



A Review On Aegle Marmelos (Bael):

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Abstract:

Aegle marmelos (L) is an important plant with various medicinal values. It is commonly known as Bael or (Bel), a wooden apple and bilva pant. It belonging to the family Rutaceae. The bael tree considered as a sacred tree by the Hindus offer its leaves to Lord Shiva during worship the essence of its fruits and leaves possess an evaporating oil which is good for human system. It contains various bioactive components in leaves, fruits, flowers, wood, root, and bark which have different biological activities and high therapeutic importance. Uses of bael in day to day life has great nutritional, environmental and commercial importance. Aegle marmelos used in preparation of summer drinks, which helps to overcome sunstrokes. Its use as formulation of Ayurvedic medicine for loss of appetite. It has many properties that are analgesic, anti-inflammatory, antibacterial, antiviral, antioxidant properties. A. marmelos leaves give relief from recurrent cold and respiratory infections. Aegle marmelos cultivated in Southeast Asia, India, Pakistan, Bangladesh, Sri Lanka and Nepal. It includes various phytochemical substances alkaloids, flavonoids, phenols, tannins, coumarins, saponins, carbohydrates, carotenoids, terpenoids, vitamins. The main phytochemical compounds isolated from A. marmelos plant are aegelenine, fragrine, halfordinol, marmelide, marmelosin, marmesin, marmin, psoralen, umbelliferone, limonene, rutin, skimmianine, lupeol, quercetin, esculetin, scopoletin, auraptene, seselin, etc.

Key words: Aegle marmelos, phytochemical constituents, Ethnobotanical uses, Pharmacological activities.

Introduction

Aegle marmelos belonging to the family of -Rutaceae is commonly known as bael in indigenous systems of medicine and has been regarded to possess various medicinal systems such as the Siddhi, Unani, and Ayurvedic systems. The bael is one of the sacred trees of the Hindus. Leaves are offered in prayers to Shiva and Parvathi. 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 trisoolam the weapon of Lord Shiva.

The journey of life for birds, animals and humans had started with utilization of plants or plant parts as food. Various plant parts like root, stem, leaf, flowers and fruits are used by the animal kingdom for survival of their lives. Humans are considered as most developed among all living species on earth.

Ancient literature such as Rigveda, Yajurveda, Atharvaveda, Charak Samhita and Sushruta Samhita also describes the use of plants for the treatment of various health problems. WHO says that 80% of the people in non-industrialized countries get their essential medical care from conventional drugs, the most common plant parts. They are a valuable source of pharmaceuticals and therapeutic products due to their secondary metabolism. That are various medicinal properties viz anticancer activity, antibacterial activity, antifungal

activity, antidiabetic activity, antioxidant activity, hepatoprotective activity, haemolytic activity, anti-inflammatory activity etc. *Aegle marmelos* is used to prepare different traditional medicines for treatment various diseases like respiratory tract infections, tumors, nausea, smallpox, mental illness, eye disorders, bronchitis, leprosy, asthma, abdominal problems, fever, inflammation, burning sensation, diarrhea, jaundice, constipation, acute bronchitis, snakebite, acidity, leucoderma, thyroid disorders, burning sensation, epilepsy, spermatorrhoea etc.

Only 350 species of the 6000 plants specified in ancient medical systems are used, The majority of which are herbs, *Aegle marmelos* (L.) Corr, is very important in everyday life. This plant is familiar with several names likes Bael, Bengal quince, Golden apple, wood apple etc.

In excess of 100 phytochemical compounds have been confined from different pieces of plant, in particular alkaloids, flavonoids, saponins, marmelin, limolin, tannins, phenolics, coumarin, etc.

The *Aegle marmelos* is a little variety of three species circulated in tropical Asia and Africa. The tree of *A. marmelos* starts from Eastern Ghats and focal India and tracked down for the most part in lower regions of Himalayas, Utter Pradesh, Madhya Pradesh, Rajasthan, Chhattisgarh and Bihar.



Fig:- Parts of Bael plant

PLANT PROFILE :**Scientific Classification**

Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidaeb
Order	Sapindales
Family	Rutaceae
Subfamily	Aurantioideae
Genus	Aegle
Species	A.marmelos
Nomenclature	Aegle marmelos (L.) Corr. Serr
Synonyms	Bel, Beli, Belgiri (Hindi) Bilva, shivdharma, shiva phala, vilva (Sanskrit) Marredy (Malayalam) Belo (Oriya) Vilva marum, Vilvama (Tamil).

Table: Varnacular names of A. Marmelos in various languages.

