



Review Article

BIOLOGICAL ACTIVITIES AND THERAPEUTIC POTENTIAL OF *AEGLE MARMELLOS* (BAEL): A REVIEW¹Seema Singh, ²Pramod Singh, ³Sandeep Kumar Singh, ⁴Mohit Trivedi, ²Dr. R.K.Dixit, ²Pratap Shanker¹Department of Pharmacy, Northern India Engineering College, Lucknow, (U.P.)²Department of Pharmacology, King George Medical University, Lucknow (U.P)³Department of Pharmaceutical Sciences, Dr. H. S. Gaur Central University Sagar (M.P)⁴Department of Pharmacology E.L.M.C. Lucknow UP

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Abstract: Bael, *Aegle marmelos* (linn.) correa is an important medicinal plant found all over India, from sub-himalayan forests, Bengal, Central and South India and in Burma is known from pre-historic time. It has a great mythological significance for Hindus. Utilization of bael in day-to-day life has great nutritional, environmental as well as commercial importance. Leaves, fruits, stem, bark and roots of *Aegle marmelos* have been used in ethnomedicine to exploit its medicinal properties including astringent, antidiarrhoeal, antidysentric, demulcent, antipyretic, antimicrobial, anticonvulsant, hepatoprotective, antioxidant, analgesic, wound healing and anti-inflammatory activities. Recent advances prove that compounds purified from bael have been proven to be biologically active against several major diseases including cancer, immunomodulatory, cardiovascular diseases. The present reviews deals with the biological activities of some isolated chemical constituents of *Aegle marmelos* and preclinical studies on some crude extracts of pure compounds to explore novel bioactive compounds for therapeutic application.

Key words: *Aegle marmelos*; Chemical constituents; Biological activities.**INTRODUCTION**

Bael an Indian plant has enormous uses against various diseases. Many bioactive compounds have been isolated from this plant. Bael is a medium sized, armed, deciduous tree belonging to the family Rutaceae. In India, it grows as wild species especially in dry forest, outer Himalayas, shivaliks, south Indian plateau. At some places it is also cultivated for its fruits. Leaves, fruits, stem and roots of this tree at all stages of maturity are used as ethno medicines against various human ailments. Extensive chemical investigations on various parts of the tree have been carried out and more than hundred compounds have been isolated.¹

Life without natural products is unimaginable. It has provided mankind with oxygen, water, fire, food, clothing, shelter and medicine. Its public health impact is considerably high, especially inform of traditional medicines and nature-based modern drugs. The traditional medicines, despite its limitations, are addressing the health needs of millions of people worldwide. It is estimated that about 65-85% of the world population uses traditional medicines for their primary health cares. It is also estimated that about 39% of all 520 new approved drugs developed in past in twenty years belong to natural products.²

Many of these natural compounds like skimmianine, aegelin, lupeol, citronellal, cineole, citral, cuminaldehyde, eugenol, marmesinin, marmelosin, luvangetin, aurapten, psoralen, marmelide, fagarine, marmin, tannin have been proved to be biologically active against various diseases including cancer. Crude extracts of plants have shown antiulcer, antipyretic, analgesic, antidiabetic, antihyperlipidaemic, antioxidant, anticancer, antimicrobial, radioprotective, anti-inflammatory and antispermatogenic effects on various animal models.¹

As there are many diseases that cannot be cured by the existing drugs and as there are increasing cases of drug resistance, there is urgent need for drugs that are effective against these pathogens. Probably, traditional medicines could provide a solution in fighting them both as a health care delivery mechanism and as a means of chemotherapeutic pool. With the advancement in science and technology, remarkable progress has been made in the field of medicine including diagnosis, treatments and pharmaceuticals. Recent drug discovery techniques based on structure activity relationships, computer modeling, combinatorial chemistry, high throughput

screening and spectroscopy (Mass spectroscopy, Nuclear magnetic resonance, and Infrared spectroscopy) have triggered and spearheaded the discoveries of many natural and synthetic drugs.²

