ABSTRACT
Since time immemorial, plants and their products have been the primary resource of food and medicines for mankind. *Aegle marmelos* commonly known as bael (or bel), belonging to the family Rutaceae, is a moderate sized, slender and aromatic tree. A number of chemical constituents and various therapeutic effects of leaves of *Aegle marmelos* have been reported by different workers. Extensive investigations have been carried out on different parts of *Aegle marmelos* and as a consequence, varied classes of compound viz., alkaloids, coumarins, terpenoids, fatty acids and amino acids have been isolated from its different parts. Various phytochemical, ethnobotanical and pharmacological evaluations have been reported in this literature for the important potential of the *Aegle marmelos*.

Keywords: *Aegle marmelos*, Bael, Phytochemical, Ethnobotanical, Pharmacological.

INTRODUCTION
*Aegle marmelos* belonging to family Rutaceae, is commonly known as Bael in indigenous systems of medicine and has been regarded to possess various medicinal properties. The bael is one of the sacred trees of the Hindus. Leaves are offered in prayers to Shiva and Parvathi since ancient times. 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 trifoliate 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. The leaflets are given to devotees as prasadam in Shiva temples and as Tulasi in Vishnu temples. In India flowering occurs in April and May soon after the new leaves appear and the fruit ripens in 10 to 11 months from bloom March to June of the following year.

PLANT PROFILE

**Scientific Classification**
- Kingdom: Plantae.
- Order: Sapindales.
- Family: Rutaceae.
- Subfamily: Aurantioideae.
- Genus: Aegle.
- Species: *Aegle Marmelos*.
- Botanical name: *Aegle marmelos*.

**Vernacular names**
- English: Bengal quince, Beal fruit, Golden apple, Indian quince, Stone apple.
- Tamil: Aluvigam, Iyalbudi, Kuvilam, Mavilangai, Vilwam, Villuvam.
- Telugu: Bilvamu, Maluramu, Maredu, Sailushamu, Sandiliyamu, Sriphalamu.
- Hindi: Bel, Bili, Sirphal, and Bela.
- Sanskrit: Adhararutha, Asholam, Atimangaliya, Bilva.
- Bengali: Bael, Bel,
- Gujarati: Bili,
- Kannada: Bala, Bilva
- Malayalam: Koovalam, Vilwam.
- Oriissa : Belo.

*Botanical Description:* *Aegle marmelos* is a slow-growing, medium sized tree, up to 12-15 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. The deciduous, alternate leaves, borne singly or in group, are composed of 3 to 5 oval, pointed and...
shallowly toothed leaflets, 4-10 cm long, 2-5 cm wide, the terminal one with a long petiole.

**Soil type:** Bael is said to do best on rich, well-drained soil, but it has grown well and fruited on the oolitic limestone of southern Florida. It also grows well in swampy, alkaline or stony soils having pH range from 5 to 8. In India it has the reputation of thriving where other fruit trees cannot survive.

**Tree management:** The tree has no exacting cultural requirements, doing well with a minimum of fertilizer and irrigation. The spacing in orchards 6-9 m between trees. Seedlings begin to bear in 6 to 7 years, vegetatively propagated trees in 5 years. Full production is reached in 15 years. Normally, the fruit is harvested when yellowish-green and kept for 8 days while it loses its green tint. Then the stem readily separates from the fruit. A tree may yield as many as 800 fruits in a season.

**ORIGIN AND DISTRIBUTION:** The bael tree has its origin in Eastern Ghats and Central India. It is native to India and is found growing wild in Sub-Himalayan tracts from Jhelum eastwards to West Bengal, in central and southern India. Bael is found growing along foothills of Himalayas, Bihar, Chhattisgarh, Uttaranchal, Jharkhand and Madhya Pradesh. It is also grown in some Egyptian gardens in Surinam and Trinidad.

**Documented species distribution**

**Native range:** India

**Exotic range:** Bangladesh, Egypt, Malaysia, Myanmar, Pakistan, Sri Lanka, Thailand.

**CHEMICAL CONSTITUENTS**

**Alkaloids:** The alkaloids comprise the largest single class of secondary plant substances. New alkaloids from the leaves of *Aegle marmelos* were reported viz., ethyl cinnamamidate, O-3,3-(di methylallyl) halfordinol, N-2-methoxy-2-[4-(3',3'-dimethylallyl)oxy] phenyl] ethyl cinnamamidate etc.

