinol³³, N-2-[4-(3', 3'-dimethylallyloxy) phenyl] ethyl cinnamide, N-2-hydroxy-2-[4-(3', 3'- dimethylallyloxy) phenyl] ethyl cinnamide, N-2-hydroxy-(4-hydroxyphenyl) ethyl cinnamide³⁴, O-(3, 3-dimethylallyl) halofordinol, N-2-ethoxy-2-(4-methoxy phenyl) ethyl cinnamide, N-2-methoxy-2-[4-(3', 3'dimethylallyloxy) phenyl] ethyl-cinnamide, N-2-methoxy-2-(4-methoxy-phenyl)- ethylcinnamide.

Polysaccharides

Galactose, arabinose, uronic acid and L-rhamnose are obtained on hydrolysis³⁵. Seed oil composed of palmitic, stearic, oleic, linoleic and linolenic acid³³.

Tannins

Tannin content is maximum in the bael fruit in the month of January. There is as much as 9% tannin in the pulp of wild fruits, less in cultivated type. Tannin is also present in leaves as skimmianine, it is also named as 4, 7, 8-trimethoxyfuro, quinoline.

The pale color of the fruit is because of the presence of carotenoids. The therapeutically Carotenoids active principles of bael plant are due to the presence of marmelosin, skimmianine and umbelliferone are. The small amount of ascorbic acid, sitosterol, crude fibers, tannins, α -amyryn, carotenoids and crude proteins are also present. The Roots contain psoralen, xanthotoxin scopoletin³³ and also compounds like praealtin D, trans-cinnamic acid, 4-methoxy benzoic acid, betulunic acid and montanin³⁶. Bael tree also possess a

large number of bioactive compounds in its various parts as shown in Table 3. The structures of some of these bioactive compounds are presented in Figure 4.

Bioactivity

Leaves, fruits, stem and roots of *A. marmelos* have been used in ethno medicine due to its astringent, anti-diarrheal, anti-dysenteric, demulcent, antipyretic and anti-inflammatory activities³⁷. Bioactive compounds of bael fruit contain relatively high content of dietary fiber, ascorbic acid, total phenolics, total flavonoids, total carotenoids and also strong antioxidants. The main components were monoterpenes and sesquiterpenes. Among these components, limonene was the major constituent producing the characteristic bael fruit flavor³⁸. The flow chart of the Biological Activities of Phenolic Compounds is shown in Figure. 5.

Antiulcer activity

Ulcer develops when there is an imbalance between the defensive mechanism on the mucosa resulting from either due to the presence aggravating factors and/or lowering of mucosal protection³⁹. Contemporary therapeutic treatment uses proton pump inhibitors and selective H₂ receptor blockers, but with several side effects and execute their actions within a limit. Bael has a prominent gastroprotective effect due to the presence of Luvangetin, a pyranocoumarin Cineole and the tannin in the fruit. Oxidative stress usually leads to gastric ulcer. Luvangetin lowers oxidative stress in the gastro duodenal mucosa preventing ulcer formation. The phenolic compounds are potent antioxidants⁴⁰ and have powerful antiulcer activities⁴¹.

Antioxidant activity

Treatment with Bael leaf extracted showed dose-related increase in their

level/activity of antioxidative parameters like reduced glutathione, glutathione peroxidase, glutathione reductase, superoxide dismutase (SOD) and catalase and a decrease in lipid peroxidation⁴². A dose of 250 mg/kg body weight of the fruit extract is more effective than glitencamide (300 µg/kg)⁴³. Leaf extract (200 mg/kg) is as effective as alpha tocopherol (60mg/kg) in isoproterenol (ISO) -treated rats⁴⁴. The antioxidant phytochemical such as flavonoids, alkaloids, sterols, tannins, phlobatannins and flavonoid glycosides present in the leaf extract possess this free radical scavenging activity⁴⁵. Diabetes causes reduction in the level of Glutathione (GSH) in erythrocyte and increase of plasma glutathione-S-transferase (GST) and malondialdehyde (MDA) in male albino rats.

However, the antioxidant potential of Bael leaves brings back the level to normal⁴⁶. Figure.6 indicates the pathway of hyperglycemia-induced endothelial dysfunction and activation. (a) Hyperglycemia induces metabolic dysfunction through the mitochondrial production of superoxide, resulting in PARP activation and subsequent altered glycolytic flux to enhance diacylglycerol production (DAG), methylglyoxal production, and hexosamine and polyol pathway activity. (b) Hyperglycemia-induced oxidative stress is further enhanced by metabolic overproduction of DAG and decreases in NADH+/reduced glutathione (GSH), as well as stimulation of the RAGE receptor. Oxidative stress reduces protective mediators (NO bioavailability) and enhances inflammatory transcription factor (NF-κB) activation resulting in inflammatory gene expression and leukocyte recruitment⁴⁷. Eugenol and Marmesinin are potent anti-oxidants may be responsible for preventing oxidative stress⁴⁸.

Antimalarial activity

Malaria caused by *Plasmodium falciparum* causes about 2 million deaths annually⁴⁹. Moreover, the species are gradually getting resistant to existing anti-malarial drugs, complicating the treatment of this dreadful disease⁵⁰. The alcoholic extracts of the Bael seeds and leaves have been tested in vivo and *in vitro* for anti-malarial activity against the NK65 strain of *Plasmodium berghei*. The seeds have shown schizontocidal activity in both the system, whereas, the leaves have shown activity only in the *in-vitro* system⁵¹.

Antidiabetic activity

The extracts of the plant have a multidirectional antidiabetic action that can significantly lower the levels of blood glucose and glycosylated hemoglobin and increased the plasma insulin as well as liver glycogen in diabetic rats⁵². It has been noted that oxidative stress of the body is closely related diabetes and its related complications⁵³, as well as with cardiovascular as well as renal disorders. Administrations of the aqueous extract of Bael fruit, orally or intraperitoneal induce a hypoglycemic effect against streptozotocin induced diabetic rats⁵⁴.

