



# *Aegle Marmelos* : A Comprehensive Review Of Its Phytochemistry And Therapeutic Potential

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**Abstract** : Plants serve as significant sources of food and medicine, offering substantial benefits to humans and animals. This article explores the medicinal properties of *Aegle marmelos* L., commonly known as bael, a member of the Rutaceae family, widely found in India. In traditional medicine, *A. marmelos* is used to treat numerous ailments, including abdominal and nerve disorders, cholera, ulcers, diarrhea, heart disease, gonorrhoea, snake bites & jaundice. Various bioactive compounds from different parts of the plant have been isolated, representing chemical groups such as Alkaloids, Terpenoids, Coumarins, Tannins, Carbohydrates, Flavonoids, Fatty Acids, Gonorrhoe, Vitamins and Essential Oils. The plant exhibits a range of pharmacological activities, including antioxidant, antibacterial, antifungal, antidiarrheal, antidiabetic, antiproliferative, cytoprotective, hepatoprotective, antifertility, analgesic, anti-arthritis, antihyperlipidemic, cardioprotective, radioprotective, anticancer, antiviral, anti-ulcer, immunomodulatory, and wound-healing effects. This comprehensive review highlights *A. marmelos* as a valuable resource for researchers and a promising candidate for further investigation into its therapeutic potential across various health conditions.

**IndexTerms** - Pharmacological activities, Phytochemistry, *Aegle marmelos*, Traditional use.

## INTRODUCTION

The India have vast knowledge about the medicine from ancient times. The books of medicinal system like Ayurveda, Siddha and Unani are blessed with the herbal medicine scriptures. The plants like Tulsi, Neem, Haldi, aloe etc. are used in many of the Ayurveda medicine and have high therapeutic efficiency with much lesser side effect than the synthetic medicines. The Bael, *Aegle marmelos* (L.) Corrêa belong to family (Rutaceae) also known as golden Apple have widely used as medicinal plant and food resources from early times.

The bael is also known as the plant of great lord Shiva. It used in the worshipping of lord Shiva and widely found near the temples of lord Shiva. It used widely by the south Indian people for medicinal purposes from about 5000 B.C. Bael is mentioned in the famous epic poem Ramayana. Bael mentioned in the renowned book Charaka samhita, a comprehensive compilation of all the essential Ayurveda information, which identified bael as a necessary item in Ayurveda medicine. The entire *Aegle marmelos* plant, known as bael, is considered a remarkable asset in Ayurveda, valued for its wide range of healing properties. (1)

Leaves, Flower's, Fruits, Bark, Roots and Seeds have different chemical constituents which widely used in the treatment of different diseases.

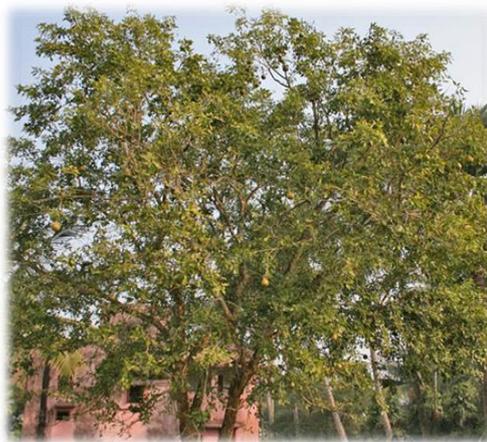
A.marmelos is often called Indian quince, Bengal quince in English. It is a slow-growing, hardly subtropical tree and these is the only plant belonging to the genus Aegle. The tree grows in forest up to the height of 12 to 15 m, even in the tough condition. They have measurely spiny branches with alternate leaves composed of three to five oval and shallowly toothed leaflets. The flowers measurely grows on the young branches. The A.marmelos various phytoconstituents like alkaloids, flavonoids, Caumarins, Tannins, Terpins and much more. The phytoconstituents present in the bael shows variety of the bael not only used as the medicine but also have benefited as the food resources and nutraceutical product.