S. No.	Language	Names
1	Hindi	Bel, Bela, Bel patra, Villi, Shivadume, Shriphal
2	Sanskrit	Bilva, Bilvam, Bilva-phalam, Mahura, Shivaphala, Shivadruma, Sripfal, Pootivat, Shaelpatra, Lakshmiputra, Shivestha
3	Urdu	Bel, Bael
4	Assamese	Bel
5	Gujarati	Bel, Bilvaohal, Billi
6	Bengali,	Bael, Bela, Shriphal
7	Kannada	Bilpatra, Malura, Kumbala
8	Konkani	Gorakamli
9	Marathi	Bela, Kaveeth
10	Malayalam	Baela koovalam, Kuvalam, Maaredy, Vilvam
11	Oriya	Belo, Baela
12	Panjabi	Beel, Bil
13	Sindhi	Katori
14	Telegu	Bilva, Bilvamu, Bilva-pandu, Maradu-pandu, Malu-remu-chettu
15	Tamil	Bilva, Bilubam, Kuvviram, Villuvam, Vilvam, Vilvama, Vilva-maram, Vilva-pazham
16	Scientific	<i>Aegle marmelos</i> Corrêa, <i>Belou marmelos</i> (L.) Lyons, <i>Bilacus marmelos</i> (L.) Kuntze, <i>Cratava marmelos</i> L., <i>Cratava religiosa</i> Ainslie, and <i>Feronia pellucida</i> Roth
17	English	Bael fruit tree, bael tree, ball tree, bela tree, Bengal quince, elephant apple, golden apple, holy fruit, Indian bael, Indian quince, maredoo, quince-apple of India, stone apple, wood apple
18	Arabic	Safarjale-hindi, Shul
19	Burmese	Ohshit, Opesheet
20	Chinese	Mu ju, Yin du gou qi, Ying pi ju
21	Dutch	Slijmappelboom
22	French	Bel indien, Cognassier du Bengal, Coing de l'Inde, Oranger de Malabar
23	German	Belbaum, Bengalische quitte, Indische quitte, Schleimapfelbaum
24	Indonesian	Maja batuh, maja
25	Italian	Cotogno del Bengala, Cotogno d'India
26	Japanese	Berunoki, Ijure marumerozu
27	Javanese	Modjo
28	Khmer	Phneou, pnoi
29	Laotian (Sino Tibetan)	Toum
30	Malay	Bel, Bila, Bilak, Maja, Maja batuh, Maja pahit
31	Nepali	Belapatra, Belpatra
32	Persian	Bah hindi, Safarjale - hindi, Shull
33	Portuguese	Marmeleiro da -india
34	Sinhalese	Beli
35	Spanish	Bela, Milva
36	Tagalog	Bael
37	Thai	Mapin, Matum
38	Turkish	Hind ayva agh
39	Vietnamese	Bau nau, Traimam

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, 2-5cm wide, the terminal one with a long petiole.

Botanical description of different parts of *A. marmelos* tree:-**1) Bark**

The bark is brownish or grey in colour contains a number of straight long spines. It contains gums which often comes out from wounded branches and the becomes solid. It is sweet at first taste and then throat irritating.

2) Leaf

Its leaves are trifoliate having round base and pointed tip. Young leaves are light green and matured leaves are dark green in colour.

3) Flower

The flower are greenish or yellowish in colour and bisexual in nature.

4) Fruit

The bael fruit has a hard outer jacket and having a diameter of approximately 5 - 12 cm. It is green in unripe condition and changes to yellowish brown when ripens. It contains upto 20 orange pulp in the inside.

5) Seed

The seeds are small (nearly 1cm in length) hard, flattened - oblong, hairy, and wrapped in a sticky sac.

Geographical Source of the Plant

A. marmelos is a subtropical plant that may reach a height of 1,200 meters above sea level. It thrives in dry woodlands on steep and plain terrain. *A. marmelos* grows in India, Ceylon, China, Nepal, Shrilanka, Myanmar, Pakistan, Bangladesh etc. In India, it may be found in Sub-Himalayan plains stretching from Jhelum to West Bengal, as well as in central and southern India. It can be found in practically all of India's states.

Nutritional Value of *Aegle marmelos* (% or per100 gram): Experiments of the physical and mechanical characteristics of bael fruit have shown that it contains a lot of minerals and vitamins.

Table: Nutritional value of *A. marmelos* plant

S. No.	components	Value Percentage
1	Water	64.2
2	Protein	1.8
3	Fat	0.2
4	Minerals	1.5
5	Fiber	2.2
6	Carbohydrate	30.6
7	calcium	0.09
8	Phosphorus	0.05
9	Potassium	0.6
10	Iron	0.3
11	Vitamin A	186
12	Vitamin B1	0.01
13	Nicotinic Acid	0.9
14	Riboflavin	1.2
15	Vitamin C	0.01
16	Calorific vlaue	129

Phytoconstituents:**Alkaloids:**

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

Table:Phytochemical constituents present in A. marmelos plant

S. no.	Chemical Compounds	Names of Chemical Compounds	Parts of the plant	Biological Activity
1	Alkaloids ^{2,22,23}	Aegelenine, Aegeline, Aegelinosides A Aegelinosides B Dictamine, Ethyl cinnamide Ethyl cinnamate Fragrine Halfordinol	Fruits and Leaves	Antidiabetic, antibacterial, anti-inflammatory, alpha glucosidase inhibitor, anti-cancerous
2	Coumarins ^{2,3,24,25}	Alloimperatorin Imperatorin Isoimperatorin Marmelide, Marmelosin, Marmesin, Marmin, Psoralen, Umbelliferone, Methyl ether, Xanthotoxol, Zanthoxol	all parts	Antidiabetic, antioxidant, anti-inflammatory, and Anti analgesic
3	Carotenoids	Alpha- Carotenoid, Beta Carotenoid, Delta- carotenoid, Gamma - carotenoid	Fresh Fruit	Healthy Pigment
4	Terpenoids ^{2,24,25,26}	Caryophyllene, Cineol, Cubedol, Elemol, Epi cubebal Hexanyl hexanoate, Humulene Isosylvestrene Limonene, Linalool, Myrcene, P- cymene, Terpinolene, Valencene Caryophyllene, Cineol Linalool, Methyl perilate, Myrcene, P-cymene, Terpinolene, Valencene	Fruit, leaves and bark	
5	Vitamins ^{2,27}	Thiamin, Riboflavin, Niacin, Ascorbic Acid, Pyridoxin, Pantothenic acid, Biotin, Cobalamines, Riboflavin	Fruits and Leaves	
6	Tannins ^{2,8}	4,7,8-trimethoxyfuroquinoline	Fruits and Leaves	Antimicrobial and helpful in reducing blood pressure, Yellow dye for calico and silk fabrics
7	Carbohydrates ^{2,8}	Xylose, Threose, Glucose, Galactose, Fructose, Arabinose, Sucrose, Galactouronic acid	Fruits	Anti-inflammatory, Wound healing
8	Flavonoids ⁸	Rutin, Flavone, Flavone-3-ols, Flavones, glycosides		Antidepressant, Anticonvulsant, Antidiabetic
9	Fatty Acids ^{2,28}	Ricinoleic, linolenic, oleic, linoleic, palmitic, myristic	Seeds	Antimicrobial Activity
10	Essential oils ^{2,8,29}	Alpha-Pinene, Beta-Myrcene, Alpha-Phellandrene, Isosylvestrene, Delta-Carene, Beta Ocimene, Linalool, Terpenolene, Alpha-Cubebene, Alpha-Terpineol, Delta Elemene, Gama-Elemene	Leaves	Antifungal, antimicrobial, and insecticidal activity