A dose of 250 mg/kg of the fruit extract proved to be more effective than the hypoglycemic drug, glibenclamide⁵⁵. Coumarins in the fruit extract have the most potent antidiabetic effect, which promotes potentiate the insulin Secretion from the islets of Langerhans⁵⁴. A 15 days clinical trial of a leaf extract for significantly reduced blood cholesterol levels with slight lowering of blood glucose in some patients with diabetes mellitus⁵⁶.

Anti-inflammatory activity

Anti-inflammatory, analgesic and antipyretic activities of the organic extracts of the ball leaves have now been established⁵⁸, may be due to the presence of

Lupeol and Skimmianine in the leaves⁵⁷. Activation of histamine receptor is essential for allergic and asthmatic manifestation⁵⁹. The alcoholic extract of Bael leaves, containing Lupeol and Citral antagonized the histamine-induced contractions and demonstrated positive chain, suggesting inhibition of H1-receptor activity⁶⁰ and act through inhibition of histamine mediated signalling⁵⁷ and relaxant effect in isolated guinea pig ileum and tracheal.

Histamine receptor antagonism

When histamine binds to a receptor on nerve or vascular cells, it produces the signs and symptoms of allergy. Antihistamines are inert molecules, stereochemically identical to histamines. However, antihistamines have a much greater affinity to receptors than histamine does, so they displace the histamine and shut down the allergic response. In fact, at marketed concentrations, antihistamines have a much greater affinity for H1 receptors than histamine does. That explains the ability of antihistamines to stop the allergic response (Figure.7).

Antifungal activity

Essential oil extracted from the leaves of the Bael tree shows potent antifungal activity against animal and human fungi like: *Trichophyton mentagrophytes*, *T. rubrum*, *Microsporum gypseum*, *M. audouinii*, *M. cookie*, *Epidermophyton floccosum*, *Aspergillus niger*, *A. flavus* and *Histoplasma capsulatum*⁶¹.

The oil of the seed has exhibited considerable in-vitro activity against various fungi namely: *Trichophyton rubrum*, *T. terrestre*, *E. floccosum*, *Aspergillus fumigatus*, *A. niger* and *A. flavus*. The ethanolic extract of the root has shown activity against *A. fumigates* and *T. mentagrophytes*⁶².

The germination of any spore (that is bacterial or fungal) is linked to Ca²⁺-dipicolinate and/or free Ca²⁺ ion availability in the medium as well as within the cytoplasm of microbes⁶³. It is possible that the essential oil from the Bael leaves may interfere with the Ca²⁺-dipicolonic acid metabolism pathway and thereby inhibit spore germination (Figure. 8).

Antibacterial activity

Various extracts of *A. marmelos* have been found to be active against several bacterial strains. For example essential oil of the leaf inhibits the growth of *Escherichia coli*⁶⁴, *Aeromonas* sp., *Pseudomonas salanacearum* and *Xanthomonas vesicatoria*⁶⁵. The ethanolic extract of the root and seed inhibits the propagation of *Vibrio cholerae*, *Salmonella typhimurium*, *Klebsiella pneumoniae*, *E. coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis* and *Staphylococcus aureus*⁶², *S. typhi*, *S. aureus*, *Pseudomonas putida* and *Bacillus anthracis*⁶⁶. Methanol and aqueous extract of Bael fruit have shown strong activity against multidrug resistant *S. typhimurium*. Methanolic extract is more potent than the aqueous extract. The minimum inhibitory concentration (MIC) value of the methanolic extract is around 256 µg/ml.

It is, thus, evident that Baal has antimicrobial activities may be by blocking protein synthesis either at transcription or translation level and/or peptide-glycan synthesis at membrane level. The antibacterial activity of leaf extract may be due to the presence of Cuminaldehyde and Eugenol⁶⁷.

Antiviral activity

The IC₅₀ of leaves, stem and stem bark, fruit, root and root bark and purified compound Marmelide are 1000, 500 to 1000, 250 to 500 and 62.5 µg/ml, respectively, whereas, the IC₅₀ of Ribavirin,

a standard antiviral agent, is 2000 µg/ml for the same viruses and at the same time period⁶⁸. Thus, marmelide is the most effective virucidal agent interfering with early events of its replicative cycle⁶⁸. It appears that Bael extracts act upon the early stages of viral replication with minimum host cytotoxicity in contrast to ribavirin (a modern virucidal chemotherapeutic agent), that act in the later stages of viral replication with a lot of side effects⁶⁹. Ranikhet disease virus can be controlled by 50% ethanolic extract of the fruits⁷⁰. Fruits also contain interferon-like activity against the same virus⁷¹. Thus *A. marmelos* has a better virucidal potential and may be exploited as a potent antiviral agent in the near future.

Anticancer activity

Anticancer effect on the animal model of Ehrlich ascites carcinoma of hydro- alcoholic extract (400 mg/kg) of Bael leaves shows the greatest antitumor effect⁷². It inhibited in-vitro proliferation of human tumour cell lines including the leucemic K562, T-lymphoid jurkat, Beta lymphoid Raji, Erythro leukemic HEL⁷³.

The plant extract exhibits cytotoxicity against tumor cell lines in brine shrimp lethality assay and methyl thiazolyl tetrazolium (MTT) based assay⁷⁴. The extract also possesses anti-proliferative activity on MCF7 and MDA-MB-231 breast cancer cell lines⁷⁵. Skimmianine in the leaf extract induces apoptosis thereby killing the tumor cells⁷². Taxol is an important anticancer drug widely used in the clinic (Figure.9). Bael also possesses an endophyte fungus *Bartalinia robillardoides* (strain AMB-9), which secretes 187.6 µg/l of Taxol, suggesting that the fungus can serve as a potential material for genetic engineering to improve the production of taxol⁷⁶.