The review mainly focus on the therapeutic efficiency and nutraceutical benefits of bael. In additional we are going to discuss in detail about hypoglycaemic and radio protective effect of bael.

Fig : Bael fruit



Fig : Bael plant



### PLANT PROFILE (2)

#### Scientific Classification

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

### Synonyms: (3)

The bael is known with the different name in different regions and languages. The names mentioned are referred in various languages to identify and address the A.mermelon

<b>ENGLISH</b>	<i>Golden Apple, Indian queance, Bengal quence, stone apple, wood apple</i>
<b>HINDI</b>	<i>Bael, Bel</i>
<b>SANSKRIT</b>	<i>Shreephal, Bilwa</i>
<b>BENGALI</b>	<i>Bel, shreefal</i>
<b>TAMIL</b>	<i>Vilva maram, vilva pazham</i>
<b>LATIN</b>	<i>Aegle marmelose</i>
<b>NEPALI</b>	<i>Gudu</i>
<b>TELGU</b>	<i>Maredu</i>
<b>VIETNAMESE</b>	<i>Mbau Nau, Trai mam</i>
<b>MARATHI</b>	<i>Kaveeth</i>
<b>FRENCH</b>	<i>Orager du malabar</i>
<b>MALYANAM</b>	<i>Pakok maja batu</i>
<b>INDONESIAN</b>	<i>Mojo tree</i>

**ECOLOGY AND GEOGRAPHICAL SOURCE : (4)**

The bael is believed to be firstly originated in India. Then it spread out in other faraway lands. The bael can grow in dry, mixed, deciduous soil of most of the countries like India, Sri Lanka, Thailand, Vietnam, Pakistan, Cambodia, Java, Egypt, Philippines, Surinam, Florida. It can be grown at high altitude of about 1000-1200 M and withstand the temperature of 50° to -7°. It needs to have pH about 5-8 in soil.

<b>Plant part</b>	Morphological characters
<b>Bark</b>	The bark is brownish in colour and has large spines. It has gums which are mostly due to injury to branches and harden in due time. The gums taste good at first but cause irritation to the throat in time.
<b>Flower's</b>	The flowers are greenish or yellowish in colour.
<b>Fruit</b>	The bael fruit has a tough outer jacket with a diameter of 5 to 12 cm. The fruit is green at first but throughout its ripening it turns yellowish brown.
<b>Seed</b>	The seeds are small, hard, flattened oblong with length up to 1 cm long which is surrounded by an adhesive sac.

**BOTANICAL DESCRIPTION OF AEGLE MARMELOS. (5)**

A marmelon also known as the bael has different ethnobotanical uses in the whole plant and each part of the plant has different phytoconstituents which show different medicinal uses.

<b>PLANT PART</b>	<b>ETHANOBOTANICAL DESCRIPTION</b>
<b>Leaf</b>	Stomach problems, diarrhoea, wound ulcer, cholera, cardio tonic, dropsy, weakness of heart, cholera, blood sugar, nervous disorder, hair tonic, acute bronchitis, wound healing, as a medicinal feed to cows and goats, child birth veterinary medicine for wound.
<b>Fruit</b>	Astringent, diarrhoea, gastric trouble, laxative, constipation, digestive, antiviral, gonorrhoea, epilepsy, brain and heart tonic, edible, jam, preserve.
<b>Root</b>	Dog bite, gastric trouble, heart disorder, intermittent fevers, anti-moebic, hypoglycemic.
<b>Bark</b>	Stomach disorder, intermittent fevers, heart disorder
<b>Seed</b>	Febrifuge
<b>Whole plant</b>	Abdominal pain, abscess, astringent, backache, jaundice, snakebite, fish poison etc.....

**Preparation of Plant Extracts**

We prepared the plant extracts using the cold percolation method, following the guidelines outlined by Rosenthaler. First, we soaked the dried and powdered plant samples in various solvents at a 1:10 ratio. This mixture was left to extract for 24 hours at room temperature, while being continuously agitated at 150 rpm. After this period, we filtered the extracts and evaporated the liquid at 40 °C until only the dry extract remained. We then ground the dried extracts into a fine powder and dissolved them in DMSO (Dimethyl sulfoxide) to achieve a concentration of 100 mg/ml.