**Terpenoids:** The essential oil of *Aegle marmelos* (L.) Correa leaves were studied very much extensively in India by various workers since 1950. α-Phellandrene was found to be the common constituent of the essential oil from leaves, twigs and fruits. α-Phellandrene (56%) and p-cymene (17%) were reported from leaf oil. Later, similar report was published on leaf essential oil by many workers. α-P-Menth-1-en-3,5-diol was isolated and characterized from *Aegle marmelos* leaves. Limonene (82.4%) was reported as the main constituent from *Aegle marmelos* leaves and it was shown that limonene is characteristic marker for identification of *Aegle marmelos* oil samples.

**Coumarins:** Marmelosin, marmesin, imperatorin, marmin, alloimperatorin, methyl ether, xanthotoxol, scopoletin, scoparone, umbelliferone, psoralen and marmelide has also been reported.

**Phenylpropanoids:** These are naturally occurring phenolic compounds, which have an aromatic ring to which three-carbon side chain is attached. Among the phenylpropanoids are included hydroxycoumarins, phenylpropanes and lignans. The most widespread plant coumarin is the parent compound, coumarin itself, which occurs in over twenty-seven plant families. Marmesin was established as a new compound from leaves, which is also a constituent of heartwood and root.

**Tannins:** 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. Tannin is also present in leaves as skimmianine, it is also named as 4, 7, 8 - trimethoxyfuro-quinoline.

**Polysaccharides:** Galactose, arabinose, uronic acid and L-rhamanose are obtained on hydrolysis.

**Flavonoids:** Mainly includes Rutin, Flavone, flavan-3-ols, flavone glycosides.

**TRADITIONAL USES**

All parts of *Aegle marmelos* are medicinally useful like leaves, fruit pulp, flower, stem bark, root bark etc.

**Leaves:** Leaves are used as mild laxative, or the inflammation of the mucous membrane having a free discharge and for asthma. The decoction of the leaves is febrifuge, or helps in eliminating fever and is an expectorant, or promotes the removal of mucous secretion from the bronchial tubes. The leaf juice is given in dropsy or the abnormal accumulation of liquid in the cellular tissue accompanied with constipation and jaundice. A hot poultice of the leaves is applied in ophthalmia or severe inflammation of conjunctiva with acute bronchitis and inflammation of the other body parts.

**Root:** The decoction of the root and sometimes the stem bark is useful in intermittent fever, also in hypochondriasis and palpitation of the heart. The decoction of root is given with sugar and fried rice for checking diarrhoea and gastric irritability in children. Root is a one of the ingredients of Dasamoora a standard Ayurvedic remedy for loss of appetite and puerperal diseases e.g. Inflammation of uterus.

**Flower:** Distillation of flowers yielded a drug used as tonic for stomach and intestine, anti-dysenteric, antidiabetic, diaphoretic and as local anaesthetic. It is also used in epilepsy and as expectorant.

**Fruit:** Fruit is eaten during convalescence after diarrhea. It is valid for its mild astringency and as remedy for dysentery. The traditional healers of southern Chhattisgarh use dry powder of fruit with mustard oil for the treatment of burn cases. One part of powder and two part of mustard oil are mixed and are applied externally. Fruits are also used in gastric troubles, constipation, laxative, tonic, digestive, stomachic, brain and heart tonic, ulcer, antiviral, intestinal parasites, gonorrhea, epilepsy etc.

**Ripe fruit:** The ripe fruit promotes digestion and is helpful in treating inflammation of rectum. The ripe fruit extract showed antiviral activity against ranikhet disease virus. Pulp of ripe fruit is sweet, cooling, aromatic and nutritious when taken fresh. Fruit pulp marmalade is used as prevention during cholera epidemics, also given to prevent the growth of piles, useful in patients suffering from chronic dysenteric condition characterised by alternate diarrhea and constipation relieves flatulent colic from a condition of chronic gastrointestinal catarrh. Fresh juice is bitter and pungent fruit extract lower the blood sugar.

**Unripe fruit:** Fine powder of unripe fruit showed significant effect on intestinal parasites and also effective against Entamoeba histolytica and Ascaris lumbricoides. Unripe fruit is used as an astringent in dysentery, stomachache in
diarrhea, tonic, digestive, demulcent, described as cardia
cial, restorative, given in piles. Decoction of unripe fruit is
astringent, useful in diarrhea and chronic dysentery.

MARKETED PRODUCTS

Food: Aegle marmelos fruits may be cut in half, or the soft
fruits broken open, and the pulp, dressed with palm sugar,
eaten for breakfast, as is a common practice in Indonesia. The
pulp is often processed as nectar. Beating the seeded pulp
together with milk and sugar makes a popular drink called
sherbet in India. A beverage is also made by combining ba
g fruit pulp with that of tamarind.