Radioprotective activity

Cultured human peripheral blood lymphocytes (HPBLs) were irradiated with different doses of gamma-radiation, which caused a dose-dependent increase in the frequency of lymphocytes bearing one, two and multiple micronuclei, which significantly reduced when treated with 5 µg/ml leaf extract. This radio protective effect was due to the scavenging of radiation-induced free radicals⁷⁷. Identical experiment was conducted in Swiss albino male mice. The mice were administered with various intraperitoneal single doses of the extract. The optimum radio protective dose of the extract has been found to be five consecutive doses of 15 mg/kg body weight⁷².

Irradiation caused an elevation in the lipid peroxidation leading to dose dependent decline in the level of glutathione. Bael leaf extract arrested glutathione decline and lipid per oxidation significantly³¹. Symptoms of sickness and mortality of the animals are due to irradiation resulting in a dose-dependent elevation in lipid per oxidation in liver, kidney, stomach and intestine as well as depletion in GSH concentration. Treatment of the Bael fruit extract before irradiation caused a significant decrease in the lipid peroxidation accompanied by a significant elevation in the GSH concentration in liver, kidney, stomach and intestine of mice⁷² (Figure.10).

Antihyperlipidaemic activity

Pre-treatment with the Bael leaf extract at 100 mg/kg and 200 mg/kg doses for 35 days have shown significant improvement in the activities of marker enzymes, decrement of lipid peroxides, plasma lipids and lipoproteins in isoproterenol-treated rats, suggesting its antihyperlipidaemic effect⁴⁵. The higher level of fatty acid and their metabolites such as acyl carnitine and long chain acyl CoA

usually interfere with Na^+ / K^+ ATPase activity level⁵⁴.

Oral administration of the aqueous extract of Bael fruits and seeds separately to streptozotocin-induced diabetic rats significantly lowered the serum and tissue lipid profile⁷⁸. Ethanolic extract of Bael leaves also inhibited the elevation of serum cholesterol and triglyceride level in triton treated hyperlipidemia rat⁷⁹. This extract also potentiates glucose utilization.

Other activities

Leaf extract (1 gm/kg) of *A. marmelos* was investigated in the regulation of thyroid hormone in male mice. While serum level of both T (3) and T (4) were inhibited by extract of *A. marmelos* could decrease only T (3) concentration about 62% indicating its possible use in the regulation of hyperthyroidism⁸⁰.

Effects of methanolic extract of the root bark of Bael, an Ayurvedic crude drug used for heart disease and constituents isolated from the extract on the spontaneous beating of cultured mouse myocardial cells were examined. The extract at a concentration of 100 μ g/ml inhibited the beating rate by approximately 50%. Among the isolated constituents, Aurapten was the most potent inhibitor; the IC₅₀ of Aurapten is 0.6 μ g/ml, which is comparable with that of Verapamil, a calcium antagonist. Addition of Aurapten at concentrations higher than 1 μ g/ml significantly reduced the ratio of morphologically changed myocardial cells, which originated from calcium overload caused by successive treatment with calcium-free and calcium-containing solutions⁸¹.

Bioassay-directed fractionation of the ethyl acetate extract of the stem bark of *A. marmelos* afforded a new compound, named Skimmiarepin C, along with Skimmiarepin A. These compounds exhibit moderate insecticidal activity against

Phaedon cholera and *Musca domestica* in comparison with natural pyrethrum extract⁸².

The Bael plant acts as a 'Sink' for chemical pollutants as it absorbs poisonous gases from the atmosphere and make them inert or neutral. It is a member of the plant species group known as 'Climate Purifiers', which emit greater percentage of oxygen in sunlight as compared to other plants. The tree is also considered under the category of 'Fragrant' species, whose flowers and volatile vapors 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 air⁸³.

Toxicological studies

A. marmelos have been used for centuries in India not only for its dietary purposes, but also for its various medicinal properties⁸⁴. Hence, it is generally considered safe and few studies have been carried out with respect to its toxicity. Nevertheless aqueous extract of *A. marmelos* fruit has been reported to be non mutagenic to *S. typhimurium* strain TA 100 in the Ames assay⁸⁵. In addition, acute toxicity studies have reported that a hydroalcoholic extract of *A. marmelos* fruit is non toxic up to a dose of 6 g/kg body weight in mice⁸⁶. Pharmacological studies on animal models involving repeated doses of *A. marmelos* fruit extract over a period of up to 30 days have not reported any adverse effect up to a maximum dose of 250 mg/kg body weight⁸⁷. There were no remarkable changes noticed in histopathological studies after 50 mg/kg body weight of the extracts of *A. marmelos* when administered intraperitoneally for 14 days successively. Pathologically, neither gross abnormalities nor histopathological changes were observed. After calculation of LD (50) values using graphical methods, we found a broad therapeutic window and a high

therapeutic index value for *A. marmelos* extracts. Intraperitoneal administration of the extract of the leaves of *A. marmelos* at doses of 50 to 90 and 100 mg/kg body weight for 14 consecutive days to male and female Wistar rats did not index any short-term toxicity. Collectively, these data demonstrate that the extracts of the leaves of *A. marmelos* have a high margin of drug safety⁸⁸.

CONCLUSION

Aegle marmelos may impart health benefits when it is used in functional food products and should also be regarded as a potential nutraceutical resource in the future. In addition, it can be used as a food additive because of its typical color, flavor and texture. These results are useful for developing and improving the quality of bael fruit cultivate in order to provide more value added and usefulness of bael fruit.