In 1999, world sales of pharmaceuticals (excluding veterinary medicines) were valued at ca. US\$ 325 billion. Amongst several factors contributing towards the potential use of herbal drugs, holistic approach to the health problems, safety, lack of adverse reactions and side effects have been mostly found to particularly influence the use of such medicines in the developed countries whereas their accessibility, affordability, historical and cultural background besides the above factors promote their use in the developing countries. Added to these strengths and the clinical evidence of safety provided by some herbal drugs, traditional herbal therapies have no doubt the potential to increasingly contribute to a better health care system in many countries.³

Biological properties of bael

The bael has got nutritive, curative and pesticidal properties. All of its parts, i.e., stem, bark, leaves, fruits, and roots at any stage of development, have one or another usage. The unripe as well as ripe fruits can be used in different ways, mainly making 'murabba' (sweet preserve), jam, candies, toffees, slabs, and soft drinks. Sundried fruit slices of green fruit are often stored for future use. The fruit pulp can be used for washing clothes. The gum from unripe fruit is used as glue as well as a protective coating on paintings. Major constituents are mucilage and pectin in unripe fruit, while ripe fruit is a tonic and is used as mild astringent for diseases like diarrhoea and dysentery. Many alkaloids, coumarin and steroids have been isolated from different parts of the plant. The pulp contains psoralen, which is employed in treatment of leucoderma. Fruit is claimed to be prescribed in case of hepatitis and tuberculosis in Cambodia. Aqueous and alcoholic extracts have cardio tonic effects. A decoction of flowers is used as an eye lotion. A bark decoction is sometime given for curing malaria. A leaf decoction is effective in relieving asthma. Extracts from leaves in combination with honey are good for catarrh and

fever. Plant parts also have antibiotic properties. Roots are used as an anti-inflammatory and antidote to snake venom in India. The leaves have got pesticidal constituents. Although the wood is not durable, it is good for carving and making handles of various tools.⁴

Chemical composition of bael products

Various chemical constituents like alkaloids, coumarins and steroids have been isolated and identified from different parts of bael tree, such as leaves, fruits, wood, root and bark.

Coumarins like marmelosin, marmesin, imperatorin, marmin, alloimperatorin, methyl ether, xanthotoxol, scoparone, scopoletin, umbelliferone, psoralen and marmelide.⁵ Marmenol, a 7-geranyloxycoumarin 7-(6-dihydroxy-7-methoxy-7-methyl-3-octaenyloxy) coumarin has also been reported.⁶

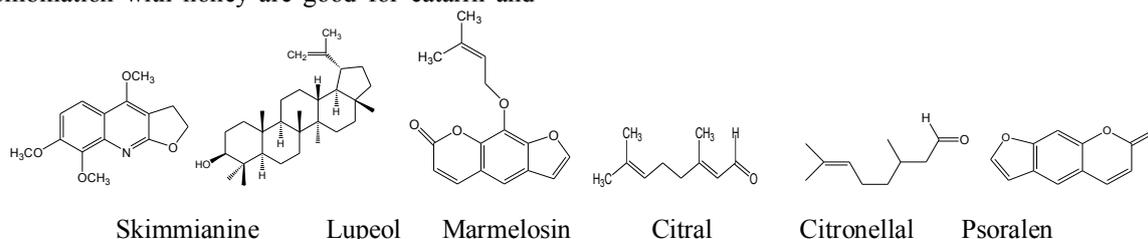
Alkaloids like aegelin, aegelenine, marmeline, dictamine, fragrine (C₁₃H₁₁O₃N), O-methylalfordinine, O isopentenylhalfordinol, N-2-(4-(3, 3-dimethylallyloxy) phenyl) ethyl cinnamide, n-2-hydroxy-2-(4-hydroxyphenyl) ethyl cinnamide,^{8,9} O-(3,3-dimethylallyl) halfordinol, n-2-ethoxy-2-(4-methoxy phenyl) ethyl cinnamide, N-2-methoxy-2-(4(3, 3-dimethylallylo) phenyl) ethylcinnamide, N-2-methoxy-2-(4-methoxyphenyl)-ethyl cinnamide.^{10,11}

