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SYZYGIUM CUMINI (LINN.) - AN OVERVIEW ON MORPHOLOGY, CULTIVATION, TRADITIONAL USES AND PHARMACOLOGY

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ABSTRACT: *Syzygium cumini* (L.) is a widely used medicinal plant for the management of various diseases. *Syzygium cumini* possesses various chemical constituents which are responsible for pharmacological activity. This plant is reported to possess many pharmacological activities like anti-diabetic activity, anti-oxidant, anti-inflammatory, anti-diarrhoeal activity, antiviral, antifertility activity, gastroprotective, antipyretic, anti-histaminic, antimicrobial and antiplaque. The present review presents specific information on morphology of plant, cultivation of plant, traditional uses and pharmacological actions of *S. cumini* (L.). Further applications of *Syzygium cumini* (Linn.) in the field of novel drug delivery have been also elaborated in the review. Apart from its application in the management of various ailments there is a need to explore the chemical and toxicity concerns of *Syzygium cumini* (Linn.).

INTRODUCTION: There has been an increasing demand for health promoting food products by the consumers all over the world. This has led to the new hybrid term between nutrients and pharmaceuticals, 'nutraceuticals' coined by Dr. Stephen L. DeFelice, in the year 1989 ¹. Nutraceuticals are diet supplements that deliver a concentrated form of a bioactive component from a food and used with the purpose of enhancing health in dosages that sometimes exceeds that of the normal foods ². Medicinal plants have been the part and parcel of human society to combat diseases since the dawn of human society to combat diseases since the dawn of human civilization ³.

To cure human disease, medicinal plants have been a major source of therapeutic agents since time immemorial. Indian flora and fauna consists of more than 2200 species of medicinal and aromatic plants. The revival of interest in natural drugs started in the last decade mainly because of the widespread belief that green medicine is healthier than synthetic products. Nowadays, there is a manifold increase in medicinal plant based industries due to the increase in the interest of use of medicinal plants throughout the world which are growing at a rate of 7 - 15% annually.

According to the WHO, 80% of the world population continues to rely mainly on traditional medicine for their health care. Since 1980, the World Health Organization has been encouraging countries to identify and exploit traditional medicine and phytotherapy. The evaluation of new drugs especially phytochemically obtained materials has again opened a vast area for research and development. With the emerging worldwide

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interest in adopting and studying traditional systems and exploiting their potential based on different health systems, the evaluation of rich heritage of traditional medicine is essential. In this regard, one such plant is *Syzygium cumini* (L.) skeels which is a large tree distributed all over India^{4, 5, 6}. The medicinal properties of several herbal plants have been documented in ancient Indian literature and the preparations have been found to be effective in the treatment of diseases. Therefore to meet the increasing demand of manufacturing modern medicines and export, the need of the medicinal plants have enormously increased. This demand is generally met with by cultivating uprooted medicinal plants^{7,8}.

Syzygium cumini (Linn.) Skeels (Myrtaceae) commonly known as Indian blackberry; Jaman, is a large tree distributed throughout Upper Gangetic Plains, Bihar, Orissa, planted in West Bengal, Deccan, Konkan region; all forest district of South India^{9, 10}; also grown in Thailand, Philippines, Madagascar and cultivated widely throughout Africa, Caribbean and Tropical America. It grows commonly along streams and damp places and in evergreen forests. The tree is planted as an ornamental in gardens and at roadsides¹¹. It is a large evergreen tree up to 30 meters height and girth of 3.6 meters with a bole up to 15 meters¹². The tree was also introduced to Florida, USA in 1911 by the USDA, and is also now commonly planted in Suriname. In Brazil, where it was introduced from India during Portuguese colonization, it has dispersed spontaneously in the wild in some places, as its fruits are eagerly sought by various native birds such as thrushes, tanagers, and the Great Kiskadee¹³. The aim of this review article is to highlight the morphological character, cultivation, traditional uses and pharmacological activities of *syzygium cumini* L. and also investigated various updated pharmacological of this plant.

Taxonomic Classification:¹⁴

Kingdom	: Plantae
Division	: Magnoliophyta
Class	: Magnoliopsida
Order	: Myrtales
Family	: Myrtaceae
Genus	: <i>Syzygium</i>
Species	: <i>Cumini</i>

Common Names from Worldwide:¹⁵⁻¹⁶

Brazil	: Azeitona
Pakistan	: Jaman
West Indies	: Jambol
Nepal	: Java plum
Thailand	: Lukwa
Japan	: Madan
Madagascar	: Rotra

Other Names:^{8, 15-16}

Hindi	: Jaman, Jam, Jamun
Bengali	: Jam, Kalajam
Gujarati	: Jambu, JamLi
Telugu	: Jambuvu
Marathi	: Jaman, Jambul

Geographical Source: The original home of jamun is India, distributed throughout India, in forest up to 1800m usually along the bank and moist localities, also cultivated as shade trees along road sides. It is widely cultivated in Haryana as well as the rest of the Indo-Gangetic plains on a large scale. Its habitat starts from Myanmar and extends up to Afghanistan.

It was cultivated in England by Miller in 1768.¹⁷ It is also found in Thailand, Philippines, Madagascar and some other country. The plant has been successfully introduced into many other tropical countries such as the West Indies, West Africa and some subtropical regions including Florida, California, Algeria and Israel¹⁸.