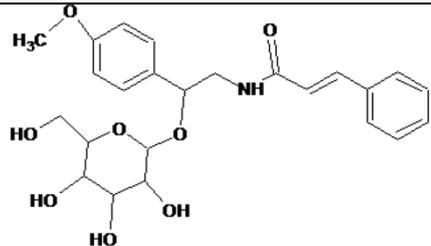
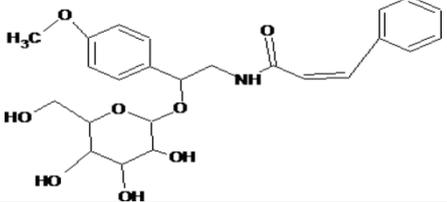
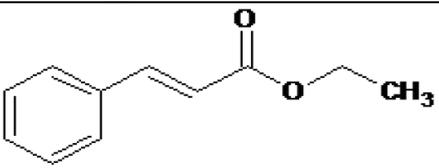
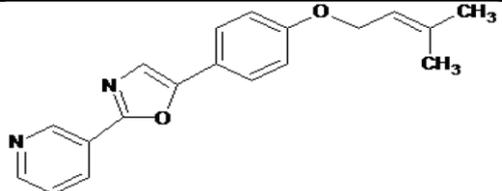
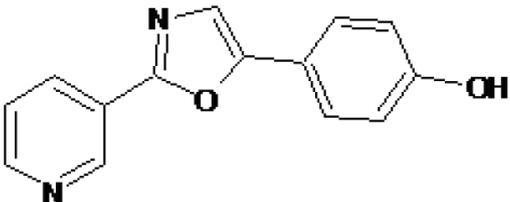
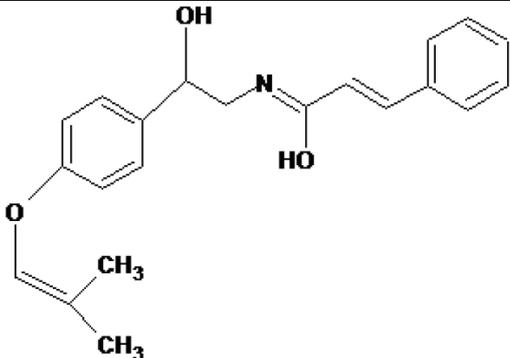
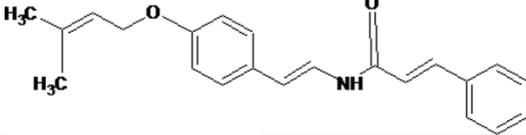
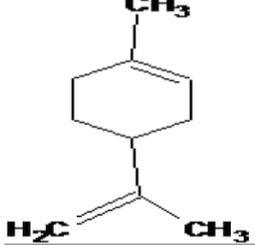
**Extraction by Continuous Hot Percolation (Soxhlet Extraction)**

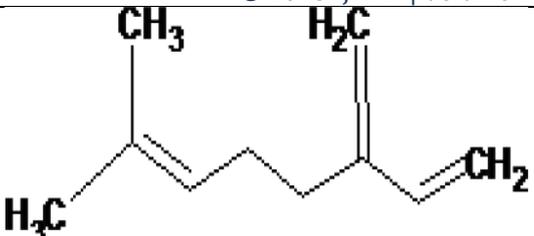
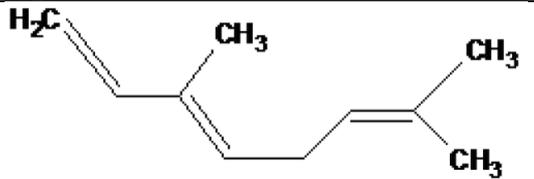
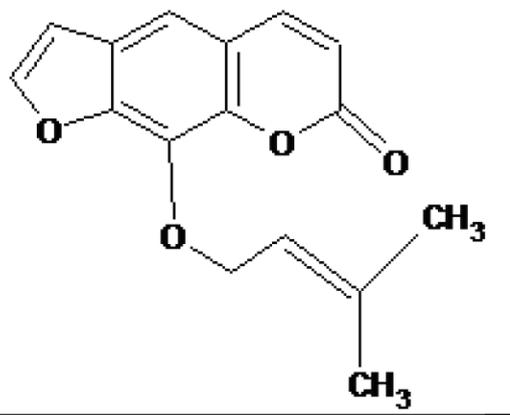
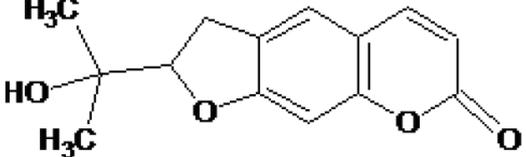
For this method, we first ground the plant material using a mortar and pestle. The powdered sample was then sifted through a mesh (retaining particles between mesh No. 10 and No. 60) for extraction. We packed this powder into a filter paper cylinder and placed it in a Soxhlet extractor. The chosen solvent was added to a flask connected to the extractor, and the entire setup was assembled correctly for the extraction process.