Timber: The wood is strongly aromatic when fresh
cut. It is gray-white, hard, but not durable; has been used for
carts and construction, though it is inclined to warp and crack
during curing. It is best utilized for carving, small-scale
turnery, tool and knife handles, pestles and combs, taking a
fine polish.

Gum or Resins: The gum enveloping the seeds is most
abundant in wild fruits and especially when they are unripe. It
is commonly used as a household glue and is employed as an
adhesive by jewelers. Sometimes it is resorted to as a soap-
substitute. It is mixed with lime plaster for waterproofing
wells and is added to cement when building walls. Artists add
it to their watercolors, and it may be applied as a protective
coating on paintings.

Tannin or dyestuff: There is as much as 9% tannin in the
pulp of wild fruits, less in the cultivated types. The rind
contains up to 20%. Tannin is also present in the leaves. The
rind of the unripe fruit is employed in tanning and also yields
a yellow dye for calico and silk fabrics.

Essential oil: The essential oil of the leaves contains d-
d-limonene, 56% a-d-phemdralene, cineol, citronellal, citral,
17% p-cymene, 5% cumin aldehyde. The limonene-rich oil
has been distilled from the rind for scenting hair oil.

Poison: The leaves are said to cause abortion and sterility in
women. The bark is used as a fish poison in the Celebes.
Tannin ingested frequently and in quantity over a long period
of time is antinutrient and carcinogenic. Leaf extract from A.
marmelos has been found to have insecticidal activity against
the brown plant hopper (Nilaparvata lugens Stal), an
important pest of rice plant in Asia.

Medicine: A decoction of the unripe fruit, with fennel and
ginger, is prescribed in cases of hemorrhoids. It has been
surmised that the sproperal in the pulp increases tolerance of
sunlight and aids in the maintaining of normal skin color. It is
employed in the treatment of leucoderma. Marmelosin
derived from the pulp is given as a laxative and diuretic.
In large doses it lowers the rate of respiration, depresses heart
action and causes sleepiness. For medicinal use the young
fruits, while still tender, are commonly sliced horizontally
and sun-dried and sold in local markets. They are much
exported to Malaysia and Europe. Because of the astringency
especially of the wild fruits the unripe bael is most prized as a
means of halting diarrhea and dysentery which are prevalent
in India in the summer months.

Other products: The fruit pulp has detergent action and has
been used for washing clothes. The shell of hard fruits has
been fashioned into pill- and snuff boxes, sometimes
decorated with gold and silver. A cologne is obtained by
distillation from the flowers. In the Hindu culture, the leaves
are indispensable offerings to the 'Lord Shiva'.

REPORTED PHARMACOLOGICAL ACTIVITIES

Antibacterial activity: Antimicrobial activity of different
leaf extracts such as Petroleum ether, Dichloromethane,
Chloroform, Ethanol and Aqueous extract of Aegle marmelos
leaves were tested against selected Gram positive and Gram
negative bacteria. Results depict that phytochemical extracts
of Aegle marmelos exhibited significant anti-bacterial
activity. However, the inhibitory activity was found to be
both organism and solvent dependent. Ethanol and
chloroform leaf extracts of Aegle marmelos were found to be
more active towards the bacterial species tested. Further, the
aqueous leaf extract was moderately active followed by
dichloromethane extract. However, petroleum ether extract
was not effective against any of the organisms tested. Growth
of Lactobacillus bulgaris and Bacillus cereus was not
inhibited by any of the tested leaf extracts of Aegle.
Marmelos.

Antihistaminic activity: Skimmianine is a quinoline alkaloid
isolated from the roots of Aegle marmelos. In the study the
effects of skimmianine on the histamine release from rat mast
cells are studied. The study was performed by using two cell
lines, rat basophilic leukemia (RBL-2H3) cell line, and rat
peritoneal mast cells (RPMCs) DNP24-BSA, thapsigargin,
onomycin, compound 48/80 were used as inducers for
histamine release from rat mast cell. Skimmianine markedly
inhibited the histamine release from RBL-2H3 cells induced
by DNP24-BSA, thapsigargin and ionomycin.

Anti-inflammatory, antipyretic and analgesic activity:
The serial extracts of the leaves of Aegle marmelos were
investigated for anti-inflammatory property. The analgesic
and antipyretic properties were also evaluated. The most of
the extracts derived from the plant Aegle marmelos caused a
significant inhibition of the carrageenan induced paw oedema
and cotton-pellet granuloma in rats. The extracts also
produced marked analgesic activity by reduction the early
and late phases of paw licking in mice. A significant
reduction in hyperpyrexia in rats was also produced by
the most of the extracts. This study was established anti-
flammatory, antinociceptive and antipyradic properties of the
leaves of Aegle marmelos.