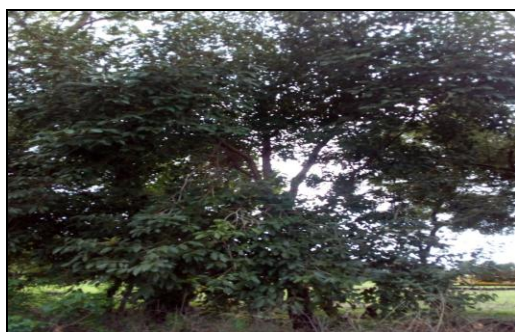
Botanical Study:¹⁹ *S. cumini* may reach 30 m tall in India and Oceania or up to 12-15 m in Florida, USA, with a broad crown up to 11 m in diameter and a trunk diameter of 0.6-0.9 m though it usually has a multi-stemmed from branching close to the ground. Bark is rough, cracked, flaking and discoloured on the lower part of the trunk, becoming smooth and light-grey higher up. Leaves have a turpentine smell, and are opposite, 5-25 cm long, 2.5-10 cm wide, oblong-oval or elliptic, blunt or tapering to a point at the apex; pinkish when young, becoming leathery, glossy, dark-green above, lighter beneath, with a conspicuous, yellowish midrib when mature. Flowers are fragrant and appear in clusters 2.5-10 cm long, each being 1.25 cm wide and 2.5 cm long, with a funnel-shaped calyx and 4-5 united petals, white at first, becoming rose-pink, shedding rapidly to leave only

the numerous stamens. Fruit appear in clusters of just a few or 10-40, are round or oblong, often curved, 1.25-5 cm long, turning from green to light-magenta, then dark-purple or nearly black, although a white-fruited form has been reported in Indonesia. The skin is thin, smooth, glossy, and adherent.

The pulp is purple or white, very juicy, and normally encloses a single, oblong, green or brown seed, up to 4 cm long, though some fruits have 2-5 seeds tightly compressed within a leathery coat, and some are seedless. The fruit is usually astringent, sometimes unpalatably so, and the flavour varies from acid to fairly sweet.

TABLE 1: BOTANICAL DESCRIPTION OF *S. CUMINI*

S. no.	Feature	Description
1	Habitat	It is widely cultivated in Haryana as well as the rest of the Indo-Gangetic plains in India. West Indies, West Africa and some subtropical regions including Florida, California, Algeria and Israel
2	Appearance	<i>S. cumini</i> may reach 30 m tall, broad crown up to 11 m in diameter and a trunk diameter of 0.6-0.9 m
3	Used parts	Dried fruits, fresh fruit, seed, leaves, root bark, flowers.
4	Leaves	Turpentine smell, and are opposite, 5-25 cm long, 2.5-10 cm wide, oblong-oval or elliptic, blunt or tapering to a point at the apex; pinkish when young, becoming leathery, glossy, dark-green above, lighter beneath, with a conspicuous, yellowish midrib when mature
5	Fruits	appear in clusters of just a few or 10-40, are round or oblong, often curved, 1.25-5 cm long, turning from green to light-magenta, then dark-purple or nearly black, although a white-fruited form has been reported in Indonesia Fruit is usually astringent, sometimes unpalatably so, and the flavour varies from acid to fairly sweet Pulp is purple or white, very juicy, and normally encloses a single, oblong, green or brown seed, up to 4 cm long, though some fruits have 2-5 seeds tightly compressed within a leathery coat, and some are seedless
6	Flowers	Fragrant and appear in clusters 2.5-10 cm long, each being 1.25 cm wide and 2.5 cm long, with a funnel-shaped calyx and 4-5 united petals, white at first, becoming rose-pink, shedding rapidly to leave only the numerous stamens
7	Seeds	2-5 seeds tightly compressed within a leathery coat
8	Barks	Rough, cracked, flaking and discoloured on the lower part of the trunk, becoming smooth and light-grey higher up
9	Flowering and fruiting	Start flowering from March to April. The fruits develop by May or June and resemble large berries



TREE



TRUNK



LEAVES



FRUITS

FIG. 1: SYGZIUM CUMINI

Cultivation and Collection:

Soil: The jamun tree can be grown on a wide range of soils. However, for high yield potential and good plant growth, deep loam and a well drained soil are needed. Such soils also retain sufficient soil moisture which is beneficial for optimum growth and good fruiting. Jamun can grow well under salinity and waterlogged conditions too. However, it is not economical to grow jamun on very heavy or light sandy soils.

Climate: Jamun prefers to grow under tropical and subtropical climate. It is also found growing in lower ranges of the Himalayas up to an altitude of 1300 meters. The jamun requires dry weather at the time off towering and fruit setting. In subtropical areas, early rain is considered to be beneficial for ripening of fruits and proper development of its size, colour and taste.

Propagation: The jamun is propagated both by seed and vegetative methods. Due to existence of polyembryony, it comes true to parent through seed. Though vegetative methods followed in most cases have attained some success, seed propagation is still preferred. However, seed propagation is not advisable as it results in late bearing. The seeds have no dormancy. Fresh seeds can be sown. Germination takes place in about 10 to 15 days. Seedlings are ready for transplanting for the use as rootstock in the following spring (February to March) or monsoon *i.e.* August to September.