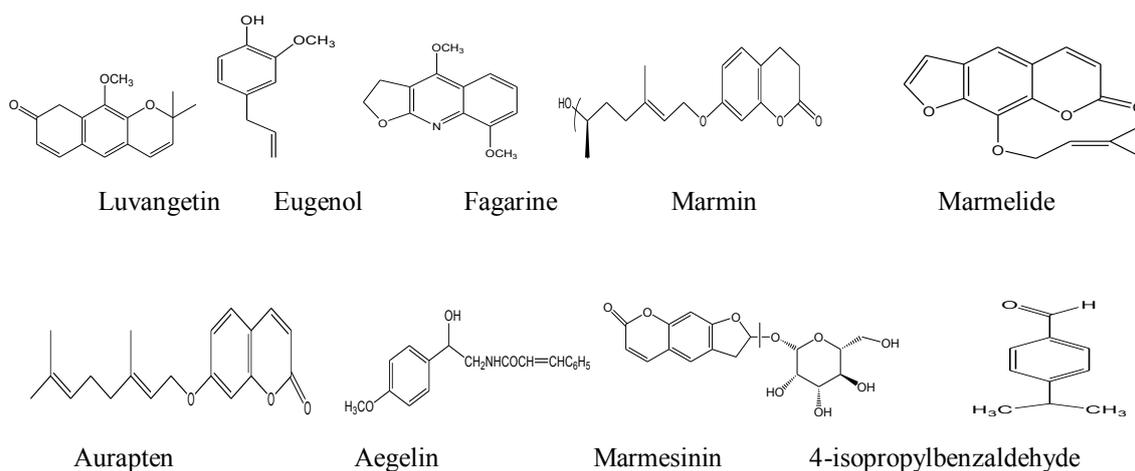
Polysaccharides like Galactose, arabinose, uronic acid and 1-rhamnose are obtained on hydrolysis.¹²

Seed oil like Composed of palmitic, steric, oleic, linoleic and linolenic acid.¹³

Tannins is also present in leaves as skimmianine. The maximum tannin content in bael fruit was recorded in the month of January. There is as much as 9% tannin in the pulp of wild fruits, less in cultivated type [14].

Carotenoids are responsible for imparting pale colour to fruit. Marmelosin, skimmianine and umbelliferone are the therapeutically active principles of bael plant.^{15,16}





Structures of purified bioactive compounds from Bael

Pharmacological properties with potential therapeutic values of Bael: utilizing the biological properties for prevention and treatment of various ailments has been evaluated by number of researchers. Some of the clinical uses have been found to be scientifically well established. Some of the role of extracts from various parts these plants are as follows:

Hepatoprotective activity

Liver is the vital organ in the body that is concerned with the detoxification and disposition of toxic substances. It is exposed to a wide variety of xenobiotics, hepatotoxins, and chemotherapeutic agents that lead to damage and subsequent impairment of its functions.¹⁷ Its hepatoprotective effect in alcohol induced liver injury in albino rat was evaluated using essential biochemical parameters and the experimental result indicate that, the bael leaves have excellent hepatoprotective properties.¹⁸ Rajasekaran *et al* suggest that ethanolic and aqueous fruit pulp extracts of *A. marmelos* had moderate to significant activity over CCl_4 treatment as compared to the control. Results of the present investigation suggest that CCl_4 induced liver damage in rats can substantially be ameliorated by treatment of ethanolic extracts from fruit pulp of *A. marmelos*. Also the study confirms the claim on this plant as a potential hepatoprotective agent in the traditional medicine.¹⁹ The ethanolic extracts of matured fruits of *A. marmelos* holds a potential to be used as effective natural hepatoprotective agent. Further, investigations on the phytochemical characterization of the components would pave way for the development of potential drug.²⁰ Premkumar *et al* evaluated the Hepatoprotective activities of ethanolic and aqueous extracts of *A. marmelos* which were examined against carbon tetrachloride