Ethnobotanical uses:

One of the really important Indian herbal remedies, *A. marmelos* has a numerous applications. Many different medications may be made from different plant sections. Eating fruit may treat most ailments, making it an essential element of a healthy diet. Ophthalmia, ulcers, and gastrointestinal disorders may all be cured with a two-times dose of bael leaf extract. Bael leaf ointment is used to cure eye problems. Taken two times a day, a combination of boiling rice water and immature fruit peel prevents morning sickness in pregnant women. Fruit is a good choice for those recovering from diarrhea. Ethnobotanical uses of different part of the *A. marmelos* plant are described below in detail.

Table: Ethnobotanical uses of A. Marmelos plant parts

S. no.	Plant Part	Ethnobotanical use
1.	Leaves	Abscess, pain, vision problems, stomach disturbances, vomiting, cuts, ulcers, dropsy, thiamine deficiency, heart failure, cholera, diarrhea, cardiostimulant, blood glucose, animal injury, neurological diseases, hair medication, respiratory tonic, child delivery. Animal wound healing, worm control, feed for sheep, goats, augmentation of breathing, and Sedated cats' contraction of the denervated nictitating membrane
2.	Fruit	Some of the diseases this herb treats include diarrhoea, stomach or digestion-related problems neurological and cardiac tonic, ulcer, antiviral, intestinal parasites, gonorrhoea, and epilepsy
3	Root	Dog bites, gastrointestinal issues, cardiac conditions, periodic fevers, antiamoebic, hypoglycemia, rheumatoid arthritis
4.	Bark	Gastrointestinal problem, periodic fevers, cardiac disorder
5.	Seed	Febrifuge
6.	Flower	Cough syrup, epilepsy
7.	Whole plant	Back pain, dog and snake bite, pain in breast, cholera, loose motions, diabetes, diarrhoea, dysentery, pyrexia, eye problems, gastrointestinal and stomach abnormalities, jaundice, laxative, nausea, nocturnal fever, cardiac problems, stomach disorder, vomiting, tonic, cuts and wounds
8.	Root, Bark	Fish venom
9.	Seed Mucilage	Walls construction
10	Seed oil	Laxative effect, Used in aromatherapy, skincare, and Compressor
11	Wood	Beads worn by members of the lowest caste and specific couches for rheumatic sufferers.
12	Gum around seed	It enhances the stickiness of aqueous-based paints.
13	Unripe fruit rind, Bark	Yellow colour dye
14	Stem	Oil and sugar mills pestles

Traditional and modern view of Aegle marmelos plant**Ayurvedic View**

A. marmelos plant is acknowledged as the most significant plant in the Ayurvedic medicinal system. It balances the Kapha (water and earth component) and Vata (space and air component) dosha. The fruit of this plant is medicinally used in the Ayurvedic, Siddha and Unani medicinal system and is considered an excellent remedy for diarrhea. The medicinal properties of the plant are briefly described in Charaka Samhita⁵⁶. All the parts of the plant i.e. trunk, leaf, seed and fruit are used to treat various types of diseases⁵⁷. The leaves of the plant carry expectorant, astringent and febrifuge properties that help in treating

bleeding disorders, edema, hemorrhoids and bowel complaints. In Ayurveda, the roots of the plant are commonly used as an important ingredient in the Ayurvedic drug named 'Dashamoola' which is used to cure dysentery, colitis, diarrhea, flatulence, loss of appetite and fever since ancient times. The fruits of the plant are used in making Chyavanprash. The unripe fruit in Ayurveda is used as a tonic for the heart and brain and is used to treat chronic diarrhea and dysenterys. The tree barks and roots of the plant relieve urinary problems and palpitation of the heart. The juice of *A. marmelos* helps in improving digestion, scurvy and strengthens stomach actions⁶⁰. In Ayurveda, the plant is used to cure indigestion, intermittent fever, typhoid, cholera, heart palpitation, heart, stomach and intestinal disorders because of the presence of carminative and digestive properties. The unripe fruit is associated with more medicinal value as compared to ripe fruit. The leaves, fruits and bark of this plant have been reported to have anti-diabetic property.