Hepatoprotective activity: The experiments were performed
with four groups of animals. The experimental animals were
administered with 30% ethyl alcohol for a period of 40 days
and the fine crude plant leaves powder was fed to animals for
next 21 days. The observed values of TBARS (Thiobarbituric
acid reactive substances) in healthy, alcohol intoxicated and
herbal drug treated animals were 123.35, 235.68 and 141.85
µg/g tissue respectively. The results were compared with the
standard herbal drug silymarin (133.04 µg/g tissue respectively).
The experimental results indicate that, the Aegle marmelos
leaves have excellent hepatoprotective effect.

Insecticidal activity: Experiments were carried out to
determine 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

Page 88
(Herbst) (Tenebrionidae). After introducing the test insects, stored gram and wheat samples were fumigated with essential oil of Aegle marmelos at 500 μg/mL (ppm). The oil significantly enhanced feeding deterrence in insects and reduced the grain damage as well as weight loss in fumigated gram and wheat samples infested with all insects except T. castaneum. The essential oil at different doses significantly reduced oviposition and adult emergence of C. chinesis in treated cowpea seeds. The oil protected stored gram from C. chinesis and wheat from R. dominica and S. oryzae for two years. Limonene (88 %) was found to be the major component in the oil through GC-MS analysis. Regression analysis of data on individuals in treated cowpea confirmed that significant reduction of oviposition and adult emergence of C. chinesis decreased with increase in doses. The findings emphasize the efficacy of Aegle marmelos oil as fumigant against insect infestations of stored grains and strengthen the possibility of using it as an alternative to synthetic chemicals for preserving stored grains18.

**Hypoglycemic and Antioxidant activity:** The hypoglycemic and antioxidant effect of aqueous extract of Aegle marmelos leaves (AEAM) carried out by using male albino rats. Glucose, urea and glutathione-S-transferase (GST) in plasma, glutathione (GSH) and malondialdehyde (MDA) levels in erythrocytes were estimated in all the groups at the end of four weeks. There was a decrease in blood glucose at the end of four weeks in group treated with AEAM, however it did not reach the control levels. There was an increase in erythrocyte GSH and a decrease in MDA in group treated with AEAM as compared to diabetic rats. The plasma GST levels were raised in diabetic rats when compared to controls. In the group treated with AEAM, there was a decrease in GST as compared to diabetic rats. Owing to hypoglycemic and antioxidant properties, AEAM may be useful in the long term management of diabetes19,22.

**Immunomodulatory activity:** The immunomodulatory action of methanolic extract of Aegle marmelos fruit (MEAM) in experimental model of immunity was carried out by neutrophil adhesion test and carbon clearance assay, whereas, humoral immunity was analysed by mice lethality test and indirect haemagglutination assay. MEAM dose was selected by Stair case method (up and down) and administered at 100 and 500 mg/kg orally. The Ocimum sanctum (OSC, 100 mg/kg, p.o) was used as standard. MEAM at 100 and 500 mg/kg produced significant increases in adhesion of neutrophils and an increase in phagocytic index in carbon clearance assay. Both high and low doses of MEAM significantly prevented the mortality induced by bovine Pasteurella multocida in mice. Treatment of animals with MEAM and OSC significantly increased the circulating antibody titre in indirect haemagglutination test. Among the different doses, low one was more effective in cellular immunity models than the high. However, all the doses exhibited similar protection in humoral immunity procedures. From the above findings, it is concluded that MEAM possesses potential for augmenting immune activity by cellular and humoral mediated mechanisms more at low dose (100 mg/kg) than high dose (500 mg/kg)20.

**Myocardial infarction:** The effect of Aegle marmelos leaf extract (AMLE) and alphalcohol on plasma lipids, lipid peroxides and marker enzymes in rats with isoproterenol (ISO) induced myocardial infarction was carried out. Rats were pre-treated orally for 35 days with different doses of an aqueous AMLE (50 mg/ kg, 100 mg/kg and 200 mg/kg) prior to ISO-induced myocardial infarction. The effects on creatine kinase, lactate dehydrogenase, plasma thiobarbituric acid reactive substances, lipid hydroperoxides, serum lipids and lipoproteins were studied. Pretreatment with AMLE at doses of 100 mg/kg and 200 mg/kg body weight for 35 days showed a significant effect on the activities of marker enzymes, lipid peroxides, lipids, lipoproteins and antioxidant enzymes in ISO-treated rats. The effect of AMLE 200 mg/kg was found to be equal to the effect of alpha-tocopherol 60 mg/kg21.