It is quite evident from this review that *Aegle marmelos* contains a number of phytoconstituents which reveals its uses for various therapeutic purposes. The extracts of this important medicinal plant can be the main form of health care for not only the poor tribal community of Jharkhand but can also form an integrated component of mainstream health care or an alternative or complement to the main form of health care. In an era when traditional know how is getting recognized, these indigenous drugs can serve as healthy, cheap and readily available substitutes of relatively more sophisticated, expensive and ill effect causing active principle based synthetic medicines. The indigenous art of healing is waiting to be transformed into an exact science.

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Table 1. Sacred grove in panchmarhi village⁷

Communities	Name of the grove	Deities worshipped	Plants symbolized as abode of deities	Age of the grove (approx)	Groove size (approx)
Gond	Khedapati	Khedapati	<i>Shorea robusta</i> , <i>Madhuca indica</i> , <i>Dendrocalamus strictus</i> <i>Terminalia bellirica</i> , <i>Ficus bengalensis</i> , <i>Mucuna pruriens</i> , <i>Phyllanthus sylvestris</i> , <i>Phyllanthus officinalis</i> , <i>Buchnanian lanzan</i>	200-250	0.20 hectares
Gond	Budh Deo	Budha Deo	<i>Aegle marmelos</i> , <i>Shorea robusta</i> , <i>Dendrocalamus strictus</i> <i>Ficus religiosa</i> , <i>Butea monosperma</i> , <i>Madhuca indica</i> , <i>Ficus bengalensis</i>	Not known	0.10 hectares

Table 2. The ethnomedicinal importance of *A. marmelos*²⁸

Leaves	Extracts of leaves are efficient to treat ulcers, abscess, backache, vomiting, cuts, weakness of heart, acute bronchitis, blood sugars, diarrhoea, dropsy, beri-beri, injuries caused by animals, etc ²⁰ . Juice prepared from leaf extract acts as laxative agent and is helpful for treating ophthalmic infections and asthmic complaints. Medicated oil prepared from leaves of the plant not only helps to prevent cold, cough and other respiratory ailments but is also a good hair tonic when mixed with cumin seeds and massaged on the scalp. Leaves are also used as a veterinary medicine for wound and fodder for animals and stimulation of denervosed nictitating membrane in anaesthetized cats ²¹ .
Root bark	Root bark is used in remission of intermittent fevers fever, fish poison, remedy for heart palpitation and melancholia. Bark juice, mixed with cumin in milk, increases seminal fluid volume. Alcoholic root extracts cure hypoglycemia ²² . It is also used in dog bite, gastric troubles, heart disorders, antiameobic, rheumatism ²³ .
Flower	Extracts of distilled flower is used as tonic for stomach, intestine, anti-dysenteric, anti-diabetic, diaphoretic and local anesthetic ²⁴ . As expectorant it is used to cure epilepsy.
Fruit	Eaten during diarrhea, dysentery and convalescence. It act as a mild astringency. Dry powder mixed with mustard oil is used to treat burn cases ²⁵ . Fruits are used in diarrhea, dysentery, gastric troubles, constipation, laxative, tonic, digestive, brain and heart tonic, ulcer, intestinal parasites, gonorrhoea, epilepsy ²³ . Fresh fruit extracts lower blood pressure ²⁶ . Fine powder of unripe fruit can be an alternative medicine to cure intestinal parasites, like <i>Entamoeba histolitica</i> , <i>Ascaris lumbricoides</i> ²⁷ .
Seed	Seed oil exhibit antibacterial effect against <i>Vibrio cholera</i> , <i>Staphylococcus aureus</i> and <i>Escherichia coli</i> ²⁹ . Essential oil also exhibit antifungal activity against <i>Physallospora tucumanensis</i> , <i>Eratocystis paradoxa</i> , <i>Sclerotium raffsii</i> , <i>Curvularia lunata</i> , <i>helminthosporium sacchari</i> ³⁰ .

Table 3. Some of the important photochemical compounds isolated from different plant parts of *A. Marmelos*¹⁰

S. No.	Part	Phytoconstituents
1	Leaf	Skimmianine, Aegeline, Lupeol, Cineol, Cuminaldehyde, Eugenol, Marmesinine, Citronella
2	Bark	Skimmianine, Fagarine, Marmine,
3	Fruit	Marmelosin, Luvangetin, Aurapten, Psoralen, Marmelide, Tannin



Figure 1. Photographs of a sacred grove plant in Ranchi⁶ Gods worship *A. marmalos* in a sacred grove, named Buddha Deo⁷(Kala, 2011)