Modern View

In the modern world, people are taking more interest in herbal medicines because of their lesser side effects, easy availability and cheaper prices. The consumption of herbal medicines has increased world widely. Reported studies have revealed an increased growth in the sale of herbal products from the year 2000 to 2008 that is reached from 3% to 12% per year. With the increasing demand of the people, adulteration and substitution also rise in the herbal drug industry which is considered as a major threat to the quality and in the research areas on commercial natural products. The main reason for the adulteration is the non-availability of the original plant product, deforestation, extinction of many herbal plant species, confusion in the species identification, etc. Also, many herbal dealers have developed new methods of high-quality adulteration that can only be identified by using chemical analysis and microscopic examination". The poor quality of the drug and lack of standardization are the two weaknesses that lay behind the acceptance of herbal products which results in the decreased market value of the product. So, there is a need to develop an Herbal Authentication System (HAS) which can serve as a regulator and helps in improving the quality of herbal trade". The herbal plant named *Aegle marmelos* is associated with multiple medicinal properties. The destruction and over-exploitation of the plant have their historical concerns. To protect the plant from over-exploitation, it is attached with the name of the tree of Lord Shiva and Goddess Laxmi to prevent it from destruction. Presently, the Bael plant has become popular because of its medicinal use in both human and animal diseases. Due to the high economic value of the *A. marmelos* plant, people who once used the plant products judiciously became ruthless and destructive collectors. To prevent the plant from destruction, the National Medicinal Plants Board of the Government of India has placed the *A. marmelos* plant on the priority list of 32 medicinal plants and many projects have been sanctioned by the government for the conservation and sustainable utilization of the plant.

Pharmacological Activities:-

Antibacterial Activity :

Various extracts of *A. marmelos* leaves, roots and fruits have been reported to be active against many bacterial strains. Bacteria are the most versatile unicellular pathogens, which are normally transmitted through soil, water, air, and food and cause diseases in human beings and animals. Such types of diseases could be treated with various natural products like *Aegle marmelos*. Different extracts of *A. marmelos* showed antibacterial activity against *Micrococcus glutamicus*, *Streptococcus faecalis*, *Staphylococcus aureus*, *S. phogenes*, *Bacillus stearothermophilus*, *Micrococcus luteus*, *E. coli* and *Pseudomonas denitrificans*.

The antibacterial activity of the different extracts was evaluated by agar well diffusion method. Ethanol and chloroform leaf concentrates *aegle marmelos* were viewed as more active towards the bacterial species tried. Further, the fluid leaf extract was tolerably active followed by dichloromethane removal. But that as it may, oil ether extract was not powerful against any of the creatures tried.

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. Result depict that phytochemical extracts of *A. marmelos* exhibited significant antibacterial activity. 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*.

Anticancer activity:-

Cancer disease is a significant general medical condition, the second most noteworthy reason for death in all kinds of people in creating and emerging nations. According to WHO 2020 report, the death rate primarily due to cancer is approximately 10 million, with a lopsided ascent in disease case and passings in emerging nations with restricted assets to handle the issue.

In-vitro studies using leukemia cell lines(K562,T-lymphoid immortal, B-lymphoid immortal, B-lymphoid first continuous human cell line, erythroleukemic HEL, malignant Colo38, and breast cancer cell lines Michigan Cancer Foundation (MCF7) and MDA-MB-231 (formed from pleural effusion of Caucasian female with malignant adenocarcinoma 1) showed that *A. marmelos* leaf extracts were highly effective.

The effect of *Aegle marmelos* fruit extract on breast cancer in rats generated by 7, 12-dimethylbenzene anthracene (DMBA). The study employed female Charles Foster rats that were 55-60 days old and weighed approximately (150g). They were stimulated orally with DMBA (20 mg/ml diluted in Olive oil). The rats were given *Aegle marmelos* ethanolic fruit pulp extract (200 mg/kg b.w./day) orally for 5 weeks after developing breast tumours (approximately 0.5cm) and the amount of tumour was assessed. Treatment with *Aegle marmelos* resulted in substantial reduction in breast tumour volume (P 0.05), as well as a substantial drop (P 0.0001) in serum biomarkers such as TNF, serum malondialdehyde (MDA), and glucose levels. In a rat model, the ethanolic fruit pulp extract has anti-proliferative effect by slowing the progression of breast cancers.

Antioxidant Activity :-

Antioxidants are the compounds which are having free radicals scavenging activity and also used to protect the cells from free radical mediated oxidative stress. The antioxidant compounds are derived from natural sources such as plants. Antioxidant activity of these plants is due to the presence of flavones, flavonoids, isoflavones, anthocyanin, coumarin, lignans, catechins and isocatechins. *A. marmelos* plays an important role in cytoprotection as well as protection against pro-oxidant-induced membrane damage. The antioxidant effect of aqueous extract of *A. marmelos* leaves carried out by using male albino rats. Glucose, Urea and glutathione-S-transferase in plasma, glutathione (GSH) and malondialdehyde (MDA) levels in erythrocytes, DT-diaphorase, superoxide dismutase, and catalase in the lung were estimated in all the groups of animals at the end of 4 weeks. These changes occurred in the body fluids of drug-catabolism. The blood glucose levels and MDA levels are decreased at the end of 4 weeks & then GSH levels in Erythrocytes are increased in group treated with *A. marmelos* as compared to diabetic rats. Leaf extract also protects antioxidant defence system and restores histological changes of pancreatic beta-cells in STZ-induced diabetic rats.