Propagation of jamun is economical and convenient. Budding is practiced on one year old seedling stocks, having 10 to 14 mm thickness. The best time for budding is July to August in low rainfall areas. In the areas where rains start easily and are heavy, budding operations are attempted early in May-June. Shield, patch and forkert methods of budding have proved very successful. The possibility of better success has been reported in forkert method compared to shield or "T" budding. Jamun can also be propagated by inarching but it is not adopted commercially. In this method one year old seedlings raised in pots are inarched with mother jamun trees with the help of wooden stands during June-July.

About 60% air layers are obtained with 500 ppm IBA in lanolin paste, provided air layering is done in spring and not in the rainy season. Better rooting

through cutting is obtained in Jamun under intermittent mist. Semi-hardwood cuttings of both *S. jambos* and *S. javanica*, 20-25 cm long, taken from the spring flush and planted in July treated with 2000 ppm IBA (indole butyric acid) give better results.

Planting: Jamun is an evergreen tree and can be planted both in spring *i.e.* February -March and the monsoon season *i.e.* July-August. The latter season is considered better as the trees planted in February-March have to pass through a very hot and dry period in May and June soon after planting and generally suffer from mortalities from the unfavourable weather conditions. Prior to planting, the field is properly cleared and ploughed. Pits of 1 × 1 × 1 m size are dug at the distance of 10m both ways. Usually, work of digging of pits is completed before the onset of monsoon. The pit is filled with mixture of 75% top soil and 25% well rotten farmyard manure or compost. Another common way of growing jamun trees is to plant them as shade trees near the farm dwellings and wells. Here they provide a welcome shadow besides fruit.

Fertilizer Application: The jamun trees are generally not manured. This is not because they do not require manuring or fail to respond to it but because they can stand a good deal of neglect. An annual dose of about 19 kg fallnyard manure during the pre-bearing period and 75 kg per tree bearing trees is considered. Normally, seedling jamun trees start bearing at the age of 8 to 10 years while grafted or budded trees come into bearing in 6 to 7 years. On very rich soils, the trees have a tendency to put on more vegetative growth with the result that fruiting is delayed. When the trees show such a tendency, they should not be supplied with any manure and fertilizer and irrigation should be given sparingly and withheld in September-October and again in February-March. This helps in fruit bud formation, blossoming and in fruit setting. Sometimes this may not prove effective and even more drastic treatments such as ringing and root pruning may have to be resorted to. A fruit grower has, therefore, to be cautious in manuring and fertilizing jamun trees and hence, has to adjust the doses according to the growth and fruiting of trees.

Irrigation: In early stages, the jamun tree requires frequent irrigations but after the trees get

established, the interval between irrigations can be greatly decreased. Young trees require 8 to 10 irrigations in a year. The mature trees require only about half the number, which should be applied during May and June when the fruit is ripening. During autumn and winter months, just an occasional irrigation may be applied when the soil is dry. This will also save the trees from the ill effects of frost in winter.

Flowering and Fruiting: Flowers are borne in the axils of leaves on branchlets. In North Indian conditions, flowering starts in the first week of March and continues up to the end of April. The pollen fertility is higher in the beginning of the season. The maximum receptivity of stigma is one day after anthesis. The jamun is a cross-pollinated and the pollination is done by honey bees, houseflies and wind. The maximum fruit set can be obtained by hand pollination when it is done after one day of anthesis. Thereafter, a sharp decline is observed in fruit set.

There is heavy drop of flowers and fruits within 3 to 4 weeks after blooming. Later natural fruit drop can be reduced with two sprays of GA3 60 ppm, one at full bloom and another 15 days after initial setting of fruits. The pattern of growth and fruit development of jamun can be divided into three phases: the first phase from 15-52 days after fruit set having slow growth of fruit, the second phase from 52 to 58 days after fruit set having fast growth and the third and last phase from 58 to 60 days after fruit set having slow growth and very little addition in fruit weight.

Harvesting and Yield: The seedling jamun plants start bearing after 8 to 10 years of planting, while grafted ones bear after 6 to 7 years. However, commercial bearing starts after 8 to 10 years of planting and continues till the tree becomes 50 to 60 years old. The fruit ripens in the month of June - July. The main characteristic of ripe fruit at full size is deep purple or black colour.

The fruit should be picked immediately when it is ripe, because it cannot be retained on the tree in ripe stage. The ripe fruits are handpicked singly by climbing the tree with bags slung on the shoulder. Care should be taken to avoid all possible damage to fruits. The average yield of fruits from a full

grown seedling tree is about 80 to 100 kg and from a grafted one 60 to 70 kg per year.

Storage and Marketing: The fruits are highly perishable in nature. They cannot be stored for more than 3 to 4 days under ordinary conditions. However, pre cooled fruits packed in polythene bags can be stored well up to three weeks at low temperatures of 8 to 10 °C and 85 to 90% relative humidity. The fruit is packed and sent to the market almost daily. For marketing, well ripe and healthy fruits are selected. Damaged, diseased and unripe fruits are discarded. These selected fruits are then carefully packed in wooden baskets and sent to the local markets⁷¹.

Traditional Uses:²⁰ Jamun or black plum is an important summer fruit, associated with many health and medicinal benefits. The black plum is known to relieve stomach pain, carminative, anti-scorbutic and diuretic. Black Plum vinegar is good to reduce enlargement of spleen, diarrhoea, and those have urine retention problems. Jamun's polyphenolic compounds are effective against cancer, heart diseases, diabetes, asthma and arthritis.