Figure 2. Worshipping deity in the sacred grove⁷





Figure 3a. Ripe fruit

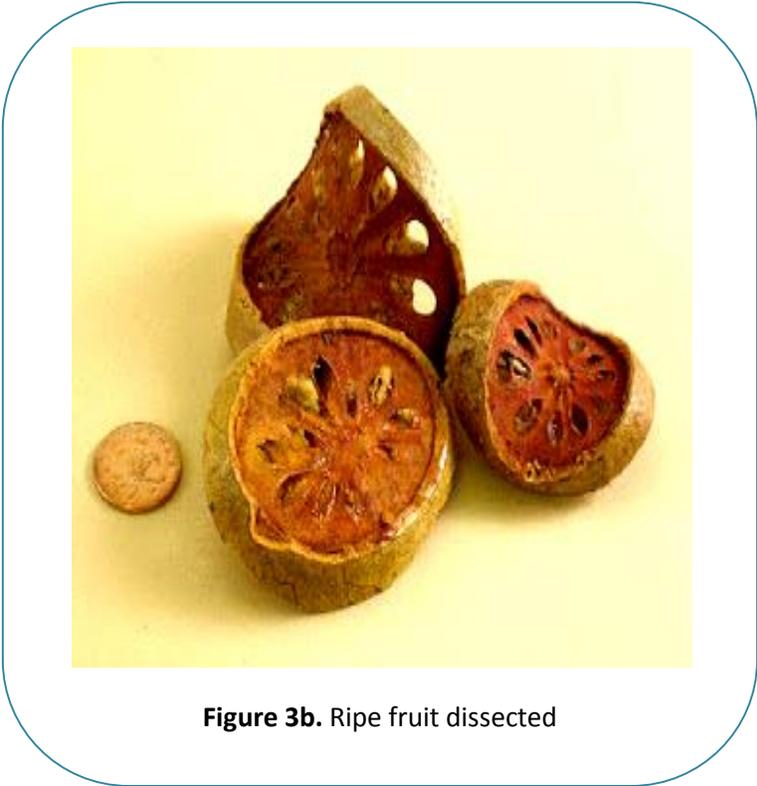


Figure 3b. Ripe fruit dissected

Article by Niraj Traders¹³



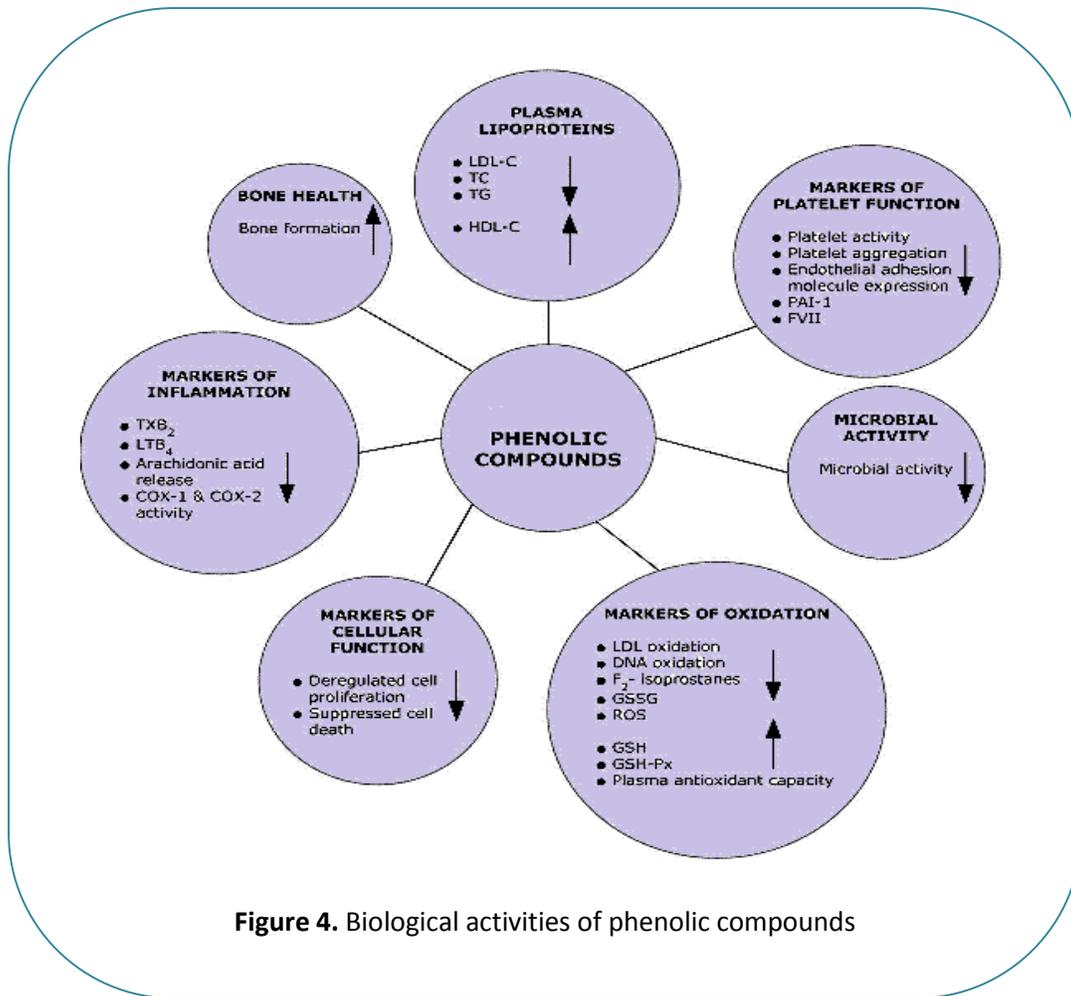
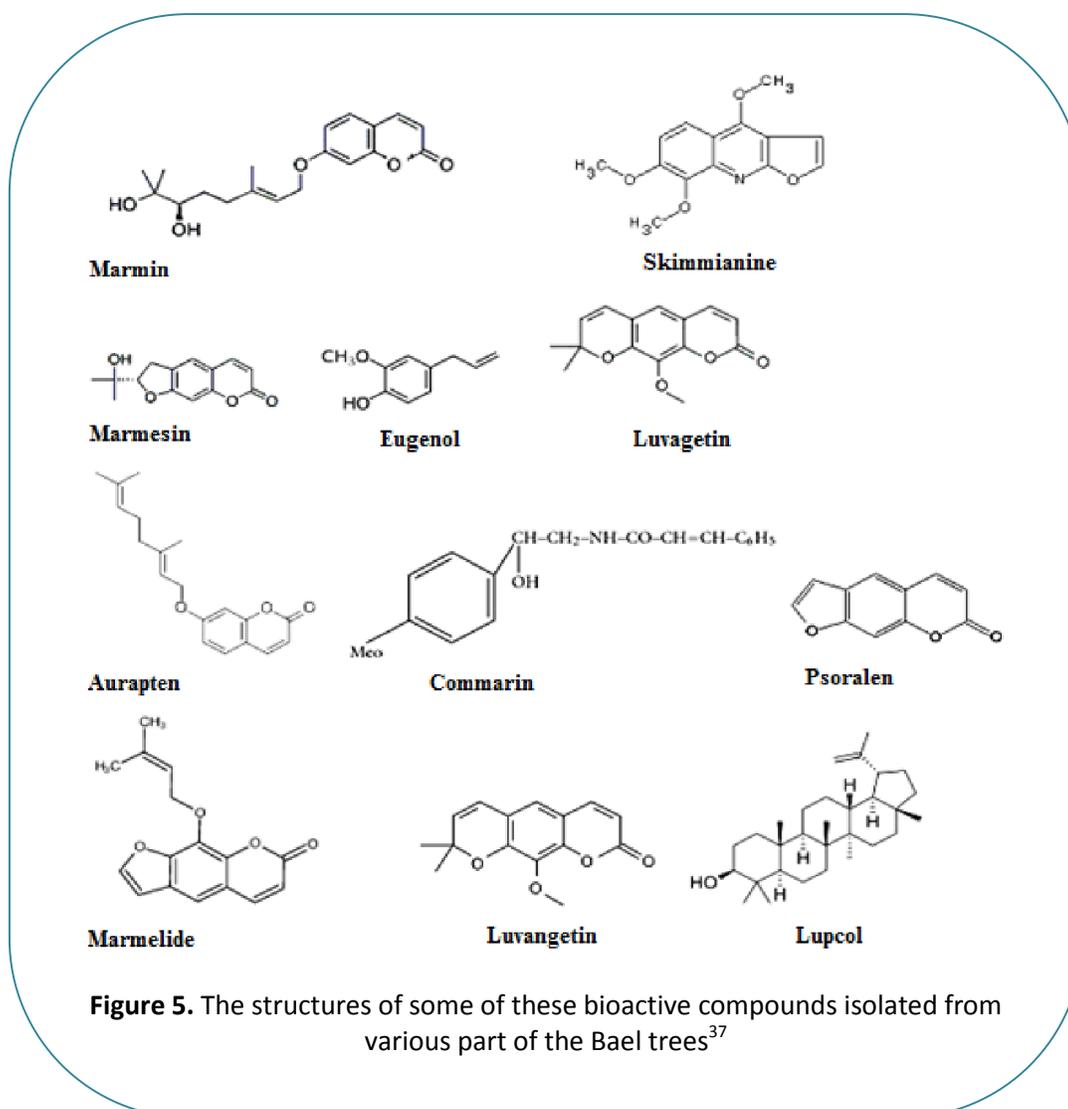