Antioxidant activity and free radical scavenging activity of *Aegle marmelos* is compared in between ripe and unripe fruit. The result of enzymatic antioxidants increased in ripe fruit when compared to unripe fruit extract (except glutathione peroxidase). The percentage of free radical inhibition is high in unripe fruit than that of the ripe fruit. Screening of fruit pulp of *A. marmelos* methanolic and aqueous extract for antioxidant activity by DPPH radical scavenging method, reducing power assay, nitric oxide scavenging assay, superoxide radical scavenging assay, ABTS radicals scavenging assay and H₂O₂ radical scavenging assay. Both aqueous and alcoholic extract exhibit good antioxidant activity.

Antimicrobial Activity:

It has been expressed that *A. marmelos* has customarily been utilized to treat different irresistible issues by repressing many destructive microorganisms. The antibacterial action of *A. marmelos* leaves and natural product remove was researched. The utilization of leaf and natural product removes against *Rouletella planticola* brought about restraint zones of 11 mm and 9 mm, individually. The plant extricate delivered a most extreme restraint zone of (18mm) movement against the contagious strain *Penicillium chrysogenum* and a base hindrance zone of (7mm) action against *Candida albicans*. (17) antimicrobial medications are utilized in restorative practice for treating food borne sickness. Utilization of restorative plants that are wealthy in antimicrobial compounds could be an elective method for wiping out these microorganisms. The concentrate of *Aegle marmelos* groups antimicrobial movement. It has been found dynamic against different species, for example, *Staphylococcus aureus*, *epidermidis*, *Proteus vulgaris*. It has additionally been utilized for ranikhet illness infection and gastrointestinal parasites.

Antimicrobial activity was stronger against gram-negative germs than against gram-positive pathogens⁴⁸. Cuminaldehyde and Eugenol, two leaf components, may be responsible for antibacterial action.

Antihistaminic Activity

Skimmianine is a quinoline alkaloid isolated from roots *Aegle marmelos*. In the study the effects of skimmianine on the histamine release from rat mast cells are tested. The study was performed by using rat basophilic leukemia (RBL-2H3) cell line, and rat peritoneal mast cells (RPMCS) DNP24, BSA, thapsigargin, ionomycin, 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.

Antiviral Activity -

The in vitro antiviral exercises of different pieces of the *Aegle marmelos* tree have through about for their adequacy in contrast to human coxsackie infections infection B1-B6. The IC₅₀ of leaves, endlessly stem bark, natural product, endlessly root bark and the unadulterated compound marmelide are 1000, 500-1000, 250-500 and 62.5 µg/ml respectively through, the IC₅₀ of ribavirin, a standard antiviral specialist, is 2000 µg/ml for the equivalent infections and simultaneously period. Marmelide is the best virucidal specialist disrupting early, occasions of its replicative cycle. It appears to be that *Aegle marmelos* has antiviral exercises in the beginning phase of viral replication with least host cytotoxicity as opposed to current virucidal chemotherapeutic specialists (ie ribavirin), which typically act in the later phases of viral replication and make powerful side impacts. The impacts of *Aegle marmelos* also acts the late protein synthesis were studied to evaluate its degree of potentiality as an antiviral agent. The 50% ethanolic extract of the fruits has shown antiviral activity against Ranikhet disease. The fruit extract has exhibited interferon-like activity against the same virus but not showed an activity against vaccinia virus. So that *Aegle* has better viricidal activity.

Antifungal Activity

The Antifungal Activity was performed by tube dilution MIC method and also This activity was performed by using 21 days old Culture of dematophytic fungi with was distilled water. The suspension was adjusted spectrophotometrically to an absorbance of 0.0600 at 450nm. Vulnerability testing was executed by microdilution method. Potent antifungal activity was found when *A. Marmelas* leaf extract was applied against *Trichophyto mentagrophytes*, *T.rubrum*, *Microsporum canis*, *M.gypseum*, *Epidermophyton floccosum*. Decoction of the fruit exhibited an activity against *Aspergillus niger*, *Aspergillus fumigates*, *candida albicans* and *Staphylococcus aureus* and the MIC results for the above particular organism were 19.5 µg/ml, 39 µg/ml, 625 µg/ml and 1.25 mg/ml.

Weakness testing was executed by miniature weakening strategy powerful antifungal action was found when *A. marmelos* leaf extricate was applied against *Trichophyton mentagrophytes*, *Trubrum*, *Microsporum canis*, *M.gypseum*, *Epidermophyton Floccosum*. The ethanolic extract of the root has exposed an activity against *Aspergillus Fumigatus* and *Trichophyton mentagrophytes*. The germination of any spore (ie bacterial or fungal) is connected to Ca^{2+} - dipicolonate and/or free Ca^{2+} ions availability in the medium as well as within cytoplasm of Microbes. This Ca^{2+} ino uptake and utilization by spore is one of the important factors that determine whether the spore will germinate or remain dormant. The essential oil from the *Aegle* leaves may interfere with the Ca^{2+} dipicolonic acid metabolism pathway and possibly inhibit spore germination. This is the possible mechanism of the protective role of *Aegle* leaf oil against fungal infection.