induced liver damage in mice and investigation confirms the traditional uses of this plant as a potential hepatoprotective agent.²¹ The aqueous extracts of bael fruits pulp and seeds are effective in the treatment and prevention of CCl_4 induced hepatic cytotoxicity. The data suggests that the daily oral consumption of an aqueous extract of the bael fruits and seeds as a part of the diet ad libitum was prophylactic to CCl_4 poisoning, achieving about 80% protection with fruits pulp and 70% with seeds. A similar percentage protection was achieved when the aqueous extracts of the fruits pup and seeds were used as a cure against CCl_4 poisoning after toxicity was induced was studied by Singh *et al*.²² The administration of herbal drug *Aegle marmelos* inversed the catalase activity in the liver tissues and protected from the free radical induced oxidative stress was studied by Rajashree *et al*.²³

Anticonvulsant activity

Incidence of epilepsy in developed countries is approximately 50 per 100,000 while that of developing country is 100 per 100, 000.²⁴ It has been observed that the presently available antiepileptic drugs are unable to control seizures effectively in as many as 25% of the patients by Mattson *et al*.²⁵ The conventional antiepileptic agents like phenytoin, carbamazepine and sodium valporate carry with them several serious side effects notably neurotoxicity was studied Gupta *et al*.²⁶ Majority of antiepileptic drugs consumed life long, concomitant administration of other drugs predisposes to the risk of drug interaction was studied by Chauhan *et al*.²⁷ The plants containing saponins or flavonoids exhibit anticonvulsant activity.²⁸ One of the approaches to search for new antiepileptic drugs is the investigation of naturally occurring compounds, which may belong to new structural classes. Pandhare Ramdas *et al* evaluated the effect of alcoholic extract of leaves and fruit of *Aegle marmelos* against seizures induced by

maximal electroshock (MES) or pentylenetetrazole (PTZ) in mice. The results indicate that the aqueous extract produced dose-dependent anticonvulsant effect against MES and PTZ-induced seizure with an ED₅₀ of 100, 200 mg/kg respectively.²⁹ Sankari *et al* evaluated the methanolic extract of *Aegle marmelos* delayed the occurrence of MES and PTZ convulsions; and suggested that the action may be interfering with gabaergic mechanism(s).³⁰

Antimicrobial activity

Antimicrobial properties of medicinal plants are being increasingly reported from different parts of the world. The world health organization estimates that plant extracts or their active constituents are used as folk medicine in traditional therapies of 80 % of the world's population.³¹ Extracts from *Aegle marmelos* have shown good antimicrobial activity against *Escherichia coli*, *Salmonella typhi*, *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Bacillus subtilis* due to the presence of alkaloids, cardiac glycosides, terpenoids, saponins, tannin, flavonoids, and steroids.³² The unsaponifiable matters as well as pure oil of *Aegle marmelos* exhibited antimicrobial and anthelmintic properties.³³ Nandkarni *et al* studied the Bark and leaves of the herb *Aegle marmelos* possess antibacterial activities.³⁴ Various extracts of bael leaves, roots and fruits have been reported to be active against many bacterial strains was evaluated by George and Joshi *et al*.^{35, 36} Sudharmeshwari *et al* described that the plant is promising the development of phytomedicine for antimicrobial properties.³⁷