Figure 4. Biological activities of phenolic compounds





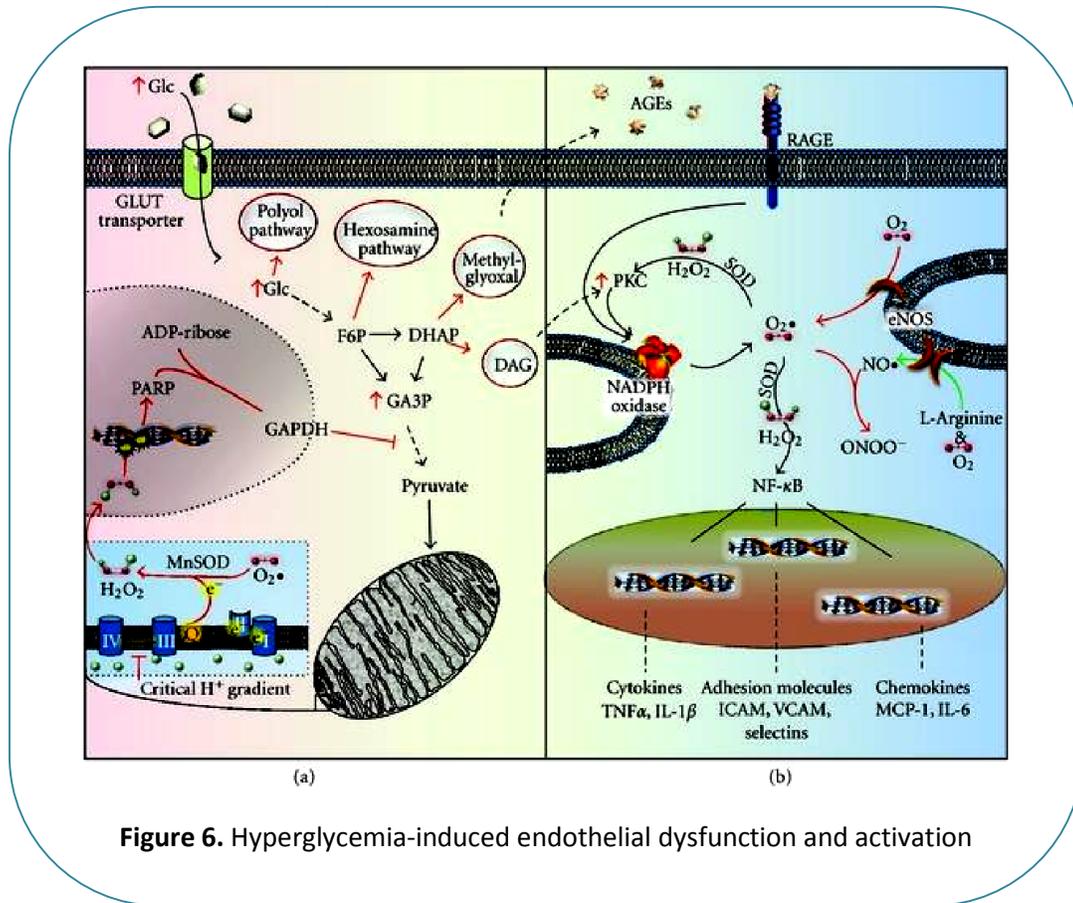


Figure 6. Hyperglycemia-induced endothelial dysfunction and activation

(<http://www.hindawi.com/journals/ijvm/2012/569654/fig3/>)