Black plum fruit and its leaves are good for diabetic patients. The black plum has anti-diabetic features. The fruit helps to convert starch into energy and keep your blood sugar levels in check. In the summer season, the sugar patient should eat Black Plum regularly because of its low glycemic index. It reduces the symptoms of diabetes like frequent urination and thirsting. The extract of bark, seeds, and leaves are too beneficial in the treatment of diabetes.

Black Plum has adequate amount of iron and vitamin C. The presence of iron in the black plum is good to increase the haemoglobin count. The fruit's iron content acts as blood purifying agent. Since, it is the medium of purifying your blood; therefore, it is good for skin and beauty. Iron content is beneficial in menses where the lady faces blood loss. People suffering from anemia and jaundice should eat black plump because of its high iron content.

Some of the amazing and surprising health benefits of this juice are given below.

- ✓ It is used to treat digestive disorders such as diarrhoea
- ✓ This juice along with curd is good against digestive problems.
- ✓ Teeth related problems can be solved by applying black Plum juice or by drinking it.
- ✓ Jamun juice is beneficial in treating of piles.
- ✓ Drinking of the fresh fruit juice helps in cough and asthma.
- ✓ Jamun juice enhances your immune system.
- ✓ It protects you from cold and acts as anti-aging agent.

Pharmacological Activities:

Anticancer Activity: Cancer is a public health problem all around the world. Exploration for anticancer agents from plant origin dates back to 1947, when the cytotoxic properties of podophyllotoxin from *P. peltatum* (Berberidaceae) were detected²¹. The discovery of the antileukemic properties of vinblastine and vincristine from *Catharanthus roseus* (Apocynaceae) shortly went behind and offered the desire for broad investigations of plant extracts and plant-derived compounds for possible anticancer activity. In the case of human cancers, thus far, nine plant-derived compounds have been approved for clinical use in the United States. They include vinblastine, vincristine, the camptothecin derivatives-topotecan and irinotecan, and paclitaxel. Numerous agents such as betulinic acid, roscovitine and silvestrol are in clinical or preclinical stage of development. Few reports have indicated potential of *Syzygium cumini* (L.) fruits to combat cancer²².

Nazim, 2007 isolated 4 anthocyanins pelargonidin-3-O-glucoside, pelargonidin-3, 5 Odiglucoside, cyanidin-3-O-malonyl glucoside, and delphenidin-3-O-glucoside from the acidic alcoholic extract of *Syzygium cumini* (L.) fruits. They performed cytotoxic activity of total alcoholic extract of the fruits against various tumor cell lines using the SRB assay. Results revealed that they showed significant cytotoxic activity for MCF7 (breast carcinoma cell line) ($IC_{50} = 5.9 \mu\text{g/mL}$), while the IC_{50} was $> 10 \mu\text{g/mL}$ for both Hela (Cervix carcinoma cell line), HEPG2 (liver carcinoma cell line), H460 (Lung carcinoma cell line) and U251 (Brain carcinoma cell line)²³. Afify et al., 2011 investigated anticancer activity of *Syzygium cumini* (L.) fruit extracts using cell viability assay

of leukemia cancer cell line. They prepared successive extracts of hexane, chloroform, ether, ethyl acetate, ethanol, and water and evaluated for anticancer activity. They reported that the ethanol extract exhibited stronger anti-leukemia activity as compared to other ones. Spectroscopic findings of active ingredients separated from ethanol extract showed that fruit extract of *Syzygium cumini* (L.) contained phenolic compounds namely Kaempferol 7-O-methylether and sterols such as γ -Sitosterol was responsible for their anticancer activity²⁴.

Anti-inflammatory Activity: Inflammation can be defined as a generalized, nonspecific but beneficial tissue response against injury. It comprises a complex array of adaptive responses to tissue injury which are both local and systemic. The local responses lead to staffing of phagocytic cells and removal of endogenous or foreign material. The systemic responses may alter the environment interior to permit these processes to occur more proficiently²⁵.

Muruganandan et al., 2001 evaluated ethanolic bark extract of *Syzygium cumini* (L.) was for its anti-inflammatory activity in animal models. The extract did not exhibit any toxicity up to a dose of 10.125 g/kg, p.o. in mice. Significant anti-inflammatory activity was found in carrageenin (acute), kaolin-carrageenin (subacute), formaldehyde (subacute)-induced paw oedema and cotton pellet granuloma (chronic) tests in rats. The extract did not stimulate any gastric lesion in both acute and chronic ulcerogenic tests in rats. Overall they concluded that *Syzygium cumini* (L.) bark extract possess a potent anti-inflammatory action against different phases of inflammation without any side effect on gastric mucosa²⁶.

Kumar et al., 2008 evaluated anti-inflammatory activity of ethyl acetate and methanol extracts of *Syzygium cumini* (L.) seed in carrageenan induced paw oedema in wistar rats at the oral dose level of 200 and 400 mg/kg. Both the extracts presented significant anti-inflammatory activity supporting anti-inflammatory activity of the seed of *Syzygium cumini* (L.)²⁷. Sharma S et al., 2012 showed the methanol extract showed highly significant anti-inflammatory activity, showing a high percentage of inhibition (62.6%)²⁸.