Antifungal activity

The antifungal activity of essential oil isolated from leaves of *Aegle marmelos* (L.) correa ex roxb., rutaceae has been evaluated using spore germination assay. The oil exhibited variable efficacy against different fungal isolates and 100% inhibition of spore germination of all the fungi tested was observed at 500 ppm. However, the most resistant fungus, *Fusarium udum* was inhibited 80% at 400 ppm. Kinetic studies showed concentration as well as time dependent complex inhibition of spore germination by the essential oil was described by Rana *et al*.³⁸ Bhuwan *et al* isolated a new anthraquinone, 1-methyl-2-(3'-methyl-but-2'-enyloxy).³⁹ Desh *et al* evaluated the antifungal constituents, 2-isopropenyl-4-methyl-1-oxa-cyclopenta [b] anthracene-5,10-dione and (+)-4-(20-hydroxy-30-methylbut-30-enyloxy)-8H [1,3] dioxolo [4,5-h] chromen-8-one in addition to known compounds imperatorin, b-sitosterol, plumbagin, 1-methyl-2-(30-methyl-but-20-enyloxy) – anthraquinone.⁴⁰

Antidiarrhoeal activity

Brijesh *et al* evaluated *A. marmelos* in infectious forms of diarrhoea.⁴¹ The results obtained in the study suggest that the decoction of *A. marmelos* can control several forms of infectious diarrhoeal diseases caused by EPEC, EIEC, LT producing ETEC, *V. cholerae*, *S. flexneri* and to some extent it can also control giardiasis and rotaviral infections.⁴² Carlo *et al* evaluated the qualitative phytochemical analysis and showed presence of carbohydrates, glycosides, amino acids, proteins, tannins, flavanoids, phytosterols, marmelosin. Tannins and flavonoids in general have been reported to have antidiarrhoeal activity through inhibition of intestinal motility, antimicrobial action and antisecretory effects.⁴³ Tona *et al* studied the antidiarrhoeal effect of ethanolic extract of the dried fruit pulp of *aegle marmelos*. It showed excellent activity against *shigella boydii*, *s. sonnei* and *s. flexneri* whereas the activity was found to be moderate against *s. dysenteries*.⁴⁴ The chloroform extract of *Aegle marmelos* root has significant bactericidal activity comparable to that of ciprofloxacin when tested *in vitro*. Further, it was also found to reduce diarrhoea in rats by inhibiting intestinal peristalsis. Hence, from preliminary studies extracts of Bael can be claimed to be a potential antidiarrhoeal agent. The underlying mechanism appears to be bactericidal and spasmolytic by which the root and its extract produces relief in diarrhoea Shoba *et al*.⁴⁵

Gastrointestinal disorders

Tannin and mucilaginous substances present in bael help as antidiarrhoeal.⁴⁶ Patients suffering from diarrhoea-predominant irritable bowel syndrome showed significantly greater improvement in symptoms when given an indigenous preparation containing *Aegle marmelos* and *Bacopa monniere* compared with placebo Haider *et al*.⁴⁷ Goel *et al* evaluated Marmelosin, which is isolated from the bael plant, has been reported to have anti-helminthic and anti-bacterial activity.⁴⁸ Oral administration of luvangetin, a pyranocoumarin isolated from the seeds of *Aegle marmelos*, protected against multiple models of gastric ulceration in rodents Maity *et al*.⁴⁹

Antioxidant activity

Oxidative stress is produced during normal metabolic process in the body as well as induced by a variety of environmental and chemical factors, which cause generation of various reactive free radicals and subsequent damage to macromolecules like DNA, proteins and lipids.⁵⁰ The antioxidant activity of essential oils present in bael has been shown.⁵¹ The essential oils isolated from aromatic and medicinal plants are important secondary

metabolites which are known since antiquity to possess biological activity.⁵² Kamalakkannan *et al* described the use of antioxidants from natural sources has become more popular as a means of increasing the self-life of food products, improving the stability of fats and oils rich in polyunsaturated fatty acids (PUFAs), in slowing down the ageing process and in the treatment of cancer.⁵³