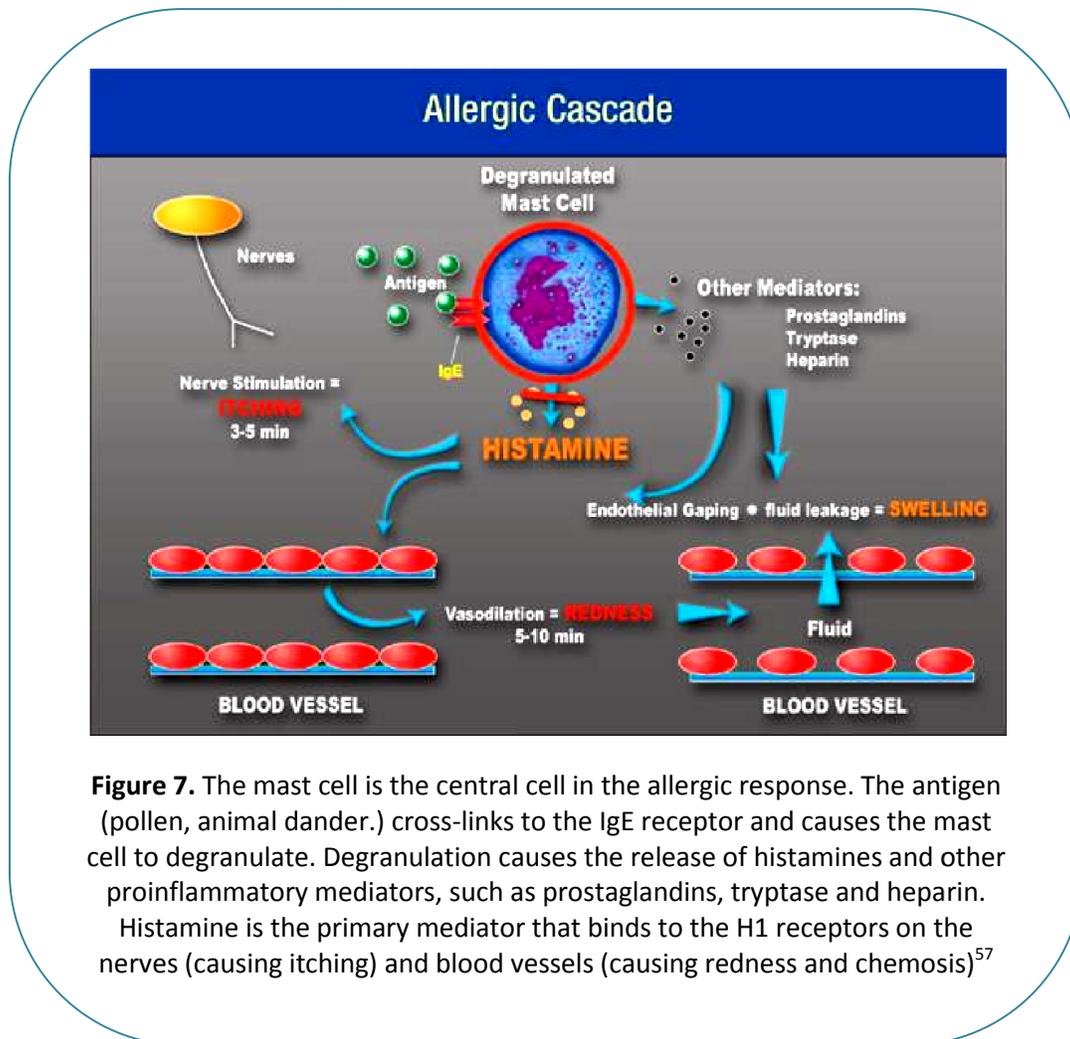


Figure 7. The mast cell is the central cell in the allergic response. The antigen (pollen, animal dander.) cross-links to the IgE receptor and causes the mast cell to degranulate. Degranulation causes the release of histamines and other proinflammatory mediators, such as prostaglandins, tryptase and heparin. Histamine is the primary mediator that binds to the H1 receptors on the nerves (causing itching) and blood vessels (causing redness and chemosis)⁵⁷

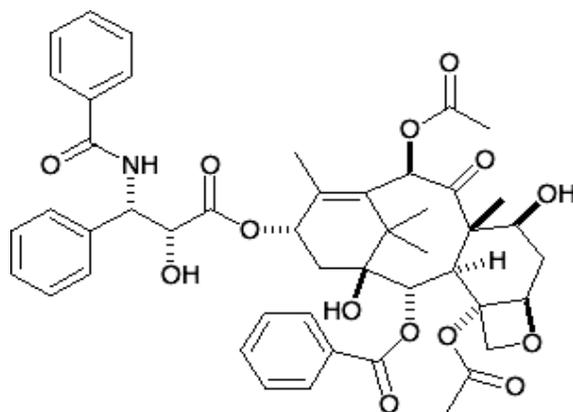
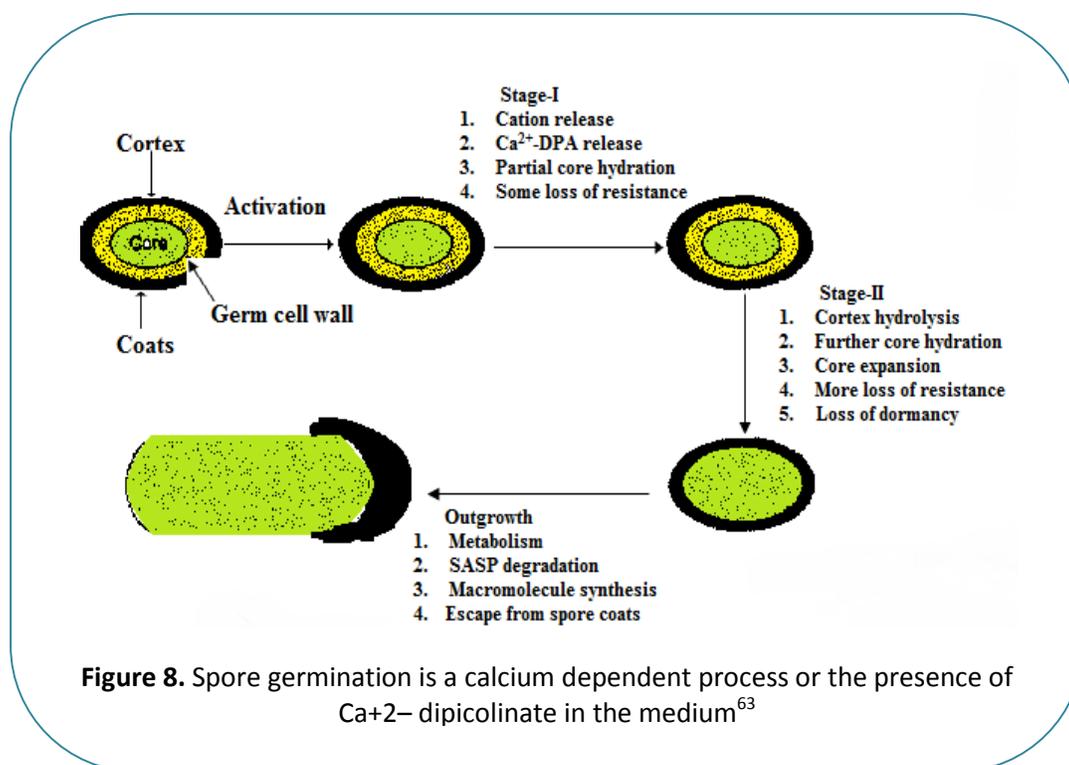