Siani et al., 2013 examined the anti-inflammatory activity of the essential oils from the leaves of *S. cumini* of their terpene-enriched fractions (+V = more volatile and -V = less volatile) obtained by vacuum distillation. Anti-inflammatory activity was accessed in the lipopolysaccharide-induced pleurisy model, by measuring the inhibition of total leukocyte, neutrophil and eosinophil migration in the mice pleural lavage, after oil treatment with the oils at 100 mg/kg. Results revealed that eosinophil migration was inhibited by SC (67%), SC (+V) (63%), PG (76%), PG (+V) (67%) and PG (-V) (74%). Conclusively they demonstrated that essential oils from *S. cumini* may be useful to treat inflammatory diseases by mechanisms that include the inhibition of eosinophil migration²⁹.

Cardioprotective: In case of SC, the hydro-alcoholic extract of leaves was evaluated in spontaneously hypertensive and normotensive Wistar rats. The findings of the research investigation revealed that the extract decreased the blood pressure as well as the heart rate. Extracellular calcium influx and inhibition of arterial tone were suggested as the most probable mechanism of action³⁰. The oral administration of the methanolic extract of SC at the doses of 250 mg/kg and 500 mg/kg consecutively for 30 days reversed and retained the activity of AST, ALT, LDH and CPK to normal levels against the isoproterenol- induced myocardial infarction³¹.

The elevated serum levels of alanine transaminase (ALT), serum creatine phosphokinase (CPK), aspartate transaminase (AST), lactate dehydrogenase (LDH), HDL-cholesterol due to doxorubicin (1.5 mg / kg/b.w., 15 days) induced cardiotoxicity were brought to normal range after the administration of aqueous suspension of SC seed extract (100 mg/kg/b.w. for 15 days)³².

The hydroalcoholic extract of SC was evaluated for its antihypertensive, and vasorelaxant effect. Polyethylene catheters were inserted into the inferior vena cava and lower abdominal aorta in the anaesthetized rats for dosing and measuring blood pressure. The extract at the doses of 0.5; 1; 5; 10; 20 and 30 mg/kg, i.v. was able to induce hypotension (due to reduction in endothelium mediated peripheral resistance) and bradycardia (due to meandering cardiac muscarinic activation)³³.

Hepatoprotective: Hepatoprotective agents are those that provide protection to the liver (which performs important functions like metabolism, secretion, storage, and detoxification of endogenous and exogenous substances). The alcoholic extract of the pulp of SC (100 and 200mg/kg/day) exhibited a significant hepatoprotective action on paracetamol (PCM)-induced hepatotoxicity in albino rats. The elevated serum levels of ALT, AST, AP were decreased and histopathological studies depicted a reduction in fibrosis and necrosis³⁴. The anthocyanins rich SC pulp extract (50 to 500 ppm) has shown its beneficial effects in preventing the CCl₄ induced liver damage by declining the lipid peroxidation, suppressing the CCl₄-induced release of LDH, and elevating the GPx (antioxidant enzyme) activity³⁵. Aqueous leaf extract and methanolic seed extract have also shown hepatoprotective effects through biochemical estimations and histopathological studies^{36,37}.

Methanol extracts of plant seeds in chemically (CCl₄) induced stress rats. Adult male, Sprague Dawley rats (n=30) were randomly segregated into 5 equal groups i.e., group-I (control), group-II (silymarin treated; 1.0 mg/kg BW), group-III (extract of *Syzygium cumini* seeds treated; 250 mg/kg BW), group-IV (extract treated; 500 mg/kg) and group-V (CCl₄ treated; 1.5 mg/kg). Rats were treated with respective treatments for 14 consecutive days. At day 14, four hours after the last dose, an oral dose of CCl₄ (1.5 mg/kg, 1:1 in olive oil) was administered to all the groups, except animals in the control group. Subsequently, 24h later, blood samples and liver tissues were collected for biochemical analysis and histopathology, respectively. The values of liver function markers were found to be significantly (P<0.05) lower while serum protein level was significantly higher in control and treated groups as compared to that of the CCl₄ treated group. Histological examination of liver tissues also indicated that the extract of *Syzygium cumini* seeds in both the doses, and silymarin protected the liver from CCl₄-induced stress. It was concluded that extract of seed of *Syzygium cumini* has hepatoprotective activity³⁸.

The methanolic extracts of *S. cumini* seeds (100 and 200 mg/kg body weight) were administered to alloxan-induced diabetic rats daily, with fasting blood glucose levels being measured by glucometry

at one-day interval for a duration of two weeks. Biochemical assays to evaluate changes in the functions of the heart, liver, pancreas and kidney were carried out. Histopathological changes in the diabetic rat organs (pancreas, liver, heart, kidney and spleen) were also observed after the 14 days of treatment with the extracts. Oral administration of methanolic extracts of *S. cumini* seeds (100 and 200 mg/kg body weight), with gliclazide as a positive control (25 mg/kg), showed beneficial effects including lowering blood glucose levels ($P < 0.001$), improved heart and liver functions, and hyperlipidemia due to diabetes. At 200 mg/kg, the extracts reversed cardiac and liver damage caused by alloxan. Anti-hyperglycemic activity of methanolic extracts of *S. cumini* seeds, the extracts demonstrated potential to minimize cardiac and hepatic complications³⁹.

Anti-diabetic Activity: Singh and Gupta 2007, investigated the effects of ethanolic extract of *Syzygium cumini* (L.) seed powder on pancreatic islets of alloxan diabetic rats. They reported that ethanolic extract of seeds of *Syzygium cumini* (L.) significantly decreased blood sugar level in alloxan diabetic albino rats. Further the histological studies showed definite improvement in the histopathology of islets. They also reported that the blood sugar level once dropped to normal levels after extract feeding was not elevated when extract feeding was discontinued for 15 days⁴⁰.