Antidiarrheal Activity-

Antidiarrheal activity is one of the most important medicinal properties of *A.marmelos* and it is extensively used to control chronic diarrhea and dysentery. Recently several in vitro and in vivo studies. are activity conducted to confirms the antidiarrheal activity in *A.Marmelos*. The in vitro antidiarrheal activity in dried fruit pulps of *A. marmelos* was performed. Antidiarrheal activity was conducted by Mc method against the causative organism of diarrhoea. Both root and leaf extracts of *Aegle* shows gastroprotective and antidiarrheal activities. against oil induced diarrhea in animals models

The ethanolic remove displays great movement against *shigella boydii*, *S. Sonnel* and *S. Flexneri*, ordinary against *S. dysenteriae*. Rough Fluid concentrate of unipe products of *A.marmelos* was isolated for causative specialists of the runs. The concentrate was indentified for antibacterial movement, anti giardial action and antirotaviral action and furthermore the concentrate displays an inhibitory action against *Giardia* and rotavirus through the reasonability of none of the six bacterial strains tried was impacted. In another review, concentrate of *A. Marmelos* was tried for its impact on colonization Of *E. coli* E134, *E. coli* B170, and *S. flexneri*. The outcomes showed that there is a lessening in colonization, maybe because of its effect on the digestion of HEP-2Cells of potentially because of change of cell receptors that limit bacterial adherence, as found in the pre-hatching of HEP-2 with the concentrate. The concentrate displays more noteworthy restraint of adherence of *S. flexneri* and *E.coli* E134 When Contrasted with intrusion of *E. coli* B170. Since microorganism grip to the covering of the gastrointestinal lot is the earlist phase of the disease cycle and hindering intrusion/adherence could be a basic piece of the antidiarrheal impact of the plant.

Anti-diabetic Activity -

Chronic metabolic illness such as diabetes is a danger to 58 human health and the global economy . The International Diabetes Federation (IDF) predicts that 463 million people will have diabetes in 2019 59. Insulin deficiency is recognized to be the cause of diabetes in humans, which is why getting insulin from an outside source is essential for the treatment of diabetes. In a similar manner, bael can substitute insulin by improving the body's ability to take in glucose from the outside source. Serum glucose levels in rodents with elevated amounts were significantly reduced after treatment with a 75% methanolic concentrate of *A. marmelos*. Leaf concentrate of *A. marmelos* is a significant medication for the treatment of diabetes. It additionally upgrades the capacity to use the outside glucose load in the body by excitement of glucose take-up like insulin. *Aegle* leaf remove fundamentally diminishes the degrees of blood urea and cholesterol and further more diminishes oxidative pressure in trial diabetic creatures, it is demonstrated by critical decrease in lipid peroxidation, Formed diene and hydroperoxide level and expanded degrees. of different proteins like superoxide dismutase, catalase, glutathione peroxidase, and glutathione levels in serum as well as liver.

In alloxan diabetic rats the leaves of *A. marmelos* were found to have anti-diabetic action. A methanolic extract of *A.marmelos* leaves lowers blood sugar levels. In the Ayurvedic system of medicine, leaf extract has been used to treat diabetes. It improves the body's ability to use exogenous glucose loads by stimulating glucose absorption with insulin. Leaf extract in *A. marmelos* shows the anti-diabetic and anti-hyperlipidaemic effect of allopoltherbal formulation in oral glucose tolerance test and STZ-induced diabetic rat model. It significantly enhances glycaemic control, protects the pancreas from degeneration, and shows

antioxidant and hepatoprotective effects. It contains umbelliferon-a-D-glucopyranosyl -(2 (I)→1(II)-aD-glucopyranoside that cut down extra glucose level in STZ induced diabetic rats. The plants of green leafy porridges are used to control hypo and hyperglycaemic responses. Leaf extract of Aegle also decreases the muscarinic M1 receptor gene expression in the cerebral cortex of STZ- induced diabetic rats. Leaf extract shows antihyperlipidemic activities and anti-diabetogenic properties and lowers down diabetic effects and in STZ-induced diabetes in experimental rats. The Chloroform extract of A. marmelos established anti-diabetic anti-glycating and antioxidant activity, effectively preventing kidney damage and the establishment of contracts Hence, the plant is used for management of type 2 diabetes.

Antimalarial Activity

The antimalarial effects of the alcoholic extracts and leaves of the A. marmelos fruit have been tested inside the living body and outside the living body in the designed environment for the experiment. Seeds seem to have some inhibitory effect in both cases. A Researcher showed that hexane, cold methanol and hot methanol extracts stop the growth of Klebsiella Pneumonia, Micrococcus luteus, Enterococcus faecalis and streptococcus faecalis in-vitro. Their study demonstrates that these three extracts do not have any effect of E. coli and proteus vulgaris.

Antiulcer Activity

According to Goel R.K (1997) Pyrano coumarin extracted from the seeds of Aegle marmelos Correa provided considerable protection against pylorus ligated and aspirin-induced ulcers. induced stomach ulcers in rats guinea pigs. induced as well as cold restraint stress induced ulcers in rats and guinea pigs. In albino rats, A. marmelos natural product mash removal brings down mucosal thickness superoxide dismutation, catalase action, and glutathione levels impressively. Ulcer record aspartate aminotransferase, alanine aminotransferase, and lipid peroxidation movement all expanded essentially. This information proposes that a cell reinforcement system might influence A. marmelos gastroduodenal precaution and antiulcerogenic impacts. Fluid concentrate of Aegle marmelos was ready and utilized for examination. A day-to-day- portion of 1gm/kg body weight of concentrate organization orally for 21 days. The volume of gastric emission, ulcer sore count pepsin count, PH absolute action, hexamine content were assessed Another review demonstrated that A. marmelos natural product mash removes skinned treated pale skinned person rodents should critical lessening in mucosal thickness, superoxide dismutase, alanine aminotransferase. lipid peroxidation movement was likewise noticed. These outcomes propose that gastro duodenal defensive and antiulcerogenic properties of A.marmelos may likewise depend upon antioxidant mechanisms.