Antidiabetic activity

Boon *et al* described Diabetes mellitus is the most severe metabolic pandemic of the 21st century, affecting essential biochemical activities in almost every cell in the body and increasing the risk of cardiac problems. It is estimated that in the year 2000, 171 million people had diabetes, and this is expected to double by year 2030.⁵⁴ Felig *et al* studied conventionally, insulin-dependent diabetes mellitus is treated with exogenous insulin⁵⁵ and non insulin-dependent diabetes mellitus with synthetic oral hypoglycemic agents like sulphonylureas and biguanides was described by Rosac *et al*⁵⁶. Mukherjee *et al* described the hormone fails as a curative agent for complications of diabetes⁵⁷ and synthetic oral drugs produce adverse health effects was evaluated by Raheja *et al*.⁵⁸ *Aegle marmelos* is widely used in Indian Ayurvedic medicine for the treatment of diabetes mellitus was studied by Kamalakkannan *et al*.⁵⁹ Hypoglycemic effect of root bark decoction (1ml/100mg) has been observed in normal fasted rats was described by Karunanayake *et al*.⁶⁰ Leaf extract produced anti-hyperglycemic activity in alloxan diabetic rats along with decreased cholesterol and blood urea was evaluated by Ponnachan *et al*⁶¹. In diabetic rats leaf extract exhibited insulin like activity was described by Paulose *et al*.⁶² Aqueous leaf extract has been shown to improve the functional state of pancreatic cells in streptozotocin induced diabetic rats was studied by Das *et al*⁶³. Aqueous leaf extract (250 & 500mg/kg, orally) produced hypoglycemic effect and increased plasma insulin level of STZ-diabetic rats. LD50 (lethal dose) observed greater than 10.0g/kg at oral administration to rats was evaluated by Sharma *et al*.⁶⁴ Anti-hyperglycemic activity caused by leaf extract (250mg/kg, orally) in glucose fed hyperglycemic rats was described by Sachdewa *et al*.⁶⁵ Aqueous fruit extract (250mg/kg, twice daily for one month) produces anti-hyperglycemic effect along with decreasing glycosylated haemoglobin level in STZ induced diabetic albino wistar rats was studied by Kamalakkannan *et al*.⁶⁶ Hypoglycemic and antioxidant activity of leaves have been observed in diabetic male albino rats was evaluated by Upadhyaya *et al*.⁶⁷ Fruit extract (125 and 250mg/kg, orally twice daily for 30 days) produced anti-diabetic, anti-hyperlipidaemic and antioxidant

activity in STZ diabetic rats along with partial repair of damaged pancreatic islets was evaluated by Kamalakkannan *et al*.⁶⁸ Treatment of severely (fasting blood glucose level >250 mg/ml) diabetic rats for 14 days with aqueous extract (250mg/kg, orally) of *Aegle marmelos* seeds reduced the fasting blood glucose by 60.84% and urine sugar by 75% than their pretreatment levels was described by Kesari *et al*.⁶⁹ Devi *et al* evaluated the lipid lowering property of an aqueous extract of *Aegle marmelos* leaves on streptozotocin (STZ) induced diabetic rats. These results further suggest that *Aegle marmelos* may be useful in the therapy and management of hyperlipidemia by reducing lipid levels.⁷⁰ Subban *et al* studied the methanol extract of the root of *Aegle marmelos*, a medicinal plant, was fractionated into eight fractions using column chromatography. The antidiabetic activity of all the fractions was studied using the glucose uptake by isolated rat hemi-diaphragm *in vitro* model. Using the bioassay-guided fractionation, two compounds **1** and **2** were isolated by column chromatography and identified as 6-methyl-4-chromanone and skimmianine respectively by NMR and mass spectral methods.⁷¹ Upadhyaya *et al* evaluated the hypoglycemic and antioxidant effect of aqueous extract of *Aegle marmelos* leaves (AML) on diabetic rats. AML may be useful in the long term management of diabetes.⁷² Rao *et al* described the leaf and callus materials contain anti-diabetic active principles, which would reduce the sugar level in STZ-diabetic rabbits. It is also inferred that the crude solvent extracts of leaf and callus powder may have some compounds in addition to the active anti-diabetic principles. Also, the solvents may affect the action of the principal compound responsible for the anti-diabetic effect.⁷³ Ismail *et al* described to investigate clinically the antidiabetic activity of Bael leaves (*Aegle marmelos*, Corr.) individually and collectively with the standard oral hypoglycemic therapy in non insulin dependent diabetes mellitus (NIDDM) patients. Antidiabetic effect was more markedly observed when it was combined with the oral hypoglycemic therapy. Bael leaves can be combined in high dose with oral hypoglycemic agents to bring the blood glucose to normal levels in patients whose diabetes is not controlled with these agents or in those patients in whom these drugs produce adverse effects on dose increments.⁷⁴ The current investigation focuses on the serum insulin augmentation, antihyperglycemic and anti-hyperlipidemic property of a combined aqueous extracts of *E. jambolana* and *A. marmelos* (EA) on alloxan induced diabetic rats. The histological studies of the endocrine region of pancreas of diabetic animals revealed that shrinkage of cells of islets of langerhans. The combined plant extracts treated animals revealed restoration of cells. The restoration of cells was evident at higher dose level that is 400 mg/by wt