Kumar et al., 2008 isolated and identify the supposed antidiabetic compound from the *Syzygium cumini* (L.) seed. They isolated mycaminose from SC seed extract and investigated anti-diabetic activity against streptozotocin (STZ)-induced diabetic rats. They reported that mycaminose exhibited significant ($p < 0.05$) reduction in blood glucose level. Glibenclamide the standard drug (1.25 mg/kg) also produced significant ($p < 0.05$) reduction in blood glucose level against STZ-induced diabetic rats. Conclusively they demonstrated that isolated compound mycaminose possess anti-diabetic activity against STZ-induced diabetic rats⁴¹. Tripathi and Kohli 2014, studied antidiabetic activity of bark extract of *Syzygium cumini* (L.) on streptozotocin (STZ)-induced diabetic Wistar albino rats. They reported that 30 min prior administration of *Syzygium cumini* (L.) extracts

before oral glucose loading significantly decreased ($p < 0.001$) the rise in postprandial blood glucose levels in treated rats as compared to control rats however the result was less significant than glibenclamide. Every day, continuous oral treatment of STZ-induced diabetic with various *Syzygium cumini* (L.) extract for 3 weeks lead to significant reductions in fasting blood glucose levels as compared to diabetic controls⁴².

S. cumini decoction and the ready to serve (RTS) herbal drink developed using the decoction. Activity guided fractionation of the decoction of the *S. cumini* was carried out by sequential extraction with organic solvents of different polarities. Thin Layer Chromatography (TLC) with authentic compounds and HPLC were performed for identification and confirmation of the compounds in the decoction and the RTS herbal drink. Presence of gallic and ellagic acids in the decoction and RTS herbal drink was proven and confirmed with HPLC. The LC UV-VIS spectra of the two compounds were identical with the corresponding spectra of the library. Further, gallic acid and umbelliferone were determined as the active compounds in the decoction by TLC and were confirmed by co-chromatography with authentic compounds. The present investigation confirmed the presence of gallic acid, ellagic acid, and umbelliferone which are proven to have antidiabetic activities in the decoction and the RTS herbal drink prepared with the decoction⁴³.

Antidiabetic and lipidemic activity of this medicine and seed extract was studied on streptozotocin induced type 2 diabetic model rats. From chemical investigation carbohydrates and steroids were present in both samples. Alkaloid was present in herbal medicine sample only. Arsenic was found to be 0.05 ppm which was less than the tolerance level. Other toxic metals lead, copper, cadmium and manganese were absent in herbal medicine (HM-01). Myristic, palmitic, linoleic, oleic, stearic and arachidic acids were found in both samples. The rats were divided into 4 groups (n = 6 in each group): a) Water controls b) Glibenclamide c) PESE d) HM-01. The parameters measured were: serum glucose and serum lipid profile. Oral consumption of HM-01 and PESE for 22 days caused significant (plasma glucose in mmol/L, Mean \pm SD; 8.57 ± 1.09 vs. 5.67 ± 0.45 ;

and 8.91 ± 0.9 vs. 5.56 ± 0.7 respectively, on the 1st day vs. 22nd day; $**p < 0.005$) reduction of fasting serum glucose level. HM-01 and PESE treated groups decreased total cholesterol level by 25% and 23%; triglyceride by 24% and 28%; LDL cholesterol by 34% and 35%; and increased HDL cholesterol by 14% and 22% respectively. The herbal medicine and its constituent *Syzygium cumini* seed powder possess antidiabetic properties in type 2 diabetic model rats ⁴⁴.

Syzygium cumini and its seed a member of Myrtaceae family acquire potential role in regulating diabetes mellitus and its seeds are moderately rich in protein (6.3-8.5%) and contains so many other phytochemicals. It gives a new therapeutic paradigm as anti-hyperglycemic agent either due to a single component or combination of different components present in the seed. Present research gives an idea about the multiple mode of action by *Syzygium cumini* seeds to control diabetes mellitus and its related complications clinically and pharmacologically ⁴⁵.

Antioxidant: RSC (Radical scavenger capacity) of SC was determined by using DPPH (2, 2-diphenyl-1-picrylhydrazyl radical) assay. The second order rate constants- k_2 was evaluated to determine RSC and then these were compared to natural and synthetic antioxidants. The k_2 value of SC was determined to be 15.60 L/mol g s in methanol at 25°C proving that it has a excellent antioxidant potential ⁴⁶. The leaf and seed extract of SC exhibited a significant antioxidant activity when they were assessed by various in vitro methods such as Ferric reducing antioxidant power (FRAP) assay, 2, 2-diphenyl-1-picrylhydrazyl (DPPH) scavenging assay, nitric oxide radical scavenging, ABTS assay, total reducing antioxidant potential, total antioxidant activity, reducing power and hydroxyl radical scavenging activity ⁴⁷.

The methanolic extract of leaves, bark and seeds of SC were fractionated in different solvents: n-hexane, chloroform, ethyl acetate, butanol and water. These fractions were studied for their antioxidant and free radical scavenging activities. Of all the fractions, the polar ones *i.e.*, ethyl acetate and water fractions showed excellent results ⁴⁸. Antioxidant activity was recorded high in seed and their parts when extracted in methanol and water.