**Preliminary Phytochemical Tests (7)**

These tests involve various chemical assays that help assess the purity of the crude plant drugs by quantitatively estimating their active chemical constituents. This method can identify either a single active compound or a group of related compounds present in the same plant material.

**Chemical constituents:**

Chemical constituents	Structure	Uses
<b>Aegelinosides A</b>		<b>Anti-inflammatory Effects:</b> <b>Antimicrobial Properties</b>
<b>Aegelinosides B</b>		<b>Gastroprotective Effects</b> <b>Cardiovascular Health:</b>
<b>Ethyl Cinnamate</b>		<b>Flavoring Agent</b> <b>Fragrance:</b>
<b>O-3,3-(di methylallyl) halfordinol</b>		<b>Natural Product Synthesis:</b> <b>Biological Activity:</b>
<b>Halfordinol</b>		<b>Natural Products Chemistry:</b> <b>Potential Biological Activity</b>
<b>Marmeline</b>		<b>Dietary Supplement</b> <b>Functional Foods</b> <b>Cosmetic Ingredients</b> <b>Pharmaceutical Applications</b>
<b>Anhydromarmeline</b>		<b>Nutritional Supplements</b> <b>Cosmetic Applications:</b>
<b>Limonene</b>		<b>Flavoring Agent:</b> <b>Fragrance:</b> <b>Solvent</b> <b>Food Preservation</b>

$\beta$ -Myrcene		Cannabis Research Aromatherapy
$\beta$ -Ocimene		Therapeutic Potential Aromatherapy
Marmelosin		Traditional Medicine Dietary Supplements: Functional Foods: Cosmetic Formulations:
Marmesin		Functional Foods Dietary Supplements

Preliminary phytochemical analysis of Bael fruits water extract Phytoconstituents	Test	Observations	Aqueous extract
Alkaloids	Dragendroff's	Orange colour ppt produced	<b>Positive</b>
Alkaloids	Mayer's Test	Cream coloured ppt produced	<b>Positive</b>
Alkaloids	Wagner's test	Reddish brown colour ppt produced	<b>Positive</b>
Proteins	Biuret test	Violet or purple colour produced	<b>Positive</b>
Proteins	Millon's test	Red colour produced	<b>Positive</b>
Carbohydrates	Molisch's test	Red or dull violet colour produced	<b>Positive</b>
Carbohydrates	Fehling's test	Yellow or red colour pit produced	<b>Positive</b>
Phytosterols	Liebermann-Burchard test	Dark red or pink colour produced	<b>Positive</b>
Glycosides	Baljet test	Yellow to orange colour produced	<b>Positive</b>
Glycosides	Keller-Killiani test	Two layer reddish brown colour produced, in upper	<b>Positive</b>

		layer turns bluish green colour produced	
Phenols	Ferric chloride test	Deep blue or black colour produced	<b>Positive</b>
Saponins	Foam test	Persistent form produced	<b>Positive</b>

### Reported Phytochemicals and Their Activities :-

The pulp of bael fruit (*Aegle marmelos*) is packed with beneficial substances, including carotenoids, phenolics, alkaloids, pectins, tannins, coumarins, flavonoids, and terpenoids. Research indicates that methanol and water are the most effective solvents for extracting these compounds, with ethanol also being useful.