extracts fed groups.⁷⁵ Hypoglycemic and antihyperglycemic activity of *aegle marmelos* seed extract in normal and diabetic rats was studied by Watal et al⁷⁶.

Wound healing activity

Jaswanth *et al* studied the effects of topical and intraperitoneal administration of methanolic extract of *aegle marmelos* ointment and injection was studied respectively on two types of wound models in rats, (i) the excision and (ii) the incision wound model. Both the injection and the ointment of the methanol extract of *aegle marmelos* produced a significant response in both of the wound types tested. In the excision model the extract treated wounds were found to epithelialise faster and the rate of wound contraction was higher as compared to control wounds. The extract facilitated the healing process as evidenced by increase in the tensile strength in the incision model. The results were also comparable to those of a standard drug nitrofurazone⁷⁷. Evans *et al* described the process of wound healing which occurs in four phases: (i) coagulation, which prevent blood loss, (ii) inflammation and debridement of wound, (iii) repair, including cellular proliferation and (iv) tissue remodeling and collagen deposition⁷⁸. Plant products have been shown to possess good therapeutic potential as anti-inflammatory agents and promoter of wound healing, due to the presence of active terpenes, alkaloids and flavonoids.^{79, 80}

Antigonadal activity

Antigonadal activity of hydro-methanolic (40:60) extract of leaf of *Aegle marmelos* was noted here by using male albino rat as model animal. This evaluation was performed by sperm count, sperm viability, sperm motility, plasma testosterone level; androgenic key enzyme activities in testis which were decreased significantly after the leaf extract treatment in respect to control. The levels of thiobarbituric acid reactive substance (TBARS) and catalase activities of testis and sperm pellet along with the count of different generation of germ cells at stage VII of seminiferous epithelial cycle were noted. This study focus the effect of this extract through hypothalamico-hypophysial axis for the induction of antigonadal activity that may lead to develop an herbal male contraceptive in future was evaluated by Das *et al*.⁸¹ All the major accessory sex organs shed weight post administration of the extract. There was a marked reduction in motility and density of the sperm derived from cauda epididymis of the treated animals. *A. marmelos* reduced fertility of male rats by 100% at the 300-mg dose level. Blood tests did not point to distress in any of the vital organs. Withdrawal of the extract restored all the altered parameters including organ weights, fertility, testosterone levels and tissue