Petroleum ether and ethyl acetate fractions showed poor in antioxidant activity in all fruit parts. Antidiabetic activity of methanol fraction is found to be high followed by the water fraction particularly in seed and kernel tissues. Among the fruit parts, seed had high antidiabetic activity followed by the kernel. Pulp tissues have antidiabetic activity in methanol fraction ⁴⁹.

Antioxidant potential of three different geographical variants of *S. cumini* seeds and to compare the phenolic profiling to know the effect of geographical variation in phenolic composition. Total phenolic and flavonoid content of *S. cumini* seeds were analyzed. Antioxidant activities in terms of 2,2-diphenyl-1-picrylhydrazyl, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid), nitric oxide and superoxide radical scavenging assays were performed.

The most active fractions were subjected to High - Performance Liquid Chromatography (HPLC) profiling to identify the phenolic composition. Among all the fractions, 70% methanol fraction of *S. cumini* seed showed significant antioxidant potential. There existed a linear correlation between phenolic content and antioxidant activity. HPLC profiling of 70% methanol (ME) fractions of all the variants revealed the presence of phenolic compounds with high concentrations of ellagic acid and gallic acid. The differences in phenolic concentration due to geographical changes might be the reason for higher antioxidant potential showed by 70% ME of Trivandrum variant. 70% methanolic fraction of *S. cumini* can act as a novel source of natural antioxidant ⁵⁰.

Anti-diarrhoeal Activity: In this context Shamkuwar *et al.*, 2012 evaluated anti-diarrhoeal activity of aqueous extract of *Syzygium cumini* (L.) seed in mice. They tested antidiarrhoeal, antimotility and antisecretory activity *Syzygium cumini* (L.) seed extract. The method of castor oil induced diarrhoea was performed for investigating antidiarrhoeal activity; whereas charcoal meal test and castor oil induced intestinal secretions were used for testing antimotility and antisecretory activity in mice. They reported that aqueous *Syzygium cumini* (L.) extract (ASC) exhibited a significant and dose dependent antidiarrhoeal, antimotility, and antisecretory effect.

Overall they concluded that antidiarrhoeal effect of ASC might be because of its antimotility and antisecretory effect.⁵¹

To evaluate the antidiarrhoeal and antispasmodic activity of the standardized extract of *S. cumini* leaves (HESc) in experimental models *in-vitro* and *in-vivo* rodents. Mice pre-treated with HESc (100, 250 and 1000 mg/kg) and atropine (1.0 mg/kg) had reduced intestinal transit velocity of 11.0; 23.2 and 19.1%, respectively compared to saline control (46.6 ± 0.9). In isolated rats jejunum, HESc (50, 150 and 300 µg/mL) shifted to the right cumulative concentration-response curves to ACh with changing maximum effect (Emax), which is characteristic of non-competitive antagonism to ACh. HESc also promoted relaxation (Emax 90.2 ± 5.8%) in preparations pre-contacted with KCl (75 mM). Additionally, it reduced the maximal CaCl₂-induced response in 15.4; 56.3 and 92.1% in a concentration-dependent manner. The study results showed that HESc has an antidiarrhoeal and spasmolytic potential that can be partly explained by the reduction of intestinal transit velocity and blockage of the voltage-dependent calcium channels in the smooth intestinal muscle.⁵²

Anti-microbial Activity: Gawri and Vasantha, 2010 examined antibacterial activity of crude methanol and aqueous extracts of the leaves of *Syzygium cumini* (L.) against standard strains and clinical isolates of some bacteria using the disc diffusion method. The extracts exhibited inhibitory activity against clinical isolates of gram negative bacteria such as *Salmonella enteritidis*, *Salmonella typhi*, *Salmonella typhi* A, *Salmonella paratyphi* A, *Salmonella paratyphi* B, *Pseudomonas aeruginosa* and *Escherichia coli* and gram positive bacteria such as *Bacillus subtilis*, and *Staphylococcus aureus*. They reported that the methanol extracts were more potent than the aqueous extracts.⁵³

Prateek et al., 2015 studied antimicrobial activity of *Syzygium cumini* (L.) fruit and leaf extract against bacterial stains such as *Staphylococcus aureus*, *Staphylococcus saprophyticus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Roultella plantikola*, *Proteus vulgaris* and fungal stains namely *Aspergillus niger* MTCC 282, *Penicillium chrysogenum* MTCC 161, *Candida albicans* MTCC 183, *Fusarium solani* MTCC 9667.

They reported antibacterial activity against all used bacteria. Maximum zone of inhibition was observed for *Roultella plantikola* (25 mm) and minimum zone of inhibition was observed against *Pseudomonas aeruginosa* by using fruit extract (14 mm). The plant extract showed maximum zone of inhibition (18 mm) against fungal strains *Penicillium chrysogenum* and minimum (7mm) against *Candida albicans*. Conclusively they demonstrated that *Syzygium cumini* (L.) extract possess potential antibacterial and antifungal activity.⁵⁴

Shaikh et al., have investigated antibacterial activity of ethanolic extracts of *Eugenia jambolana* against gram positive and gram negative organisms. Bhuiyan et al., reported antibacterial activity of methanol and ethyl acetate extracts of the seeds of *E. jambolana* at a concentration of 200 µg/disc against five Gram positive bacteria (*Bacillus creus*, *B. subtilis*, *B. megaterium*, *Steptococcus β*-haemolyticus, *S. aureus*) and nine Gram negative bacteria (*Shigella dysenteriae*, *S. Shiga*, *S. boydii*, *S. flexneriae*, *S. sonnei*, *E. coli*, *S. typhi* B, *S. typhi* B- 56 and *Klebsicella species*) by disc diffusion method.⁵⁵