Several key phytochemicals in *A. marmelos* include:

1. Alkaloids: These nitrogen-containing compounds have known pharmacological effects. Some alkaloids identified in the leaves and roots of *A. marmelos* are marmesin, marmelosin, and aegeline.

2. Tannins: Commonly found in many plants, tannins are recognized for their astringent and antioxidant qualities. Bael fruit is rich in tannins, which provide powerful antioxidant and anti-inflammatory benefits.

3. Flavonoids: These compounds are known for their anti-inflammatory, anti-cancer, and antioxidant effects. Flavonoids present in the leaves and roots of *A. Aegle marmelos* has been shown to help relieve pain and lower fever.

4. Terpenoids: These compounds are recognized for their medicinal properties. Terpenoids found in *A. Aegle marmelos* has shown effective antifungal and antibacterial properties.

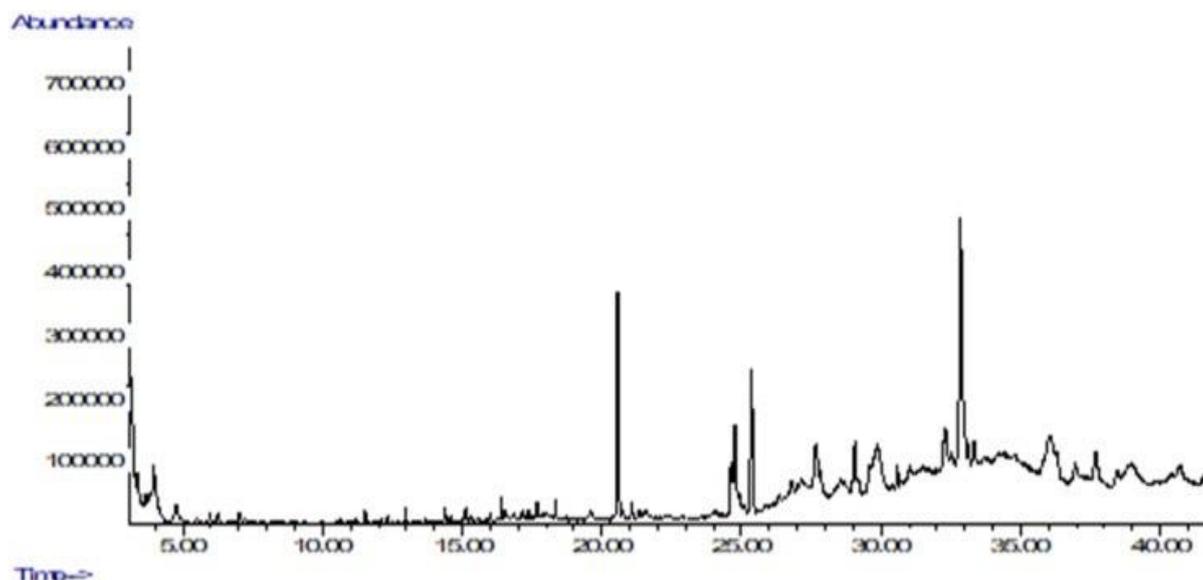
5. Saponins: Known for their foaming and emulsifying characteristics, saponins identified in the fruit and leaves of *A. marmelos* also exhibit pain-relieving and anti-inflammatory effects.

6. Glycoside: These compounds, valued for their medicinal benefits, have been found in the fruit and leaves of *A. marmelos*. Some glycosides show similar pain-relieving and anti-inflammatory activities.

The most commonly studied compounds from *A. marmelos* are summarized in Table, while their chemical structures are illustrated in Table

### Chemical Profiling of *A. marmelos* Extract Using GC/MS : (9)

GC/MS profiling identified a total of 51 compounds. The identified phytochemicals are listed in the accompanying table, and a typical chromatogram from the GC/MS analysis is shown. The peaks in the total ion chromatogram (TIC) were matched to known phytochemicals using the NIST GC/MS library for accurate identification.