biochemistry to control levels after 120 days was described by Agarawal *et al*.⁸² The aqueous extract of leaf *aegle marmelos* at the dose 50 mg/100mg body weight resulted a significant diminution in the activities of key testicular steroidogenic enzymes along with low levels of plasma testosterone and relative wet weights of sex organs in respect to control without any significant alteration in general body growth. Germ cells numbers in different generation at stage VII of seminiferous epithelial cell cycle were diminished significantly after the treatment of the above extract. The above mentioned dose did not exhibit any toxicity in liver and kidney. Therefore, it may be predicted that the aqueous extract of leaf of *aegle marmelos* has a potent antitesticular effect at a specific dose was described by Jana *et al*.⁸³ Proper scientific research on the contraceptive effects of *Aegle marmelos* and its mode of action has not previously been conducted.⁸⁴

Insecticidal activity

Dubey *et al* determined the potential of using essential oil from leaves of *Aegle marmelos* to control insect infestation of stored gram from *Callosobruchus chinensis* (L.) (Bruchidae) and wheat from *Rhyzopertha dominica* (F.) (Bostrychidae), *Sitophilus oryzae* (L.) (Curculionidae) and *Tribolium castaneum* (Herbst) (Tenebrionidae).⁸⁵ The essential oil from the leaves of *A. marmelos* is known to exhibited antifungal properties evaluated by Renu *et al*.⁸⁶

Immunomodulatory activity

Asdaq *et al* described the Immunomodulatory action of methanolic extract of *Aegle marmelos* fruit in experimental model of immunity at 100 and 500 mg/kg produced significant increases in adhesion of neutrophils and an increase in phagocytic index in carbon clearance assay.⁸⁷

Antigenotoxicity activity

Bhardwaj *et al* studied the isolation of 24-epibrassinolide from *Aegle marmelos* and its antigenotoxic effects against MH employing *Allium cepa* chromosomal aberration assay.⁸⁸ Methanol extract inhibited the genotoxicity of H₂O₂ by 70.48% and that of AFB₁ by 84.65%. The extracts showed significant decrease in the tail moment induced by hydrogen peroxide (9µM) in the Single Cell Gel Electrophoresis (SCGE) assay. The antigenotoxic activity exhibited by the extracts may be attributed the various polyphenolic constituents present in these extracts was studied by Kaur *et al*.⁸⁹ Natural antioxidants such as polyphenolic compounds are found to play protective roles against many human chronic diseases which are associated with oxidative stress. Epidemiological

studies showed that a high intake of antioxidants rich foods is inversely related to cancer risk.⁹⁰ Among the possible causes of cancer, damage to DNA and other cellular molecules by reactive oxygen species ranks high as a major culprit in the onset and development of diseases. These by-products of normal metabolism; which increase in inflammation and in exposure to exogenous sources including nitrogen oxide pollutants, smoking, certain drugs and radiations, can induce cancer

Conclusion

It is quite evident that Bael contains several important bioactive compounds and some have already shown their therapeutic potential. Unfortunately, most of the compounds have not properly been evaluated for the exploration of new lead molecule or pharmacophore. Moreover mechanisms of action of a few bioactive compounds have been identified so far. Hence, extensive research is required to find out the mechanisms of action as well as bioactivity of other compounds in crude extracts and to exploit

causing mutations oxidize lipids proteins and alter signal transduction pathways that enhance cancer risk.^{91,92}

Analgesic activity

The methanol extract of leaves of *aegle marmelos* at a dose level of 200 and 300 mg/kg showed significant analgesic activity on acetic acid-induced writhing and tail flick test in mice was evaluated by Shankarananth *et al.*⁹³

their therapeutic potential to combat various diseases. A drug development programme can be developed through extensive investigation of the bioactivity of various compounds, their mechanism of action, pharmacotherapeutics, toxicity, standardization and clinical trials. Thus in near future Bael may play a very important role in modern system of medicine. As in this opinion, that we Indians are equipped with modern scientific techniques and enriched with strong traditional knowledge are best studied and well placed harness to maximum potential of this plant of panacea for human and environmental well-being.

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