Shafi et al., had, reported good antibacterial action from essential oil of *E. jambolana* leaves.⁵⁶ Pitchai Daisy et al., have worked on the antibacterial activity of the extract of *Syzygium cumini* by disc diffusion method using extended spectrum beta lactamase (ESBL) producing bacteria. Methanol, acetone and hexane extract of *Syzygium cumini* seeds were examined for antibacterial activity on *Aeromonas hydrophila*, *Acinetobacter baumannii*, *Citrobacter freundii*, *E. coli*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Proteus mirabilis*. Methanol extract of *Syzygium cumini* seeds exhibited significant antibacterial activity against bacteria.⁵⁷

Inhibits Lipid Peroxidation: A research investigation utilized the pulp extract (enriched with anthocyanins) to study its potential to inhibit the iron (FeSO₄)-induced lipid peroxidation in different organs of rat (Liver, liver mitochondria, brain, testes etc.) *in-vitro*. A concentration of 5ppm was found to show beneficial results with highest lipid peroxidation inhibition in liver mitochondria (86%), followed by liver (83%), testes (72%) and

brain (68.3%)⁵⁸. SC seed extract when administered orally for 15 days to alloxan treated rats, exhibited an elevated antioxidant the enzyme level and declined lipid peroxidation activity⁵⁹.

Antipyretic Activity: According to Chaudhari *et al.*, chloroform extracts of dried seeds showed antipyretic activity and Mahapatra *et al.*, studied methanol extracts of dried seeds administered intraperitoneally to rats at doses of 50 mg per kg were active versus yeast induced pyrexia⁶⁰.

Antihistamine Activity: Mahapatra *et al.*, found the methanol extract of dried seeds, administered intraperitoneally to rats was active vs. histamine induced pedal edema⁶⁰.

Antiplatelet Activity: Namba *et al.*, have studied aqueous, methanolic and methanol-water (1:1) extracts of the bark were able to suppress plaque formation *in-vitro*. All were active against *Streptococcus mutans* at 260, 120 and 380 µg per ml respectively⁶¹.

Antifertility Activity: Rajasekaran *et al.*, has revealed antifertility effect of oleanolic acid isolated from the flowers of *E. jabolana* significant decreased the fertilizing capacity of the male albino rats without any significant change in body or reproductive organ weights. It causes significant reduction in conversion of spermatocytes to spermatides and arrest of spermatogenesis at the early stages of meiosis leading to decrease in sperm count without any abnormality to spermatogenic cells, leydig interstitial cells and sertoli cells⁶².

Gastroprotective: Natural products provide a safer remedy to protect the gastric mucosa of aggressive or irritating agents. Seed kernel extract of SC (200 mg/kg) was evaluated for its antiulcer activity. First, the diabetes was induced using low dose streptozotocin (35mg/kg) in combination with high fat diet. Then the gastric ulceration was produced in diabetic rat's ethanol and indomethacin models. It was observed that there was a significant decrease in the gastric ulcer index after the administration SC extract alone and as well as in combination with acarbose (5mg/kg)⁶³.

In another research investigation, the hard liquor (48% ethanol- 1ml/150gm b.w.) and aspirin (200

mg/kg, orally) were used to induce gastric ulcer in rats. The aqueous extract of SC leaves at the doses of 200 and 400 mg/kg produced ulcer inhibition (%) of 32.17% and 61.09% respectively in hard liquor model and 23.01% and 70.33% respectively in aspirin model⁶⁴. SC fruit extract at the dose of 200mg/kg b.w. was administered orally for 10 days to streptozotocin induced diabetic and to rats exposed to ulcerogens (like aspirin, 95% ethanol, cold-resistant stress and pylorus-ligation). The observations of the study revealed that there was a decrease in acid-pepsin secretion, cell shedding and LPO while an increase in the GSH (in gastric mucosa), mucosal glycol-protein and mucin^{65, 66, 67}.

Antiviral: With the changing environment, new viral diseases are being identified, so there is a demand for a safer, non-toxic remedy. The cold and hot aqueous extracts of leaves and barks of SC were evaluated for their antiviral potential against H5N1 (avian influenza virus which causes a highly contagious disease of poultry) using CPE reduction assay to establish virucidal, pre-exposure and post-exposure potential of these extracts. With hot and cold aqueous bark extracts and hot aqueous leaf extracts, 100% inhibition of the virus was observed in virus yield reduction assay and in egg based in ovo assay. CC₅₀/EC₅₀ (selective index) for cold aqueous extract (43.5) and hot aqueous extract (248) of bark exhibited their potency against H5N1 virus⁶⁸. The aqueous extract of leaves was also found to inhibit the goatpox virus⁶⁹ and the buffalopox virus⁷⁰.

CONCLUSION: *Syzygium cumini* (Linn.), a traditional plant medicine having multiple pharmacological actions possess clinically value. *Syzygium cumini* (L.), raw and value added products should be advertised to urban population for its health benefits and especially for promotion of Jamun growers in tribal areas of India. The plant has many imperative compounds which are responsible for various ailments. Though many works on pharmacological activities of phyto-chemical constituents of *Syzygium cumini* (L.) has been carried out.

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