Anti-inflammatory Activity

The review inspected the likely mitigating exercises of the rehashed separated from A. marmelos leaves. An evident pain relieving impact was shown mouse models of carrageenan-actuated paw edema and cotton-pellet granuloma to lay out the antipyretic and pain relieving exercises of the leaf extricates. Furthermore, the early and late Periods of paw licking were lessened, and hyperpyrexia diminished. watery concentrate from unripe A.marmelos natural product was found to have a portion subordinate effect in an alternate examination focused on provocative gut illness in pale skinned person wistar rodents with a lot higher Grass and lower MDA levels and safeguard against pole cell degranulation, A. Marmelos organic product had calming, cancer prevention agent, and pole cell cancer balancing out properties In another research, the anti-inflammatory properties of the aqueous extract of A Marmelos dry Flowers are investigated in wistar rats. The anti-inflammatory activity of water extract were more effective at 200 mg/kg two hours after administration

Cardioprotective Activity-

The leaf extract of bilwa has preventing- effect in isoprenaline induced myocardial infraction in rats Use of bilwa as a cardiac depressant and in palpitation has also been reported. Fresh fruit juice of bilwa with different dilution were used for cardiotoxic activity. The present studies confirm the better cardiotoxic activity of bilwa than digoxin.

Immunomodulatory Activity-

The aim of the present study was to investigate immunomodulatory activity of methanolic extract of A.Marmelos fruit (FEAM) in experimental model of immunity. Methods-cellular immunity was carried out by neutrophil adhesion test and carbon Clearance assay, whereas, humoral immunity was analyzed by mice lethality test and indirect haemagglutination assay. FEAM dose was selected by stair case method (up and down) and administered at 100 and 500 mg/kg orally. The ocimum sanctum (OSE, 100 mg/kg, P.O) was used as standard. FEAM 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 FEAM significantly prevented the mortality induced by bovine pasteurized multocida in mice. Treatment of animals with FEAM and OSE significantly increased the circulating antibody 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 FEAM possesses potential for augmenting immune activity by cellular and humoral mediated mechanisms more at low dose (100mg/kg) than high dose (500mg/kg) (Patel et al, 2010).

Wound Healing Activity :

There are several stages involved in the healing of wounds, including inflammation, the multiplication of cells, and stiffness during the development of a collagen matrix. Reddening, soreness, and swelling are some of the most common symptoms linked with wounds, and they are also present when inflammation is present. It has been discovered that one defense mechanism involves the emission of reactive species.

Aegle marmelos fruit extract decreased wound size and enhanced tissue regeneration in beta-catenin, Akt signaling and ERK (extracellular signal- regulated kinase) pathway-regulated keratinocyte migration in Aegle marmelos fruit extract-treated rats. A. marmelos fruit extract and its active ingredient stimulate mRNA expression, decrease nitric oxide and PGE2 production, and encourage the movement of HaCaT keratinocytes during rat wound healing in culture 52. When applied to the wounds of rats. A. marmelos fruit extract significantly reduced the wound sizes. Re- epithelialization of skin lesions occurred more quickly than expected. A further investigation into the effects of bael extract using an evacuation and an incisions model demonstrates that bael has a positive effect on wound healing. Essential oils, bioflavonoids, and nitrogenous-containing organic compounds like alkaloids and sterols are some phytochemical compounds found in bael. These phytoconstituents are responsible for the wound- healing properties of bael, the accelerated epithelialization, tightening of the wound, flexible power, and hydroxyproline composition. The capacity of bael to promote wound healing is comparable to that of the medication nitrofurazone.

Activity against SARS-COVID -2:

Seselin, a chemical constituent obtained from the leaves of A. marmelos and tested against many SARS-CoV-2 targets, including the viral spike protein S2, the COVID-19 major protease, and the SARS-CoV-2 (2019-nCoV) free enzyme. Seselin bound to receptors with a binding energy of 6.3 kcal/mol, spike protein S2 with a binding energy of 6.9 kcal/mol, and COVID-19 major protease with a binding energy of 6.7 kcal/mol.

As shown by a docking study with three distinct receptors, intermolecular hydrogen bonds and stacking interactions are responsible for stabilizing the complexes with the lowest projected energy. Results from a

molecular dynamics simulation and an MM/PBSA (Molecular mechanism/Poisson Boltzmann surface area) study confirmed that seselin binds to its target receptors and has therapeutic potential for COVID-19. Marmin, which was isolated from *A. marmelos*, was shown to be a possible inhibitor of RNA-dependent RNA polymerase and 3CLpro of SARS-COVID-2 by an in-silico investigation.

Antidandruff Activity:

The rind of the *A. marmelos* fruit is utilized in dandruff treatment. Excess hair loss and flaky scalp skin can also be treated by soaking the rind in coconut oil or ginger oil.