Figure 9. Taxol

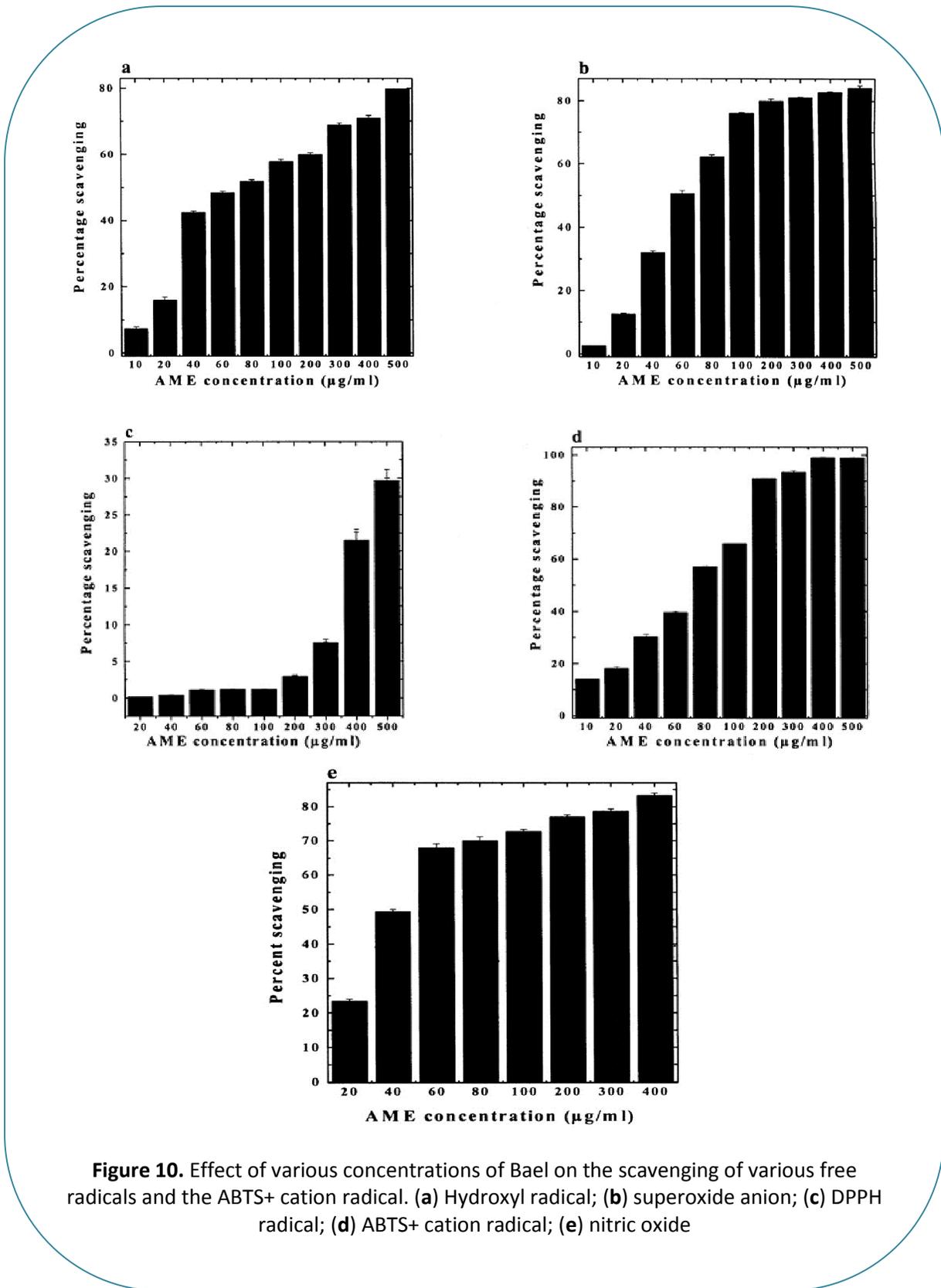


Figure 10. Effect of various concentrations of Bael on the scavenging of various free radicals and the ABTS+ cation radical. (a) Hydroxyl radical; (b) superoxide anion; (c) DPPH radical; (d) ABTS+ cation radical; (e) nitric oxide