GC/MS total ion chromatogram of *A. marmelos*.

**GC/MS profiling of Aegle marmelos :**

<b>S. No</b>	<b>Name of Metabolite</b>	<b>RT</b>	<b>%</b>
1.	2-hexanone	3.643	0.38
2.	PENTAN-2-ONE	3.746	0.59
3.	Methyl-2-pentanone	3.841	0.60
4.	1-penten-3-ol	3.936	2.92
5.	Cyclopentanol	4.756	1.05
6.	p-mentha-1 (7),3-diene	6.250	0.36
7.	p-cymene	7.019	0.22
8.	8-hexadecenal	11.522	0.24
9.	(E)-1-(methoxymethoxy)-1-tetradecene-3-ol	12.972	0.26
10.	1-dodecanol	14.385	0.47
11.	Heneicosane	15.146	0.43
12.	Cyclooctasiloxane	16.420	0.57
13.	Tetradecamethylcycloheptasiloxane	16.508	0.42
14.	Dotriacontane	17.687	0.62
15.	Cyclononasiloxane	18.346	0.82
16.	Phthalic acid	19.613	0.56
17.	Hexadecanoic acid	20.572	7.23
18.	Cyclodecasiloxane	21.070	0.91
19.	Tetradecanoic acid (myristic acid)	acid 21.326	0.70
20.	Methyl linolelaidate	24.628	1.86
21.	Oleic acid	24.767	3.52
22.	9,17-octadecadienal	24.906	0.99
23.	Octadecanoic acid	25.360	4.87
24.	Hentriacontane	26.334	2.26
25.	9,12,15-Octadecatrienoic acid, methyl ester (Linolenic acid, methyl ester)	26.788	2.72
26.	Octadecanoic acid (Stearic acid)	27.059	1.05
27.	Alpha-Neodene	27.147	0.80
28.	Sulfurous acid	27.191	0.82
29.	Phenol	27.660	4.09
30.	Tetracosamethyl-cyclododecasiloxane	27.835	2.42
31.	Oleyl alcohol	28.567	2.37
32.	2-propenoic acid, 3-(4-hydroxy-3-methoxyphenyl)-, methyl ester (cinnamic acid, 4-hydroxy-3-methoxy-, methyl ester)	28.692	0.87
33.	cis-13-eicosenoic acid	29.073	3.20
34.	Nonahexacontanoic acid	29.607	1.49
35.	Nonacosane	29.878	5.93
36.	Benzoic acid	31.035	1.36
37.	Vitamin-E	31.247	0.21
38.	Gamma-tocopheryl	31.504	0.30
39.	1-heptadec-1-ynyl-cyclopentanol	32.316	2.65
40.	7-pentadecyne	32.514	0.90

S. No	Name of Metabolite	RT	%
41.	13-docosenoic acid	32.851	14.58
42.	Docosanoic acid	33.334	2.53
43.	Z,Z-10,12-hexadecadien-1-ol acetat	34.220	0.71
44.	n-triacontane	36.080	5.67
45.	Tetracosamethyl-cyclododecasiloxane	36.299	2.53
46.	(+)-(9.beta.H)-labda-8(17),13(E)-diene-5-ol	36.973	0.84
47.	15-tetracosenoic acid	37.698	2.68
48.	Benchequiol	38.452	1.16
49.	Retinoic acid	38.979	3.33
50.	Cyclodecasiloxane	40.722	1.38
50.	Cyclodecasiloxane	40.722	1.38

### **Theraupatic effect:-**

#### **Antidiabetic activity : (10)**

The extract of bael show masoure antidiabetic activity in rabbit. although various extract of leaves show quite good antidiabetic property. the methanolic extract was introduced in alloxan induced diabetic rats and after the time line of 12 days sugar level found to be reduced to 54%.