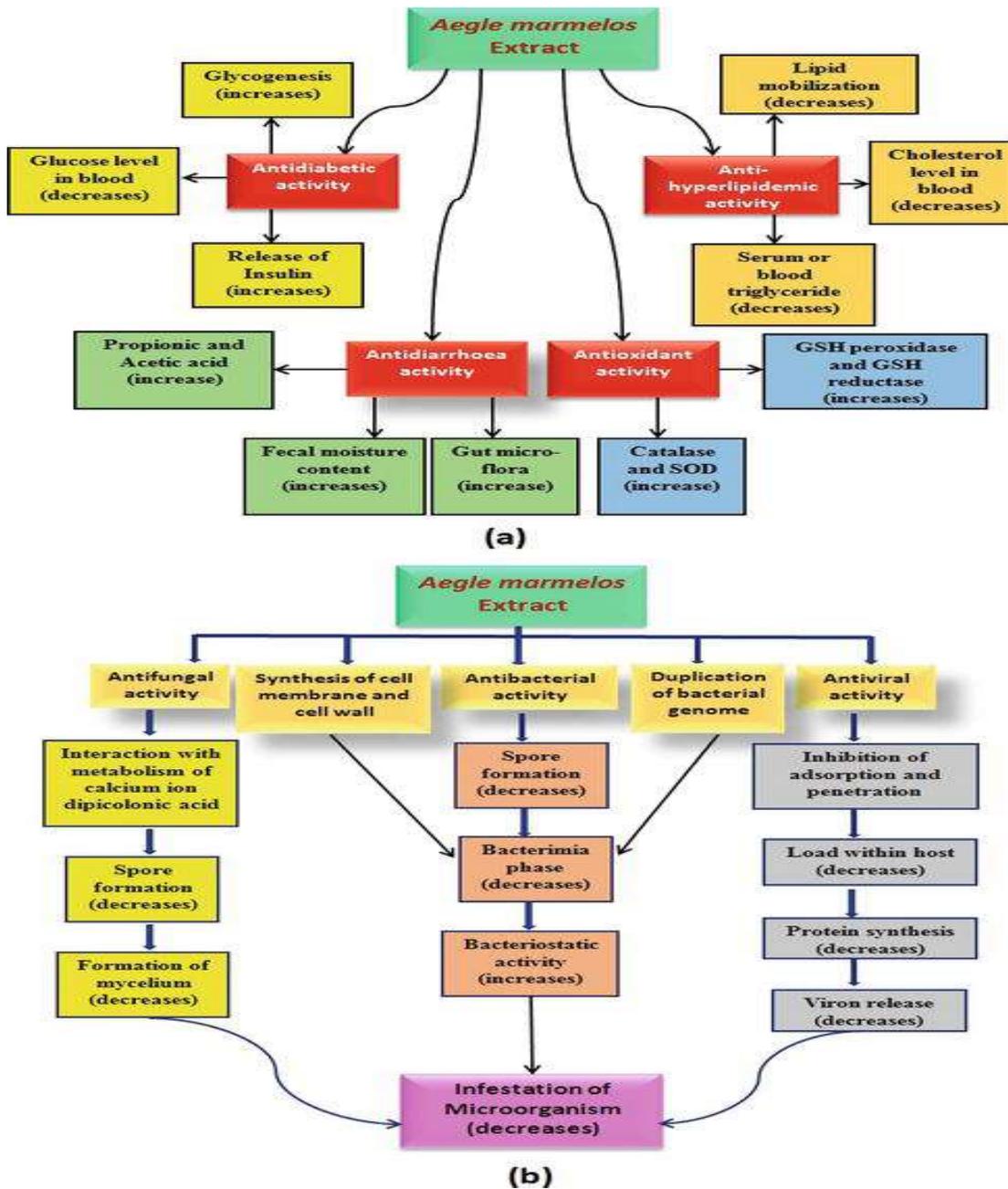
Reproductive Dysfunction:

It has been shown that *marmelos* can have a detrimental effect on male fertility. Bael's ethanolic bark extract is capable of fully inhibiting sperm activity. It leads to an increase in germinal epithelium degeneration, epididymal sperm density, and acrosomal integrity. In the preimplantation stage, bael extract works, and preimplantation failure results in sterility. Bael effects negatively to sperm activity due to blockage of the calcium channel. It has been demonstrated that fagarine and marmin, which both exist in a larger amount in the stem bark of *A. marmelos*, inhibit male fertility. The *A. marmelos* methanolic extract causes infertility in a dosage amount and time-dependent approach. This is because the extract lowers testosterone hormone levels and the weight of reproductive organs. The researchers also noted that once the extract therapy was discontinued, all morphological and physiological indications in the rats given the extract returned to normal". According to these findings, the extract of *A. marmelos* shows significant potential for use as a birth control pill. It has been demonstrated to eliminate the possibility of a pregnancy occurring, but if treatment is stopped, fertility typically returns within a few months.

Toxicology

According to Veerappan et al., (2007) intraperitoneal administration of the leaves extract of *A. marmelos* at doses of 50, 70, 90 and 100 mg/kg body weight for 14 consecutive days to male and female wistar rats did not induce any short term toxicity. It was observed that the extract of leaves of *A. marmelos* have a high margin of drug safety (Rana et al., 1997). Another study revealed that the *A. marmelos* was non-toxic up to a dose of 1750 mg/kg body weight and LD50 of extract was 2250 mg/kg, i.p in mice (Jagetia et al., 2005). Porchelvan and Porchelvan and Venkatakrishnamurali, (2014) reported that chronic administration of leaf powder of *Aegle marmelos* was non-toxic up to dose of 2000 mg/kg b. w. in rats.

Figure : Biological importance of *Aegle marmelos* for the treatment of various diseases and mode of action.



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 drug for diseases have led to growing emphasis on the use of plant material as source of medicine for human beings. *Aegle marmelos* is an important medicinal herb and extensively used in Ayurveda, Siddha and other medicinal system. The different parts of this plant such as leaf, fruit, seed, bark, and root are used to cure a variety of diseases like antibacterial, ulcer healing, antiviral, antifungal, cancer, SARS-CoVID 2. etc. This is because it contains such as many phytochemical compound, aegelenine, fragrine, halfordinol, marmin, umbelliferone etc. This review mainly focused on several phytochemical and reported pharmacological Studies of *A. marmelos*.

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