**Testicular activity:** The aqueous extract of leaf of Aegle marmelos at the dose 50 mg/100 g 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 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 dose22.

**Cardiotonic activity:** Fresh fruit juice of Aegle marmelos plant with different dilutions were used for cardiotonic activity. The activity was tested by using isolated frog heart assembly. The present preliminary studies confirm the better cardiotonic activity of Aegle marmelos than digoxin. Further studies can confirm the reduced toxicity & this will be the advantage of Aegle marmelos over digitals23.

**Anxiolytic and Antidepressant activity:** The objective of the study was to evaluate the anxiolytic and antidepressant activities of methanol extract of Aegle marmelos (MEAM) leaves as well as its interaction with conventional anxiolytic and antidepressant drugs using elevated plus maze and tail suspension test in mice. Albino mice were treated with MEAM (75, 150 and 300 mg/kg, po), imipramine (20 mg/kg, po), fluoxetine (20 mg/kg, po), and combination of sub effective dose of AM with imipramine or fluoxetine. Effects were observed on (a) time spent on (b) number of entries into (c) number of stretch attend postures (d) number of head dips in arms of elevated plus maze and on duration of immobility in tail suspension test. Antidepressant activity of MEAM (150 mg/kg, po) was significantly decreased by prazosin, haloperidol and baclofen. MEAM showed insignificant effect on locomotor activity of mice. It is concluded that MEAM possess potential anxiolytic and antidepressant activities and it enhances the anxiolytic and antidepressant activities of imipramine and fluoxetine24.

**Wound healing activity:** Effect of topical and intraperitoneal administration of methanolic extract of Aegle marmelos ointment and injection was studied respectively on two types of wound models i.e. the excision and the incision wound models in rats. Both the injection and the ointment of the methanolic extract of Aegle marmelos produced a significant response in both of the wound type tested. In the incision model the extract treated wounds were found to epithelialize 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 nitrofurazone.25

**Anticonvulsant activity:** The anticonvulsant effect of ethanolic extract from the leaves of Aegle marmelos on maximal electroshock (MES) or pentylenetetrazole (PTZ) in male mice examined in this study. This medicinal plant...
Anti stress and Adaptogenic activity: The standardised dried aqueous extracts of Aegle marmelos (SDEAM) were evaluated for anti stress and adaptogenic activities using Swimming endurance and post-swimming motor function test, Cold swimming endurance test and forced swim test in rats. The extracts showed the presence of phenolics, flavonoids, carbohydrates and volatile oils in preliminary phytochemical screening. In present study the test extracts when subjected to forced swim model for adaptogenic activity in rats does not showed an increase in serum cholesterol and serum triglyceride level, but the increase was not sustained on subsequent groups. It also increases the swimming endurance time significantly along with the post motar function like Rota rod falling time and spontaneous motar activity. The test extract also increases the cold swimming endurance time significantly. The test extracts could restrict the increase in the level of these markers during stress.

Antifertility activity: The study was carried out to evaluate the effective concentration of aqueous extract of Aegle marmelos leaves on male reproductive system of albino rats. The study was divided into three groups of six animals each. The first group (I) received distilled water serve as control. The second and third groups (II and III) of animals were administered the aqueous leaf extract daily at 250mg/kg body wt and 350mg/kg body wt., respectively for a period of 45days. Significant decreases in the weights of testis, epididymes and seminal vesicle were observed. A dose related reduction in the testicular sperm count, epididymal sperm count and motility and abnormal sperm count were observed. The results showed that Aegle marmelos has effects on male rat reproduction, affecting the sexual behavior and epididymal sperm concentration.

CONCLUSION

Traditional system of medicine continues to be widely practised for various reasons. Fast populations, inadequate supply of medicines, side effects of several allopathic drugs and ever increasing resistance to current drugs for diseases have led to growing emphasis on the use of plant materials as a source of medicines for human beings. It is strongly believed that detailed information as presented in this review on the phytochemicals and various biological properties of the plant extracts might provide detailed evidence for the use of this plant in different medicines. Historically, Aegle marmelos has been used for the number of ethnobotanical purposes. At present Aegle marmelos has become an important source of medicine for curing various human and animal diseases. Apart from exploring possibilities to prepare standardized drugs by using different plant parts of Aegle marmelos, production of jam by using its fruits should be promoted as a health tonic at commercial scale. 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 the various phytochemicals and efficacy of the medicinal values of Aegle marmelos. Thus in the near future Aegle marmelos could be further exploited as a source of useful phytochemical compounds and may play a very important role in modern system of medicine.

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Source of support: Nil, Conflict of interest: None Declared