#### **Antioxident activity: (11)**

The pharmacological study of alcoholic extract of A.marmelones was performed which determines the glucose uptake,antidiabetic and antioxidant activity. the study conduct the cytotoxic characterestics in HepG2 cells in vitro , which showed the cytoprotective activity. the *antioxidant* study of extract was determined with using 2,2diphenyl-1-picrylhydrazyl (DPPH) and ferric reducing antioxidant power (FRAP) methods. the marvelous antioxidant potential was shown.

#### **Diuretic activity:- (12)**

Singh and colleagues examined the diuretic activity of a various organic extracts and their fractions derived from the Aegle marmelos fruit using experimental The extracts were given to rats through intraperitoneal injection at doses of 300, 400, and 500 mg per kilogram of body weight.. The extracts were administered intraperitoneally to rats at doses of 300, 400, and 500 mg/kg. The diuretic effect was assessed by a measuring urine volume and sodium content in the urine. They observed that the ethanolic extract significantly increased sodium excretion at the higher dose of 500 mg/kg. Additionally to the petroleum ether, chloroform, and ethyl acetate fractions also demonstrated effectiveness in promoting diuresis

#### **Anti-inflammatory activity :-**

Various organic extracts of Aegle marmelos The leaves of *Aegle marmelos* have shown strong anti-inflammatory effects in both short-term and longer-term studies.. Studies using both acute and chronic inflammatory animal models have revealed that A. marmelos exhibits notable anti-inflammatory properties, indicating its potential as a promising anti-inflammatory agent. These effects are likely attributed to the presence of lupeol and skimmianine, compounds found in the leaves, which have shown similar therapeutic effects when tested in their pure forms.

Histamine receptor activation plays a key role in allergic reactions and asthma. The alcoholic extract of A. marmelos leaves was found to counteract histamine-induced contractions and promote relaxation in isolated guinea pig ileum and tracheal chains. This suggests that the extract may inhibit H1 receptor activity, which could explain its relaxant and anti-allergic effects.

#### **Radioprotective effects : (13)**

The effectiveness of radiotherapy in curing and alleviating cancer is often limited by the side effects caused by the radiosensitivity of nearby healthy tissues. These tissues are inevitably exposed to the harmful effects of ionizing radiation during treatment. In this context, radioprotective compounds that shield normal tissues from radiation damage are highly valuable. The harmful effects of radiation are mainly due to the production

of free radicals, and antioxidant compounds that neutralize these radicals are believed to be highly beneficial in preventing such damage.

#### **Anticancer:- (14)**

The effectiveness of radiotherapy in curing and alleviating cancer is often limited by the side effects caused by the radiosensitivity of nearby healthy tissues. These tissues are inevitably exposed to the harmful effects of ionizing radiation during treatment. In this context, radioprotective compounds that shield normal tissues from radiation damage are highly valuable. The harmful effects of radiation are mainly due to the production of free radicals, and antioxidant compounds that neutralize these radicals are believed to be highly beneficial in preventing such damage.

#### **Conclusion:-**

*Aegle marmelos*, commonly known as Bael or the Golden Apple, has been an integral part of traditional medicinal systems such as Ayurveda, Siddha, and Unani for centuries. This plant, revered for its connection to Lord Shiva, is rich in various bioactive compounds that contribute to its extensive therapeutic and nutraceutical benefits. From its barks, leaves, seeds, fruits and roots, each part of the plant serves a specific medicinal purpose, treating conditions ranging from gastrointestinal disorders and diabetes to inflammation and cancer.

The phytoconstituents, such as alkaloids, flavonoids, tannins, and terpenes, provide the plant with remarkable pharmacological activities including antidiabetic, antioxidant, anti-inflammatory, diuretic, and radioprotective effects. The plant's ability to thrive in diverse ecological conditions across multiple regions underscores its significance both as a medicinal resource and as a nutraceutical product.

In summary, *Aegle marmelos* stands as a versatile plant with wide-ranging medicinal applications, showing significant potential in both traditional and modern healthcare systems. Its radioprotective and anticancer properties further emphasize the plant's importance, making it a promising subject for future pharmacological research and therapeutic development.

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